Design of the automation of a prototype of cheese production line.

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Summary - In the country there is a considerable production of cheeses of artisan form, for its manufacture exists a high degree of physical wear and tear. With a low asepsis in the handling of material under development, for this reason this project helps to solve the need with the design and construction of an automation system implemented in the prototype. The methodology used is a functional analysis and a modular division of the complete process. Field research through surveys of cheese and milk producers to obtain information from the customer's voice was a basis for the development of the present system. The design of the automation system was done by means of flowcharts and grafcet to be taken to the programming in Ladder. With this, the design of the control board of the system, its assembly, was carried out to carry out calibration and validation tests. The results of this project reflected that the automation system aided in production by reducing manufacturing times by having a controlled process sequence without having a stop during a continuous process. Avoiding the contact of the operator and raw material.

Keywords: automation, ladder, grafcet, cheeses.

I. INTRODUCTION

The elaboration of mature cheeses made by micro-enterprises in Ecuador is insufficient in terms of quality, low levels of hygiene and technification, since they do not have the machinery that integrates the different processes both in preparation and in the extraction of serum.

It requires an improvement of the process and a direct integration in a horizontal production line that covers all the processes with a synchronization between them.

According to data from the National Agricultural Statistics System of the north of Ecuador, approximately 745,000 liters of milk are produced per day, where Carchi and Imbabura are the main producing provinces. Of this figure, 80% is destined for the manufacture of dairy products, 20% the rest goes to the artisanal use in the elaboration of cheeses and feeding in the property. [1]

At present, the development of mature cheeses in micro-enterprises is done manually with a high degree of physical wear and tear on the workers, contaminating the product in the cutting and pre-pressing processes. There are low levels of hygiene in the processes since in these places a control in the manipulation of the raw material of the product is not obtained. The restriction of the technical documentation and the high costs of the commercial lines represent a limitation in the technological development for the change of the productive matrix.

Faced with this problem the Technical University of North through the Faculty of Applied Sciences Engineering and the Mechatronics Engineering Career is implementing a prototype line to produce cheeses, this project aims to implement the automation system of the prototype. Health standards (NTE INEN 2604, NTE INEN 1528) were considered, allowing the improvement of the quality and minimum intervention of the worker in delicate operations (cutting and pre-pressing) in the production of this product. Provide solutions to the problems of raw material residues, low hygiene, processing time and product life. The system of control of the line will have as configurable parameter the quantity of milk to be processed.

In Ecuador, policies have been developed to achieve a transformation of the productive matrix to achieve good living conditions. The country has been characterized by the production of primary goods with little or no technification in this case in the elaboration of cheeses. To solve this problem systems have been developed. For example, around small-scale micro-enterprises according to surveys and visits made it possible to observe that they use a kettle or industrial kitchen for preparation, carrying the milk at a temperature of approximately 33ºC, the operator introduces his hand to know if the milk is at the ideal temperature without using a thermometer. The processes of curd cutting, serum extraction, molding and pressing are performed manually by operators with unsuitable utensils. In industries that already have more technology use methods and equipment; such as kettles or boilers in which the pasteurization and preparation process is carried out, these equipment's are constructed in stainless steel, with different capacities ranging from 500 liters to 5000, are adapted to different types of heating media: electricity, gas, heating oil, steam, superheated water in closed circuit. These devices already have controls, it can be through a PLC, a pyrometer, among others. With a stirrer of different types of pallets to perform the curd cutting process with an AC motor. In the process of pre-pressing and pressing a pneumatic cheese press is used, its construction in stainless steel, equipped with pneumatic pistons, with a mesh on the sides of the table that facilitates the extraction of the whey from the curd. Another option found is a press with a capacity that varies according to its dimensions, with a lever and a chrome screw, a stainless table, and a serum manifold, can be pressed different numbers of molds per floor according to the configuration of the press.

In automated processes were found solutions as: [2] Designed a system of pasteurization of milk, this system performs the control through a PLC that controls the passage of gas, activates a water circulation pump, conducts the temperature census using a PT100 sensor and activates a single-phase motor. This system does not have a mechanism that facilitates the extraction of the curd since it counts on a considerable quantity; [3] At Universidad Técnica del Norte, a semiautomatic system was used to mix milk and cut the curd for a 500-liter cheese vat which handled a frequency inverter to perform the curd cut and temperature sensing; the author does not specify parameters of the control system used, It is not mentioned whether or not the system has a mechanism that facilitates the extraction of the curd. [4] They designed and built an automated kettle for cheese making at the Polytechnic School of Chimborazo. The characteristics are: with a maximum volume of 122 liters, a pasteurization temperature of 70 ° C the addition of rennet is made at 38 ° C, used a frequency inverter with a motor for mixing, no mention was made of the control system used and finally this system does not have a mechanism that facilitates the extraction of the curd. At the international level, it was found [5] They developed an online control of the cheese processing process using optical fiber sensors, Universidad De Antioquia. They used fiber optic sensors to measure the infrared light scatter because of an objective and precise method to control the milk coagulation process during cheese production, which allowed to obtain appropriate models for the prediction of parameters such as coagulation time and the cutting time of the curd.

II. IMPORTANCE OF THE PROBLEM.

The process of making handmade cheeses is slow and at certain points have low levels of hygiene. Such processes lack automation. Due to their high prices limiting imports of these types of machines, therefore, the artisans who require this equipment need sufficient economic resources to access an automated line. For these reasons, a prototype is developed with the aim of improving production times and increasing product quality. All the automation executed in this line leads to an industrialization of the same with reduction of costs, which will cause an inevitable increase of the profits of the artisan, benefiting zone 1.

III. METHODOLOGY

The steps or methods to follow to apply the methodology are: Characteristics of the user. Functional analysis, modular division, system description, flowchart, device description, logic controller selection, PLC programming, mathematical temperature modeling, Ziegler Nichols tuning rule, Control panel design, Caliber calculation cables and calculation of protections.

A. Characteristics of the user.

After carrying out the respective surveys to the cheese and milk producers, it was obtained that the artisanal producers of cheeses gave an acceptance towards an automation in the process would be of great helping to increase the levels of production with minimal intervention of the worker in delicate operations such as cutting and pre-pressing, therefore, the information provided is of great help for the development of this prototype. The responses of milk producers and collectors indicate that there is a higher profitability by making cheeses than by selling unprocessed raw milk, so they would be willing to make an investment to obtain a prototype cheese production.

B. Functional analysis.

Functional analysis is the identification, through the disaggregation or disaggregation, and the logical ordering of the productive functions that are carried out in the process, is applied from the general to the according to the level at which the analysis is being developed. This technique proposed by the American engineer Lawrence D. Miles, whose purpose is to separate the action that is done of the process, in this way to look for new solutions to a same problem. Functional analysis can obtain better products at a lower cost [6]. When applying this technique in solving a problem, it is necessary to clearly subdivide the primary functions and secondary subfunctions into functions that are necessary to perform each sub function of the product. In this case is to make cheeses. The secondary ones are those that allow the primary function to develop. [7]. Once all secondary functions or subfunctions are determined, solutions are proposed to solve these functions, then select those that fit the best solution. These functions can be grouped to obtain modules that can fulfill a set of secondary functions, thus obtaining a modular design. [6]).

The functional breakdown of the process is done through flowcharts that appear each function, in which you can have 3 types of inputs and outputs: control, material and energy. Flow diagrams are presented at different levels, starting with level 0 or global function, and continuing to the level that is convenient. [7]

C. Definition of modules

The modularity consists of dividing the product into several functional or constructive blocks (modules). The design of products considering the modularity helps enormously in several aspects such as cost reduction, level of automation to be performed, ease of maintenance, and ease of production. [7]

Since several functions are fulfilled within the cheese processing process, it is advisable to carry out a modular division. For this, the functional diagrams in Figure 1 are carefully analyzed to establish the most appropriate modular division considering the interfaces of energy, material, and signal flows. [7]

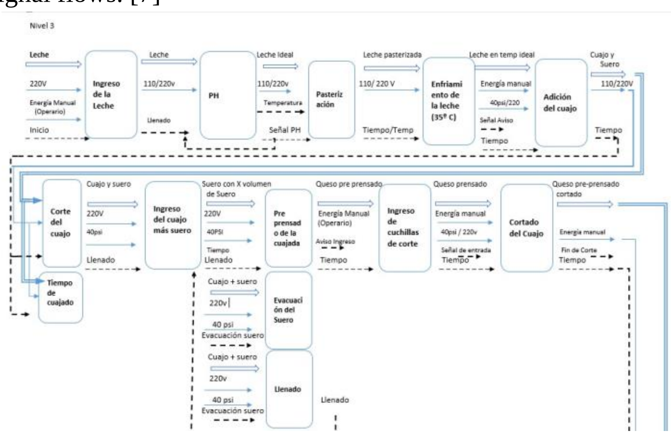

Fig 1 Modular Division (modules of the elaboration process)

When studying the functional diagram four main sets of functions can be established:

• The intake of milk from the raw material intake function to the permitted pH census.

• Pasteurization and cooling. In this module they have a relation of signals and energy.

• In the preparation goes from the addition of the rennet to the total time of curdling equally with a ratio of its signals.

• The extraction of the serum in this process goes from the entrance of the rennet plus serum to the squeegee, continuing with the pre-pressing and the evacuation of the serum arriving until the cut of the curd by means of blades.

This first division has been affected by the relative dependence with which these four sets of functions operate. The first of these sets is responsible for entering the raw material into the machine.

The second has the task of pasteurizing and reaching the correct temperature. The third process is that of preparation with the addition of rennet. It is considered that there is dependence between these sets since there is a material flow interface, which means, in other words, that these processes cannot operate with separate. As for the fourth process, there is an independence with the previous processes so that the extraction of the serum and the pre-pressing can be developed without interaction of the preparation process.

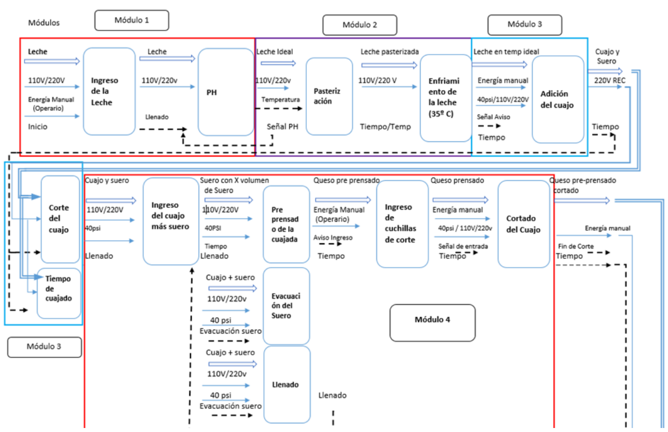

Fig 2 Functional Analysis of the process.

D. System Description

In the development of the elaboration of mature cheeses there are two main points such as the preparation, the extraction of the serum and maturation. In which there are various devices that intervene in the process. Therefore, the need for a detailed description of each of the steps of the process.

E. Flow chart.

In the flowchart is a graphical representation of the steps in the process. This diagram is useful for determining how the process works. The diagram is used in most of the phases of the process for continuous improvement, especially in the design and implementation of solutions and process procedures. [8]

F. Description of system equipment

In the system different devices are used which were explained in the functional analysis and the modular analysis with their corresponding groupings according to their interrelation both in their inputs and their outputs.

G. Selection of the PLC

In the Automation of the prototype of cheese production line, this project has the purpose of reaching an industrialization of the process mentioned above, we will start using a PLC as a controller. The determination of inputs and outputs required in the system is typically the main characteristic in the selection of a controller having a wide number of digital and analog inputs and outputs (voltage or current signals, pulses of 0/5 V, 0 / 24 V, alternating voltages 110 V, 220 V, continuous voltages 12/24/48 V, etc.), managing multiple devices simultaneously (sensors, actuators, etc.), with a more precise control of the process depending on the brand and configuration of these equipment, provide a higher speed of response, flexibility in its programming, depending on the application can be used expansion modules for more specific applications, we can use HMI depending on the manufacturer a display option and relationship with the operator are some of the features that were taken into account when selecting a PLC therefore the selection of this device. [9]. A selection matrix with a score of 5 points according to the disadvantages indicated by the different alternatives in the subsections (equipment cost, software cost, expansion capacity, HMI intercommunication, expansion capacity, minimum inputs and outputs, use from external sources), we took into account the data obtained in the decision matrix and considering the needs of this prototype, we can determine that the most optimal and viable alternative for the case presented, and for the indicated characteristics of inputs and outputs, a 24 I / O XINJE XC3-24RT-E PLC shall be used for the above-mentioned characteristics.

H. PLC Programming

There are two forms of programming for the PLC: The heuristic or informal method (memory function) and the formal method (GRAFCET). The grafcet method is the one that best matches our automation, therefore it is the method to be used. First, the diagram, which consists of a graphical diagram of stages and transitions, by means of which the programming of the chosen PLC can be easily carried out according to the software of the same one. [8]

According to the GRAFCET diagram, the inputs and outputs involved in the program are described for better visualization of the program. This helps in part to the next stage that refers to the programming of the PLC.

It must be considered to make an environment diagram with the inputs which provide the information necessary for the control system to start the process and thus provide outputs from the control system that handles or controls the PLC figure3.

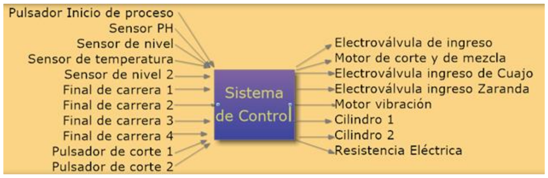

Fig 3 Diagram Grafcet of the process

I. GRAFCET Diagram

According to the GRAFCET diagram, the inputs and outputs involved in the program are described for better visualization of the program. This helps in part to the next stage that refers to the programming of the PLC. Figure 4 shows the grafcet plot developed from the prototype.

J. Programming in the xcppro software

Once the selection of the PLC has been made and the Xinje XC3-24RT-E 24 I / O PLC is the best alternative, we will use the free xcppro version 3.3 software. The language of this software is the Ladder or graphic programming very popular within the PLCs. For the part of the human-machine interface (HMI) operator panel used 4 monochrome lines with TOOL OP20 software with a graphical programming language to communicate with the PLC. Our program was based on three stages that are detailed below.

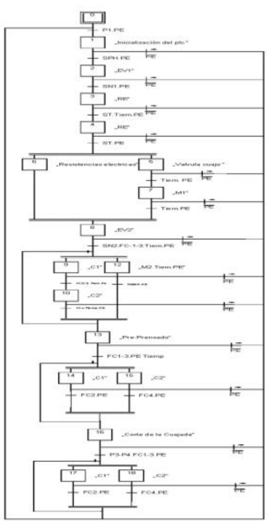

Fig 4 Diagram Grafcet of the process

K. Data Acquisition.

Reading of the signals of the different sensors distributed throughout the prototype such as PH sensors, temperature, tank filling, sash, and end of stroke.

L. Control

Develop control or command actions of the system sent from the PLC to the actuators and pre-actuators of the prototype.

M. Dialogue Man machine

Maintain a communication with the process operator, obeying his orders and informing the status of the process. For this stage there is an operator panel in which the operator of the process status will also be informed with luminous signals at different critical points in the system.

N. Mathematical modeling of the temperature part

As for the mathematical modeling of the preparation temperature part, the data acquisition method was used. Basically, the model is a tool that allows us to predict the behavior of our process.

O. Data Acquisition

In terms of data collection, we use an acquisition card (NI MYDAQ). This card made a census and a storage in a .xlsx file, with a temperature sensor PT100 and a nickel to be used in the process. The acquired data to be used in the modeling are: the input signal the temperature obtained by the temperature sensor signal conditioner (Voltage of the conditioner 0-10V) and output signal the voltage of the card to the solid-state relay (0-10V output voltage) the two values stored in the .xlsx file to perform plant modeling.

P. Data Modeling.

The part of the data management conducted in the MATLAB software with your ident to build the mathematical model of the system from input-output (voltage-voltage conditioner) tool. Using time domain data to identify the transfer function. The tool also provides algorithms for estimating different parameters and minimizing error prediction.

With a sampling time of 100 ms and the data obtained by the data acquisition card (MyDAQ), they were taken to the Matlab software and its ident tool, obtaining the transfer function that governs the relation between the 10V input to the nickel with its respective circuit and feedback by Pt100 sensor with 0-10v signal conditioner with a range of -50 oC to 100 oC a function of our system with an acceptance percentage of 95.17% was obtained.

$$\frac{7.031e-07}{s^3 + 0.006814\, s^2 + 0.000135\, s + 3.385e-07}$$

Fig 5 Transfer function (Data obtained after applying the ident command of Matlab)

Q. Tuning the Controller.

Once the transfer function of our plant was found, a PID controller was selected. The controller is fed back, the purpose of the proportional part is to accelerate the response of our system producing an offset or steady state error, by means of the use of an integral action it is possible to decrease and eliminate said offset caused by the proportional action. The derivative part of the controller can anticipate the future with a predictive effect on the output of the process.

For tuning the controller, the Ziegler-Nichols Rules will be used to tune PID controllers. Ziegler and Nichols proposed rules to determine the values of the proportional gain Kp, the integral time Ti and the derivative time Td, based on the transient response characteristics of a specific plant.

R. Ziegler - Nichols Tuning Rule

The PID controller has the transfer function.

Equation 1 PID controller transfer function [6]$Gc(s) = Kp\left(1 + \frac{1}{Ti\,s} + Td\,s\right)$

Applying a Ziegler-Nichols tuning rule for the determination of the values of the parameters Kp, Ti and Td.

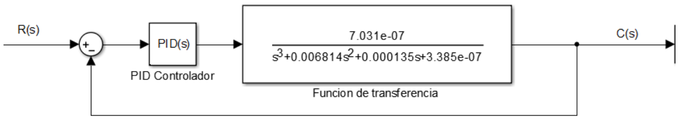

Fig 4 System with a PID controller

Step 1. Establishing Ti = □ and Td = 0, we obtain the closed loop transfer function as follows:

Equation 2 Closed loop transfer function

$$\frac{C(s)}{R(s)} = \frac{7.031e^{-7}.Kp}{s^3 + 0.006814s^2 + 0.000135s + 3.385e^{-7} + 7.031e^{-7}.Kp}$$

Step 2. The value of Kp that makes the system marginally stable for a sustained oscillation to occur is obtained by the Routh stability criterion. Since the characteristic equation for the closed-loop system is:

Equation 3 Characteristic equation for the closed-loop system

$$s^3 + 0.006814s^2 + 0.000135s + 3.385e^{-7} + 7.031e^{-7}.Kp = 0$$

Routh's arrangement becomes:

$$\begin{array}{lll} S^3 & 1 & 0.000135 \\ S^2 & 0.006814 & 3.385e^{-7} + 7.031e^{-7}.Kp \\ S^1 & \frac{(0.006814\ x\ 0.000135) - (1\ x\ 3.385e^{-7} + 7.031e^{-7}.Kp)}{0.006814} & \end{array}$$

Step 3. Examining the coefficients of the first column of the Routh array, we find that a sustained oscillation will occur if Kp = 0.8268951785. Therefore, the critical gain Kcr is: Kcr = 0.8268951785

With the gain Kp set equal to Kcr = 0.8268951785 the characteristic equation becomes:

$$s^3 + 0.006814s^2 + 0.000135s + 0.8268951785 = 0$$

Step 4. To find the frequency of the sustained oscillation, we

Fig 5 Values of the controller tuned by Matlab.

substitute s = jw in the characteristic equation, as follows:

$$jw^3 + 0.006814jw^2 + 0.000135jw + 0.8268951785 = 0$$

$$0.006814jw^2 + 0.8268951785 = 0$$

$$0.006814jw^2 = -0.8268951785$$

$$jw^2 = -\frac{0.8268951785}{0.006814}$$

$$w = 11.0160\ Hz$$

Step 5. From this we find that the frequency of the sustained oscillation is w = 11.0160 Thus, the period of sustained oscillation is:

$$Pcr = \frac{2.\pi}{w} = 0.57036860$$

Step 6. We determine the values of Kp, Ti, Td as follows:

Kp=0.6Kcr= 0.496137

Ti=0.5Pcr= 0.285184

Td=0.125Pcr=0.35124

Step 7 We substitute the values in the transfer function of equation 1:

$$Gc(s) = Kp\left(1 + \frac{1}{Ti\,s} + Td\,s\right)$$

$$Gc(s) = 0.4961(1 + \frac{1}{0.28518s} + 0.07129s)$$

$$Gc(s) = \frac{0.035366969s^2 + 0.141477s + 0.4961}{0.2851s}$$

The closed loop transfer function C (s) / R (s) is obtained by Figure 5.

Equation 4 Transfer function closed loop applied a theoretical PID.

$$\frac{C(s)}{R(s)} = \frac{7.09143e^{-9}s^2 + 3.48807e^{-8}s + 9.9472e^{-7}}{0.2851s^4 + 1.9426714e^{-3}s^3 + 3.84885e^{-5}s^2 + 9.65e^{-8}s}$$

The maximum amount exceeded is excessive. Fine tuning reduces the parameters of the controller. This tuning is done in engineering software by reducing the reference values of Kp, Ti, and Td. After having reduced the reference values with the help of Matlab software and its Simulink tool, the following answer was found.

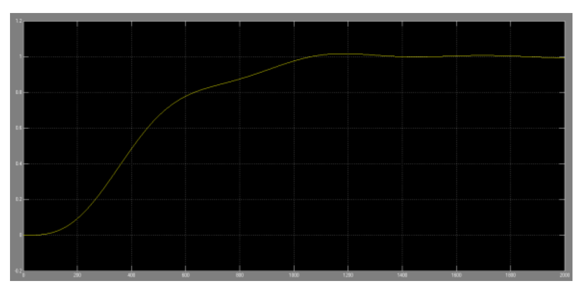

Fig 7 Response after applying the PID controller

Fig 8 Characteristics of the transfer function applied a PID control

In making a brief comparison between the transfer function of the plant as seen in Fig. 9 and the transfer function applied a tuned PID controller shown in Fig. 10 there are large differences, such as the lifting time which is required for that the answer reaches 95% of its final value.

Significant differences in the values of the lifting and settling times show that the times are smaller and give a better performance in the transfer function with a PID controller. With a smaller overpass than the transfer function figure 9 indicates that with a lower gain can be achieved to stabilize faster observed in figure 10 and without over peaks in the response so many have better results with a PID controller.

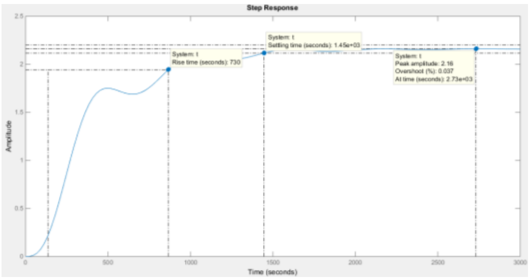

Fig 9 Features of the transfer function without the PID controller.

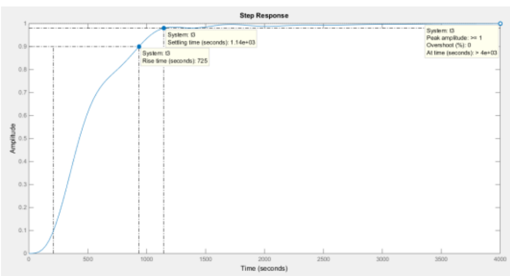

Fig 10 Characteristics of the transfer function applied a PID control

S. Design of the control panel.

For the design of the control board was split with standard measures of the market, having a wide range of measures starting from 60x40x20 cm these measures found more easily and taken to mechanical design software in which we assemble the devices with real measurements give us an idea of the final board. Once the assembly is completed, the stockings are obtained.

1) Front Panel

The front panel considered characteristics and recommendations that facilitate the interaction of the user and the system. Different levels were considered starting from a first level from a switch of ignition that energizes all the devices of the control board, as second level considered the HMI in the central superior part that allows to the operator to have a greater field of vision of her, a third arrangement is to the light signals which allow to observe which process is being developed or the device that is in operation, Next, an emergency stop was arranged which is in a place of easy and fast operation. Finally, the two push-buttons were placed at the end of the front panel so that the operator uses both hands for this operation. Figure 11 shows a raised front panel model.

Fig 11 Control Panel Front Panel

2) Internal Panel

In this panel there were several considerations in the placement of the devices a hierarchical arrangement. At the top you have the power guards, power terminals and power supply. Then, the main part of the board controls you in this case takes the PLC responsible for the whole process is carried out. Finally, drive, conditioning, sensing, and terminal devices were arranged which have the external connections to the board. In figure 12 it is possible to appreciate the proposal of internal panel of the board.

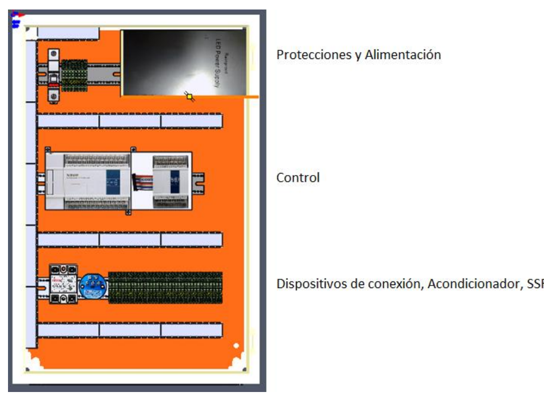

Fig 12 internal panel

T. Calculation for cable selection

For the part of the selection of cables will be considered the power and power from an alternating 120v / 60Hz power supply will be fed to 24v / 5A power supply, a PLC, a nickel of 1000w. The table below shows the maximum amount of current that the cables support, so a comparison was made between 16 AWG gauge supporting 8 amps and the conductor 14 with a maximum current capacity of 20 therefore the selection is the 14-gauge. For the internal wiring, the source current that is equal to 5 A was considered as a result the number 16AWG was selected.

Table 1 Power consumption of the elements

Element	Potency	Corrientes
Fuente 24V/5A	120W/120V	1 a
Niquelina	1000/120V	8.33 A
PLC	12W/120V	0.1 A
	Total:	9.43 A

Table 2 Awg cable characteristics chart and gauge selection 14-16

		H	HILO	COND	APROX	PROM	APROX	APROX	APROX	*	**
	AWG	#	mm	mm	Kg/Km	mm	mm	Kg/Km	Kg/Km	Amp	Amp
TF	18	1	1,02	1,02	7,32	0,76	2,54	5,96	13,28	6	7
TF	16	1	1,29	1,29	11,62	0,76	2,81	6,85	18,47	8	10
TWS	14	1	1,63	1,63	18,51	0,76	3,15	7,98	26,49	20	25
TWS	12	1	2,05	2,05	29,40	0,76	3,57	9,40	38,80	25	30
TWS	10	1	2,59	2,59	46,76	0,76	4,11	11,19	57,96	30	40
TWS	8	1	3,26	3,26	74,39	1,14	5,54	22,08	96,47	40	60
TWS	6	1	4,12	4,12	118,23	1,14	6,40	26,35	144,58	55	80
TWC	8	7	1,23	3,70	75,91	1,14	5,98	27,10	103,01	41	62
TWC	6	7	1,55	4,66	120,39	1,52	7,70	45,80	166,19	57	82
TWC	4	7	1,96	5,88	191,71	1,52	8,92	56,61	248,32	70	105
TWC	2	7	2,47	7,42	305,13	1,52	10,46	71,12	376,25	95	140
TWC	1/0	19	1,89	9,46	484,38	2,03	13,52	115,10	599,48	125	195
TWC	2/0	19	2,13	10,63	611,61	2,03	14,69	128,83	740,44	145	225
TWC	3/0	19	2,39	11,94	771,64	2,03	16,00	144,66	916,30	165	260
TWC	4/0	19	2,68	13,40	971,89	2,03	17,46	162,87	1.134,76	195	300

U. Calculation of protections.

For the calculation of protections, the maximum current consumption of each of the elements in Table 1 is considered. And the nominal current as constant 1.5.

Equation 5 Formula for calculation of protections.

$$Proteccion = 9.43A \ x \ 1.5 = 14.15A$$

The value obtained was 14.15 A in the market was found a circuit breaker against loads of 16 A.

IV. Results

You obtain a control board with the characteristics mentioned above in the part of the design, with the market measures of 60cm in height, 40cm in width and 20cm in depth. With the arrangement of the devices of the front panel which allows visualization of the development of the process figure 13. The internal part has the protections, control (plc) and connection terminals in figure 14 shows the internal part of the board.

Fig 13 Control Panel Front Panel

Fig 14 Control panel internal panel

A. PH

The sensing part will be carried out with a pH sensor, it gives us an analog type output with a measurement range of 0-10v corresponding to values of 2 - 12 pH, these measured values are acquired by the PLC and analyzed. Said analysis within a range of 6.5 to 6.8 are the minimum and maximum values, within that range the raw material can be used for cheese processing. The measurement is shown on the HMI screen after an analogue-digital conversion is performed for the display of the pH value. In the conversion there is a digital value of 16383 corresponding to the analogue maximum values of input l0v.

B. Input Raw Material

In the input of raw material, the preparation tank after the pH sensing in the same way was used an analog sensor with a control of maximum filling of the tank, according to the arrangement of the quantity of raw material a manual option was used in programming the PLC is given a dynamic mode of different quantity of milk. For this process a digital analogue conversion was not performed on the screen directly shows a digital value that refers to the level of the tank.

C. Pasteurization

The following process after filling the tank is processed to a batch or slow pasteurization which has a minimum temperature of 62 ° C and maximum of 65 ° C. In this process there is a time of 30 minutes in accordance with the standard NTE INEN 0010 which specifies the time and temperature, in the tests carried out applying the PID controller it is observed that it is kept within the proposed ranges with small temperature variations 66. 4 ° C a maximum value which is acceptable in the acceptable prototype.

D. Preparation.

By means of a natural cooling after the pasteurization process is completed and according to the characteristics of the rennet, as average addition temperature 35-37 ° C, a set time or preparation time of 40 minutes. The addition of rennet was done by means of a solenoid valve. The mixing and cutting are performed by a motor with a mechanism suitable for this process. Also, that the above procedure has a temperature control by the PID control by the PLC.

E. Filling the Zaranda

Once the preparation is finished the mixture will be brought to the squeegee, the passage of the mixture is controlled by means of an electro valve which closes its passage once the analog level sensor detects the maximum quantity. Programming two types of filling arranged it, one normal reaching the maximum levels of said squeegee, and one filling which the operator selects to continue the process with an amount different from the maximum set.

F. Serum Extraction

For the extraction of serum from the mixture, a motor was used for the vibration procedure and two pneumatic cylinders which with the sequence + A, -A, + B, -B resulted in a greater serum extraction with the combination of the two mechanisms.

G. Pre-Pressed.

The extraction and pre-pressing processes are used to separate the excess serum from the curd. For the pre-pressing only the cylinders are used, deactivating the vibration motor. The sequence of the actuators is + A. + A, -B, -B.

H. Cut.

In the process of cutting using the same mechanism, the operator is indicated with a light signal the change of the cutting blades. Once the blades make the change two pushbuttons P1-P2 are presented to perform the cut.

I. PID Controller

From the raised controller and to perform several tests starting from the theoretical values obtained, the following results were obtained:

J. Theoretical values

When implementing the theoretical values in the PID of the plc, a maximum peak of 72º C was obtained, with a stabilization time of 6 minutes. Therefore, based on these results, a new PID controller tuning is proposed, starting from the theoretical values. In the preparation part with a lower temperature, it does not tube errors as in pasteurization with a maximum peak of 36.8 ° C.

K. PID Calibration.

When performing a new calibration in the PLC controller of the PLC with values recommended by the PLC manufacturer according to thermal processes and considering the theoretical controller of the Ziegler Nichols tuning rules, the values were found.
With the calibration and the new ones, a maximum peak of 66.5 ° C was obtained which is smaller than the theoretical peak obtained and a stabilization time of 2 minutes. The PID controller with the maximum peak and lower settling time is acceptable for this process in which a maximum temperature range of 65 ° C according to the NTE INEN 0010 standard is therefore established as final values of the controller.

V. CONCLUSIONS

Because of this research, it is possible to conclude that the factors that influence the quality of the mixture of the preparation are: The ideal temperature in this case the pasteurization temperature of 62-65 ° C, with a maximum difference obtained from 0 49 ° C degrees between measurements in a measuring range of 3 ° C therefore this variation does not affect the process. In the addition of rennet is 35 ° C said value is given by the manufacturer of the coagulating agent which must be considered at the time of programming and calibration, the amount of rennet to be added according to the volume of raw material was determined as a major impact factor in the preparation. Another very important factor is the pasteurization time 30 min, mixing time 35 min and curd cut in these cases the time indicated by the manufacturer of the rennet or based on the regulation of this activity.

The programming developed based on grafcet diagram with sequences of times between the processes of preparation, serum extraction, pre-pressing and cutting. Implemented in the PLC influenced the automation of the prototype with continuous production, efficient and minimal intervention of the operator.

A control board in which they cover features that facilitate human interaction with a machine with a luminous display and signals. In this board the automation system was implemented with the control devices.

Tests and calibrations were performed according to standards such as NTE INEN 0009 for handling raw milk and NTE INEN 0010 according to pasteurization characteristics.

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