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Control of a Station of Irrigation by Sprinkling

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Abstract — The aim of the paper is to improve the performance of a station of irrigation by sprinkling which we tried to incorporate a new control law guaranteeing a certain performance. To get the best performance, we analyzed the control law PI planted in an educational station sprinkler, and then applied a fuzzy control law and we ended up with encouraging results. An idea of combining the two control laws through a fuzzy supervisor, has improved the results significantly.

Keywords* — *pressurized irrigation, fuzzy control, hybrid control.

I. INTRODUCTION

In the context of the rarefaction of the water resources, effects of the climatic change and exponential increase in the needs, the problems to save the water wasting are accentuated. The area of North Africa will be particularly affected by these evolutions, on the one hand, because of the already perceptible pressure on the natural resources, because then, of the increase in the temperature, involving a strong evaporation of surface waters, with the glance finally, importance of the agricultural sector for most of these countries [1].

The French company LEROY SOMMER offers researchers a pumping station teaching (Fig. 1), but with practical constraints existing in the real irrigation stations.

We will try to develop a control hybrid combines the PI implanted on the station with another fuzzy logic [2] [3]. But to have a law of control which checks the constraints of safety and guaranteeing the desired performances it is necessary that it respects the following constraints:

<u>Regulation of the flow and water pressure:</u>

$$Q(F,t)\Rightarrow Q_{ref} \qquad ; \qquad P(F,t)\Rightarrow P_{ref}$$

<u>Constraints on the control :</u>

$$N_{min} \leq N(t) \leq N_{max}$$

The pump at speed fixes will be <u>active</u> <u>or not</u>
N: The numbers of turns of the variable speed pump

<u>Constraints on the state:</u>

$$Q_{min} \leq Q(x,t) \leq Q_{max}$$

x: unspecified position of drain

<u>Constraints on the output:</u>

$$P_{min} \leq P\ (F,t) \leq P_{max}$$

<u>Constraints over the computing time:</u>

Period of sampling: Te =0.2s

<u>Energy constraints</u>

Concerning the operation of electrical equipment, cost optimization of pumping and turbine.

<u>The constraints of operation</u>

As they may be related to the geometry of the system levels maximum, minimum, and so on. How it should be managed to ensure the functions given to him: instructions, etc.
How to manage the system where the resource is not controlled.

<u>The constraints of safety</u>

This may result in the need to keep such a volume of safety in reserve, ensuring the supply in case of unforeseen demand or incidents on the network.

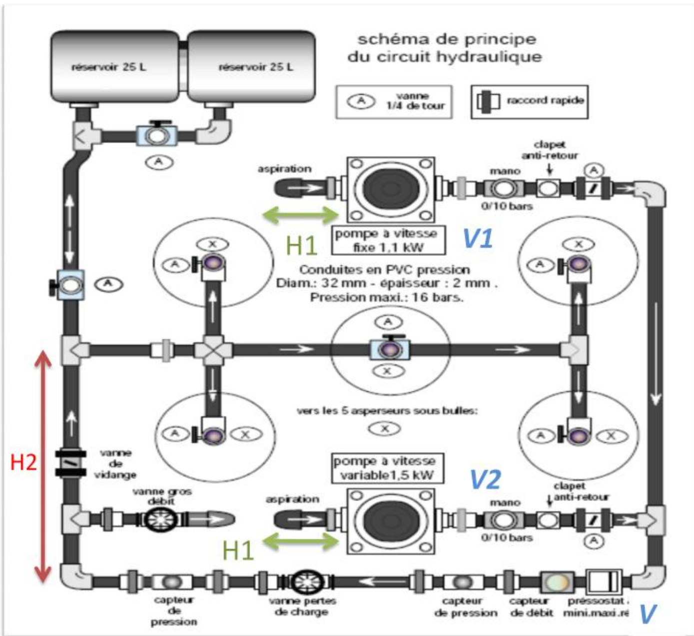

Fig. 1 Pumping Station: Block diagram of the hydraulic element

After the famous accident of the nuclear reactor of Chernobyl the control engineers would find that the constraints on the automatic control of the systems and even on the human intervention are very necessary, of which the respect of these conditions in the synthesis of law of order guaranteed the safety of the process and of the same safety of the operator.

We can control a measurement by respecting a constraint on another. Like the case of the studied process, to control a flow by respecting a maximum value of pressure in the pipe. We will thus have only one regulator reacting with two different instructions to two measures; the body will be ordered by the largest order. If the constraint of pressure were not reached, the place order will be that outgoing of the volumetric governor. If the aspersers are closed, the pressure will go up; then the regulator automatically controlled will place a request for deceleration of the pump at variable speed or the stop of the pump at fixed speed.

II. PI REGULATOR

The Leroy-Somer manufacturer chose to equip the station with irrigation under pressure by a type of regulation based on a controller PI.

Logic would like that the originators had time to carry out tests on the process to define the good parameters of adjustments of them. Actually, the constraints of production make that the loops generally will be positioned on standard values. There are many steps of test for the adjustment (Ziegler-Nichols, Broida...). That we want to work in open loop (regulator off-line) or in closed loop. The goal is to reduce as quickly as possible a disturbance or a variation of instruction. This leads us to have to support a going beyond of the instruction.

It is admitted that a going beyond of 10 % is acceptable. The originators in the Leroy-Somer company, chose the parameters of adjustments following Kp = 0, 5 and Ti = 4 minute [4].

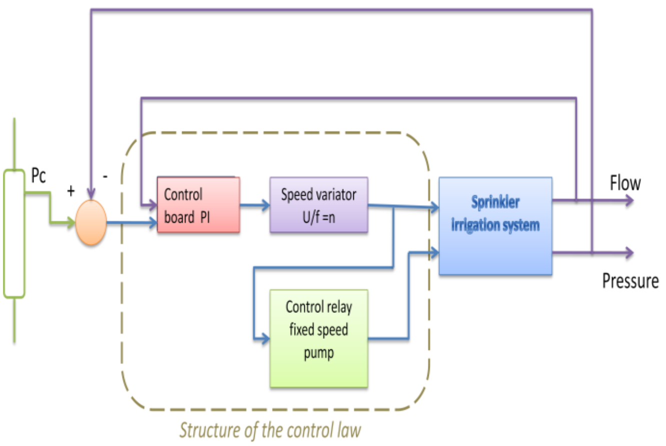

Fig. 2 Graphical representation of the architecture of the closed loop system

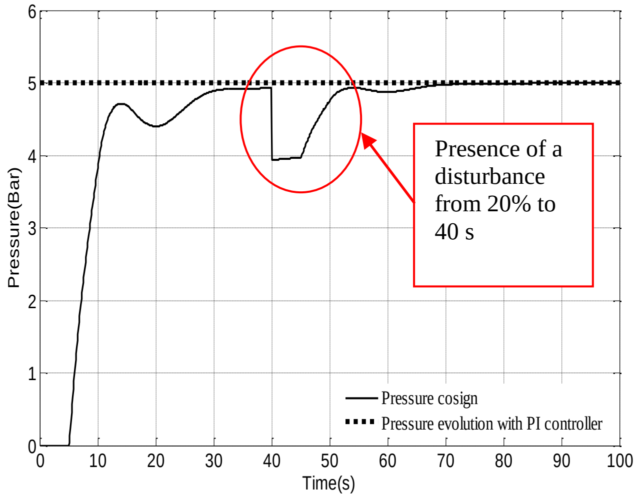

Fig. 3 Evolution of the pressure in the wastewater sprays irrigation enslaved by a PI controller

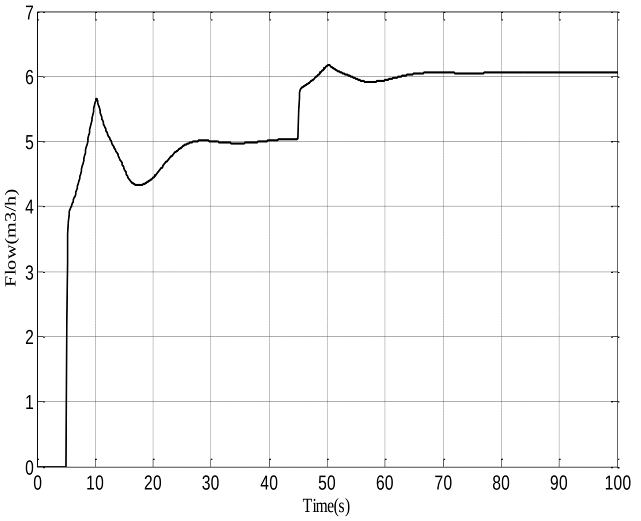

Fig. 4 Evolution of the flow in the wastewater sprays irrigation enslaved by a PI controller

Within sight of the results obtained we can say that regulator PI ensures the control of the pressure perfectly. The robustness of this technique of regulation appears of which it can remains stable and precise against a disturbance of 20%.

The disadvantage of this method of regulation is that the controller does not adapt with the variations which can appear on the level of the system is for example an extension of network of drain, the existence of the escapes and others, therefore it is necessary to find a law of order which ensures the piloting of system for a range of uncertainty of model of knowledge all as a scientist that the approximate model represents only one area of operation of the station of irrigation by real sprinkling whose the latter is represented by a perfectly nonlinear model. To solve this problem we will use a fuzzy controller who can solve part of this problem [5].

III. FUZZY REGULATOR

The design and the implementation of the information systems advanced, of software of decision-making aid, stations of supervision of the industrial processes (with the problems of communications man machine which accompanies them) are characterized by the constant handling of information of which much is subjective, vague, dubious.

We conceives the interest to insert the fuzzy approach in the regulation or the control of the industrial processes, for which information available is often vague, dubious and sometimes qualitative, in sometimes incomplete control loops.

The knowledge to make of the operator, made up amongst other things often of simple rules, enables him to operate each machine more correctly sometimes than a traditional algorithm.

A. *Establishment of the Fuzzy Order*

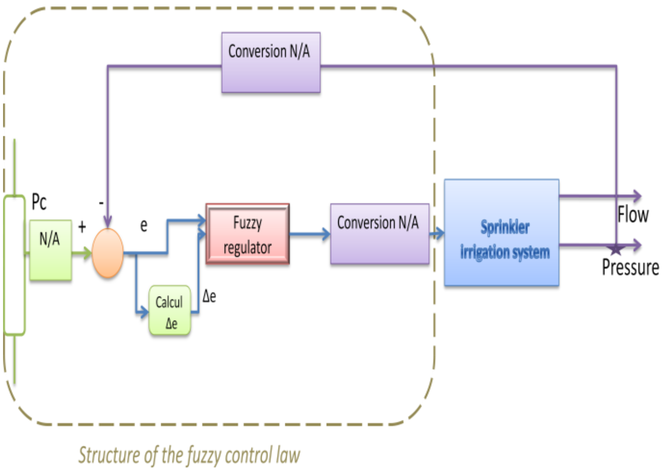

Fig. 5 Graphical representation of the architecture of the closed loop system

B. *Design the Fuzzy Regulator*

The majority of the problems of the real world must take account of vague, dubious information where appear the difficulty of interpretation of the linguistic variables sees. Appearance of fuzzy logic as a enough simple solution for these problems from where this vague and dubious information can be reformulated in the form of fuzzy rules IF-THEN [6].

In the case of our system, the wastewater spray irrigation, the fuzzy controller has the error « e » and its derivative « $\dot{e}$ » as inputs and the command « C_{cf} » as output.

Thus the “ i ” fuzzy rule programmed is given by:

$$\text{IF (e is A) AND } (\dot{e} \text{ is B) THEN } C_{cf} = S_i(e, \dot{e}) \qquad (1)$$

A and B are fuzzy sets corresponding to « e » and « $\dot{e}$ ».

S_i : *is a singleton for the output* C_{cf} .

Using the product as inference engine and center of gravity for defuzzification.

The output of the proposed fuzzy controller can be written as follows [7]:

$$C_{cf} = \sum_{i=1}^{N} S_i(e, \dot{e}) \times (\mu_A^i(e) \times \mu_B^i(\dot{e})) / \sum_{i=1}^{N} (\mu_A^i(e) \times \mu_B^i(\dot{e})) \qquad (2)$$

N: Number of fuzzy rules; N=25.

μ_A: Degree of membership of « e » in A.

μ_B: Degree of membership of « $\dot{e}$ » in B.

To synthesize the fuzzy controller, we divided the universe of discourse for the error and its derivative into five groups: NG, NM, Z, PM, and PG .

Thus, using all possible combinations, 25 fuzzy rules were generated for nine singletons at the party accordingly, as shown in TABLE I:

TABLE I
MATRIX INFERENCE OF FUZZY CONTROLLER

$\dot{e}$ \ e	NG	NM	Z	PM	PG
NG	AP	AP	DM	DG	DTG
NM	AM	AM	DM	DM	DG
Z	AM	AP	VZ	DP	DM
PM	AG	AM	AM	AM	DM
PG	AG	AG	AG	AP	DP

NG: Large Negative
NM: Medium Negative
Z: Zero
PG: Large Positive
PM: Medium Positive
AG: Large Acceleration
AM: Medium Acceleration
AP: Acceleration Plus
VZ: Neighborhood Zero
DP: Deceleration Plus
DG: Large Deceleration
DM: Medium Deceleration

Where the notation considered for the universe of discourse Output: A is the acceleration and deceleration D is the speed of the pump with variable speed. From Table I, there is symmetry in the state space that helps to reduce the computation time.

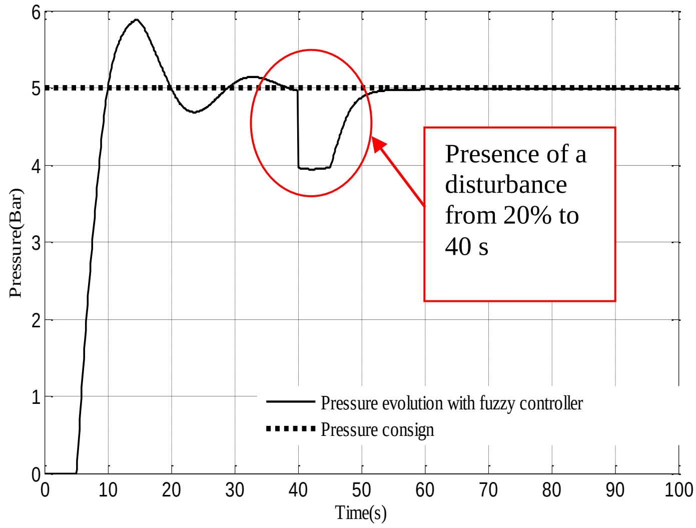

Fig. 6 Evolution of the pressure in the presence of a fuzzy controller

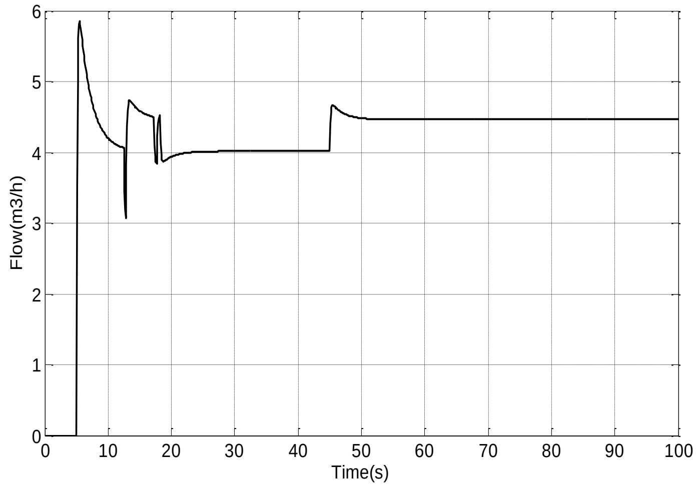

Fig. 7 Evolution of the flow in the presence of a fuzzy controller

In view of the results, we find that for both controllers, the proposed fuzzy approach provides the best speed / power control but the fuzzy control provides a static error of 10% in the evolution of pressure but this disappears when injecting a disturbance. The servo using the fuzzy controller is perfect against by the PI controller installed appears robust and accurate viewpoint adaptation against external disturbances.

IV. OPTIMIZATION OF A CONTROL BY USING A HYBRID CONTROLLER

The fuzzy approach overcomes the problem of modeling and control ensures a smoother energy level control but we note that the optimal choice of parameters of the fuzzy controller (the membership functions, fuzzy rules, gains entry-output, etc ....) is a very difficult task. This task requires time, experience and skill on the part of the experimenter. In principle, there is no general method for the adjustment of fuzzy control though and iterative heuristics have been proposed in the literature to adjust the membership functions.
Since we want to improve the behavior of the real system with minimal expense, we have proposed in this project to develop an advanced control law that makes a good compromise between power management control and the robustness against disturbances of structural a fuzzy controller on the one hand and on the other hand the accuracy of the PI controller recently installed.

The feasibility of a hybrid controller allows us to exploit the advantages of each approach control and ensure a finite time convergence and improve process performance.

A. *Design of a Hybrid Controller*

To ensure the robustness of the closed loop system and a fast dynamic response with the best performance, we propose to use the combination of the two controllers defined above, PI and Fuzzy.

To avoid abrupt switching from one controller to another, we use a gradual switch as follows:

$$C = \beta \times C_{cf} + (1-\beta) \times C_{PI} \tag{3}$$

C: control signal at the output of the hybrid controller.

Where β is a weighting factor generated by a fuzzy supervisor whose inputs the tracking error and its successive derivatives.

The rule base of the latter is constructed so that the output is "1" when the tracking error and its derivatives converge to zero and is "0" when the system is far from reference trajectory.

B. *Programming Fuzzy Supervisor*

To ensure a smooth switching between the fuzzy controller and PI controller recently installed must schedule a fuzzy supervisor which can improve switching between the two regulators and we have guaranteed the performance expected by this combination.

To reduce the computation time and simplify the structure of the supervisor, we considered only the absolute values of the entries were considered. This reduces the basic rules only nine components as shown in the matrix following inference, as shown in TABLE II:

TABLE II
MATRIX INFERENCE FUZZY SUPERVISOR

e / Δe	VZ	P	GP
VZ	TGP	GP	P
P	P	VZ	VZ
GP	VZ	VZ	VZ

VZ: Neighborhood zero
P: Positive
GP: Large positive
TGP: Very large positive

In this section, we propose to study the hybrid control law expressed by (3): Or

$$C_{cf} = \sum_{i=1}^{N} S_i(e, \dot{e}) \times (\mu_A^i(e) \times \mu_B^i(\dot{e})) / \sum_{i=1}^{N} (\mu_A^i(e) \times \mu_B^i(\dot{e})) \quad (4)$$

To simplify the writing of the control law of fuzzy controller we have rephrased as follows:

$$C_{cf} = f_1(e, \dot{e}) \times e + f_2(e, \dot{e}) \times \dot{e} \quad (5)$$

The control law provided by the PI controller installed on the machine can be written as follows:

$$C_{PI} = K_p(\text{Pconsign} - \text{Poutput}) + \frac{K_p}{T_i} \int (\text{Pconsigne} - \text{Psortie})dt \quad (6)$$

So if we integrate (5) and (6) in the analytical expression of the hybrid control law (3) becomes:

$$C = \beta \times [f_1(e, \dot{e}) \times e + f_2(e, \dot{e}) \times \dot{e}] + (1 - \beta) \times [K_p \times e + \frac{K_p}{T_i} \int e\, dt] \quad (7)$$

V. RESULTS OF SIMULATION

In this part we represent the results of simulation with a comparative study showing the differences between the three types of studied orders which we took the normal operating conditions previously presented.

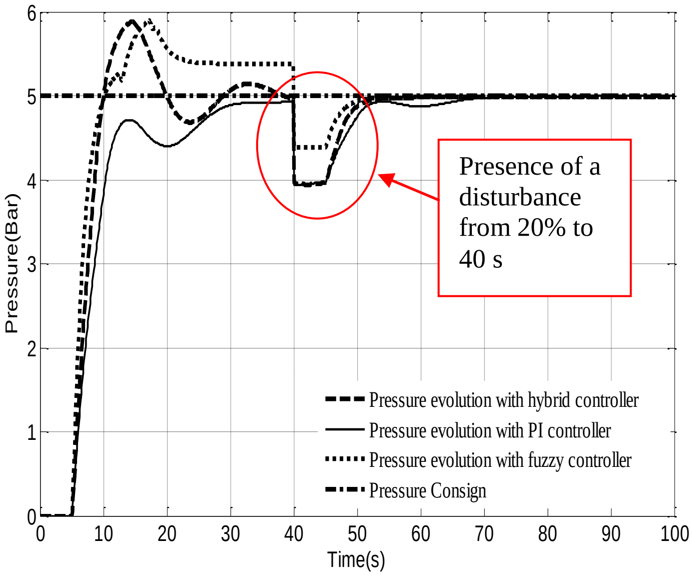

Fig. 8 Evolution of the pressure in the pipes of the station for three types of regulators

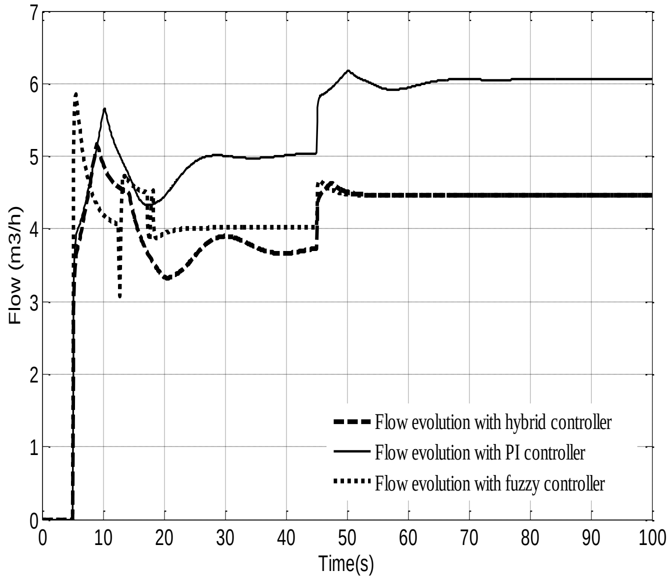

Fig. 9 Evolution of the flow in the pipes of the station for three types of regulators.

TABLE III
COMPARISON BETWEEN PI TECHNIQUES, FUZZY AND HYBRID RELATIVE TO THE PRESSURE

	PI controller	Fuzzy controller	Hybrid controller
Response time to 80% of final value	11.2 s	7.8s	9.5 s
Static error of position (Bar)	0.015	0.01	0.01

TABLE IV
COMPARISON BETWEEN THE TECHNIQUES OF PI, FUZZY AND HYBRID RELATIVE TO THE FLOW

	PI controller	Fuzzy controlle r	Hybrid controller
Response time to 80% of final value	5.2 s	5.07s	5.12 s
Static error (m^3 /h)	1.4	0.3	0

Note:

For the comparative study of evolution of the flow is considered the lowest rate as a benchmark for other approaches to regulation studied.

VI-DISCUSSION

Within sight of the results obtained, we note well that a hybrid order by the intermediary of a fuzzy supervisor makes it possible to ensure a gradual commutation between an order by regulator PI and a fuzzy controller. The purpose of this structure is to exploit the advantages of each approach of order where one exploits the precision of PI and the flexibility of the fuzzy regulator.

VI. CONCLUSIONS

In this paper we have presented a new method to optimize the hydraulic state of a water system to reduce losses. In the first place, we have studied the dynamics of the PI station where we found that this controller appears very strong in the area of operation selected by the manufacturer of the model teaching. For our purposes we directed to change the type of control used by a more flexible where we found the results very encouraging. In order to improve further the control law associated with this machine we tried to combine the two control laws.

Finally, we found that the hybrid control law developed in this work provides the desired performance, saving energy and perfect pressure regulation.

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