DESIGN OF A FUZZY CONTROLLER OF PH BY THE GENETIC ALGORITHMS

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ABSTRACT
The fast extension of systems enslaved by the modern algorithm development making call to the practiced, network-fuzzy systems, genetic algorithms. . .
In general manner the controls appropriate of the pH, put the inherent problem to the no linearity . We transplant an GA to the FLC developed previously for a regulation of the pH and tempt to explain in our work grounds of our choice and improvements gotten.
KEY WORDS: Genetic algorithms, fuzzy Logic Controller, regulation of the pH.

I.INTRODUCTION

The acidity or the alkalinity of solutions that are indicated by a value of the pH are a means especially importing chemical or biologic technical process control in the worn-out water treatment. The significance of the value of the pH in the industrial processes resides in the fact that several phenomena, as floating, the precipitation and the coagulation, produce themselves better to a certain value of the pH. In the food industries for example where fermentation constitutes a very important parameter, its efficiency rests on a very precise value of the pH. Stations of purification worn-out water domesticate have an objective duplicate:
Production and growth of resources in water. Protection of the environment.
The neutrality of water before his/her/its evacuation on the receiving middle is guaranteed by an operation of coloration foreseen in the last work of the station this operation rests on an order of the value of the pH.
The main difficulty, for the control of the pH in the case of a process continues, view count algorithm comes of two essential features:
The no linearity of the pH in reactions.
The effect tampon that translates himself by an incomplete weak acid/base dissociation.

II. DESIGN OF A FLC [1],[3],[4]

The technological development produced some complex systems, greatly no linear or difficult to identify and to command by the classic controllers (PID, adaptive. . .).
But the apparition of the fuzzy logic and his principle that are analogous to the human thought, gave a new approach for which laws of commands are replaced by the linguistic rules that achieve the objective of control. This last requires the availability of the human appraisal, and fuzzy system performances depend on the reliability of knowledge gotten. The phase of knowledge acquirement presents a very delicate stain, especially in absence of an expert that can provide his ability on problems to treat. For this reason, some very advanced researches drove to the systematic and optimal method development for the conception of the effective fuzzy controllers.
These techniques permit:
The automatic extraction of knowledge under shape of the fuzzy rules. The optimization of adherence functions. The conjoined utilization of the these two approaches (genetic algorithm, fuzzy control) permits to achieve a fuzzy inference system, to exploit the wealth of each and to get some as flexible and efficient intelligent systems that possible. The conception of a FLC requires the following parameter choice:
The definition of variable of E/S of the system.
The choice of the fuzzy partition of E/S variable by functions of adherence defined on the suitable speech universes.
The shape of adherence functions of the space of E/S (triangular, gaussienne,...).
The basis of rules.
The choice of the inference method and the strategy of defuzzification.
The efficiency and performances of fuzzy system are bound by two important factors:
The availability of the appraisal.
The validity of techniques of knowledge acquirement and the reliability of data acquired.
The solution is the automatic extraction of the knowledge without need of the expert.
However, with the expert and the automatic extraction technique one leads to a FLC of degree of efficiency and suppleness of manipulation raised.

III. GENERATION OF THE BASIS OF KNOWLEDGE OF A FLC BY THE GA [1],[5]

The figure(1) illustrates the architecture of a command system, organized of one:

- block of optimization representing the GA.
- fuzzy controller block.
- system to command (process).

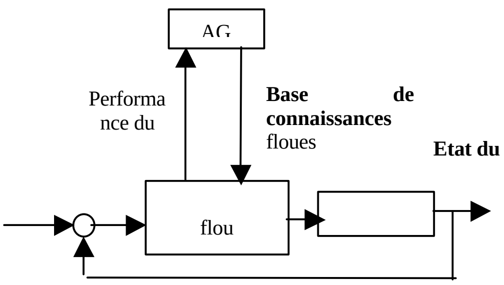

Fig.1 *Architecture of the command system*

The interaction between these blocks summarizes himself as follows:

After the determination of the mode of coding and the decoding of parameters to optimize, the GA generates a population uncertain of chains (basis of knowledge).

These chains are injected on the fuzzy controller, after counts (normalization, fuzzification, inference, defuzzification and demoralization), the action of command will be present to the controller's exit to attack the process.

What permits to indicate the controller's performances on the other hand.

The GA must have a model of the system to value the criteria of performance of the controller (the minimization of the total error between the present state of the system and the state wanted).

After the evaluation of all chromosomes of this initial population, a new generation will be gotten while applying the genetic operators (selection, crossing, mutation).

This process repeats itself until the satisfaction of the criteria of stop of the GA of which rules of inference used are type of MAMDANI, and the defuzzification is made by the method of the gravity center.

IV. CODING OF PARAMETERS [5]

The used coding is a coding whole multiparameters. Parameters are coded and are juxtaposed to form chromosomes of the GA. Parameters to optimize are:

The fuzzy rules basis. Parameters describing functions of adherence of a FLC.

All these parameters are coded in a chromosome (whole chain) of length 58, whose genes are {1, 2,..., 7}.

For a controller (777) we have:

Seven fuzzy partitions for the space of speech of the error.

Seven fuzzy partitions for the space of speech of the error variation.

Seven fuzzy partitions for the space of speech of the control. Therefore we have 49 fuzzy rules, that constitute the first 49 alleles of the chromosome.

Functions of adherence used are triangular symmetrical definite on an universe of speech normalized in the interval [-1, 1], as the shows the following figure:

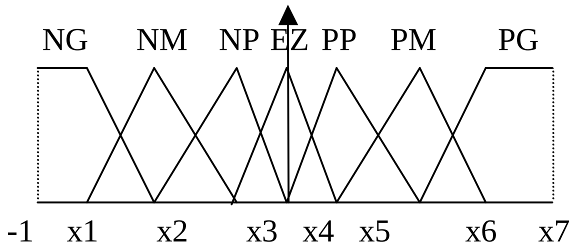

Fig.2 *Description of parameters of adherence functions*

$x_1, x_2. \ . \ , x_7$ represent picks of every adherence function respectively (NG,NM,... ,PG), and as the shape of functions used is triangular symmetrical one can only define parameters x_5, x_6, x_7 because:

$x_1 = - x_7$; $x_2 = - x_6$; $x_3 = - x_5$; $x_4 = 0$ (the pick of EZ is always zero).

Therefore for each variable we define three parameters (the pick of PG, the pick of PM and the pick of PP). Parameters to optimize for the three variables are:

- epiPP the pick of PP, epiPM the pick of PM and epiPG the pick of PG. (for (e))
- vpiPP, vpiPM and vpiPG. (for(e))
- upiPP, upiPm and upiPG. (for(u))

The chromosome will have the following structure:

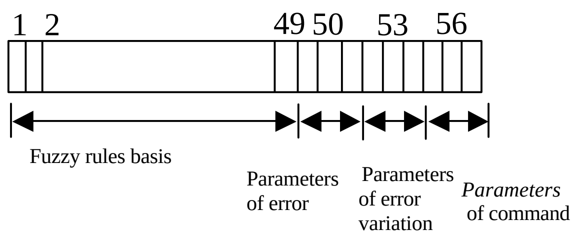

Fig. 3 *Structure of the chromosome.*

V. DECODING OF PARAMETERS:

As we have already mention it, the reserved alleles to the fuzzy rules basis correspond to the fuzzy wholes of the part consequence. This correspondence defines the decoding of the rules basis and is described explicitly in the tableau(1).

Tableau(1) *: Decoding of the fuzzy rules basis*

Allele(*chrom*[i]=1..7) i=1..49	1	2	3	4	5	6	7
Fuzzy wholes	NG	NM	NP	EZ	PP	PM	PG

The decoding of parameters of adherence functions, is described by the tableau(2).

***Tableau(2)**: Decoding of parameters of adherence function*

Error	epiPP =chrom[50] * 0.1 ; epiPM =chrom[51] * 0.1* (1 epiPP) + epiPP ; epiPG =chrom[52] * 0.1 * (1- epiMP) + epiPM ;
Error variation	vpiPP =chrom[53] * 0.1 ; vpiPM =chrom[54] * 0.1* (1 vpiPP) + vpiPP ; vpiPG =chrom[55] * 0.1 * (1- vpiPM) + vpiPM ;
command	upiPP =chrom[56] * 0.1 ; upiPM =chrom[57] * 0.1* (1 upiPP) + upiPP ; upiPG =chrom[58] * 0.1 * (1- upiPM) + upiPM ;

VI MECHANISM OF THE GENETIC ALGORITHM

The GA uses the selection by wheel of fortune, an operator of crossing in a point and the mutation. In the mutation we change the allele (the whole) by an uncertain value going of 1 to 7 different of its current value. We use the technique of selection of the state then permanent steady-state selection to construct a new more effective generation that the previous. The stop of the GA is determined by the maximal number of generations (Maxgen).

VII. DESCRIPTION OF THE PROCESS [1],[2]

The theoretical example that we propose is a continuous process. It is constituted of four (04) reservoirs containing each a solution, all solution has the same composition but to different concentration.
The operation consists in drawing the solution of the reservoir (I) with a debit of 1 l/min in continuous that will be poured in the reactor, then to provoke disruptions with other reservoir solutions how shown in the figure (4).

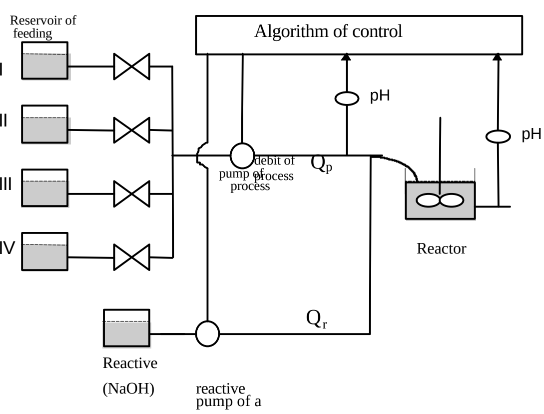

***Fig.4** Schematic of the process*

The gotten solution will be adjusted by a reactive foreseen to this effect. The two reactive used are NaOH and Hcl.
The chemical composition, concentrations and the constant of dissociation are given by the following tableau

Tableau (3): Constant of dissociation and concentration of species in the reservoirs of feeding

Elements	Constant of dissociation
Acid Chlorhydric (C_{Ap}) Nitrophenol (C_{a1p}) Pyridine (C_{b1p}) Ammoniac(C_{b2p})	∞ $K_{a1}= 7.24 *10^{-8}$ $K_{b1}= 1.5 *10^{-9}$ $K_{b2} = 1.78*10^{-5}$

Concentrations (mole/ l)			
I	II	III	IV
0.0065	0.0015	0.065	0.025
0.01	0.01	0.01	0.01
0.002	0.0005	0.0009	0.0005
0.00035	0.0005	0.0009	0.0005

VIIICHEMICAL MODEL OF THE PROCESS [4],[5]

The chemical solution considered in the survey of the process is composed of:
C_A : concentration of the strong acid (Hcl).
C_B : concentration of the strong basis (C_B=0).
C_{a1} : acid at weak concentration (Nitrophenol)
C_{b1} and C_{b2}: bases of weak concentration Pyridine and Ammoniac.
C_r: concentration of the reagent used.
Concentrations to the entrance and the exit of the reactor are supposed known.
The ionic balance equation is given as follows:

$$C^+ - \frac{Kw}{C^+} - C_A + C_B - \frac{K_{a1}}{C^+ + K_{a1}} C_{\alpha 1} + \frac{K_{b1}C^+}{K_{b1}C^+ + K_w} C_{\beta 1} + \frac{K_{b2}C^+}{K_{b2}C^+ + K_w} C_{\beta 2} + C_r = 0 \quad (1)$$

C_+: is the concentration of hydrogen ions.
K_W: is the ionic product of water.
K_{a1}, K_{b1}, K_{b2}: the constant of dissociation of acid and the weak bases.
H_r takes the value (+1) or (-1) according to the used reactive.
Hr = +1: the used reactive is a basis.
Hr = -1: the used reactive is an acid.
The value of the pH is given by:

$$pH = -\log[C (mole/l)] \quad (2)$$

The ionic balance condition is valid to every point of the reactor.

The chemical dynamic phenomenon in the reactor translates himself by the differential equations of the first order no coupled following:

$$\dot{c}_{\alpha\beta} = \frac{Q_p}{V} c_{\alpha\beta p}\left(t - \frac{vd}{Q_p + Q_r}\right) - \frac{Q_p + Q_r}{V} c_{\alpha\beta}(t) \quad (3)$$

$$(\dot{c}_A - \dot{c}_B) = \frac{Q_p}{V} (c_A - c_B)_p \left(t - \frac{vd}{Q_p + Q_r}\right) - \frac{Q_p + Q_r}{V} (c_A - c_B)(t) \quad (4)$$

$$\dot{c}_r = \frac{Q_r}{V} c_{rc}\left(t - \frac{vd}{Q_p + Q_r}\right) - \frac{Q_p + Q_r}{V} c_r(t) \quad (5)$$

Where: Q_p: the debit of the process.
Q_r: the debit of the reactive.
V: the volume of the reactor (V=3.20 l).
V_d: the volume of the piston (V_d =0.166l).
C_{rc}: concentration of the reactive in the stock.
C_r: concentration of the reactive to the output of the reactor.

IX . DEVELOPMENT OF THE FLC [2],[3]

The objective consists in getting a pH in output near the reference.
The controller's entrances are:
the error: e(k) = pHref - pHmesured(k).
the variation of the error: e(k) = e(k) - e(k-1).
the variation of the control noted: Qr.
For a fast answer of the system, two (02) types of regulating are used:
- Coarse regulating.
- Thin regulating.
Intervals partners to the error, his variation and to the variation of the control for every type of regulating are given by:
-Thin regulating
$-1 \le e \le 1$; $-1 \le \Delta e \le 1$; $-0.215 \le \Delta Q_r \le 0.215$ [l/min].
-Coarse regulating
$-7 \le e \le +6$; $-7 \le \Delta e \le +6$; $\Delta Q_r = 0.4$ [l/min] fixed debit
The FLC is identical the one described previously and the function of cost is:

$$J = \sum_{k=1}^{150}$$

The GA are procedures that look for the maximum, what gives back the problem of minimization of J in a problem of maximization of the objective function given by

$$F = \frac{1}{1-J} \quad (7)$$

Parameters of the genetic algorithm:
the size of population is fixed to 50.
the equal mutation probability to 0.03.
the probability of crossing equals to 0.8.
the maximal number of generation is 50.

X. RESULTS OF TRAININGS OF THE GA:

The following tableau gives the basis of rules gotten:

Tableau(4): *Fuzzy rules basis.*

Δe	**NG**	NM	NP	EZ	PP	PM	**PG**
NG	NM	PG	NM	PP	PM	NP	PG
NM	NP	NM	NG	PP	NP	EZ	NP
NP	EZ	PM	NG	NG	NG	PP	EZ
EZ	NP	PM	PP	EZ	PP	PG	PP
PP	PM	NM	PP	EZ	NP	PG	EZ
PM	PM	PM	NP	PP	NG	PP	NM
PG	NM	NM	PG	PG	NG	PM	PP

XI. RESULTS OF SIMULATION:

The utilization of the knowledge basis (rules of inference, functions of adherence) for the control of the pH gave the following simulation results:

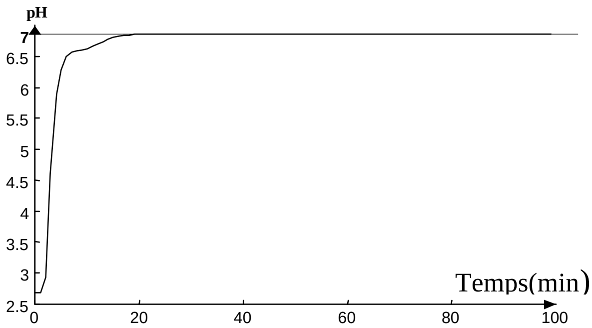

Fig. 5 : Response of the system

The exploitation of this curve shows:
- a very short answer time.
-the absence of overtaking (no oscillation).

XII. EXPERIMENTAL RESULTS:

The example of acid and basic regulating achieved to the laboratory figure(6), provided the following results figure(7), figure(8).

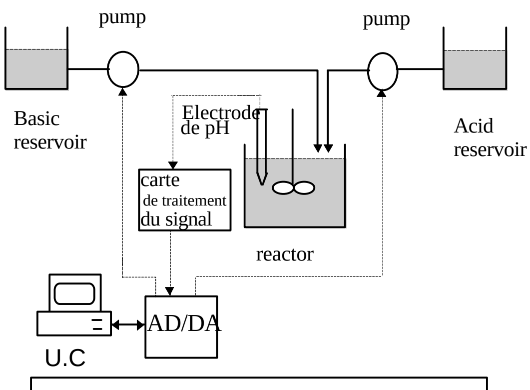

Fig.6 Schematic of the process

For a volume of reactor V=200ml we used the following concentrations: C (NaOH) = 1M. C (Hcl) =0.05M

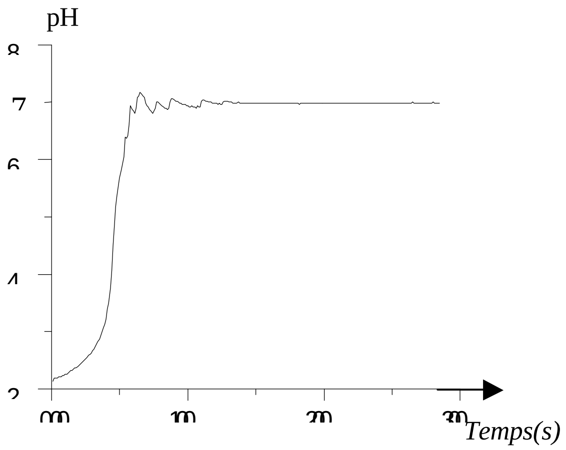

Fig.7 *:response of the regulator*

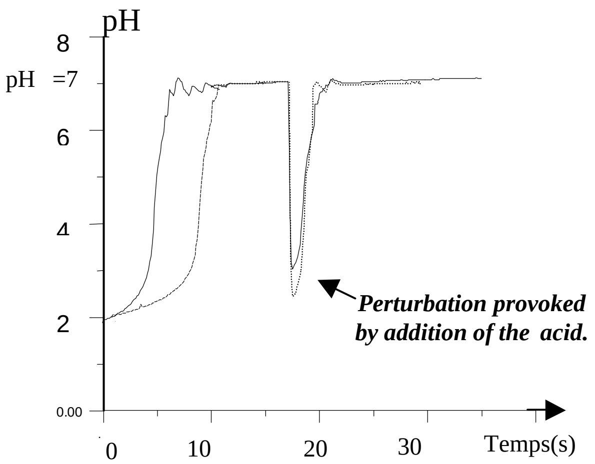

Fig.8 comparative representation between FLC with GA and FLC without GA

....	Response FLC(without AG)
————	Response FLC(with AG)

Universes of speech partners to the fuzzy variable are as follows:

For the coarse regulating:

$-7 \leq e \leq +6$; $-7 \leq \Delta e \leq +6$;

ΔQr = 2.5 [ml/s] fixed debit (maximum speed of the pump)

For the thin regulating :

$-1 \leq e \leq 1$; $-1 \leq \Delta e \leq 1$;

$-0.75 \leq \Delta Qr \leq 0.75$ [ml/s].

CONCLUSION:

The fuzzy controller for the case of an acid-basic regulation showed a good hardiness and well stocked of very good results.

It is gotten to the price of a certain major difficulty that requires a knowledge perfect of the process.

The genetic algorithms hybridized with the fuzzy logic permitted the elimination of knowledge mastered by the operator and the outcome to a "pseudo-intelligent system"

The gotten results are distinctly better that those gotten previously.

Finally, the achieved work finds an impact in the biotechnology and offer a perspective for the survey of systems discreet multivariables.

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