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AN EXPERT SYSTEM FOR WASTEWATER pH CONTROL

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Abstract: *A very important parameter for all water categories, inclusively for wastewaters is pH that is a measure of a solution acidity or alkalinity. The problem of wastewater pH control is one of present interest, due to the complexity and non-linearity of the pH neutralization process. For pH control can be applied conventional or advanced control techniques. Some of the advanced techniques belong to artificial intelligence domain (AI), such as: expert systems, fuzzy logic, neuro-fuzzy, neural networks, genetic algorithms, etc. In the present paper it is developed a prototype expert system for pH control, system named SEpHControl that can be implemented as a controller into an automatic system for pH control.*

Keywords: *expert system, pH control, controller, neutralization*

1. INTRODUCTION

The most advanced application of expert systems (ES) is in the control of certain parameters (for instance: pH, flow, level, etc.), that describe various processes. In literature, there is presented a set of expert systems (ES), in some cases combined with other instruments (like fuzzy logic, etc.), ES used for controlling certain parameters from a wastewater treatment plant (WWTP), such as the BIOEXPERT system or for the optimal adjustment of control loops, such as EXPERT_AT system [3, 4, 1].

In control problems, an ES can be implemented to work like a controller. According [5], the expert systems implemented as controllers are, from conceptual point of view, similar to fuzzy controllers, but their knowledge base (KB) and the inference engine (IE), can use more evolved strategies to determine which rules will be applied at a certain moment. Plus, ES and fuzzy controllers have in common the fact that for generating the adequate command it is used the plant operator's knowledge and expertise, fact that is a major advantage especially in the case of complex processes.

2. THE EXPERT SYSTEM SEpHControl

2.1 System architecture. In figure 1 it is proposed the architecture of an automatic system for pH control named SRA-pH that uses as controller the developed expert system SEpHControl.

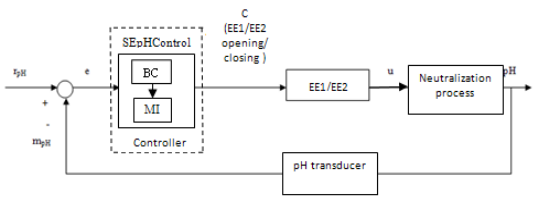

Fig. 1. SRA-pH architecture

As we can observe in figure 1, the SRA-pH system has the following components:

1. the expert system SEpHController which is in fact the system controller;
2. two execution elements EE1and EE2 used for acid or alkaline neutralization agents dosage;
3. the command (C) generated by the controller (SEpHController), respectively the EE1 or EE2 opening percentage;
4. the model of the neutralization process from literature [2]
5. a pH transducer that measures the pH value at the process output;
6. the error (e) defined as the difference between pH reference value (r_{pH}) and the pH measured value (m_{pH}) at the process output.

For developing the expert system SEpHControl (the SRA-pH controller) it was used the ES generator VP-Expert 2.1, developed by Paperback Software International.

After studying the wastewater pH neutralization process, we developed the SEpHControl analysis tree with the structure presented in figure 2.

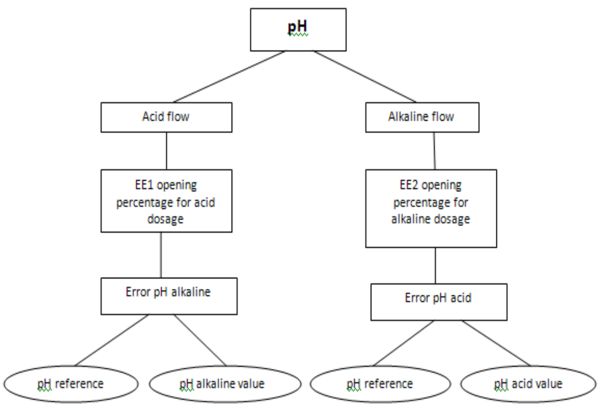

Fig. 2. SEpHControl analysis tree

As we can observe in figure 2, the goal variable is pH, namely the pH value at the neutralization process output (neutral, weak acid, strong acid, weak alkaline or strong alkaline pH).

In table 1 are presented the analyzed variable and their values, numerical and symbolical (the possible domain of values).

Tabel 1. The values domain

Variable	Domain
pH (units)	neutral ∈ (6.5 7.5) strong acid ∈ [2 5] weak acid ∈ (5 6.5] strong alkaline ∈ [9 12] weak alkaline ∈ [7.5 9)
Acid flow (acid_flow)	high (≈98 l/h) big (≈ 90 l/h) medium (≈ 85 l/h) low(≈ 80 l/h) zero (≈ 75 l/h)
Alkaline flow (alkaline_flow)	high (≈ 200 l/h) big (≈ 190 l/h) medium (≈ 180 l/h) low (≈ 175 l/h) zero (≈ 150 l/h)
EE1 percentage opening for acid F1 dosage (percent_opening_ee_acid)	high ∈ [45% 100%] big∈ [30% 50%] medium ∈ [15% 35%] low ∈ [0% 20%] zero ∈ [0% 0.05%]
EE2 percentage opening for alkalineF2 dosage (percent_opening_ee_alkaline)	high ∈ [45% 100%] big ∈ [30% 50%] medium ∈ [15% 35%] low ∈ [0% 20%] zero ∈[0% 0.05%]
Error pH alkaline (error_ph_alkaline)	high ∈ [-5 -2] big ∈ [-3 -1] medium ∈ [-2 -0.5] low ∈ [-1 0] zero ∈ [-0.5 0]
Error pH acid (error_ph_acid)	high ∈ [2 5] big ∈ [1 3] medium ∈ [0.5 2] small ∈ [0 1] zero ∈ [0 0.5]
Reference value pH (reference_ph)	REF (=7)
Influent alkaline pH value (ph_infl_alkaline)	B1 ∈ [9 12] B2∈ [8 10] B3 ∈ [7.5 9] B4 ∈ [7 8] B5 ∈ [7 7.5]
Influent acid pH value (ph_infl_acid)	A1 ∈ [2 5] A2 ∈ [4 6] A3∈[5 6.5] A4 ∈ [6 7] A5 ∈ [6.5 7]

The knowledge base (KB) of the SEpHControl expert system (of the controller), it is composed from a number of fifty two heuristic rules, from which are presented the following ones:

1. if reference_ph=REF and ph_infl_alkaline =B1 then error_ph_alkaline=high;

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2. if error_ph_alkaline=high then percent_opening_ee_acid=high;
3. if opening_ee_acid=high then acid_ flow =high;
4. if reference_ph=REF and ph_infl_acid =A1 then error_ph_acid=high;
5. if error_ph_acid=high then percent_opening_ee_alkaline=high;
6. if percent_opening_ee_alkaline=high then alkaline_flow=high;
7. if acid_flow=high and alkaline_flow=zero then pH=strong_acid;
8. if acid_flow=big and alkaline_flow=low then pH=strong_acid;
9. if acid_flow=medium and alkaline_flow=low then pH=weak_acid;
10. if acid_flow=low and alkaline_flow=big then pH=weak_alkaline;
11. if acid_flow=zero and alkaline_flow =high then pH=strong_alkaline;
12. if acid_flow=zero and alkaline_flow = zero then pH=neutral.

2.2 SEpHControl user interface. In figure 3 it is presented the expert system SEpHControl interface developed in VP-Expert 2.1.

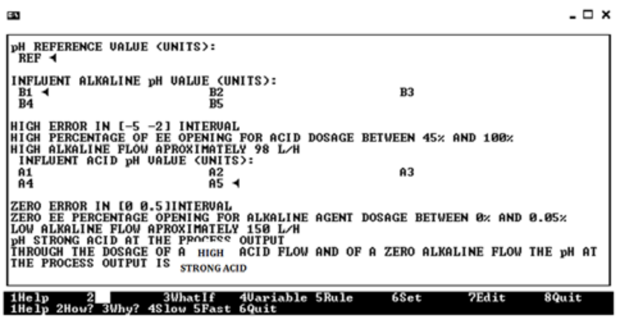

Fig. 3. SEpHControl interface

As we can observe in figure 3 for obtaining the pH value (neutral, strong acid, etc.) at the process output, respectively the flow of alkaline or acid neutralization agent necessary for bringing the pH value at the reference value, the user must give to the system the reference value for pH and the influent pH value (influent with alkaline or acid pH). Depending on these values, the system determines the error which that becomes input for the system controller. Dependent on this error it is determined the EE1 or EE2 percentage opening for acid or alkaline neutralization agent dosage necessary for pH adjustment.

2.3 Experimental results. In tables 2 and 3 are presented the experimental results for different influent pH values, either acid or alkaline. After consulting the system knowledge base, using the corresponding rules, the developed system determines the necessary neutralization agent flow (NaOH or H_2SO_4) for bringing the pH value at the reference value (pH=7, neutral pH), and also the pH character (acid or alkaline/basic) after dosing a certain reactive flow.

Tabel 2. Experimental results

pH reference	Influent alkaline pH value (units)	Influent acid pH value (units)	Error pH alkaline	EE1 percentage opening (%)
REF (=7)	B1 ∈ [9 12]	A5 ∈ [6.5 7]	high ∈ [-5 -2]	high ∈ [45 100]
	B2 ∈ [8 10]	A4 ∈ [6 7]	big ∈ [-3 -1]	big ∈ [30 50]
	B3 ∈ [7.5 9]	A3 ∈ [5 6.5]	medium ∈ [-2 0.5]	medium ∈ [15 35]
	B4 ∈ [7 8]	A2 ∈ [4 6]	low ∈ [-1 0]	low ∈ [0 20]
	B5 ∈ [7 7.5]	A1 ∈ [2 5]	zero ∈ [-0.5 0]	zero ∈ [0 0.05]
	B5 ∈ [7 7.5]	A5 ∈ [6.5 7]	zero ∈ [-0.5 0]	zero ∈ [0 0.05]
	B4 ∈ [7 8]	A5 ∈ [6.5 7]	low ∈ [-1 0]	low ∈ [0 20]
	B5 ∈ [7 7.5]	A4 ∈ [6 7]	zero ∈ [-0.5 0]	zero ∈ [0 0.05]

Table 3. Experimental results

Acid flow(l/h)	Error pH acid	EE2 percentage opening (%)	Alkaline flow (l/h)	pH
high (≈98)	zero∈ [0 0.5]	zero ∈ [0 0.05]	zero (≈ 150)	strong acid
big (≈ 90)	low ∈ [0 1]	low ∈ [0 20]	low (≈ 175)	strong acid
medium (≈ 85)	medium ∈ [0.5 2]	medium ∈ [15 35]	medium (≈ 180)	weak acid
low (≈ 80)	big ∈ [1 3]	big ∈ [30 50]	big (≈ 190)	weak alkaline
zero (≈ 75)	high ∈ [2 5]	high ∈ [45 100]	high (≈ 200)	strong alkaline
zero (≈ 75)	zero ∈ [0 0.5]	zero ∈ [0 0.05]	zero (≈150)	neutral
low (≈ 80)	zero ∈ [0 0.5]	zero ∈ [0 0.05]	zero (≈150)	neutral
zero (≈ 75)	low ∈ [0 1]	low ∈ [0 20]	low (≈ 175)	neutral

As it can be observe in tables 2 and 3 when the acid flow it diminish, the basic flow raises and inverse, this because at a certain moment it works just one actuator (or EE1 for acid flow dosage or EE2 for basic flow dosage). It was obtained a neutral pH at the process output when both actuators are on zero action (are closed) fact that means that the pH value it reached the reference value and that isn't necessary the dosage of reactive (when one of the actuators is thinly opened or the other one it is closed).

3. CONCLUSIONS & ACKNOWLEDGMENT

The knowledge based systems, category from which make part the expert systems, it is one of the most known and used technique of artificial intelligence, with applicability in a large number of domains.

The developed expert system SEpHControl, implemented as a controller of a control system, function of its rules and heuristics, supplies solutions for improving the automatic process of pH control through the establishment of the necessary reactive flow for basic or acid pH neutralization.

The expert system SEpHControl is from conceptually point of view similar to a fuzzy controller, according [5]. This problem it will be discussed in a future paper, where it will be developed a fuzzy controller for an automatic system dedicated to pH control.

Using knowledge and certain inference rules, an expert system is capable to suggest to a plant operator the most adequate action for solving different problems that can appear in a plant, such as: pH control, level control, flow control, etc.

Due to the fact that expert systems can be used as controllers in automated control systems and due to the similarity with fuzzy controllers and neuro-fuzzy ones, the expert systems proves to be a useful tool in control problems and more.

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