3rd International Conference on Automation, Control, Engineering and Computer Science (ACECS'16)
Proceedings of Engineering & Technology (PET)
pp. 166-172

Modeling and Intelligent Monitoring: Application on an Irrigation Station under Pressure

Mohamed Radhouane MEJRI[#1], Abderrahmen ZAAFOURI[*2], Abdelkader CHAARI[*3]
[#*]*Research Unit on Control, Monitoring and Safety of Systems C3S*
[#]*Institut Supérieur des Etudes Technologiques de Tozeur ISET Tozeur Tunisie*
* *Ecole Nationale Supérieure des Ingénieurs de Tunis, ENSIT, Tunisie*
[#] mejri.mohamed.radhouane@gmail.com
* abderrahmen.zaafouri@yahoo.fr

***Abstract*—the problem of adaptation of the control laws, in different complicated processes, with the existence of defaults has been studied intensively in the last few years and more successful industrial applications have been reported. In this paper, we apply an adaptive control, on a real irrigation under pressure system, based on intelligent fault detection and isolation algorithm (block) and a mathematic model characterize the flow of water in our process where we tacked into account the slow phenomena transient and the probability of appearance of leaks.**

This paper reports an application of fuzzy technique, which can provide an adjustment tool for the on line control and a diagnostic tool of the process malfunction.

Finally the effectiveness of our adaptive control structure which is based on an intelligent diagnostic module are represented and discussed through simulation.

***Index Terms*— modeling, adaptive control, Intelligent Diagnosis of faults, leaks.**

I. Introduction

During the last decade, there have been immense advances in the areas of adaptive process control and intelligent diagnosis based on the fuzzy technique.
For under pressure irrigation system, the most important goal is to assure water distribution to all users and to reduce the water losses.
The objective of this development is to be able to detect the leak and other faults in our system and update the control law to ensure the continuity of the proper functioning.
The problem of leaks reduction is complex and requires coordinated action in different areas of management of the pump station well pipes and sprinkler distribution.
In a context of scarce resources of water, reduce the leakage be very necessary.
Undetected leaks do not cause interruption of service and distribution system continues to function properly. However, these leakage losses are responsible for up to 20% of the volume of water introduced in the network.
Water losses caused by undetected leaks depend directly on the pressure in the pipes. When distribution conditions permit, the pressure reduction results in reduced losses. It is obtained by the introduction of valves, pressure reducers, stabilizers, in certain points of the network but in our work we will use another method is the intelligent diagnosis and the adaptative control where it ensures the desired dynamic and minimize the leak volume by reducing the pressure.
In order to achieve our goal we built a intelligent diagnosis block based on a fuzzy technique into the control of our system who has the supervisory role of the station and the detection of leaks and at the same time adapting the parameters of PI controller.
To validate our proposed command structure, in the first place was modeled pumping station taking into account the possibility of occurrence of fault such as leaks, in order to simulate the dynamics of the station with the fuzzy diagnosis supervisor and the adaptive PI control.

II. MODELING THE STATION

It was necessary for us to seek a reference model on the one hand it helps to know the instantaneous operating area of the station and helps the diagnostic module to detect and locate faults and secondly to ensure the simulations necessary.
Hydraulic equations representing the flow of water in a pressurized pumping station are written. For this, the Naviers-Stokes equations were derived for the Saint-Venant equations adapted to our problem. Several assumptions are made, including the compressibility of the flow, the presence of slow transient phenomena and the presence of leaks. We develop the calculations starting from the Saint-Venant equations [3] [4] [5] applied to the flow supported on an irrigation network under pressure.
Extract the Naviers-stokes equations:
To describe the flow, we used the Naviers - Stokes equations that describe the hydraulic behavior of a Newtonian fluid.
First is considered that the two velocities of the two pumps are superimposable and linear which the following equation can be found.

$$V = V1 + V2\ (N) \tag{1}$$

V1: flow velocity of water due to the growth of turbine fixed speed pump.
V2: flow velocity of water due to the growth of turbine variable speed pump "N".
V: total velocity of water flow in the pipe of the station.

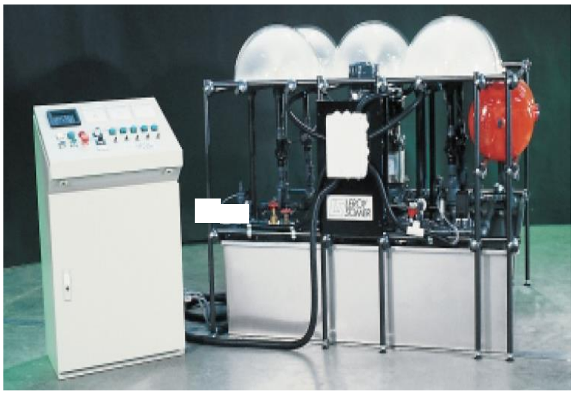

Fig 1: Pumping Station

ISSN: 2356-5608

The mass of water does not vary during its flow in the pipeline then:

$$\nabla.\mathrm{V} = \frac{\partial \mathrm{V}_x}{\partial \mathrm{x}} + \frac{1}{\mathrm{r}} \times \left(\frac{\partial \left(\mathrm{r} \times \mathrm{V}_r \right)}{\partial \mathrm{r}} \right) + \frac{1}{\mathrm{r}} \times \left(\frac{\partial \mathrm{V}_\theta}{\partial \theta} \right) = 0 \tag{2}$$

(∇ : Operator nabla)

Assuming that the reference is of Galilee, where one can write the equation of conservation of momentum as follows:

$$\frac{\partial \tau qm}{\partial t} = \sum \tau\, fext \tag{3}$$

τqm: momentum tensor.

τfext : tensor of the external forces.

Cauchy's equation is as follows:

$$\rho \times \gamma = \nabla.\left(\sigma\right) + f \tag{4}$$

It is assumed that water is under the sole action of gravity, so we will:

$$\rho \times \gamma = \nabla.\left(\sigma\right) + \rho \times g \tag{5}$$

Where σ: the tensor of the constraints for a viscous Newtonian fluid. With

$$\sigma = -P.\,I + 2\mu\, D \tag{6}$$

μ: Coefficient of shearing.

D: Tensor speeds of deformation.

P: Pressure in Bar.

ρ Water density in Kg/l.

g : Gravity or acceleration of gravity in N/Kg

f : Force external in N

Applying the operator nabla in the tensor of the constraints we have:

$$\nabla.\sigma = -\nabla.P + \nabla\,.\,\left(2\mu D\right) \tag{7}$$

Really, the pipe is PVC so we can neglect the thermal effect in the station so we can consider that the viscosity coefficients as constants and therefore we have:

$$\nabla.D = 0\,.5\nabla.\left(\nabla V\right) \tag{8}$$

We integrate the equations (6), (7), (8) in equation (5), we arrive to find the Naviers-Stokes equations as follows:

$$\rho \times \left(\frac{\partial V}{\partial t} + V.\nabla V \right) = -\nabla.P + \mu \nabla^2 V + \rho g \tag{9}$$

A-Simplification the Naviers-Stokes equations

The pipe of the station is closed because it supposedly has a check valve so there is no air in the pipe and therefore no friction between water and air.

The water under pressure circulates in the axial direction.

The leakage flow is in the radial direction.

The velocity of the water flow along the tangential axis is null.

The flows are axisymetric: meaning that they are invariant with angle "θ"

We can write the equation of conservation mass (continuity) (2) as follows:

$$\nabla.\mathrm{V} = \frac{\partial \mathrm{Vx}}{\partial \mathrm{x}} + \frac{1}{\mathrm{r}} \times \left(\frac{\partial \left(\mathrm{r} \times \mathrm{Vr} \right)}{\partial \mathrm{r}} \right) = 0 \tag{10}$$

- Can be deduced Naviers-Stokes equation starting from equation (9):

$$[\rho \times \left(\left(\frac{\partial Vx}{\partial t} \right) + Vx \times \left(\frac{\partial Vx}{\partial x} \right) + Vr \times \left(\frac{\partial Vx}{\partial r} \right) \right) = -\left(\frac{\partial P}{\partial x} \right) + f_x + \mu \left[\left(\frac{\partial^2 Vx}{\partial x^2} \right) + \frac{1}{r} \times \frac{\partial}{\partial r} \left(r \left(\frac{\partial Vx}{\partial r} \right) \right) \right] \tag{11}$$

f_x : Coefficient of friction.

B-Writing the equations of Saint-Venant:

To simplify the equations of Saint-Venant we will oversize equation (11)

We will consider a line length of pipes is 'L' and radius 'R', since the flow is incompressible so we have $\rho = \rho_0 = cst$.

Is noted with $(\bar{.})$ the dimensionless quantities and we pose that:

1- $Vx = vx \times \left(\overline{Vx} \right)$: Where 'vx' is the unit of the velocity scale along the axis of pipe.

2- $Vr = vr \times \left(\overline{Vr} \right)$: Where vr is the unit on the scale of speed along the radial axis.

3- $t = K \times \left(\bar{t} \right)$ where $K = \frac{kL}{c}$ is the unit on the scale of time
   - c: is the celerity of the pressure wave.
   - k: is a scale factor.
   - L/c : is the time the wave to run through the entire pipe.

4- $P = \frac{\rho_0 c V_x}{k} \left(\overline{P} \right) = \frac{\rho c V_x}{k} \left(\overline{P} \right)$ Where $\frac{\rho c V_x}{k} = L \frac{\rho v_x}{K}$; $\left(\overline{P} \right)$ is the unit on the pressure scale.

5- $x = L \times \left(\bar{x} \right)$ where $\left(\bar{x} \right)$ is the unit on the scale of the position along the pipes.

6- $r = R \times \left(\bar{r} \right)$ where $\left(\bar{r} \right)$ is the unit on the scale along the radius of the conduits.

7- $Ma = \frac{v_x}{c}$ is Mach number […]

8- $\rho = \rho_0 \times \left(\bar{\rho} \right) = \rho \times \left(\bar{\rho} \right)$

This type of distribution system water under pressure involve numerous dynamic phenomena as open sprinklers, closing sprinklers and operation of the two pumps and other phenomena called slow transient phenomena.

In order to adapt our model to these phenomena we tried to add the other assumptions such as:

9- $Rel = \frac{\rho L V_x}{\mu}$ is the Reynolds number relative to the longitudinal length of the pipe.

It is known that the study of this station requires consideration of the effect of long pipes, nodes and of course the rating of land so we can make all these charges, applied to the system, in a term called "hydraulic load H (t, x)."

The hydraulic load is modeled as follows:

$$H(t,x) = \frac{p(t)}{\rho \times g} + h(x) \quad (12)$$

According to Brenouillie, we can write the hydraulic load as follows:

$$H = \left(\frac{P}{\rho \times g}\right) + (h1 + h2 + hx) \quad (13)$$

h1 and h2 are the heights to the tank as shown in Fig 2.

10- $H = \frac{cV_x}{gk}\left(\overline{H}\right)$

11- $Q = SV_x\left(\overline{Q}\right)$

Integration of the equations in the case of a leak in the pipes:

In order to apply the assumptions mentioned later we'll start first by reformulating Naviers -Stokes equations.

In the first place we will integrate the equations found on the right section of the pipe.

A-integration and averaging of the equation of continuity:

The equation of conservation of mass (13), we will integrate it on the S section of the pipe it is posed constant throughout pipes S = cst; then we can write:

$$\int_0^S \left(\frac{\partial Vx}{\partial x} + \frac{1}{r}\frac{\partial(rVr)}{\partial r}\right) ds = \int_0^S \frac{\partial Vx}{\partial x} ds + \int_0^S \frac{1}{r}\frac{\partial(rVr)}{\partial r} ds = 0 \quad (14)$$

If the formula Leibnitz integration is applied there will be the following equation:

$$\int_0^S \frac{\partial Vx}{\partial x} ds = \frac{d}{dx}\int_0^S Vx\, ds - \frac{\partial S}{\partial x} Vx = \frac{d}{dx}\int_0^S Vx\, ds \quad (15)$$

Similarly for the second part of the equation (16) but for ease of writing we will apply this change of variable:

$$S = \pi R^2 \; ; s = \pi r^2 \Longrightarrow ds = 2\pi r\, dr$$

$$\int_0^S \frac{1}{r}\frac{\partial(rVr)}{\partial r} ds = \int_0^R \frac{1}{r}\frac{\partial(rVr)}{\partial r} 2\pi r\, dr = 2\pi R Vr^* \quad (16)$$

Vr^* : this is the boundary condition reflecting the presence of leaks in a pipe:

$$Vr^* \neq 0 \quad (17)$$

Finally we can write (16) in this form:

$$\frac{d}{dx}\int_0^S Vx\, ds + 2\pi R Vr^* = 0 \quad (18)$$

It is assumed that the average velocity of the flow is written as follows:

$$\overline{V} = \frac{1}{S}\int_0^S Vx\, ds \quad (19)$$

From equation (20) can have the following relationship:

$$\frac{\partial S\overline{V}}{\partial x} = -2\pi R Vr^* \quad (20)$$

The flow is written as follows:

$$Q = S\overline{V} \quad (21)$$

So (22) will be as follows:

$$\frac{\partial Q}{\partial x} = -2\pi R Vr^* \quad (22)$$

$2\pi R Vr^*$: is called radial mass flux which indicates the existence of leaks in the pipes:

If $2\pi R Vr^* = 0$ so no leaks

If $2\pi R Vr^* > 0$ leak exists

B-Integration of the equation of Naviers- Stokes:

We begin by determining the equation of 'fx' in the equation of Naviers-Stokes.

Since ρ = cst and gravity drift potential, 'fx' takes the following form:

$$f_x = -\frac{\partial}{\partial x}\rho\ g\ x \quad (23)$$

Using equation (13) and (23) the equation (12) takes the form:

$$\rho \times \left(\left(\frac{\partial Vx}{\partial t}\right) + Vx \times \left(\frac{\partial Vx}{\partial x}\right) + Vr \times \left(\frac{\partial Vx}{\partial r}\right)\right)$$
$$= -\frac{\partial}{\partial x}(P + \rho\ g\ x) + \mu\left[\left(\frac{\partial^2 Vx}{\partial x^2}\right) + \frac{1}{r} \times \frac{\partial}{\partial r}\left(r\left(\frac{\partial Vx}{\partial r}\right)\right)\right]$$
$$= -\frac{\partial H}{\partial x}(\rho\ g) + \mu\left[\left(\frac{\partial^2 Vx}{\partial x^2}\right) + \frac{1}{r} \times \frac{\partial}{\partial r}\left(r\left(\frac{\partial Vx}{\partial r}\right)\right)\right] \quad (24)$$

In order to apply the formula Leibnitz it develops the first part of equation (24) using (11):

$$\rho\times\left(\left(\frac{\partial Vx}{\partial t}\right)+Vx\times\left(\frac{\partial Vx}{\partial x}\right)+Vr\times\left(\frac{\partial Vx}{\partial r}\right)\right)$$
$$=\rho\times\left(\left(\frac{\partial Vx}{\partial t}\right)+\left(\frac{\partial Vx^2}{\partial x}\right)+\frac{1}{r}\times\left(\left(\frac{\partial rVxVr}{\partial r}\right)\right)-Vx\times\left(\frac{\partial Vx}{\partial x}+\frac{1}{r}\frac{\partial(rVr)}{\partial r}\right)\right)$$
$$=\rho\left(\left(\frac{\partial Vx}{\partial t}\right)+\left(\frac{\partial Vx^2}{\partial x}\right)+\frac{1}{r}\times\left(\left(\frac{\partial rVxVr}{\partial r}\right)\right)\right)$$
(25)

$$\int_0^S\rho\left(\left(\frac{\partial Vx}{\partial t}\right)+\left(\frac{\partial Vx^2}{\partial x}\right)+\frac{1}{r}\left(\left(\frac{\partial rVxVr}{\partial r}\right)\right)\right)ds$$
$$=\rho\left(\frac{\partial}{\partial t}\int_0^S Vx\,ds+\frac{\partial}{\partial x}\int_0^S Vx^2ds+\int_0^R\frac{1}{r}\frac{\partial(rVxVr)}{\partial r}2\pi r\,dr\right)$$
$$=\rho\left[\frac{\partial Q}{\partial t}+\frac{\partial\beta S\overline{V}^2}{\partial x}\right]$$
(26)

Where: $\beta=\frac{1}{S\overline{V}^2}\int_0^S V_x{}^2ds$: The coefficient of Boussisneq.

Second Baths:

$$-\int_0^S\frac{\partial H}{\partial x}(\rho\,g)ds=-\frac{\partial H}{\partial x}(\rho\,g\,S) \quad (27)$$

Third Baths:

$$\int_0^S\mu\left[\left(\frac{\partial^2 Vx}{\partial x^2}\right)\right]ds=\mu\left[\left(\frac{\partial^2 S\overline{V}}{\partial x^2}\right)\right] \quad (28)$$

$$\int_0^S\mu\left[\frac{1}{r}\times\frac{\partial}{\partial r}\left(r\left(\frac{\partial Vx}{\partial r}\right)\right)\right]ds=\mu\int_0^R\frac{1}{r}\frac{\partial(rVx)}{\partial r}2\pi r\,dr$$
$$=2\mu\pi R\overleftrightarrow{(\partial Vx/\partial r)}=-2\pi R\tau$$
(29)

$\tau=-\mu\overleftrightarrow{(\partial Vx/\partial r)}$: The wall shear.

Recapitulation :

After integrating the equations of Naviers-Stokes on the section of the water pipe, the Saint-Venant system obtained for an incompressible flow:

$$\begin{cases}\frac{\partial Q(t,x)}{\partial x}=-2\pi RVr^*\\ \rho\times\left[\frac{\partial(Q(t,x))}{\partial t}+\frac{1}{S}\times\left(\frac{\partial(Q^2(t,x)\times\beta)}{\partial x}\right)\right]+\rho\times g\times S\times\frac{\partial H(t,x)}{\partial x}\\ -\mu\times\frac{\partial^2(Q(t,x))}{\partial x^2}+2\pi R\;\tau(t,x)=0\\ H(t,x)=\left(\frac{P}{\rho\times g}\right)+(h1+h2+hx)\end{cases}$$
(30)

Now we can apply the assumptions that were mentioned later which are obtained the following equation without dimension:

$$\frac{\partial\overline{Q}}{\partial\overline{t}}+k\;Ma\;\beta\frac{\partial\overline{Q}^2}{\partial\overline{x}}+\frac{\partial\overline{H(t,x)}}{\partial x}-k\frac{Ma}{Rel}\frac{\partial^2\overline{Q}}{\partial\overline{x}^2}+k\;Ma\;L\frac{f}{4R}\overline{\tau}=0 \quad (31)$$

f : coefficient of friction

$\overline{\tau}$: The unit of the scale on the shear line.

Note: To make some simplifications, can be illustrated here the orders of a few variables:

R≈ 1.5 cm, L≈ 1Km, Rel≈ 10^9, Ma≈ 10^{-3}, f > 10^{-2}, μ≈ 10^{-3}Kg/m*s, k≈100, β≈1 : uniform flow, c≈ 1000 m/s, ρ≈ 1000kg/m^3, V_x≈ 1m/s, Q≈ 5m^3/h, P≈ 5 Bar, V_r≈ 10^{-3} m/s, K Ma/Rel <<1, K= 10s

Can be simplified to equation (31) whose we have:

$$\frac{\partial\overline{Q}}{\partial\overline{t}}+k\;Ma\;\beta\frac{\partial\overline{Q}^2}{\partial\overline{x}}+\frac{\partial\overline{H(t,x)}}{\partial x}+k\;Ma\;L\frac{f}{4R}\overline{\tau}=0$$
(32)

Recapitulation :

Since it was in front of a real problem, we chose to keep the equations with its dimensions and finally found the Saint-Venant system that characterizes the flow of water in the under pressure pumping station, taking into account the slow phenomena transient and the probability of the existence of leaks.

$$\begin{cases}\frac{\partial Q(t,x)}{\partial x}=-2\pi RVr^*\\ \left[\frac{1}{gS}\frac{\partial(Q(t,x))}{\partial t}+\frac{1}{gS^2}\left(\frac{\partial(Q^2(t,x)\times\beta)}{\partial x}\right)\right]+\\ \frac{\partial H(t,x)}{\partial x}+J(Q(t,x))=0\\ H(t,x)=\left(\frac{P}{\rho\times g}\right)+(h1+h2+hx)\end{cases} \quad (33)$$

$$J(Q(t,x))=2\frac{\pi}{gR}\tau(t,x) \quad (34)$$

III. DEVELOPMENT OF LAW ORDER

The objective of this work 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 and minimize the leak volume.

In normal operation, the PI controller implemented in the control board of the station of irrigation appears very robust and efficient, but most real-world problems must take into account imprecise and uncertain information. The static PI controller shows the difficulty of adaptation.

With the law of continuity, we know that the volume of water falling into the system is equal to the volume of water coming out of the system so if we want to save water and reduce the volume of leaks we choose to act on the pressure.

In this work we choose to develop a fuzzy logic supervisor to view the status of the station and make the adequate action to make the necessary adaptation of the parameters of PI as a simlpe solution to reduce the effect of the leak in the station.

The pressure regulation should be made taking into account two constraints. The first indicates that the pressure must be sufficient to ensure the necessary amount of water users. The second requires that the pressure should not be excessive so as not to increase leakage and show the burst pipes.

A. Design of a fuzzy supervisor:

The fuzzy supervisor has the error « e » and its derivative « $\dot{e}$ » as inputs and the command « C_{cf} » as output.

The output of the proposed fuzzy supervisor can be written as follows:

$$C_{cf} = \sum_{i=1}^{N} S_i(e,\dot{e}) \times (\mu_A^i(e) \times \mu_B^i(\dot{e})) / \sum_{i=1}^{N} (\mu_A^i(e) \times \mu_B^i(\dot{e})) \quad (35)$$

N: Number of fuzzy rules; N=25.

μ_A : Degree of membership of « e » in

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

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

Table 1: Matrix Inference of fuzzy supervisor.

e / $\dot{e}$	NG	NM	Z	PM	PG
NG	K	K	KM	KM	KTG
NM	KM	KM	KM	KM	KG
Z	KM	KP	VZ	KP	KM
PM	KG	KM	KM	KM	kM
PG	KG	KG	KG	KP	KP

B. Control station with PI controller and fuzzy supervisor:

In order to control the irrigation station by a PI controller and fuzzy supervisor is considered the functional diagram of the following command:

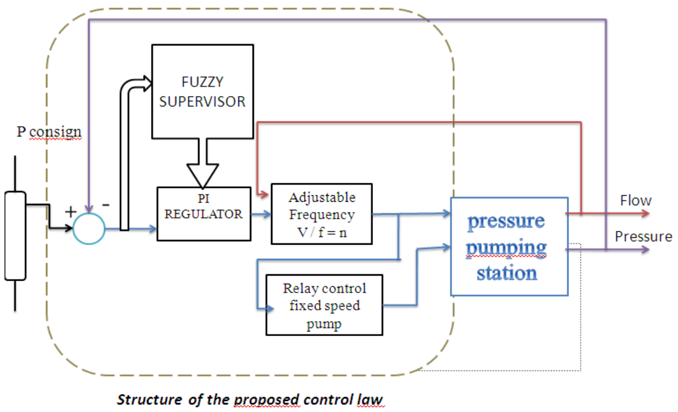

Fig 2: The functional diagram of the command.

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

$$C_{PI} = K_{C_{cf}}[(Pconsign - Poutput) + \frac{1}{T_i}\int(Pconsigne - Psortie)dt] \quad (36)$$

Where:

$$C_{cf} = f_1(e,\dot{e}) \times e + f_2(e,\dot{e}) \times \dot{e} \quad (37)$$

IV. RESULTS OF SIMULATION

In this part we represent the results of simulation with a comparative study showing the differences between the simple command with a PI controller and the influence of adding a fuzzy supervisor on the dynamics of flow leakage.

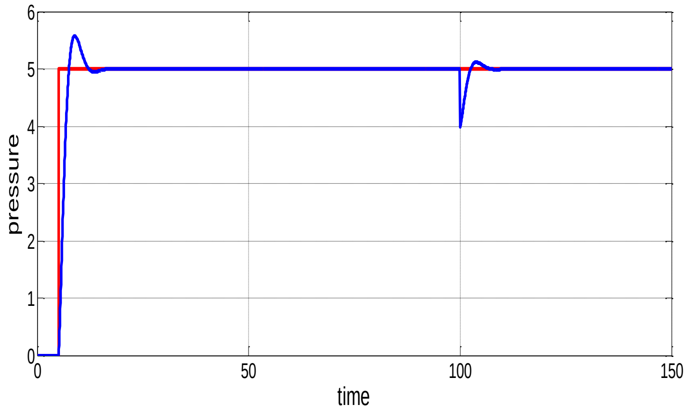

Fig 3: Evolution of the pressure in the station controlled only with a PI controller

The signals represented in Figure 3 shows that initials parameters of the PI controller ensures the desired performance and robustness against a disturbance which can reach up to 20% at the pressure.

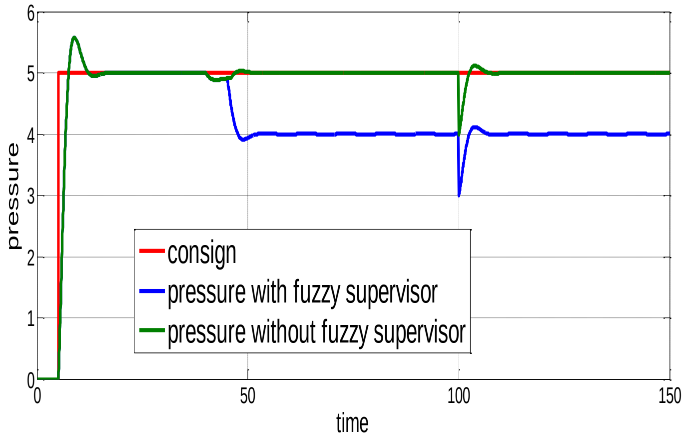

Fig 4: Evolution of the pressure in the station.

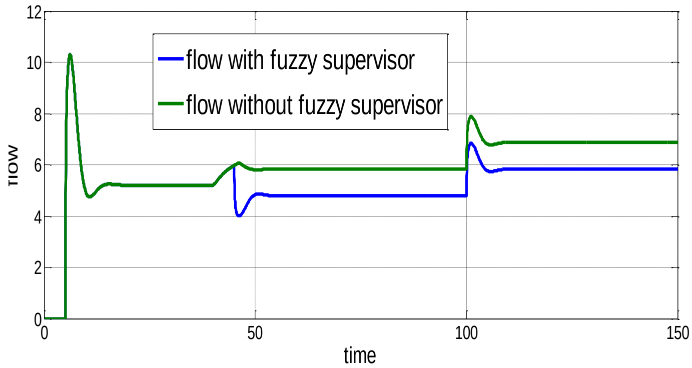

Fig 5: Evolution of the flow in the station.

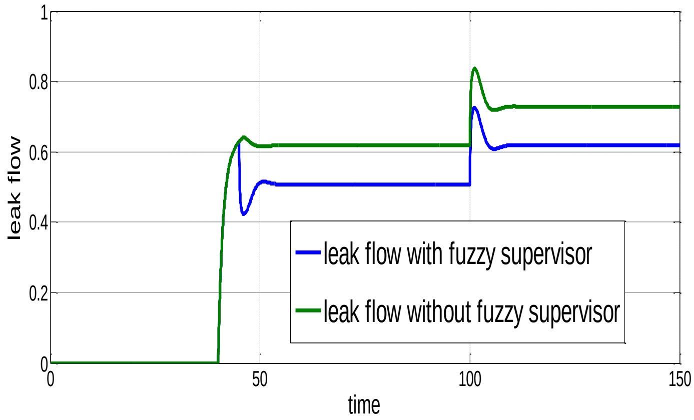

Fig 6: Evolution of the leak flow in the station.

The signal (Fig 4) shows that the PI controller installed on the station irrigation sprinkler leakage evolves as if the operation and not a fault disturbances, which we note that the latter has provided a set pressure in the order of 5 bar; consequently an increase in energy consumption was noted. The "Fig 5" illustrates the evolution of the flow is directly proportional to the energy consumption where it was noted that the PI controller commissioned to increase the flow station to dissipate the effects of pressure on leaks. In the third signal we consult with a PI controller the volume of leakage is increasing during regulation.

The integration of a diagnostic block, which is based on techniques of artificial intelligence and especially fuzzy logic gives us the ability to program the diagnostic function using only the operator's expertise; has proved its effectiveness.

The intelligent diagnostic block not only the role of diagnosis but also has an adaptive role he reacts to the pressure to reduce the volume of detected leaks.

The intelligent diagnostics block distinguishes the difference between a disruption and leakage by analyzing the temporal evolution of the last two of which were noted after the practical tests of the dynamic leakage standpoint pressure and slower than disturbances.

The adaptation of the order must be made taking into account the three constraints. The first indicates that the pressure must be sufficient to ensure the proper functioning sprinklers. The second requires that the pressure should not be excessive so as not to grow the volumes of leaks that cause the bursting of pipes and damage to equipment levels (sprinklers, filters, corrosion of turbines ...). Third, we need to keep the desired performance.

The technique of reducing the set point is commonly used in high pressure hydraulic systems and especially in the distribution of drinking water.

In Figure Fig 4, the blue signal illustrates the dynamics of the terminal pressure pipes which we simulated the existence of leaks by the action on "the drain valve" at a time t = 40s. The diagnostic algorithm has detected that dynamic and has classified as leaks then she changed the set parameters to respect the constraints that were mentioned above. The set will therefore be equal to 4 bar in the presence of leaks.

To ensure the desired performance, we injected a disturbance at a time t = 100s and it was found that the control loop reacts perfectly and provides the desired performance for that area of operation of the pressurized irrigation station.

The addition of a block of the diagnostic to moderate energy consumption and volumes of leaks, there is illustrated respectively in that the evolution of the signal flow and the dynamics of the volume of water lost.

VI. CONCLUSION

In this work we tried to improve the performance of a water pumping station under pressure by integrating a adaptive control law and a block of diagnosis based on a fuzzy supervisor.

Initially, we worked to find a mathematical model represents the dynamics of the different variables in the station incorporating the long phenomena and the probability of leaks.

This model was very necessary to us even if it seems very complicated, but we chose to leave it with the real dimensions because our goal is not just simulation but more than that we want to pass an implementation practice on the station.

Then we chose to order the station with an adaptive PI controller which its parameters are calculated using a fuzzy supervisor.

The fuzzy supervisor does not have a diagnostic block, but more than that is change the parameters of PI regulator to reduce the pressure and therefore reduce leaks.

Simulation results are very encouraging who's a fuzzy supervisor has detected the existence of leaks and it has also reacts well; against part he has distinguished the difference between a disturbance consumption and leakage.

Our regulation also remains perfect whose the supervisor reacts reducing pressure, but also ensuring continuity of good station operation with minimal pressure.

REFERENCES

[1] MEJRI Mohamed Radhouane, Abderrahmen ZAAFOURI and Abdelkader CHAARI," HYBRID CONTROL OF A STATION OF IRRIGATION BY SPRINKLING" International Journal of Engineering and Innovative Technology (IJEIT),Volume 3, Issue 1, July 2013

[2] Litrico X, Fromion V. Analytical approximation on open-channel flow for controller design. Appl Math Model 2004.

[3] E. Jaumouillé, O. Piller, and J.E. Van Zyl. Advantages of a hydraulic saint-venant type model with pressure-dependent leakage 2008.

[4] S.L. Prescott and B. Ulanicki. Improved control of pressure reducing valves in water distribution networks. Journal of hydraulic engineering 2008.

[5] M. Jansson et B. Wahlberg. On consistency of subspace methods for system identification. Automatica, Décembre 1998.

[6] L. Belkoura, J.-P. Richard, M. Fliess, On-line identification of systems with delayed inputs, MTNS'06, in: 16th Conf. Mathematical Theory of Networks & Systems, 2006.

[7] W. E. Larimore. Canonical variate analysis in identification, filtering and adaptive control. pages 596–604. 29iéme IEEE Conference on Decision and control, 1990. Hawaï, USA.

[8] M. Jansson et B. Wahlberg. On consistency of subspace based system identification methods. pages 181–186. 13th IFAC World Congress, July 1996. San Francisco, USA.

[9] M. Bahat, G. Inbar, O. Yaniv, M. Schneider.A fuzzy irrigation controller system. Engineering Applications of Artificial Intelligence 13 (2000). Elsevier Science.

[10] W. Chebbi, M. Benjemaa, A. Kamoun M. Jabloun, A. sahli. Development of a WSN Integrated Weather Station node for an Irrigation Alert Program under Tunisian Conditions. 8th International Multi Conference on Systems, Signals & Devices, Tunisie 2011.

[11] P. Fabrie and M. Colin. Cours et exercices d'optimisation. MATMECA, Ecole d'ingénieurs en Modélisation Mathématique et Mécanique, 2008.