UNIVERSIDAD SAN FRANCISCO DE QUITO USFQ

Colegio de Ciencias e Ingenierías

Desarrollo de una Práctica de Laboratorio Interactiva para Procesos con Retardo Variable

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Ingeniería Electrónica y Automatización

Trabajo de fin de carrera presentado como requisito para la obtención del titulo de Ingeniero en Electrónica

Quito, 5 de mayo de 2023

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HOJA DE CALIFICACIÓN DE TRABAJO DE FIN DE CARRERA

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Development of an Interactive Lab Practice for Processes with Variable Delay

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***Abstract*—This paper proposees a virtual laboratory for teaching advanced control of a variable delay system. For this process, the user has the posibility to practice controll techniques and validate their controllers in the system. The process and the result is shown in a interactive way easy to manipulate by the user.**

***Index Terms*—controllers, virtual laboratory, control education, PI controller design.**

I. Introduction

In recent years, we have witnessed significant technological advances that have had a profound impact on the field of education. One such advancement is interactive virtual laboratories, which have gained popularity as an effective tool for teaching complex concepts and processes.

These virtual labs allow students to experiment and learn hands-on without the need for access to expensive equipment or specific physical environments. Through realistic models and simulations, students can interact with complex concepts and situations, providing them with a more immersive experience and a better understanding of the topics studied.

In the specific case of this project, an interactive virtual laboratory is being developed for the study of control processes with variable delay. The control of systems with variable delay is an important area in engineering and has applications in various industrial fields, where systems with variable delay are common.

The virtual laboratory developed uses MATLAB Simulink software to simulate a mixing tank system and calculate the temperature considering variable delay. This provides students with a realistic simulation environment where they can explore and experiment with the behavior of a control system under variable delay.

In addition, a user interface program has been developed using Unity, allowing users to interact with the control system intuitively and visually. Students can adjust parameters, observe the effects in real time, and understand how variable delay affects the behavior of the system. This provides them with a more hands-on learning experience and helps them acquire knowledge in greater depth.

The importance of this project lies in the growing demand for trained professionals in the field of process control, especially in systems with variable delay. These systems are common in many industrial applications, such as chemical processes, temperature control and conveying systems, among others. Understanding how to properly design and control these systems is critical to ensure efficient and safe operation.

By providing an interactive virtual laboratory for the study of variable delay control processes, this project offers students and professionals an accessible and effective tool for acquiring practical knowledge in this specific field. It allows them to develop relevant and applicable skills to real situations, contributing to their academic and professional training in the field of process control.

II. System Model

This section present the variable delay system (mixing tank) used to create the virtual laboratory.

A. Mixing tank: variable delay system

This model is obtained from the book ”Control de Procesos” from Camacho, Rosales and Rivas (1), see Fig.1. The tank have two income flows one hot $W_1(t)$ and one cold $W_2(t)$, and the objective is to mantain the temperature inside the tank to a certain set point, the problem is that the temperature is measured at a distance L from the tank.

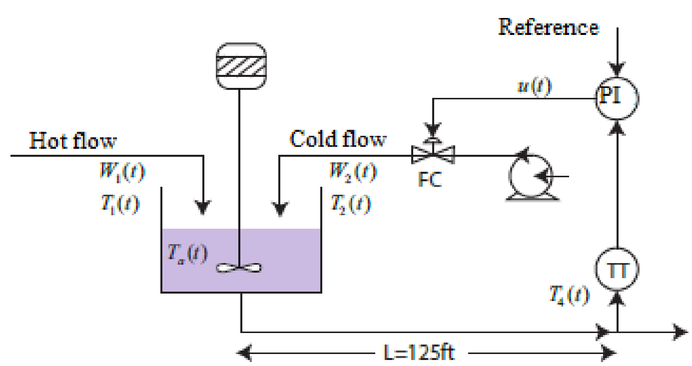

Fig. 1. Mixing Tank.

The hot water flow is constant, but two different perturbations can be produced. Also, the set point of the temperature can be altered in order to see the effects in the system.

Using this mixing tank process the users using the virtual laboratory can:

- Design their own controller by the method they want.
- Analyse the effects of perturbations on a control process with delay.
- Analyse the effect of designing a bad controller.

III. System Development

A. Matlab/Simulink

The whole control system was made in Matlab/Simulink. For the same control process, two systems where developed, the first one Fig.2, is the mixing tank without a controller, which is used in the virtual laboratory to make the users get the parameters in order to create their own controller in the way they can.

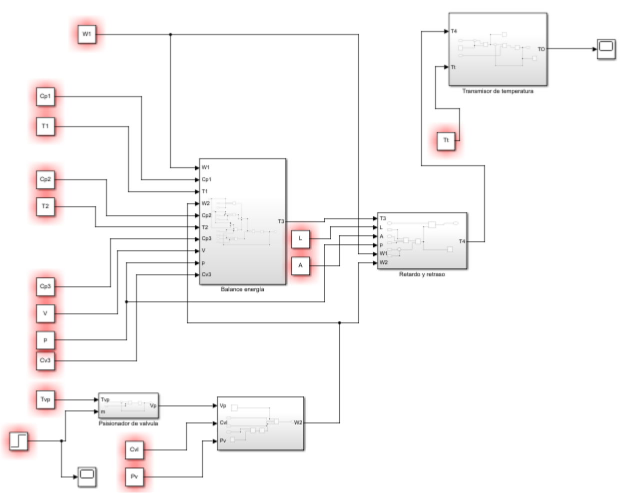

Fig. 2. Manual mode system.

For this mode, the only change the user can made is how much percentage they vary the input of the system, with a max of 10 percent.

The second system, Fig.3, has already a controller developed, and the user can use it to create the perturbations or change the set point, or even alter the PI controller in order to see how every one of these changes affect the whole system response. Both of these systems can be used, and in the interface they are called the manual o auto mode respectively.

As mentioned before, for this mode the user can vary no only the set point in which he/she wants the temperature of the fluid inside the tank, but also the basic parameters of the controller, and if they want, the perturbation of the hot flow.

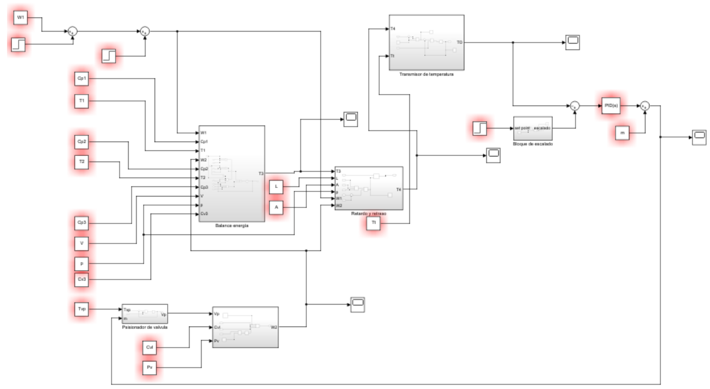

Fig. 3. Auto mode system.

B. Unity

Unity is a game engine software used to create the user interface of the virtual laboratory. It is programmed in C, and it contains the whole code that enables the simulation of the control process and the interface in which every user of the virtual laboratory can make the changes of their convenience.

Fig. 4. Unity User Interface.

This is the only thing visible to the user, and it enables the simulation to start with the given mode the user choose, and the parameters that where adjusted. Runs the simulink simulation of the control process (mixing tank), and retrieve the signals important for the user. In the Manual mode, it retrieves the input and output signals, so that the user can obtain the basic parameters to create the controller, and in Auto mode it retrieves the temperature of the tank signal, and the control signal, so that the user can see how all the changes they have made affects the system.

IV. Experimental Enviorment

This section describes the functions of the virtual laboratory developed in Unity. Graphic tools have been included so that the user can easily visualize the control process.

The user interface have six different panels, the main panel (Fig.4.)which is an intro to the virtual lab and have four different buttons. A ”Start” button which directs you directly to the main panel in which the user can start the simulation of the system by giving the parameters and the mode of use (Fig.6.) A ”Info” button, which directs the user to a brief introduction of the system we proposed as the virtual lab (Fig. 5.). A ”Guide” button which directs the user to a brief tutorial on how to navigate around the virtual laboratory (Fig.7.) and finally, an ”Exit” button, to leave the virtual laboratory.

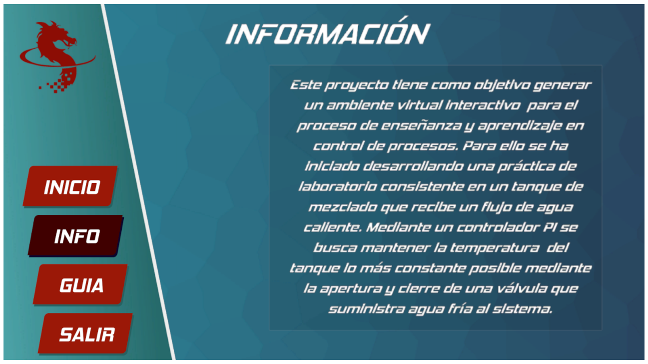

Fig. 5. INFO panel.

As mentioned before, this panel shows a brief description of the system proposed for the virtual laboratory, in this case, the mixing tank, and how it works.

Fig. 6. Guide panel.

This panel shows in fours simple steps how to use the virtual laboratory after clicking the ”Start” button. First, at the top left, an image of the mixing tank showing the principal items: The two flows, the mixing tank, the temperature transmitter, and the controller with the valve controlling the cold water flow. The next two steps, at the bottom left, the two possible tabs containing the possible parameters that can be changed for the simulation depending on the mode of operation of the system (Auto o Manual mode). Finally, in the right, the tabs in which the signals will be displayed after the simulation of the control process.

Lastly, the simulation panels, when the user click the ”Start” button the interface goes to this final panel in which you can choose the parameters for the simulation. Fig.7 shows when the panel is in manual mode, and the user can only change the input ti the system in order to obtain the output signal and calculate the basic parameters to construct their own controller,

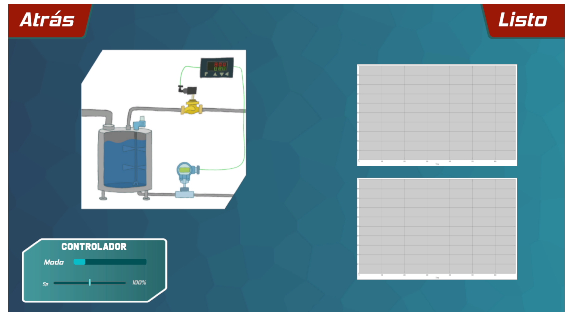

Fig. 7. Manual Mode panel.

also, the user can change the simulation mode to automatic, which will lead to the Auto mode panel shown in Fig.8.

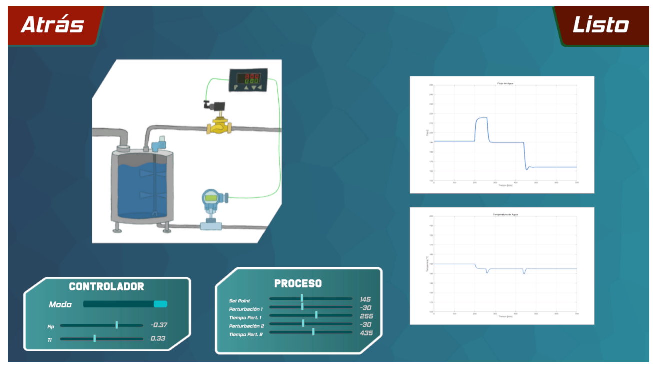

Fig. 8. Auto Mode panel.

The difference in this panel is that now the user can change a variety of parameters, firstly, in the left, the user can go back to the Manual mode panel, and below it he/she can change the basic parameters of the PI controller. Next to it, on the right are the sliders for the set point, the temperature of the tank, and the two different perturbation for the hot water flow as well as the times in which both perturbations are made.

After all the sliders are selected, the only thing left is to click on the ”Ready” button, and the simulation starts, and finally, the signals will be shown in the space on the right as in Fig.9.

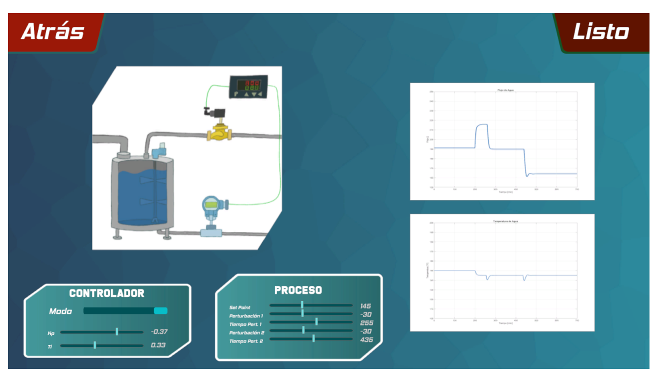

Fig. 9. Simulation results.

V. Example

This section presents an example of the utility of the virtual laboratory, with a description of how the user would be able to proceed.

For this example it is selected a PI controller, it is only shown the equations for the design by using the result obtained by the virtual laboratory.

A. PI controller

The objective of the experiment is to maintain the temperature set at a specific point. With this in mind, the user can make a change of +10% / -10% of the initial value in stable state, and then push the ”Listo” button

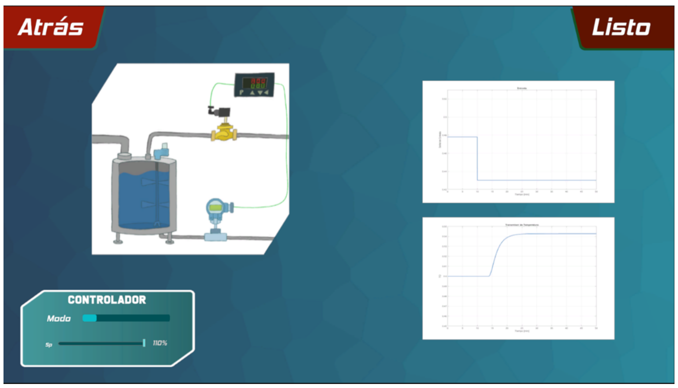

Fig. 10. PI controller design

As we can see in Fig. 10, we obtained the input and output of the system, with these graphs it is easy to obtain the data to design the controller:

$$K = \frac{Change_{input}}{Change_{output}} \tag{1}$$

$$t_1 = Output\ time\ at\ 28,3\% \tag{2}$$

$$t_2 = Output\ time\ at\ 63,2\% \tag{3}$$

$$\tau = 1,5(t_2 - t_1) \tag{4}$$

$$t_0 = t_2 - \tau \tag{5}$$

The next step is to design the PI controller, in this case, with dahlin's equations:

$$K_p = (\frac{1}{K})(\frac{\tau}{t_0}) = -0,42 \tag{6}$$

$$T_i = \frac{1}{\tau} = 0,36 \tag{7}$$

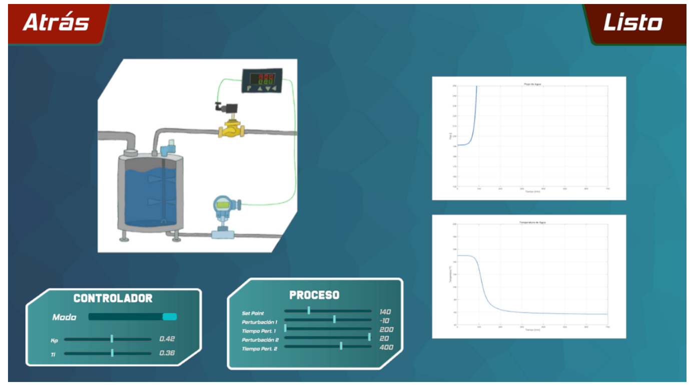

Fig. 11. Results

B. Resutls

After designing the PI controller the next step is to pass to the Automode of the virtual laboratory. Now the new variables are shown, and select Kp and Ti as the result calculated before.

For these examples, the perturbations and the set point have also been altered as shown in Fig. 11. Two perturbations in the hot water, the first one at -10 at a time of 200 minutes, and a second one of 20 at a time of 400 minutes and the set point at 140 degrees.

The virtual laboratory show the results of the data entered, the temperature of the tank and the flow of cold water. Since this is a simulation of a real process the graphs only show what in real life is possible. The flow of cold water goes beyond the limits because there is no way the flow can go that up, this means the system would have break if not a simulation.

This way the user can see how different variations in the controller or in the flow of water due to perturbations in the system would affect the mixing tank, and learn how to solve all these problems.

VI. Conclusions

The work presented the design and implementation of a virtual laboratory which allows to apply control techniques in a non linear variable delay process. It help students to have a more ”real” approach to a control system in real life. The virtual laboratory provides interactive and easy to use tools to practice the control theory learned, and it is what expected to implement all control knowledge.

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