NUMERIC SYSTEM FOR ADJUSTING THE LEVEL IN 3 BASINS CONNECTED IN CASCADE

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Abstract: In this paper will be presented a laboratory model which tests real time optimization problems specific to a hydro-energetic system, formed of many hydrographic basins connected in cascade on the same water flow. Because of the fact that mathematical modelation simulated with the help of the Matlab package of programs leads to very good results, in a real process, because of the inherent nonlinearities, the things are not quite like that, so we tried to make at a smaller scale, a miniature hidro-energetic system.

1.Introduction: optimization problems related to a hydro-energetic system

In this paper we will try to approach some optimization problems related to a hydro-energetic system, formed of many hydrographic basins connected in cascade on the same water course. For simulation will be used a laboratory model which tries to create relatively real functioning conditions for the hidro-energetic system. The motivation of the word "optimization" appears because of the fact that in the automated modern systems, next to the two conditions that the adjustment structure should carry out: **S-condition for stability of the process**, meaning to find a command which firstly to lead to a convergent solution to a finite value of the system's response, and **R-adjustment condition**, meaning that convergence to be done with certain performances, besides these two appears a third very important condition, the command designed within the adjustment structure to be OPTIMAL relatively to the functioning requirements of the process.

2. Implementation with three independent adjustment loops – adjusting the level in each basin

The practical realization is conceived as a model formed of 3 basins connected in cascade which simulates 3 accumulation lakes connected in cascade. The water supply is made through 3 faucets which simulates the pluviometrical variations, and the hydra-electric power station turbine is simulated through 3 pumps (one on each basin) which force a higher flow than free drain. The level is measured through 3 floaters connected to potentiometers. The flow which sloops through pumps (when the pumps are stopped) may be considered the minimum flow which must go through the hydra-electric power station in order not to drain all the river on which it is on. In the analysed process we will consider the evacuation of the liquid through free fall, as in fig.1.The mathematical model can be obtained on the basis of the material balance.

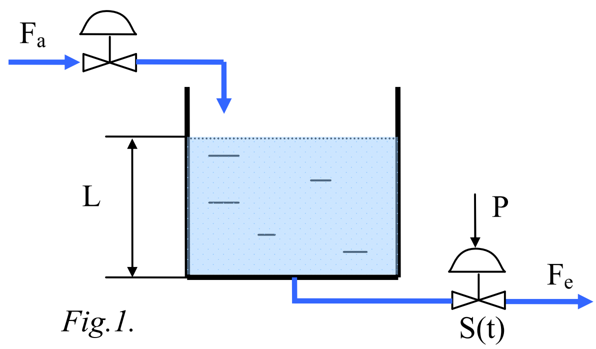


Fig.1.

In stationary regime, we will have:

$$F_{a0} = F_{e0} \quad (1)$$

In dynamic regime:

$$A \cdot \frac{dL(t)}{dt} = F_a(t) - F_e(t) \qquad (2)$$

where: F_a - volume of supply flow; F_e-volume of drain flow; A-transversal section of the basin, L - liquid level.

According to Bernoulli's equation applied to the flow through openings, we will have: $F_e = cS(t) \cdot \sqrt{\frac{\Delta P(t)}{\rho}}$ in which $\Delta P(t) = \rho g L(t)$, in the hypothesis that the output pressure is equal to the atmospheric pressure. In this situation, for the dynamic regime we will have:

$$A \cdot \frac{dL(t)}{dt} = F_a(t) - c \cdot S(t) \cdot \sqrt{\frac{\rho g L(t)}{\rho}}; \qquad (3)$$

where S is the surface of flow through the drain vent..

Because relation (2.3) is not linear, to obtain the transfer function, the linearization will be made around a static point of functioning: F_{e0}; L_0; S_0; F_{a0}. We will have:

$$F_e(t) = F_{e0} + \left[\frac{\partial F_e(t)}{\partial S}\right]_{L=L_0=ct.} \cdot \Delta S(t) + \left[\frac{\partial F_e(t)}{\partial L}\right]_{S=S_0=ct} \cdot \Delta L(t) \qquad (4)$$

or: $\Delta F_e(t) = F_e(t) - F_{e0} = c\sqrt{g \cdot L_0} \cdot \Delta S(t) + \frac{cS_0 g}{2\sqrt{gL_0}} \cdot \Delta L(t)$

$$\left.\begin{array}{l} \Rightarrow \Delta F_e(t) = \frac{cS_0\sqrt{gL_0}}{S_0} \cdot \Delta S(t) + \frac{cS_0 g\sqrt{gL_0}}{2gL_0} \cdot \Delta L(t) \\ pt.\ L = L_0\ si\ S = S_0 - regim\ stationar \Rightarrow F_{e0} = cS_0\sqrt{gL_0} \end{array}\right\} \Rightarrow \Delta F_e(t) = \frac{F_{e0}}{S_0} \cdot \Delta S(t) + \frac{F_{e0}}{2L_0} \cdot \Delta L(t) \qquad (5)$$

We assume a variation of the supply flow which varies between the stationary regime value: $F_a(t) = F_{a0} + \Delta F_a(t)$, we will have:

$$A \cdot \frac{d\Delta L(t)}{dt} = \Delta F_a(t) - \frac{F_{e0}}{S_0}\Delta S(t) - \frac{F_{e0}}{2L_0}\Delta L(t)$$

$$\Rightarrow \frac{2L_0}{F_{e0}} \cdot \frac{d\Delta L(t)}{dt} + \Delta L(t) = \frac{2L_0}{F_{e0}} \cdot \Delta F_a(t) - \frac{2L_0}{S_0} \cdot \Delta S(t) \qquad (6)$$

Applying the Laplace transform in null initial conditions reported to the stationary point we will have:

$\frac{2L_0 A}{F_{e0}} \cdot s \cdot \Delta L(s) + \Delta L(s) = \frac{2L_0}{F_{e0}} \cdot \Delta F_a(s) - \frac{2L_0}{S_0} \cdot \Delta S(s)$ where we notate: $\frac{2L_0 A}{F_{e0}} = T$; $\frac{2L_0}{F_{e0}} = K_F$; $\frac{2L_0}{S_0} = K_S$.

$$\Rightarrow (Ts+1) \cdot \Delta L(s) = K_F \cdot \Delta F_a(s) - K_S \cdot \Delta S(s) \qquad (7)$$

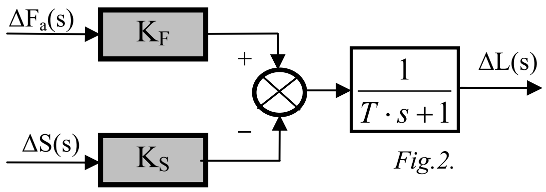


Fig.2.

We will obtain the block scheme from fig.2., where the transfer functions are actually the transfer functions of the variations (Δ) of the quantities in the process around a stationary functioning point.

As we observe, the liquid level is modifying either through modification of the supply flow $F_a(t)$, or through modification of the section S(t) of the drain vent, which in our case we consider to be the flow of the drain pump, meaning a flow considered proportional with the command given to the pump. As a principle, on the basis of the previous block scheme, the adjustment scheme will be established, choosing as a command quantity the drain flow (command of the drain pump), as in fig.3.

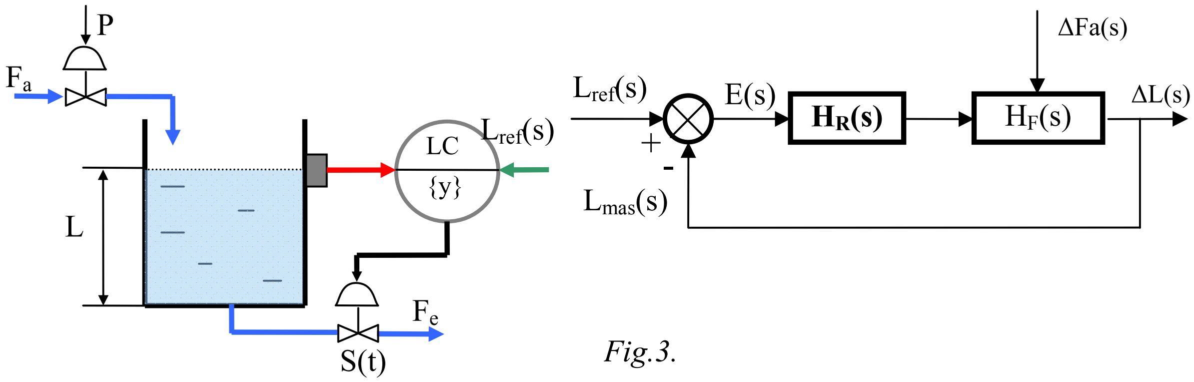


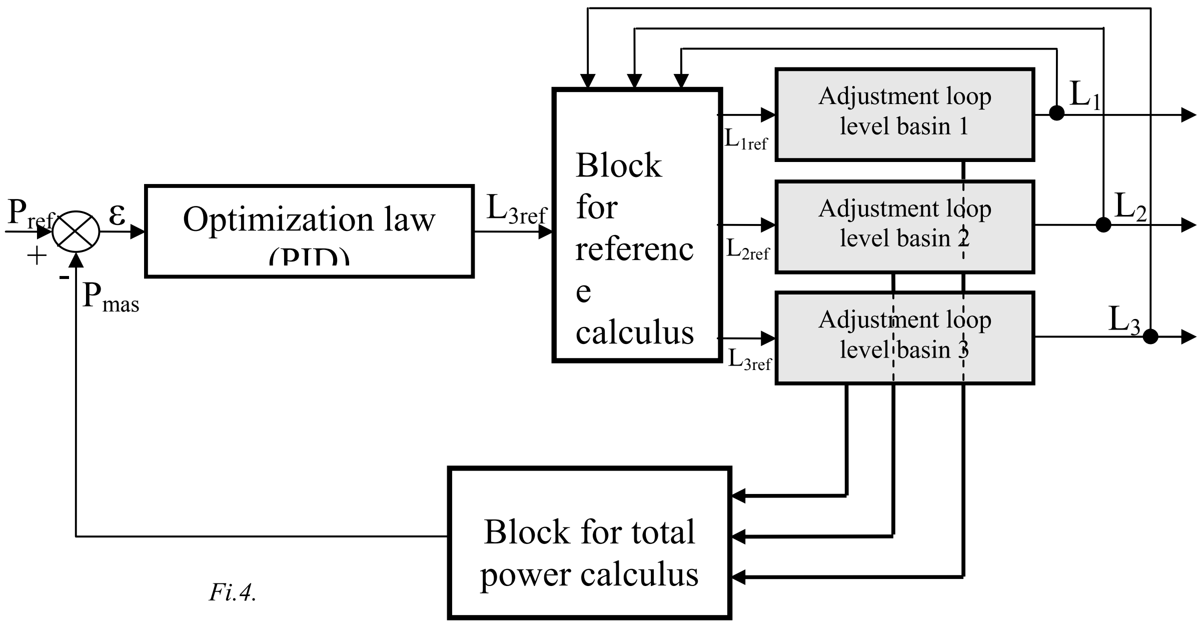
Fig.3.

We have considered the power on the generator as being proportional to the input flow in the turbine which engages the generator, and the energy needed for the flow will be transferred to the system through a drain pump and we can say in a brutish approach for our model that the power is directly proportional to the command applied to these pumps. The scheme of the adjustment loop of the level for each basin is presented in fig.3.

The transfer function of the $H_R(s)$ regulator has been chosen as a PI, because the D element cannot be used because of the oscillations which may appear at the free liquid surface, under the following form: $H_R(s) = K_R(1+\frac{1}{T_i s})$; where K_R-amplifying factor ;T_i-integration time constant. The regulator's parameters were found in an experimental manner.

3. Implementation of the optimization algorithm – power reference

Within this type of optimization we want the total power obtained through the sum of the powers of the three basins to be maintained constant, at a value set by user, as much time as possible.



Fi.4.

The optimization algorithm must begin from the following premise: considering that the power is directly proportional with the command to the pumps, at a certain moment, the higher command will correspond to the basin with the higher level, so the command will be established proportionally function of the report between the existent levels in the basins. The adjustment block scheme is presented in fig.4:

The block on the reaction is to calculate the total power we considered proportional with the volume of the three pumps, starting from the following relations:

$$P = P_1 + P_2 + P_3 \qquad (8)$$

where $P_1 = ku_1$, $P_2 = ku_2$ and $P_3 = ku_3 \Rightarrow P = k(u_1 + u_2 + u_3)$ (9)

According to the presumptive power variation domains $P_i \div 0..10[MW]$ and of the command variation domain $u_i \div 0..100[\%]$ and of the relation (2.9), k's value will be:

$$k = \frac{P_i}{u_{i\ 1}} = \frac{0..10[MW]}{0..100[\%]} = \frac{1}{10}[MW] = 0.1[MW] \qquad (10)$$

To underline the operations which are carried out in the calculus bloc of the references, we make the following notations: $\frac{L_1}{L_2} = K_1$ and $\frac{L_2}{L_3} = K_2$. From these relations and knowing the fact that the power is directly proportional with the command, we will obtain the following relations for the new level references which are applied to the level adjustment loops: $\frac{L_{1ref}}{L_{2ref}} = K_1$ and $\frac{L_{2ref}}{L_{3ref}} = K_2$. $\Rightarrow L_{1ref} = K_1 L_{2ref}$ and $L_{2ref} = K_2 L_{3ref}$, so, the operations which are carried out in the calculus block of the references are:

$$\begin{cases} L_{1ref} = K_1 K_2 L_{3ref} \\ L_{2ref} = K_2 L_{3ref} \\ L_{3ref} = L_{3ref} \end{cases} \qquad (11)$$

For the calculus of the input quantity into the reference calculus block (L_{3ref}) we use a PID adjustment law, with the following transfer function:

$H_{PID}(s) = K_R(1 + \frac{1}{T_i s} + \frac{T_d s}{T_\gamma s + 1})$, where: K_R -proportionality coefficient, T_i -integration time; T_d -derivation time, T_γ -parasite time constant

This law works in inverse logic: for a power increase, the command is decreasing the levels, meaning pumping more water out. Regulator adjustment was done experimentally. To understand better how this law should work, we'll present the following example: we consider that the level of the first basin is L1=20%, the level in the second basin is L_2=40% and L_3=80% and assuming that the value of the power which must be ensured by the three parts of the process is 20MW. With these levels we calculate the values of the two constants: K_1=K_2=0.5. Because we have the values of the levels above, we realize that the third basin should produce more energy.

Taking into account the relation (11) and k's value, we have the following relation: $u_1 + u_2 + u_3 = PK = 200$ [%]. The u_3 command must be higher, actually $u_3 > u_2 > u_1$.

4.Implementarea hardware şi software

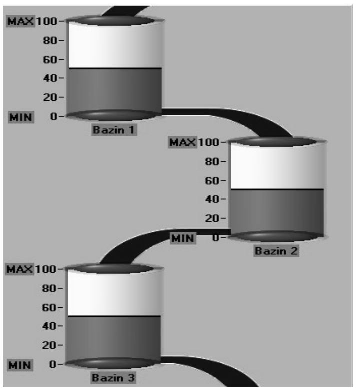


Fig.5.

For the simulation and the observation of the way of thing of the process finded out under consideration, the one three barrier lakes were transposed in the likeness of a basins from the glass conected in cascade where the levels shall be controlate. The transducers of levels are realizate on the strength of a floating conectate by dint of a draw-bar to one potetiometer. The way of placement of the basins is presented in fig.5.

Control of the process is achieved with help which computer implements the adjusting algorithm and with data acquisition and command board achieve dates from process(the level) and and it shall transmit the statement to the element of which execution is pump what force a variable flow between 2 successive basins, or between last basins and exterior. The hardware structure of the system is presented in fig.6.

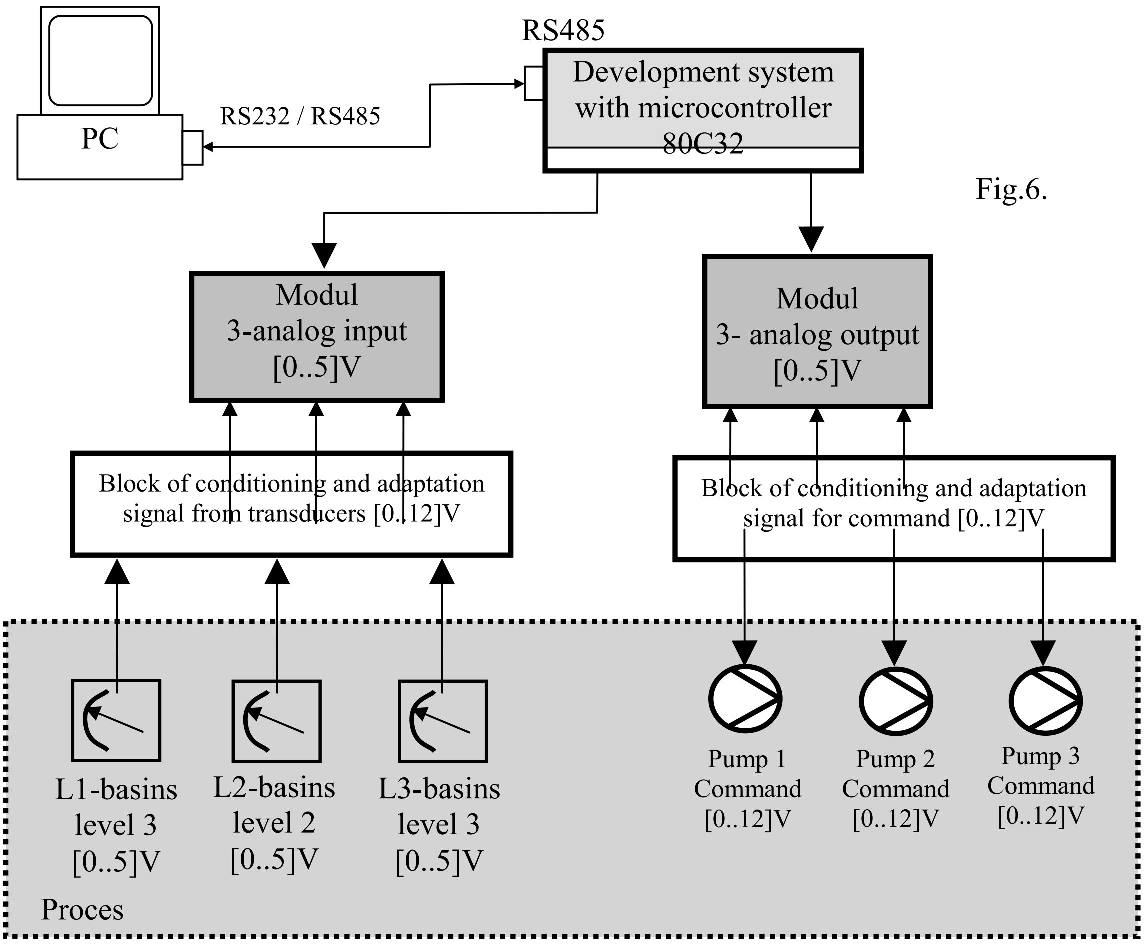


Fig.6.

For data acquisition and command is used a electronic board organized around of a nucleus with microcontroller Intel 80C32 and one extension analogic board equipment with convertors CAN and CNA per 12bits, which realized conversion from analog signal in digital signal and otherwise. Communication between PC and acquisition board is done with help of serial port RS232, and electronic board disposes of modules RS485 for connection for a long distance.For the reading of the levels from basins I used transducers of levels realizated with of a floating help conectated the draw-bar to how many a fader. Software implementing of application in real-time is realized using programming environment LabWindows CVI 7.0.

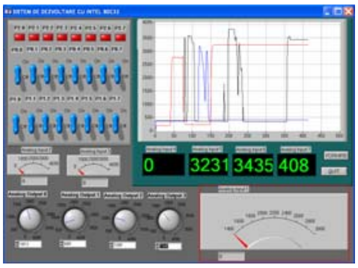


fig.7.

The implementation of the algorithm is in real-time, because the task from application is executed in the moment when is generated a break from the real time clock, Implementarea algoritmului de reglare este de timp real, deoarece taskurile din aplicație se execută în momentul când se generează o întrerupere de la ceasul de timp real, therefore period of sampling is holded constant to the value prescribed. The calibration of the system of acquisition and command relateing to were realizated with an another program which funtioning in manual regimes, what it has the graphic interface presented the in the fig.7. In this graphic interface can observed information transmited by the aquisition board and information received from the board.

5. Experimental results

In the following figures are presented some results obtained through the implementation aplication on the real process.

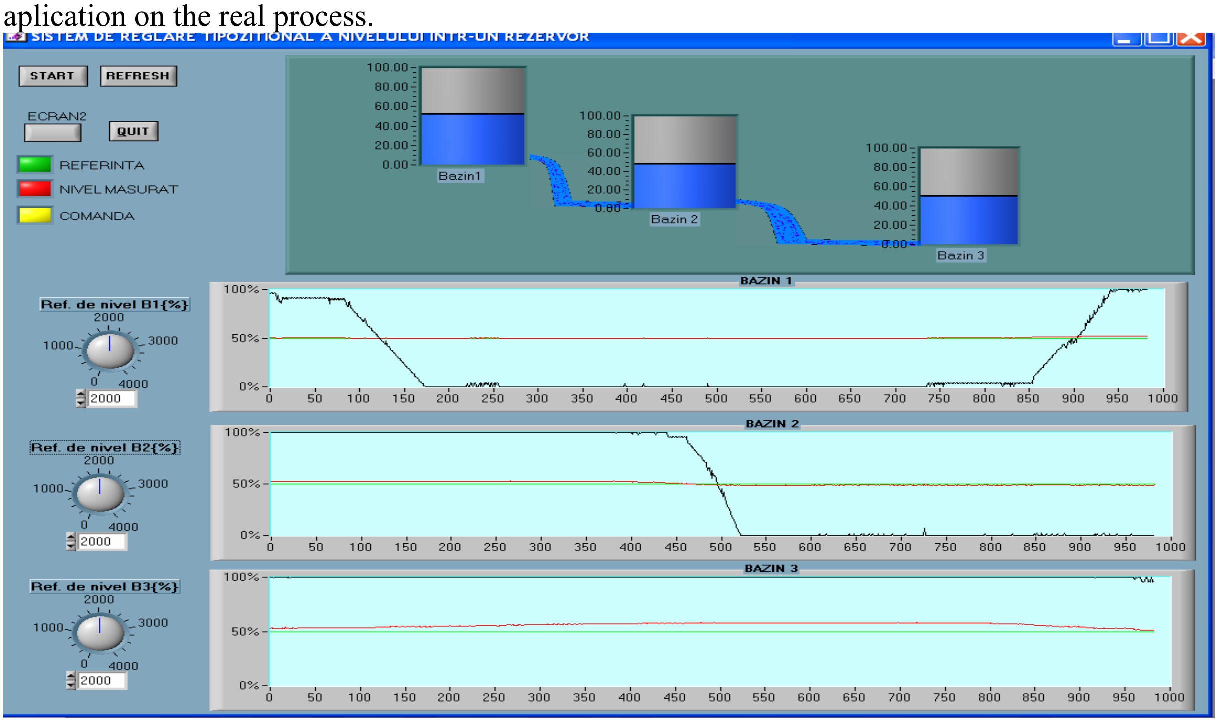


Fig.8. Answered for the 3 loops of control to maintain the sizes of constant reference, whereat is added the modification of the perturbance for the basin 3 (the down). Is can observed on the graph 3 as the tunning loop try to bring back the level to the value of reference, but this thing is done with great time for answer, due and the fact as the the level in the down basin is strong stricken of the overfalls from other basins.

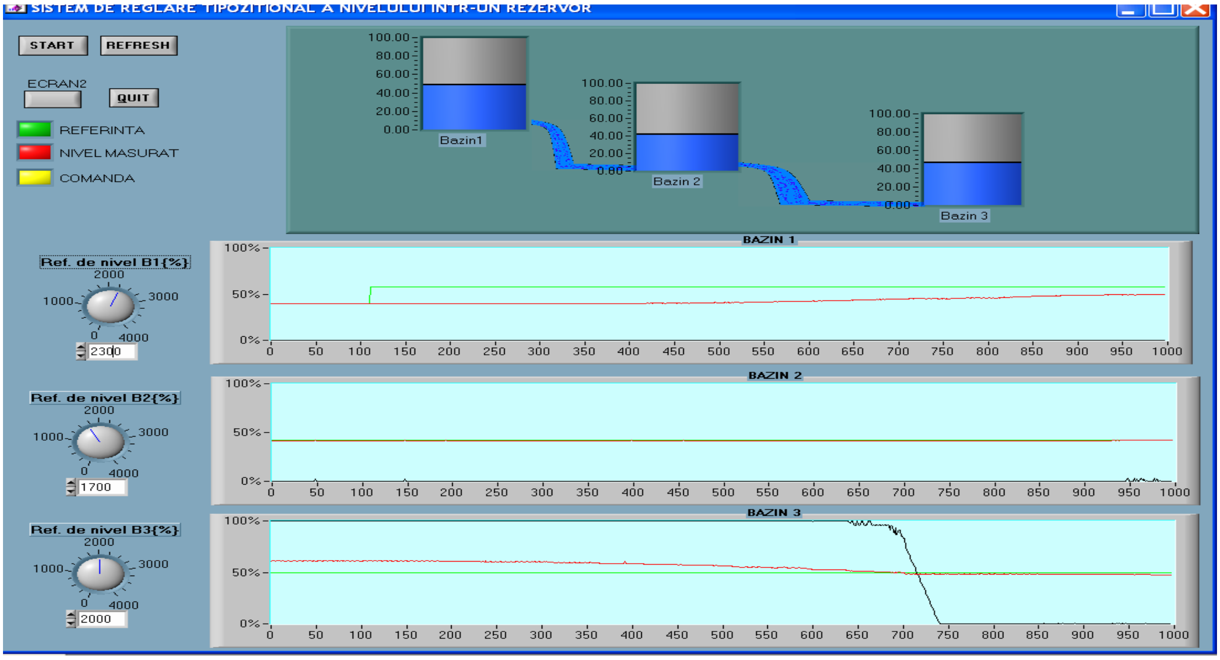


Fig.9. The response for 3 tune loop relateing to maintain of the sizes of constant reference for the basins 2 and 3, and the variation of the size of reference for the basin 1 (the down). Is can observed as one 3 process are as a matter of fact slow process, and he is very knowed the idea as "the slow process the very hard contolling" because they have great time answers and the response can be inflenced by the perturbation what can appear in this time and as a matter of fact response has right the diverse cause of perturbation from made to command signal which applied the process.

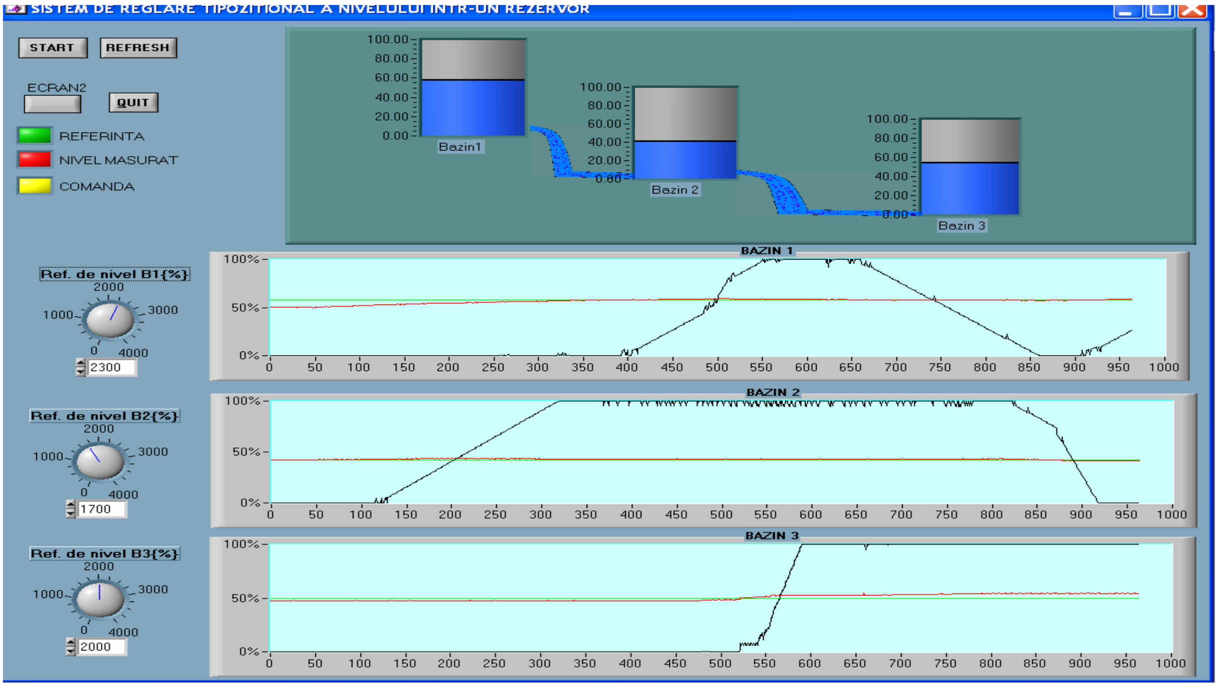


Fig.10.The response for 3 tune loop relateing to mantain of the sizes of constant referenceIs can noticed, as by reason of connecting-up in the cascade of the basins and of a implementation

independent tune loop, the one 3 systems interact between they, having great possibility to go to instability. This results from the visualization commands (graph of black color).

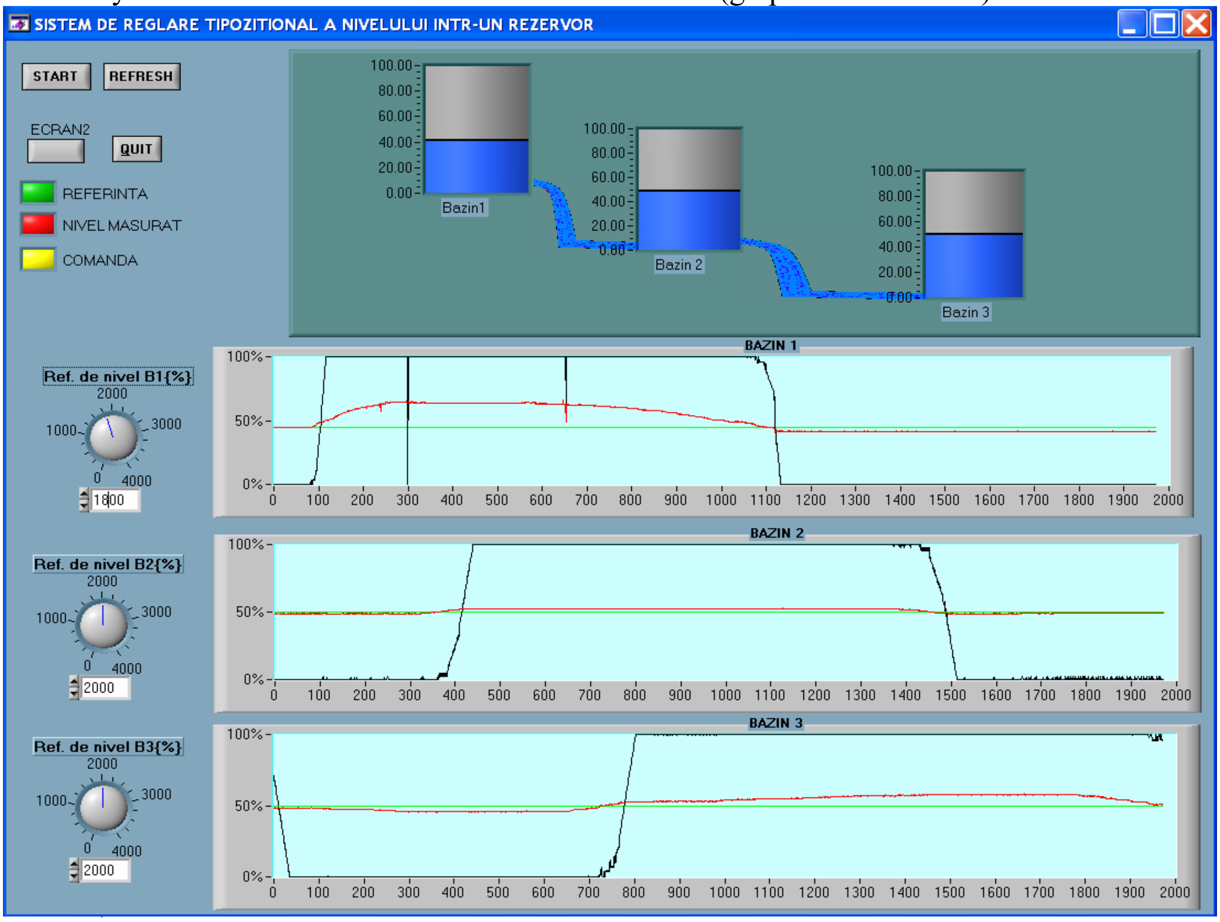


Fig.11. The response for 3 tune loop relateing to maintain of the sizes of constant reference, whereat is added the modification of the perturbance for the basin 1 (One upper the which influence of the basins from aval). Is can noticed on the graph 1 as the loop of regulation try to bring back the level to the value of reference, but this thing is done with for less comparative answer with fig.10, where is visualized the influence of perturbation for the basin 3. Is can noticed as perturbance(rain and big accumulation) to the basin from amonte can influence strong all the basins from aval, according as observed from the figure, first the level 2, and then the level

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