

Development of a Fuzzy Expert system based on PCS7 and FuzzyControl++



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ABSTRACT: *The basic idea of this work was to study the application of expert systems and fuzzy logic in the field of diagnostic and industrial maintenance. For this, a fuzzy expert system designed, developed and simulated in Ain Touta cement society in Batna in the East of Algeria. Dedicated to control cement mill. The application of fuzzy logic and expert systems to control the difference shown in the control system using fuzzy regulators for the operation of the grinding without unnecessary stops, it also helps the operator to know the maintenance task to perform. In addition, regulators decentralization allows the availability of fuzzy control, even if one of the regulators is absent, it does not prevent the other to complete its task to control fineness, mill's temperature and feed.*

Keywords: Diagnostic, Fuzzy logic, Maintenance, Expert systems, Programmable Logic Controller

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1. Introduction

In many cement industries, plant optimization is purely depending on the operator. As he was to control all the process parameters and change the set points as per requirement of the plant conduction, diagnostic alarms and maintains them. So manual intervention was more and power consumption is high.

In this paper, we propose an approach to using fuzzy logic and expert systems in cement industry for diagnostic and maintenance. This approach designed to enable wider range of advanced technologies for high-level controller design. Including fuzzy Programmable Logic Controller in cement mill by using Siemens PLC and FuzzyControl++ to control a crucial parameter determining the grinding demand is product fineness, based on real time figures for fineness and adequate control techniques; in witch, we control mill's temperature and feed.

Therefore, avoiding unnecessary over-grinding, product quality variations reducing, also, specific energy consumption reduced. Cement mill controlled, including operation stability, and feed control with clinker. Fineness's control until now; based on manually provided off-line fineness measurements strategy in Ain-Touta cement society. From a process point of view, the relatively fast dynamic response to changes in separator speed in the cement grinding process enables a fast and good control of the fineness based on continuously available figures of the product fineness.

2. Problematic

The old control systems applied in industry have shown several shortcomings, especially regarding the control of product quality. Present in the cement, the control system is based on Artificial Intelligence techniques such as fuzzy logic, expert systems, neural networks ... The SCIMAT our scope is one of them.

The expert system ECS (Expert Control & Supervision) installed at the SCIMAT, is the system of process control. It deals with the progress of diagnostic equipment and various alarms. However, an alarm to the operator knows what to do or how to maintain it. It is his experience that the guide, or extensive training.

The SCIMAT also has a system based on fuzzy logic, ECS/ProcessExpert. For the fineness fuzzy controller and the quality of the product, the problem is that the system put in place to SCIMAT on the application of fuzzy logic starts only if the system is stable. In addition, if not, it is very absent. In other words, the operation is binary in case of instability.

Our goal is to apply fuzzy logic in regulators / supervisors separately, where the decision of a regulator/controller does not require discontinuation of fuzzy control. In addition, we will apply expert systems and fuzzy logic for,

- Fuzzy regulators.
- The diagnosis of the various alarms generated during execution of the process.
- The maintenance of alarms.

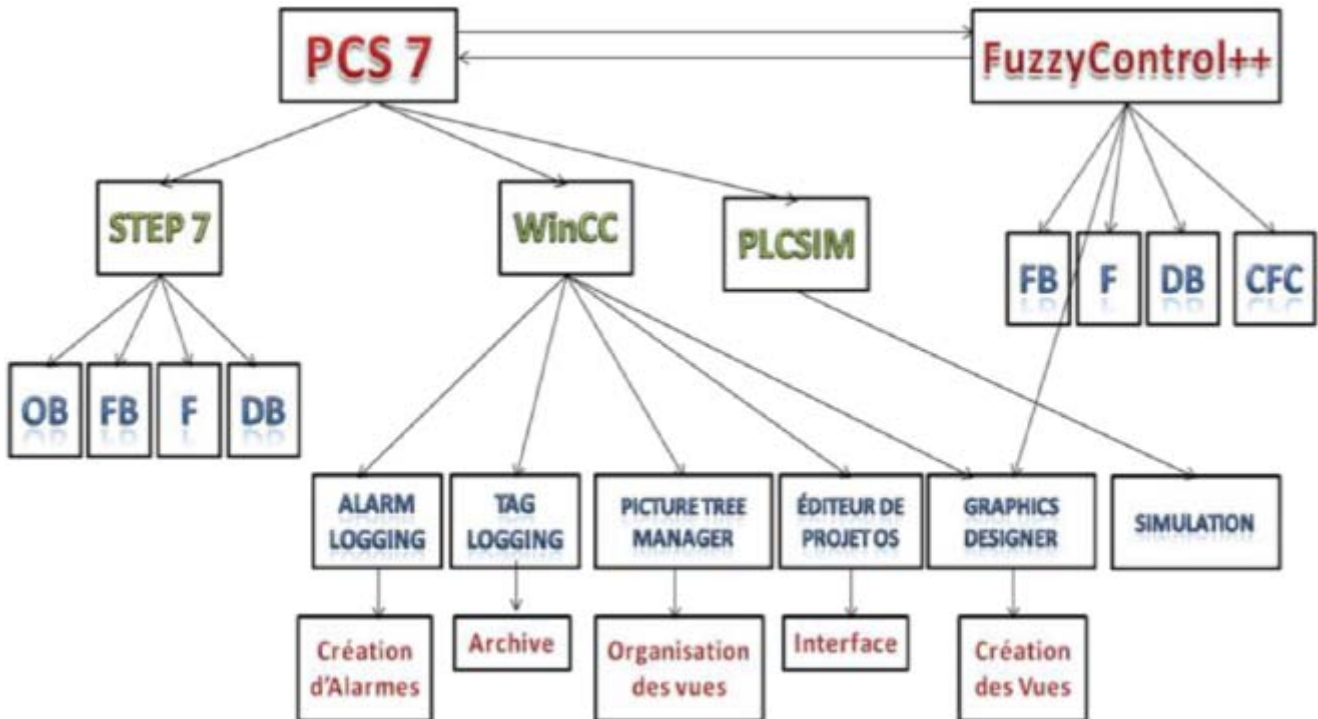


Figure 1. Tools used in our application

3. Tools Used In Our Applicatrion

Several tools are use for the realization of our application. The base is platform PCS 7 of Siemens, and FuzzyControl++ for the creation of the fuzzy controllers. The whole of the tools used in our application, is included in Figure 1.

3.1 FuzzyControl++

The FuzzyControl++ configuration tool for the automation of technical processes enables the efficient development and configuration of Fuzzy systems. Empirical process expertise and verbalized knowledge by experience can directly transformed into controllers, pattern identification or logic decisions.

Associated functions are also easy to configure with the help of FuzzyControl++. The rules are inputs either via a table or via a matrix editor. Dynamic changes of the rules basis identified immediately and, if no rule should be applicable, a value previously prescribed for each output will be use. The inference and defuzzification method used by FuzzyControl++ is the well-known Takagi-Sugeno method. FuzzyControl++ can execute on SIMATIC S7 PLCs, the SIMATIC PCS7 process control system and the WinCC SCADA system and provides special function blocks. [2]

3.2 Step 7

STEP 7 is the standard software package used for configuring and programming SIMATIC programmable logic controllers. It is a part of the SIMATIC Siemens industry software.

- Based on several types of programming: Flow chart, Contact List, SCL, Grafcet, ...
- Expandable with applications offered by the software industry SIMATIC.
- Calculation of functional modules and communication modules.
- Data transfer ordered by event using communication blocks and function blocks.
- Configuring Connections.[3]

3.3 WinCC

Siemens software for process control monitoring, it is a:

- Graphics system: display and operator control of the process pictures.
- Trend system: analysing the process.
- Message system: process diagnostics.
- Logging system: documenting the process.
- Archive system: storage and display of process values, messages and logs. [4].

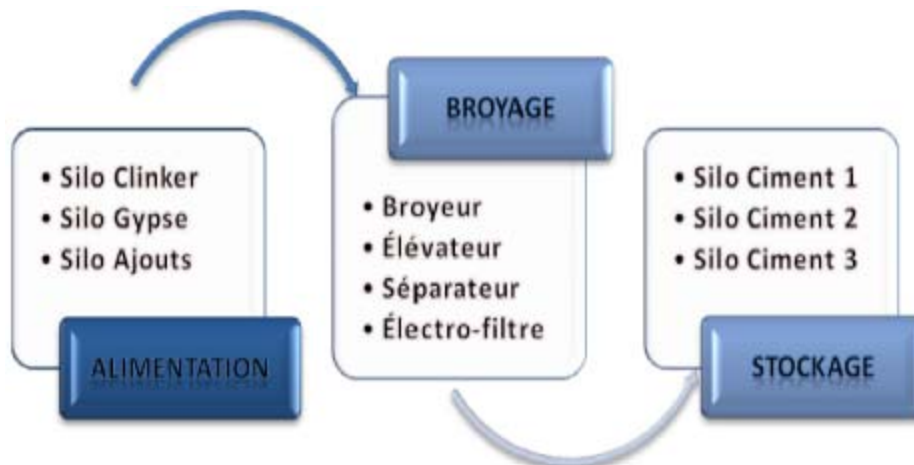


Figure 2. Cement mill process

4. Cement Mill Process

The cement mill process consists of three main parts, cement mill feed with clinker, the cement mill and cement mill storage silos as is shown in Figure 2.

4.1 Sequence starting

The starting of the equipment begins the last with the first to guarantee the availability of the equipment, and to avoid the stop of the sequence. The flow chart of Figure 3 illustrates this sequence.

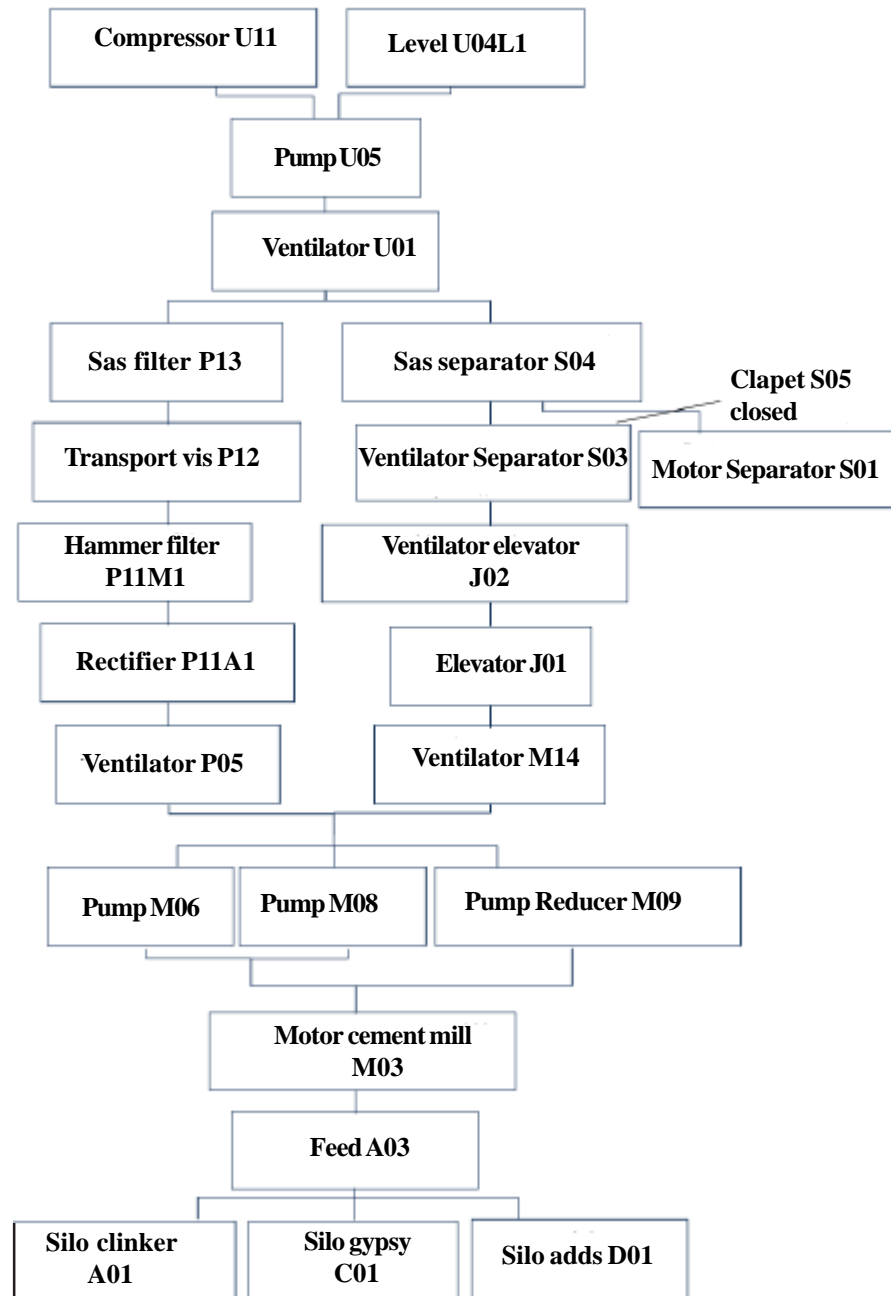


Figure 3. Equipments sequence start

4.2 Alarms and acceptance start of the program

If no alarms generated and within others conditions, the sequence restarts constantly, the of block acceptance start program is shown in Figure 4.

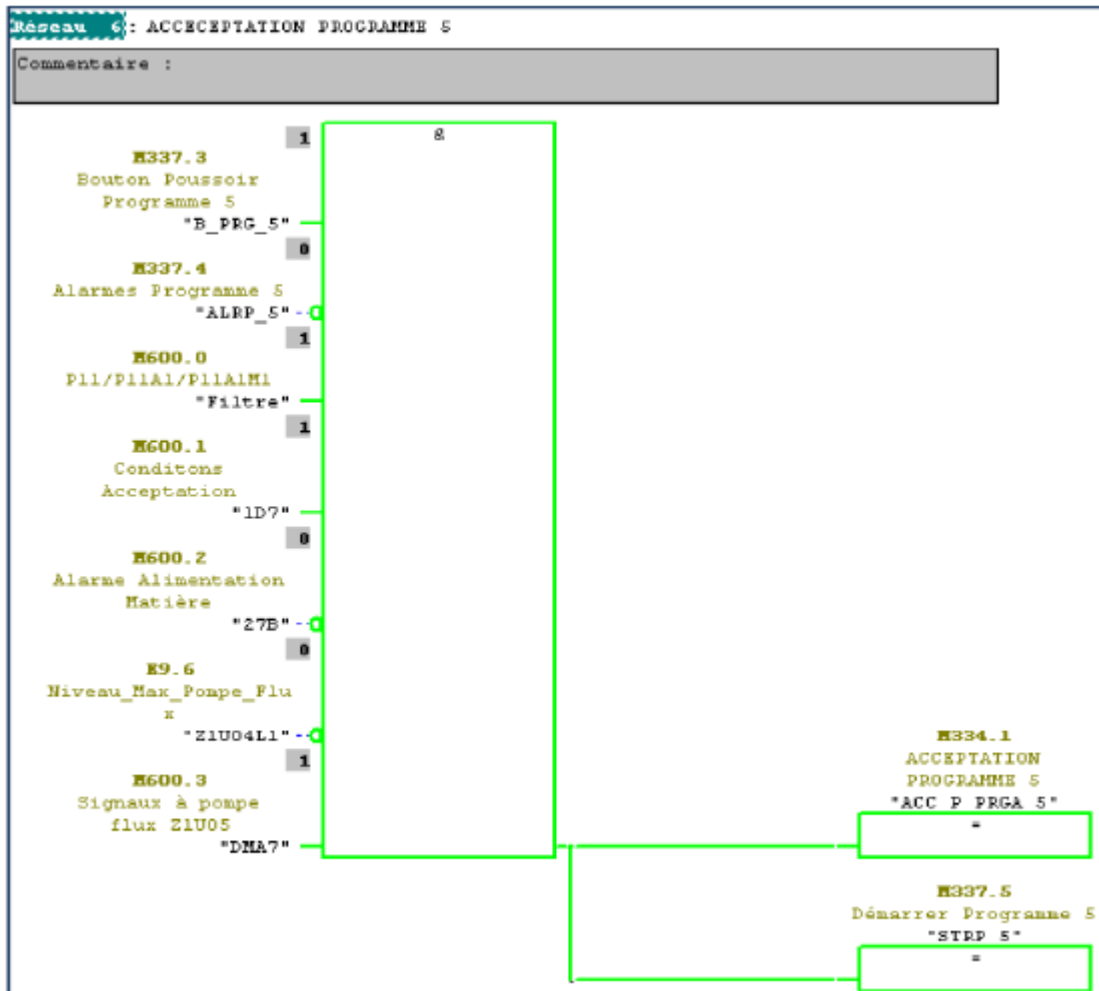


Figure 4. Different alarms and acceptance start of the program

5. Application

An application is made within the SCIMAT in order to have a fuzzy expert system for system monitoring, alarms diagnostics and maintenance, named SEF-DIAGMA (*Système Expert Flou pour DIAGnostic et Maintenance* - Fuzzy Expert System for Diagnostic and Maintenance).

5.1 Equipments selection

The selection of the equipment shown in Figure 5 is achieved by the selection of groups; each group contains a number of devices ordered in the boot sequence. The start of the group means starting equipment included, if the latter did not cause alarms.

In some groups, if the equipment is redundant or his progress is not mandatory. The choice of starting the equipment is separate from the others and selected by a button that corresponds to it. In the event of a malfunction of equipment, its color is red, it is a warning to the operator to say it does not start or maintain it if it is already running.

5.2 Cement mill feed within clinker

Cement is composed of three elements, the clinker with 80% of the total diet, gypsum of 08% and 12% additions. Each one of them in a silo, the clinker is the product of cooking the raw meal in the oven. In the oven, the clinker cooled, and then stored in a silo (feeder). After that, Transport belt grinder transports the clinker. Figure 6 shows the feeders of crushing cement realised with WinCC Graphics Designer.



Figure 5. Equipments selection

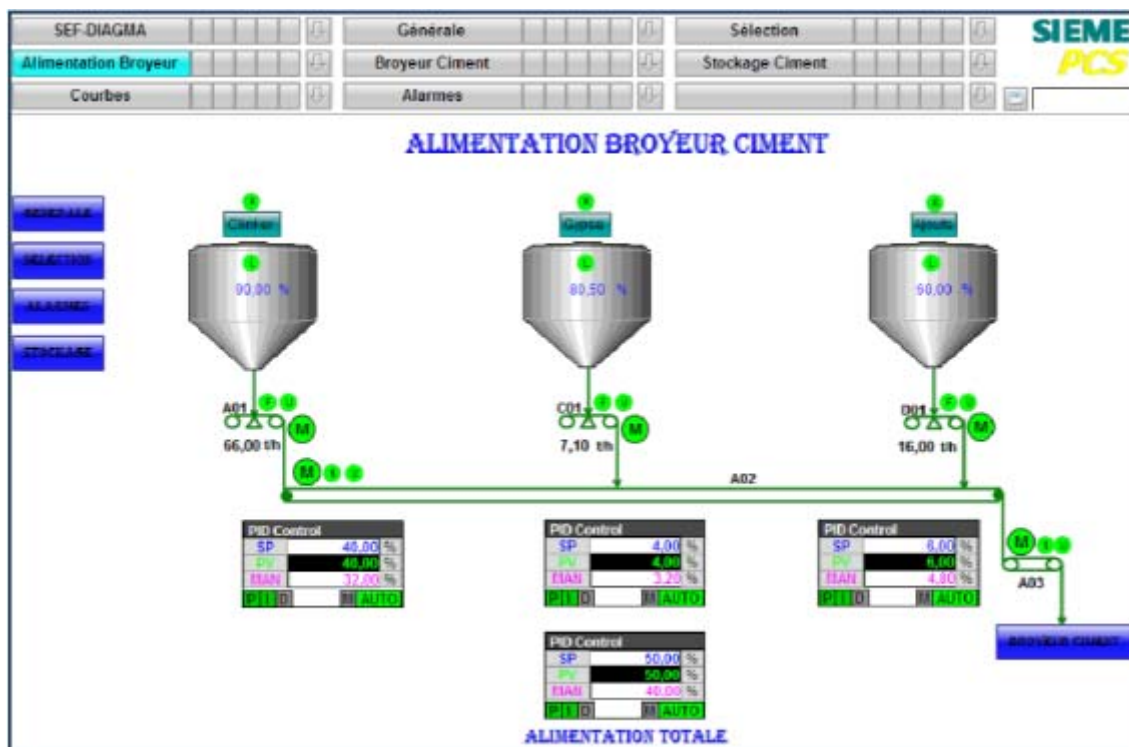


Figure 6. Cement mill feed by clinker

A cascade controller carries out the regulation of clinker. The point is the total diet. This point is dividing into three set points. The first relates to the clinker, gypsum for the second and the third for additions. Gypsy should not exceed 10% of set point; the sum of the three percentages must not exceed 100%. If the mode is automatic, the operator gives the set point (SP); the system gives the Process Value (PV). Moreover, if the mode is manual, the operator gives SPMAN. The other values entered as required necessary, as shown in Figure 7.

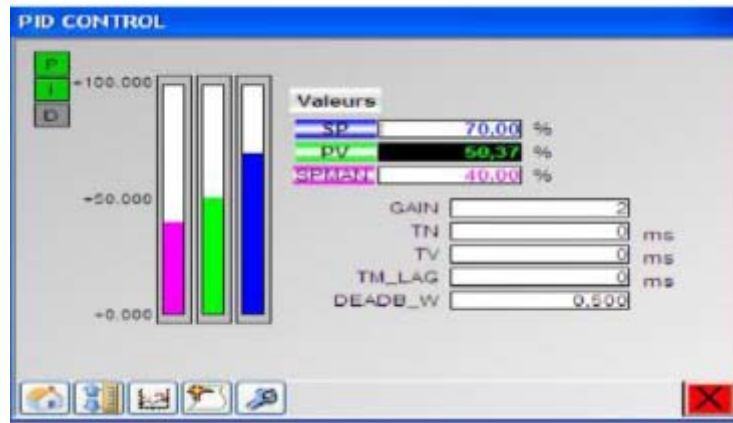


Figure 7. Value's regulation

The control curves of the total diet are made with WinCC OnlineTrendControl. These curves correspond to the values: SP, PV, SPMAN presented in Figure 8.

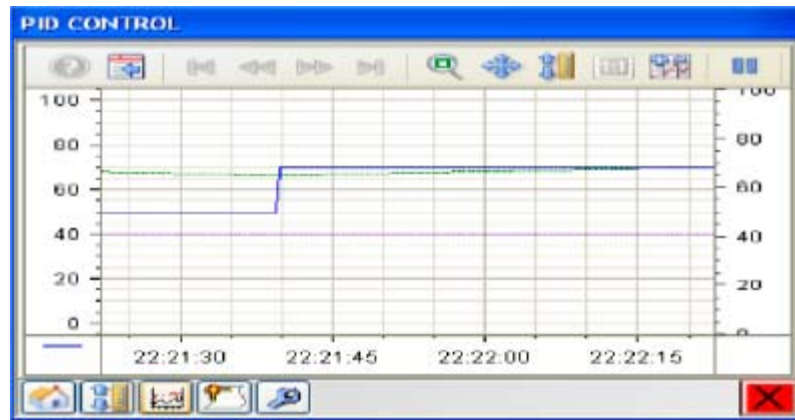


Figure 8. Regulation's curves

5.3 The Cement Mill

The cement mill plant contains four main parts, the cement mill (M01), elevator (J01), the separator (S01) and the electro-filter (P11). Figure 9 shows the cement mill's operator station.

The grinding plant contains two fuzzy controllers, the speed control of the separator and the injection temperature of water leaving the mill. These two fuzzy controllers realized using FuzzyControl++. The operator can see the fuzzy controller in the

operator station, as shown in the Figure 10 by click on the button



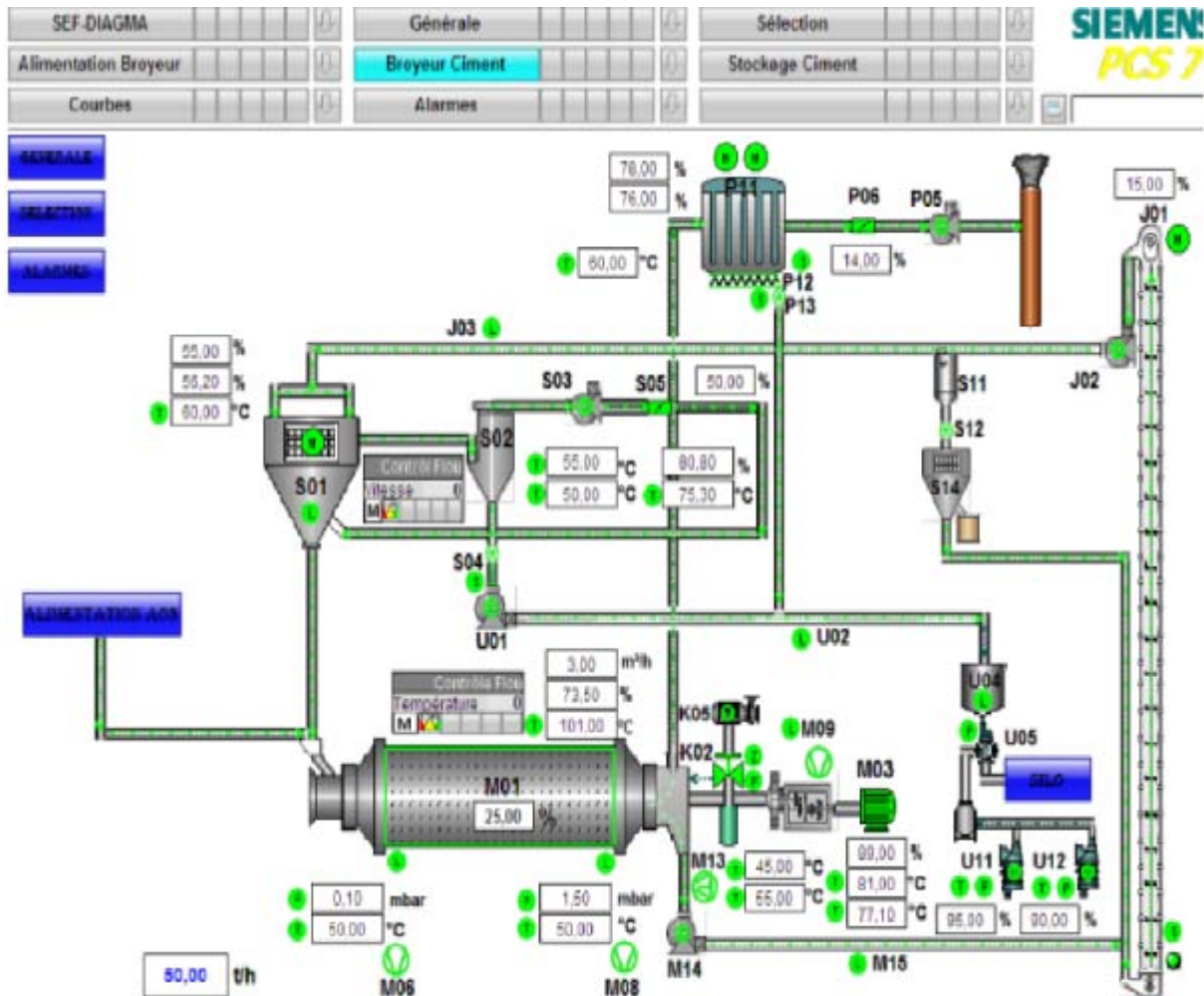


Figure 9. The Cement Mill workshop

According to the result of the analyses of the laboratory, the fineness of cement and its composition are adapted in order to obtain a product of quality constant. The tests (mechanical resistances) as well as the analyses required by the standard norms carried out at the laboratory on samples taken with forwarding. A Blaine Surface Specification regulates the fineness, the product of quality transported towards the storage bins of cement, and the remainder turned over to the crusher for the second crushing. The principle of regulation is according to the two rules:

- If cement is too fine then to reduce speed,*
- If cement is too bold then to increase speed.*

Figure 11 shows the fuzzy controller of the separator speed created on FuzzyControl++.

The cruise control of the separator consists of a single input, which is the rejection or the cement fineness. The Figure 12 presents the input of the fuzzy controller.

The system controlling the separator speed, according to the following rules:

- If refusal = 17%, the speed of the separator is = 60%.
- If the refusal is < 17% then to reduce the speed of 2%.

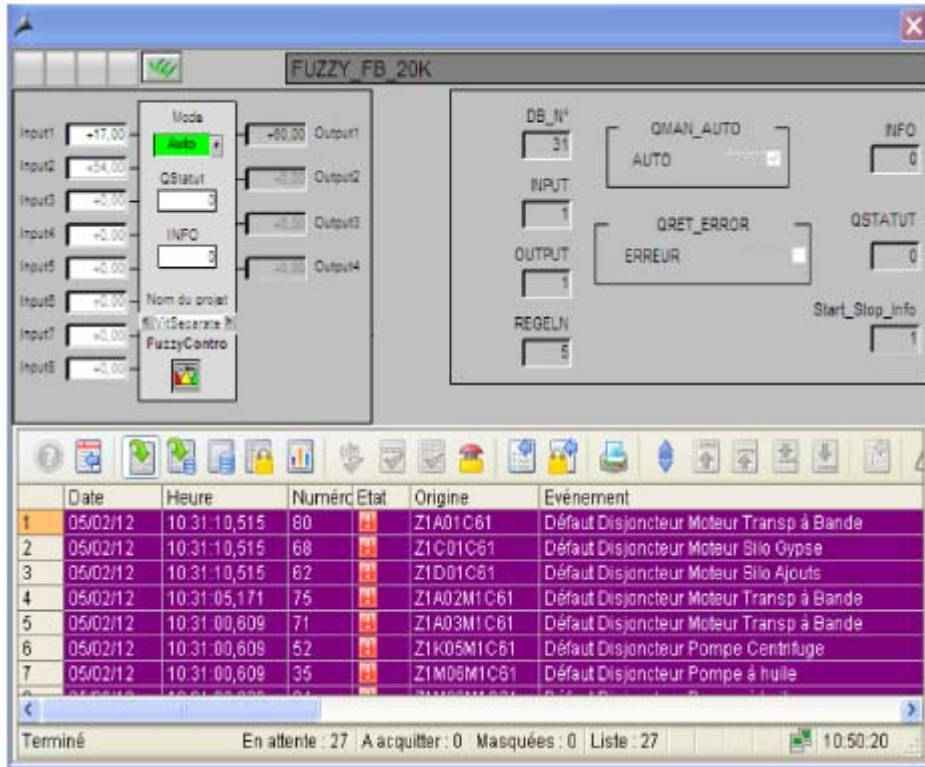


Figure 10. The fuzzy controller of the separator's speed

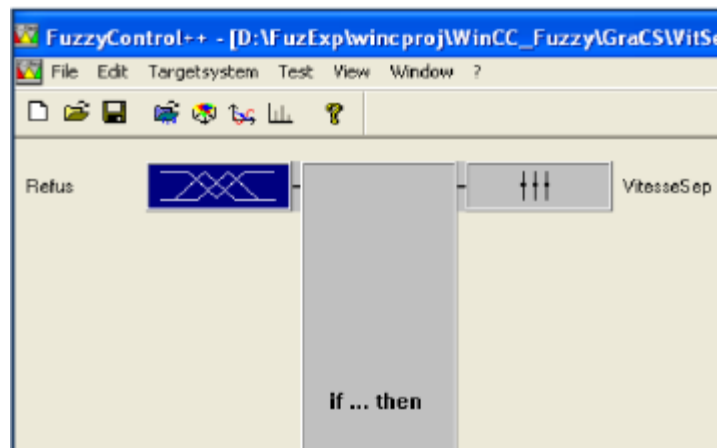


Figure 11. Fuzzy controller of the separator speed created on FuzzyControl++

- If the refusal is $> 17\%$ then to increase the speed of 2%.
- If the refusal is $< 14\%$ to reduce the speed of 3%.
- If the refusal is $> 18\%$ to increase the speed of 3%.

Figure 13 presents the output of the fuzzy controller of speed of the separator.

The fuzzy rule table presented in the Figure 14 contains rules controlling the separator speed, according to the rules already showed.

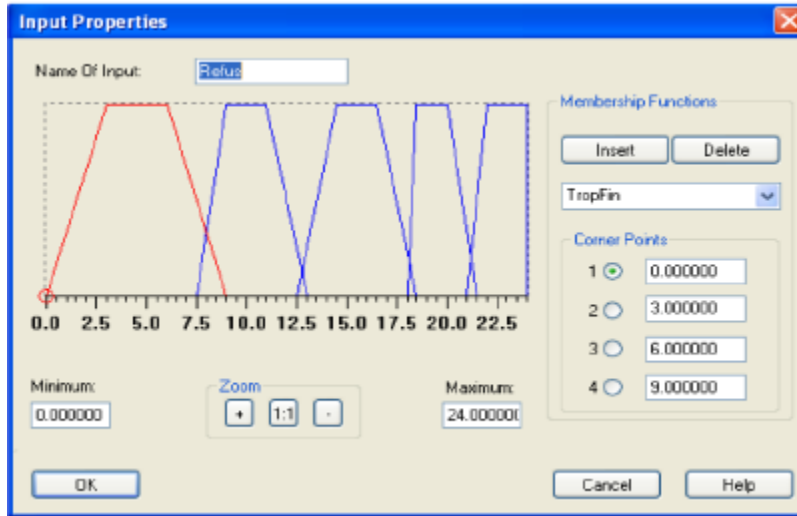


Figure 12. Fuzzy controller's input

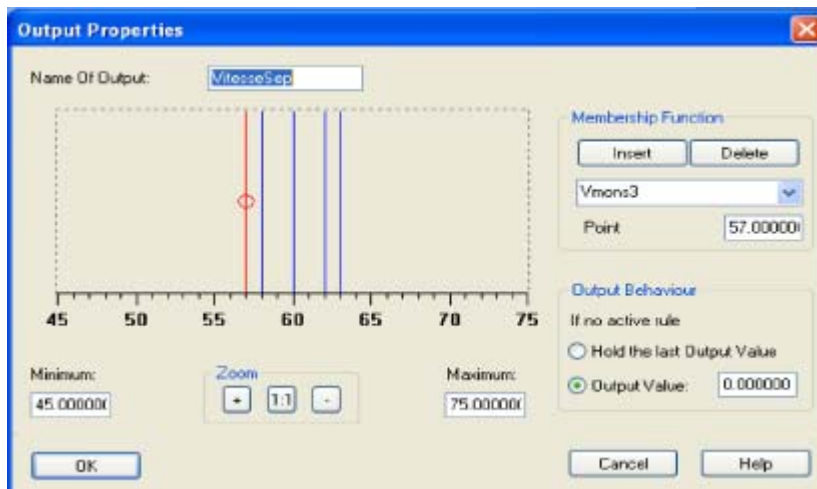


Figure 13. The output of the fuzzy controller

The curve of regulation speed according to the refusal appears on Figure 15, by the FuzzyControl++ Curve Plotter.

In the extreme cases, it is to the operator to check some points, if the refusal is $< 9\%$ then is: The matter was easy to crush, and the flow of the crusher is raised, then the operator must check the food crusher. Alternatively, the separator started with a high speed.

On the other case, the speed of the separator is low ($< 50\%$) and does not increase itself, then the operator must check the coupling of the separator. The entered matter is wet ($\geq 8\%$) and causes a coating on the balls and it will not be crushed, or the matter is very difficult to crush where the operator must reduce the food. The surface generated in this loop of regulation illustrated on Figure 16.

The starting of recharging of the data launched at the same time execution of the fuzzy rules of the configured system. The file saved with an extension ".arv" in the hard drive. Figure 17 presents the connection between the FuzzyControl++ tool and its block in Step 7.

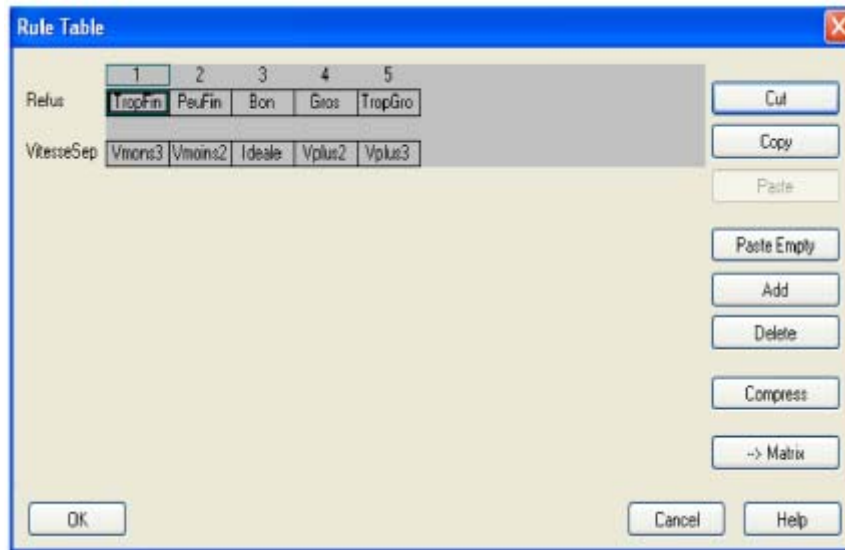


Figure 14. the fuzzy rule table

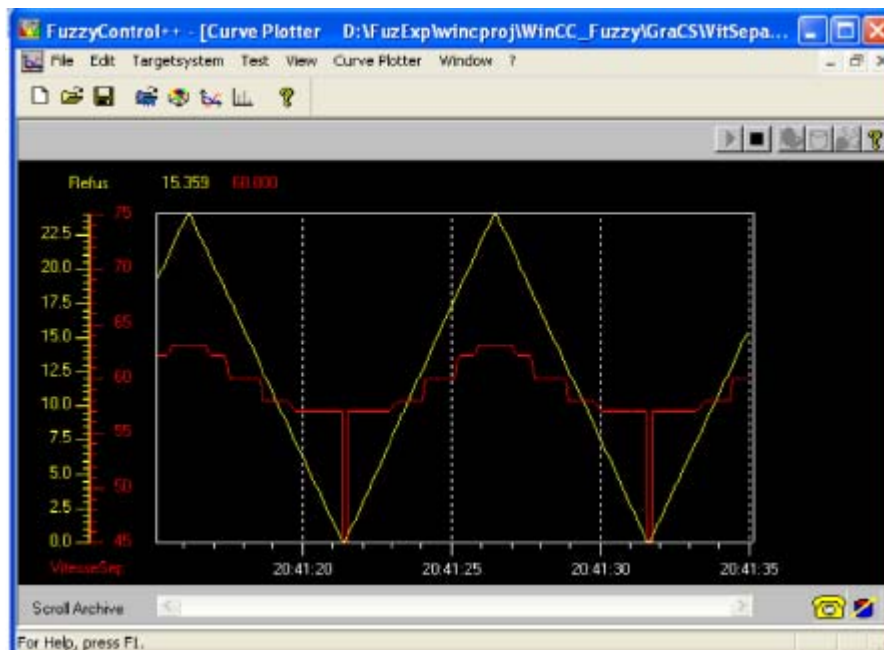




Figure 15. The fuzzy controller regulation's curve plotter

5.4 Cement storage

After crushing, cement is stored in three silos, and then sent towards forwarding by way road with means of transport like the trucks. Each silo has a max. If one of the three levels is max, an alarm can stop the cement mill. Figure 18 shows the workshop of the cement storage.

The operator can choose the cement silo with a button click (Select) , and the valve (*clapet*) will open. If the silo is full, the operator must close the valve and change the path of movement of cement by clicking on the button (Deselect) .

6. Curves

By using WinCC Tag Logging tool, we archive values of quantities or measurements. For each size or measurement, the operator

can display the curve of variation values for the time, on Figure 19 the curves of temperature values of the mill.

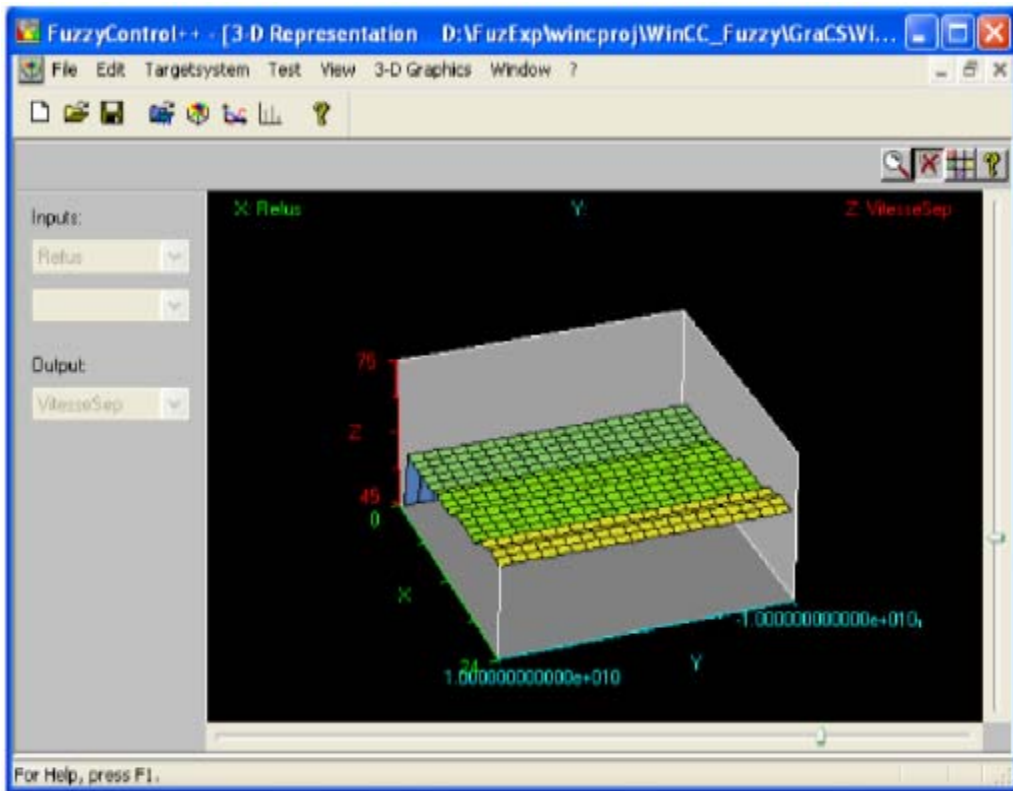


Figure 16. The fuzzy controller regulation's surface

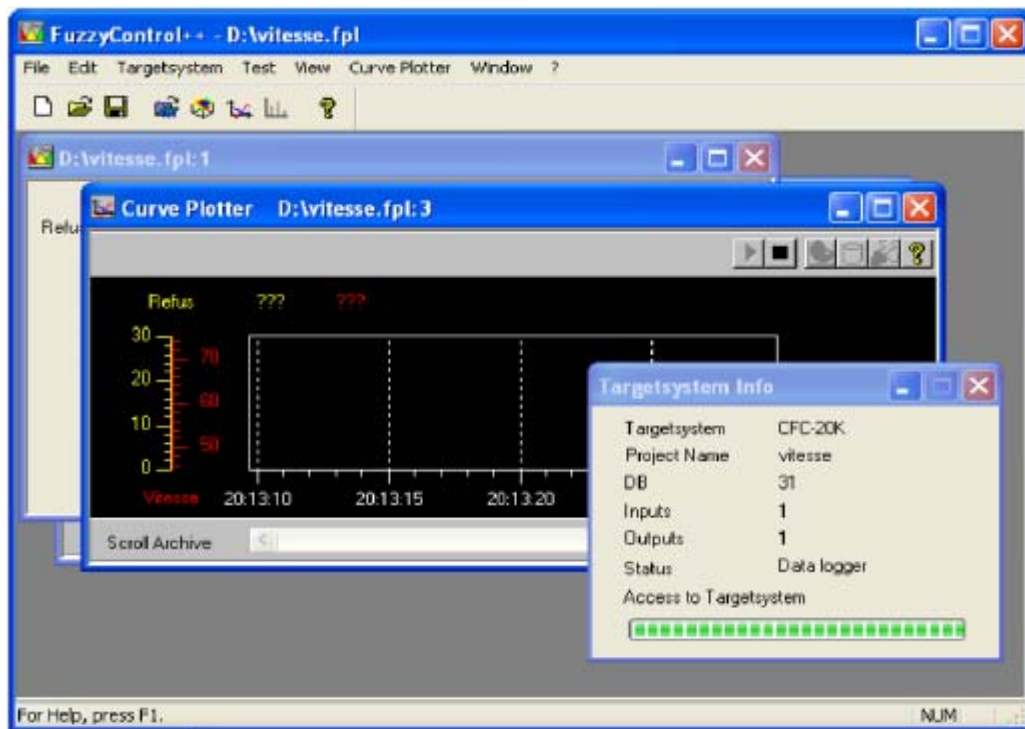


Figure 17. Reloading data for the execution of fuzzy rules

SEF-DIAGMA	Générale	Sélection
Alimentation Broyeur	Broyeur Ciment	Stockage Ciment
Courbes	Alarmes	

STOCKAGE DU CIMENT

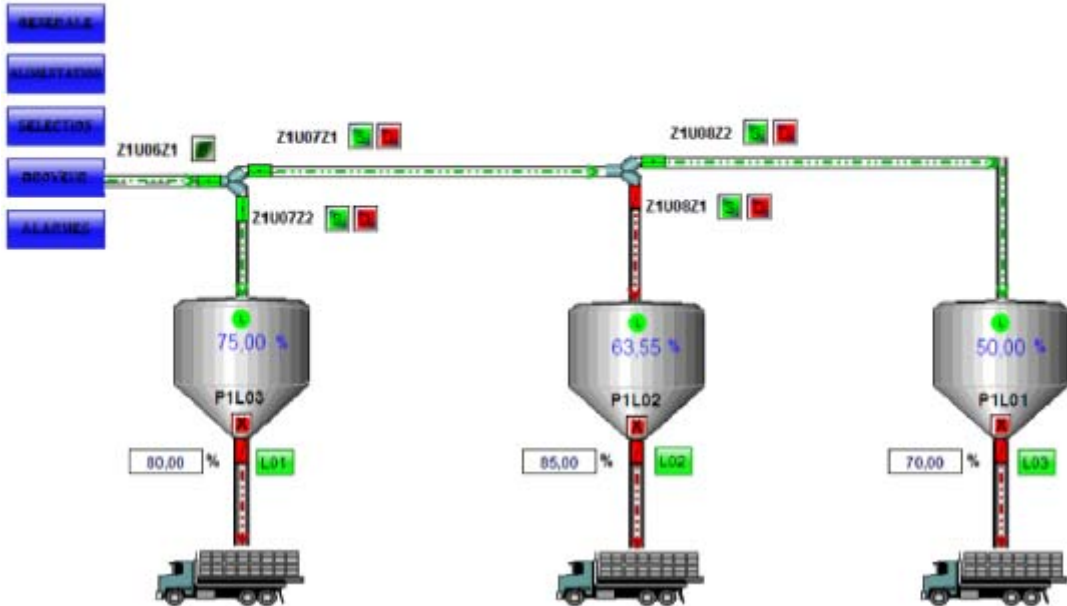


Figure 18. Cement storage workshop

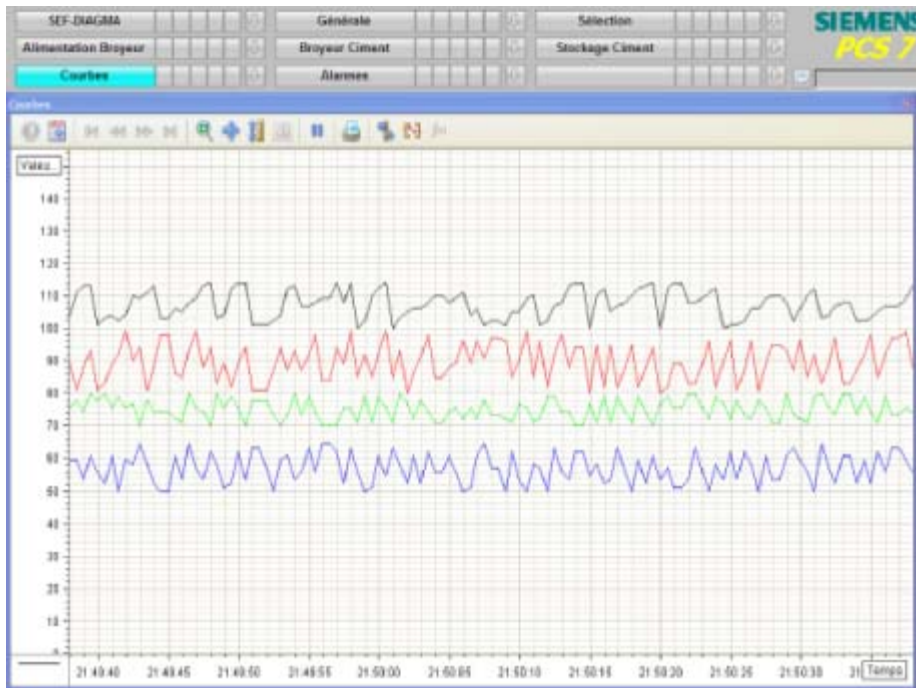


Figure 19. Curves



7. Diagnosis and maintenance of alarms

In the operator station, several alarms occur during the course of the workshop the cement mill, or in food, crushing or storage. Each apparition of an alarm is displayed the performed maintenance action. However, the operator can judge this action by his experience. Alarms created in WinCC Alarm Logging, several types of alarms may occur, among them, system alarms and process alarms. Figure 20 illustrates some alarms and maintenance actions.

Origine	Evénement	Maintenance
Z1S05Z1	Registre à Persienne Ouvert	Fermer le registre pour démarrer le Ventilateur
Z1L01L1	Niveau Min Silo Clinker	Vérifier le transport du Clinker
Z1L03L1	Niveau Min Silo Gypse	Vérifier le transport de la matière première
Z1L04L1	Niveau Min Silo Ajouts	Vérifier le transport de la matière première
Z1P06Z1	Registre à Persienne Ouvert	Fermer le registre pour démarrer le Ventilateur
Z1P11T2	Température Filtre Mini	Vérifier la température
Z1L01L1	Niveau Min Silo Clinker	Vérifier le transport du Clinker
Z1L03L1	Niveau Min Silo Gypse	Vérifier le transport de la matière première
Z1L04L1	Niveau Min Silo Ajouts	Vérifier le transport de la matière première
Z1P11T2	Température Filtre Mini	Vérifier la température
Fuzzy_FB	Des erreurs dans l'exécution du bloc: IF	
STATION	Liaison Programme\$S7(1) non établie	
STATION	Liaison Fuzzy_FB_20K non établie	
STATION	Liaison Fuzzy_FB_20K non établie	
STATION	Liaison Control_Flou non établie	
STATION	Liaison Control_Flou non établie	
Z1L01L1	Niveau Min Silo Clinker	Vérifier le transport du Clinker
Z1L03L1	Niveau Min Silo Gypse	Vérifier le transport de la matière première
Z1L04L1	Niveau Min Silo Ajouts	Vérifier le transport de la matière première
Z1P11T2	Température Filtre Mini	Vérifier la température
Z1L01L1	Niveau Min Silo Clinker	Vérifier le transport du Clinker
Z1L03L1	Niveau Min Silo Gypse	Vérifier le transport de la matière première
Z1L04L1	Niveau Min Silo Ajouts	Vérifier le transport de la matière première
Z1L01L1	Niveau Min Silo Clinker	Vérifier le transport du Clinker
Z1L03L1	Niveau Min Silo Gypse	Vérifier le transport de la matière première
Z1L04L1	Niveau Min Silo Ajouts	Vérifier le transport de la matière première
Z1L01L1	Niveau Min Silo Clinker	Vérifier le transport du Clinker
Z1L03L1	Niveau Min Silo Gypse	Vérifier le transport de la matière première
Z1L04L1	Niveau Min Silo Ajouts	Vérifier le transport de la matière première

En attente : 6 A acquitter : 6 Masquées : 0 Liste : 1000 06/12/2011

Figure 20. Diagnosis and maintenance of the alarms

On the table of alarms, the operator can acknowledge the alarm by clicking on the button , or all alarms by using the button .[5]

8. Conclusion

Application of Artificial Intelligence techniques in industry, often find difficulties, either in the technical side of programming, either in the quality of the material on this application. The cement factory of Ain Touta (SCIMAT) is very old, where the application of fuzzy logic requires highly efficient and advanced sensors.

Our application is based on the technique of fuzzy logic, implemented using the tool FuzzyControl++ of Siemens, is not used in all Algerian cement, hence the creation of SEF-DIAGMA, a new expert system blur for diagnosis and maintenance, performed within the SCIMAT is developing an approach to diagnosis and maintenance and also the fuzzy control, applying the techniques already mentioned.

The system helps the operator to diagnose alarms and for their maintenance. Moreover, the fuzzy control is provided by the fuzzy controllers, where even in case of unavailability of the other can continue its task. In addition, the continuous fuzzy

control ensures consistent quality of the finished product. On the other hand, the fuzzy controllers have a greater effect than ordinary regulators, especially for time control and stabilization system.

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