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SUPERVISION OF AN INDUSTRIAL PROCESS USING ARTIFICIAL INTELLIGENCE

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Abstract - Process controls (basic as well as advanced) are implemented within the process control system, which may mean a distributed control system (DCS), programmable logic controller (PLC), and/or a supervisory control computer. DCSs and PLCs are typically industrially hardened and fault-tolerant. Supervisory control computers are often not hardened or fault-tolerant, but they bring a higher level of computational capability to the control system, to host valuable, but not critical, advanced control applications. Advanced controls may reside in either the DCS or the supervisory computer, depending on the application. Basic controls reside in the DCS and its subsystems, including PLCs. Because we usually deal with real - world systems with real - world constraints (cost, computer resources, size, weight, power, heat dissipation, etc.), it is understood that the simplest method to accomplish a task is the one that should be used. Experts usually rely on common sense when they solve problems. They also use vague and ambiguous terms. Other experts have no difficulties with understanding and interpreting this statement because they have the background to hearing problems described like this. However, a knowledge engineer would have difficulties providing a computer with the same level of understanding. In a complex industrial process, how can we represent expert knowledge that uses vague and fuzzy terms in a computer to control it? In this context, the application is developed to control the pretreatment and pasteurization station of milk localized in Batna (Algeria) by adopting a control approach based on expert knowledge and fuzzy logic.

Keywords - Intelligent Control; Data Acquisition; Industrial Process Control; Fuzzy Control.

I. INTRODUCTION

The overall process control objectives, such as the quality and the quantity of product, have been left in the hands of human operators in the past. Nowadays, computational intelligence has been used to solve many complex problems by developing intelligent systems, extracting expert's knowledge. Fuzzy logic has proved to be a powerful tool for decision-making systems, especially expert and pattern classification systems. Fuzzy set theory has been used in some chemical processes.

In traditional rule-based approaches, knowledge is encoded in form of antecedent-consequent structure. When new data are encountered, it is matched to the antecedent's clause of each rule, and those rules where antecedents match a data exactly are fired, establishing the consequent clauses.

This process continues until the desired conclusion is reached, or no new rule can be fired. In the past decade, fuzzy logic has proved to be useful for intelligent systems in chemical engineering. Most control situations are more complex than we can deal with mathematically.

In this situation, fuzzy control can be developed, providing a body of knowledge about the existing control process, in the form of a number of fuzzy rules. Fuzzy logic is used for the early detection of hazardous states and for the implementation of logic decision-making. In this work, the expert's knowledge was extracted and fuzzy logic was integrated in the SCADA system to control an industrial process, milk production, to resolve problems and replace the old supervision system by a new architecture. The advantages of this architecture is its flexibility in control, its ability to data process a lot of information in order to improve the productivity and to reduce maintenance costs. In Section 2, related works concerning fuzzy logic are presented. Section 3 is dedicated to the case study and the proposed approach. The implementation and the results of the developed system are discussed in Section 4. We conclude and discuss the results in a conclusion.

II. FUZZY LOGIC BASED WORKS

In reasoning about a complex system, humans reason approximately about their behaviors, thereby maintaining only a generic understanding about the problem. Fuzzy logic adds a range of logical values to Boolean logic. Classical binary logic now can be considered as a special case of multi-valued fuzzy logic [1].

The generality and ambiguity are sufficient for human comprehension of complex systems. As the quote above from Zadeh's principle of incompatibility suggests that complexity and ambiguity (imprecision) are correlated: "closer one looks at a real-world problem, the fuzzier becomes its solution" [2].

Complex industrial processes, such as a batch chemical reactors, cement kilns and basic oxygen steel making are difficult to control automatically. This difficulty is due to their non-linear, time varying behavior and the poor quality of available measurements. In such cases, automatic control is applied to those subsidiary variables, which can be measured and controlled, for example temperatures, pressures and flows. The overall process control

objectives, such as the quality and quantity of product, has been left in the hands of human operators in the past [3].
Security and reliability needs require the implementation of preferment solutions, such as artificial intelligence techniques. Expert systems and fuzzy logic are the most useful techniques to control industrial processes. Expert systems have the ability to process information with real time updating, deal with uncertain or incomplete knowledge, incorporate new knowledge into the program easily and put less pressure and responsibility on the human operator and it can evaluate the effect of different manufacturing parameters [4].

Fuzzy logic has rapidly become one of the most successful of today's techniques for developing sophisticated control systems. The reason is very simple, fuzzy logic addresses such applications perfectly as it is similar to human decision making with ability to generate accurate solutions from uncertain or approximate information. It fills an important gap in engineering design methods left vacant by purely mathematical approaches (linear control design), and purely logic-based approaches (expert systems) in system design [5].

Fuzzy logic offers several advantages that make it a particularly good choice for many control problems. It can control either linear or non-linear systems that are difficult or impossible to find a mathematical model. For this reason, fuzzy logic is integrated in several works and applied in different domains, in process control, decision making [6], as well as in failure mode and effect analysis [7].

III. CASE STUDY: MILK PRODUCTION

Production milk process
There are various products in the studied industrial system, pasteurized milk (milk for consumption), sterilized, fermented (called Laban), steamed yogurts, brewed and fresh cheese. To obtain a final milk product, the process is composed of several steps:

- Step 01: Milk receiving unit used to collect and analyze the milk.
- Step 02: Pretreatment unit contains 03 parts:
- Plate Heat Exchanger: the goal is to exterminate the bacteria.
- The degasser: used to remove the air present in the product.
- The homogenizer: used to make the products more homogeneous, which helps to improve their quality and extend their duration of the conversation.
- Step 03: Pasteurization unit to exterminate the bacteria, and ensure the safety of the product.
- Step 04: Storage unit allows storing the milk before sending it to pasteurization.

The process of milk production passes through two principal workshops, i.e., Pretreatment and Pasteurization:

a) **Pretreatment station**
The process of the pretreatment station is composed of the following parts:

i. Plate Heat Exchanger:
It consists of a number of heat transfer plates, deposited in such a way that a passage between two plates is accessible to each of the two liquids (water and milk). It contains five sections:

- Section 01 (heating section): Composed of hot water from (60 to 71) C°.
- Section 02 (heating section): Composed of hot water (64 to 70) C° and milk, this section heats the milk from (58 to 68) C°.
- Section 03 (Recovery Section): Composed of hot milk and cold milk. This section allows for heat exchange with convection to conserve energy, and heat the milk gradually.
- Section 04 (cooling section): Composed of tap water from (30 to 42) C° and milk. This section allows the milk to cool from (42 to 30) C°.
- Section 05 (cooling section): Composed of cold water (2 to 4) C°.

ii. Degasser
The milk preheated to 68 ° C is introduced tangentially into the vacuum vessel. The steam gases rise up the chamber and are sucked by the vacuum pump, and the steam condenses in the condenser and returns to the milk.

iii. Homogenization
Homogenization step consists in passing the milk under high pressure to 60 bars through very narrow orifices, which reduce the size of the fat globules and partially destroy the casein micelles.

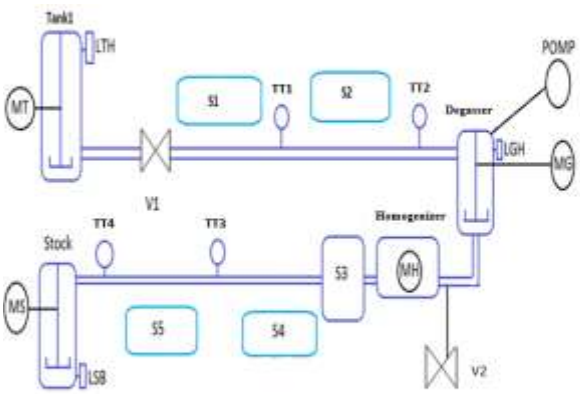

Fig-1Schematic of the Pretreatment station.

b. Pasteurization station
To carry out the pasteurization (Figure 2), a plate exchanger is used. The plate heat exchanger is composed of five stations, heating (S1P and S2P), recovery (S3P) and cooling (S4P and S5P).

- Section 01P (heating section): Composed of hot water from (60 to 70) C°.
- Section 02P (heating section): Composed of hot water (96 to 100) C° and milk, this section heats the milk from (90 to 95) C°.
- Section 03P (Recovery Section): Composed of hot milk and cold milk. This section allows for heat exchange with convection to conserve energy, and heat the milk gradually.
- Section 04P (cooling section): Composed of tap water from (32 to 35) C° and milk. This section allows the milk to cool from (32 to 35) C°.
- Section 05P (cooling section): Composed of cold water (8 to 10) C°.

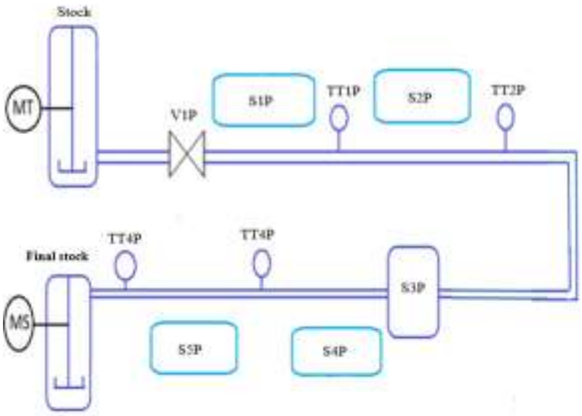

Fig2. Schematic of the pasteurization station.

B. Problems and proposed solutions

During the internship within the company Aures Batna, and after the collection of the information, we observed the following shortcomings of the system:

- The production system of the unit is not automatized.
- Lack in the old system of supervision, which is not an HMI.
- There is no quality control feedback at the pretreatment and pasteurization stations.

Lack of control of different equipment because most of them are very old and missing sensors for measurement.

To solve the above problems, we will try to build a powerful application that can correct the problems presented in the old system and that offers the services necessary to better supervise the stations. Our application offers the following advantages:

- Synthetic and dynamic representation, which has a graphical visualization of the behavior of the stations.
- Precise control of valves and actuators, taking into account several parameters, and at the same time the possibility of making the best decisions.
- Fuzzy control of the various equipment of the stations.
- Diagnosis of alarms that inform the operator about the status and problems of the system.
- Display messages that help the operator to make decisions.
- History of alarm occurrence with the possibilities of printing and recording.
- Secure access to the supervision system with a password and a user name.

IV. APPLICATION OF THE APPROACH IN INDUSTRY

To realize our approach, we divided it in two parts; the first one is the creation of the supervision system and the second is the creation of different fuzzy controllers in which we present one example.

A. Interface of the supervision system

After description of all steps parameters, we created a graphical programming in LabVIEW (Figure 3); we designed the supervision system that offers the following solutions:

- The system is no longer in half-automatic mode using solenoid valves and the implementation of fuzzy logic as a control technique.
- Now, we have a feedback circuit for quality control in the station to ensure the stability of the system.
- A system for generating alarms to identify and localize alarms.

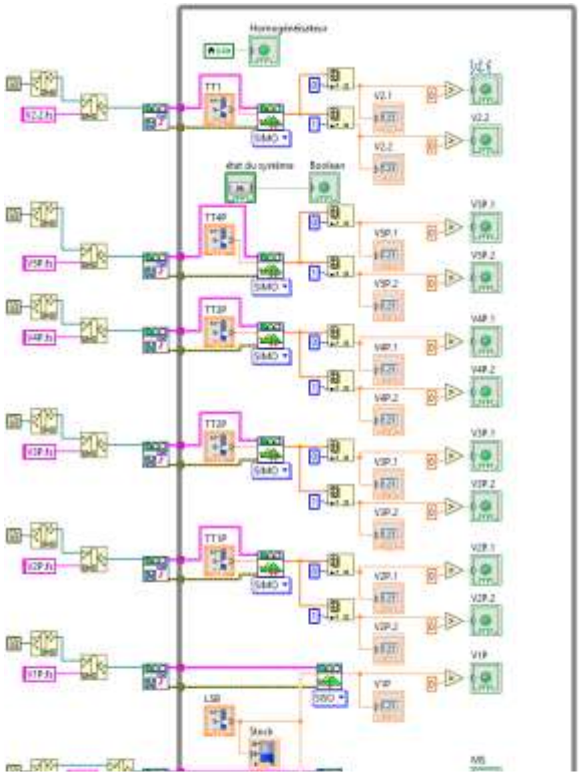

Fig3. Part of the Block diagram of the control system.

Operators and engineers use HMIs to monitor and configure set points, control algorithms, and adjust and establish parameters in the controller. The HMI also displays process status information and historical information. To solve different problems in the workshop, we proposed to insert a feedback circuit in the process controlled by an HMI to control again the temperature of the product. This circuit is controlled by a fuzzy loop (Figure 4); it ensures the desired quality of the product and avoids its rejection like the situation in the installed system controlling different stations.

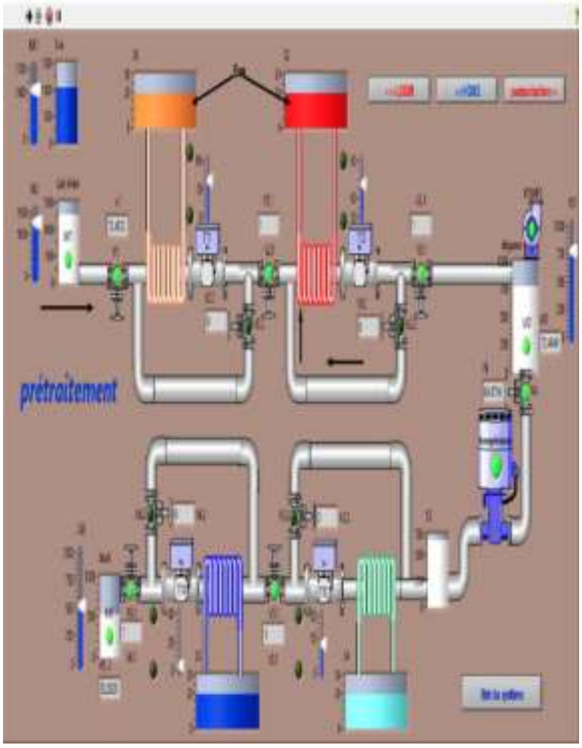

Fig4. Implementation of the feedback circuit in the pretreatment station.

Diagnostics and maintenance utilities are used to prevent, identify and recover from abnormal operation or failures. In this reason, we created an interactive interface that locates exactly the alarm and its nature that signals the existence of an abnormal condition (for example, high pressure, max level in tank, etc.). To see all the generated alarms, a register of alarms was created. Figure 5 shows a block diagram that illustrates the system generating alarms and defaults.

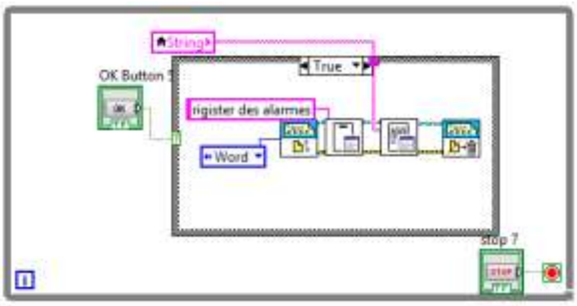

Fig6. Block diagram of alarms generating system.

B. Creating Fuzzy Controllers

The creation of fuzzy controllers consists of two steps, establishing the relationship between inputs and outputs by fuzzy controller file Virtual Instrument (VI) and calling Fuzzy Controller files that contains the rules and membership functions of the fuzzy controller.

We presented in Table II some parameters used by the workshop, with their specifications, that will be used to control different stations.

Parameter	Definition	Type	Value
NE1	Main water tank level sensor	Input	0-15000L
NLI	Initial milk tank level sensor	Input	0-15000L
MT	Engine of the initial milk tank agitator	Output	0%-100%
V1	Solenoid valve of milk	Output	0%-100%
V2.1, V2.2	Solenoid valve of milk	Output	0 ;1
TT1	Section 1 Temperature Sensor	Input	0°C-100°C
TT2	Section 2 Temperature Sensor	Input	50°C-80°C
V3.1, V3.2	Solenoid valve of milk	Output	0 ;1
ND	Degasser Level Sensor	Input	0-10000L
PUMP	Pump in the degasser for ejecting gases	Output	0 ;1
MD	Engine of the degasser agitator	Output	0%-100%
V4	Solenoid valve of milk	Output	0%-100%
Homogenizer	Homogenizing motor	Output	0 ;1
TT3	Temperature sensor of section 4	Input	0°C-80°C
V5.1, V5.2	Solenoid valve of milk	Output	0 ;1
TT4	Section 5 temperature sensor	Input	0°C-40°C
V6.1, V6.2	Solenoid valve of milk	Output	0 ;1
MS	Stock tank agitator motor	Output	0%-100%
LSB	Stock level sensor	Input	0-10000L
V1P	Solenoid valve of milk	Output	0%-100%
TT1P	Temperature sensor of section 1P	Input	30°C-80°C
V2P.1, V2P.2	Solenoid valve of milk	Output	0 ;1
TT2P	Temperature	Input	50°C-

	sensor of section 2P		110°C
V3P.1, V3P.2	Solenoid valve of milk	Output	0 ;1

Table.1. Different process's parameters

After determining all parameters, we need all conditions to control the process, which are presented in Table III.

Rules
The valve V1 opens only if the level of the two tanks (water, initial milk) > 0, and the degree of opening depends on the level of these tanks
The MT motor only operates, if the level of the milk tank > 300 L
Valve V2.1 opens only if the temperature is between 60 C° and 71 C°
Valve V2.2 opens only if the temperature is not between 60 C° - 71 C°
Valve V3.1 opens only if the temperature is between 64 C° - 70 C°
Valve V3.2 opens only if the temperature is not between 64 C° - 70 C°
The pump only operates if the degasser level > 250 L
The MD motor operates only if the degasser level > 250 L, and the rotational speed is dependent on the degasser level.
The V4 valve opens only if the degasser level > 250 L and the degree of opening depends on the level of this tank
The Homogenizer motor operates only if the degasser level > 250 L
Valve V5.1 opens only if the temperature is between 30 C° - 42 C°
Valve V5.2 opens only if the temperature is not between 30 C° and 42 C°
Valve V6.1 opens only if the temperature is between 2 C° - 4 C°
Valve V6.2 opens only if the temperature is not between 2 C° and 4 C°
The MS motor operates only if the degasser level > 250 L, and its speed depends on the stock level
The valve V1P only opens if the stock level > 0, and the degree of opening depends on the level of this tank
The valve V2P.1 opens only if the temperature is between 65 C° - 70 C°
The valve V2P.2 opens only if the temperature is not between 65 C° - 70 C°
The valve V3P.1 opens only if the temperature is between 90 C° - 95 C°
The valve V3P.2 opens only if the temperature is not between 90 C° and 95 C°
The valve V4P.1 opens only if the temperature is between 32 C° and 35 C°
Valve V4P.2 opens only if the temperature is not between 32 C° and 35 C°
The valve V5P.1 opens only if the temperature is between 8 C° and 10 C°
The valve V5P.2 opens only if the temperature is not between 8 C° and 10 C°

Table2. Rules of control

We applied different rules to create fuzzy controllers. Figure 6 shows details of one of fuzzy controllers that controls the valve V1.

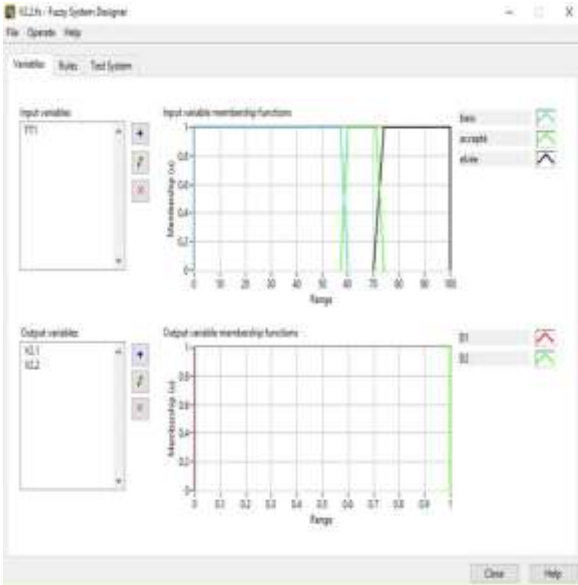

Fig6. Inputs and outputs of the fuzzy controller of valve V2.1 and V2.2.

To integrate fuzzy control, we used some fuzzy rules (Figure 7), like:

- If 'TT1' is (low 'BAS') then 'V2.1' is 'D1' and 'V2.2' is 'D2'.
- If 'TT1' is (accepted 'accepté') then 'V2.1' is 'D2' and 'V2.2' is 'D1'.
- If 'TT1' is (high 'élevée') then 'V2.1' is 'D1' and 'V2.2' is 'D2'.

Fig7. Inputs (TT1) and outputs (V2.1 and V2.2).

Results obtained according to variation in inputs, outputs and the surface generated after executing the fuzzy controller are showed in Figure 8.

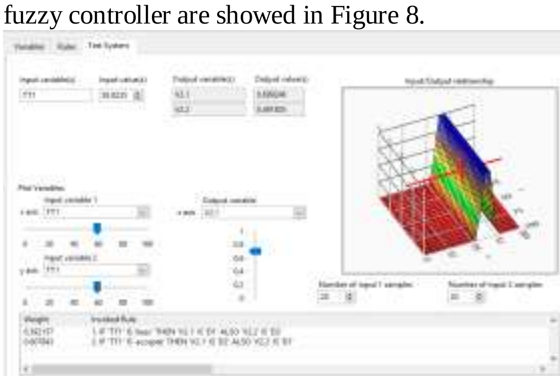

Fig8. Relationship between inputs (TT1) and outputs (V2.1 and V2.2)

We tested the system response and its performance by compare it with old controller using Matlab Simulink. The obtained results improve the advantages of the proposed method.

As hardware application, S7-300 PLC saves on installation space and has a modular design. A wide range of modules can be used to extend the system centrally or to create decentralized structures depending on the task to be performed. To connect S7-300 with LabVIEW software, we used NI OPC server to communicate between the PLC and LabVIEW interface.

V. CONCLUSION

Presently, companies often require innovative solutions to make their plant operating systems function at peak efficiency. Using latest in equipment technology, resources, and materials. However, complex industrial processes are difficult to control because of inadequate knowledge of their behavior. This lack of knowledge is principally a lack of structural detail and it is this, which prevents the use of conventional control theory. However, a human operator who makes decisions based on inexact and linguistic measures of the process state often controls these processes with great skill. Fuzzy logic is considered as a superset of standard logic, which is extended to deal with the partial truth. It has become one of the most successful technologies for developing complex control systems.

Fuzzy logic reflects how people think. It attempts to model our sense of words, our decision-making and our common sense. As a result, it is leading to new, more human, intelligent systems. Therefore, to improve control system reliability and availability, we implemented all solutions by creating a supervisory system, and we applicate different steps to ensure a fuzzy control of the system.

The main objective of these solutions is to improve the old system. The solutions given are divided into two types. The first is a material solution and we proposed a feedback circuit implemented in each section with solenoid valves to automate the system. In addition, we proposed some equipment needed to implement the application. The second one is a software solution in where fuzzy logic has been used as a technique to control the milk production process. The augmented productivity in the factory, minimum downtime, reduced costs of maintenance are improved the advantages of our solutions.

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