Automation Systems in LabVIEW

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Abstract: - This paper presents a "Virtual Instrument" for analysing components for an automation system. This system is a didactic model for educational purpose. The important point is to learn the influence of the three parameters of the controller, respectively proportional (P), integrator (I) and derivative (D). Also, in order to study the performance of the system, it is necessary to know the influence of the amplification factor (K_p), the time constant (T), the pulsation (ω) and the damping factor (ξ).

Key-Words: - controller, damping factor, time constant, pulsation, amplification factor, control laws.

1 Introduction

The virtual instrument is made by means of programming means and can include the software at the top, and the hardware elements are connected to the computer for the care of the virtual instruments. The program replaces a number of physical electronic devices and instruments, thus receiving the names of virtual instruments. They replace the instruments used for the classic, are self-contained, much more flexible, being sufficient or modifying a program to reproduce another instrument. In the graphical programming environment LabVIEW, virtual software tools for a module (a program), based on the user interface - the front panel (which simulates the intuitive part of a classical tool) and a top-of-the-block diagram program. (a block diagram, accessible only to the programmer) [1], [2]. On the front panel (Front Panel) can be placed various objects corresponding to elements of the classical instruments, such as buttons, signal display elements, switches, etc. The connection between these and the insertion of additional processing elements can be made through the block diagram of the built tool.

For the automatic systems you can access a series of commands grouped in the Control & Simulation menu through which you can build the graphical interface necessary for their study. The possibilities are multiple, being able to simulate various types of elements (for example, delay), adjustment laws (for example, PID), etc. Graphical representations of signal evolution and time or frequency analysis become much easier and more intuitive for the user.

2 Automatic system

The block diagram for an automatic system is presented in figure 1.

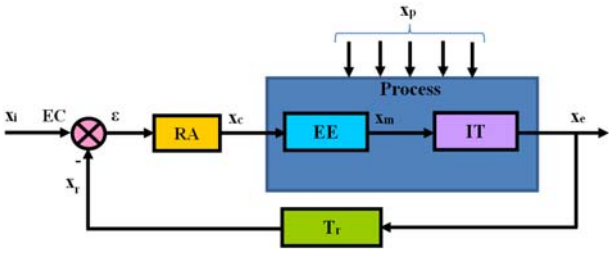

Fig.1 Block diagram. EC – comparison element, RA – controller, EE – execution element, IT – technological installation, T_r – transducer, x_i – input, ε – error, x_c - command, x_m – measured, x_e – output, x_r – feedback, x_p – perturbations.

2.1 The controller

The controller has the role of operatively processing the error signal ε, obtained from the linear - additive comparison of the input x_i and the feedback x_r in the comparison element. The information about the automated process is obtained with the help of the reaction transducer T_r and is processed by the controller RA according to a certain law defining the automatic adjustment algorithm.

The conventional control algorithms (regulation laws) commonly used in the regulation of automated processes is of proportional - integrator - derivative (PID) type [3], [4].

The implementation of a certain regulation law can be achieved through a fairly wide variety of regulator construction, such as electronic, pneumatic, hydraulic or mixed regulator. Typical forms of regulation (PI, PID and, in the least case PD) algorithms are often used in industrial applications, the reason for this being the high degree of robustness conferred to the adjustment loop, the ease of implementation of the algorithm and the intuitive knowledge of the determined effects on the performance of the automatic system of the three components, proportional (P), integral (I), respectively derivative (D).

In the case of the typical adjustment, the decision algorithm can be expressed generically through the idealized transfer function, corresponding to the non-interactive PID regulation law:

$$G_{PID}(s) = K_P\left(1+\frac{1}{T_I s}+sT_D\right) \qquad (1)$$

where: K_p – proportional factor
T_I – constant of integration time
T_D – constant of derivation time

The PI and PD algorithms can be considered as limit cases of the PID algorithm being obtained by canceling the derivative and integral components respectively. The associated transfer functions are:

$$G_{PI}(s) = K_P\left(1+\frac{1}{sT_D}\right) = G_{PID}(s)\Big|_{T_D \to 0} \qquad (2)$$

$$G_{PD}(s) = K_P(1+sT_D) = G_{PID}(s)\Big|_{T_I \to \infty} \qquad (3)$$

According to the idealized relationship (1), the action of the PID regulator can be broken down into the three essential components P, I and D, resulting in the equivalent block diagram is presented in figure 2. The equivalent function will be:

$$X_c(s) = P(s)+I(s)+D(s) \qquad (4)$$

with:

$$P(s) = K_P E(s) \qquad (5)$$

$$I(s) = \frac{K_P}{T_I}\frac{1}{s}E(s) \qquad (6)$$

$$D(s) = K_P T_D s E(s) \qquad (7)$$

$$E(s) = X_i(s) - X_r(s) \qquad (8)$$

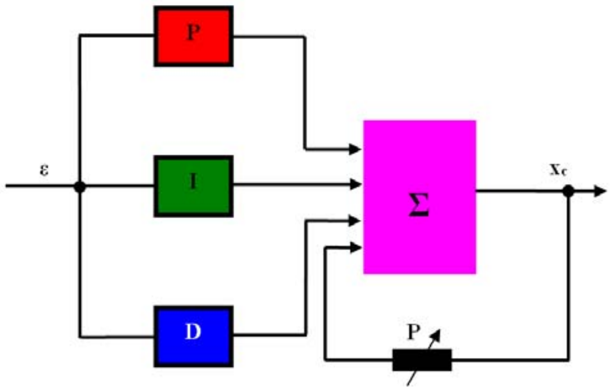

Fig. 2 Equivalent block diagram for P, I, D

2.1.1 Model of controller in LabVIEW

An model with PID controller is presented in figure 3 and figure 4.

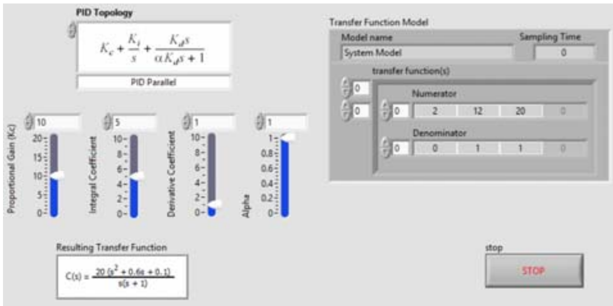

Fig. 3 Front panel for PID controller

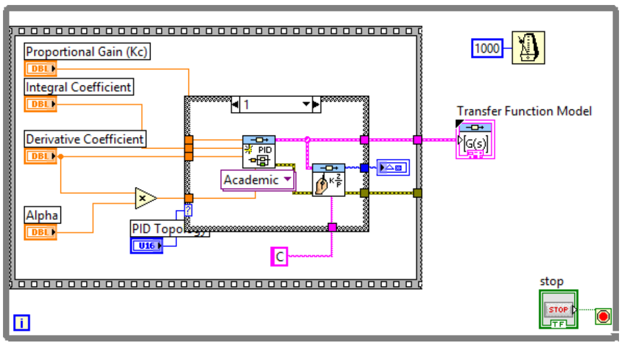

Fig. 4 Block diagram for PID controller

The choice of the type of controller is determined by the transfer characteristics of the technological process and the performances imposed on the control system.

Another problem is granting the parameters of a regulator. In practice, is used the Ziegler-Nichols method, which proposes the following values for parameters P, I, D:

The Ziegler-Nichols method is applied to the regulators used in the regulation of slow processes in which the disturbances are determined by the load and have a long duration. He proposes the following procedure:

- for a PID regulator, the agreement for T_I is set to the maximum value ($T_I = \infty$) and the agreement for

T_D to the minimum value ($T_D = 0$). K_P is modified until the system's response to oscillations is brought in, which means that the system is at the stability limit. The two parameters respectively K_{P0} and the period of oscillations T_0 are retained. For PID controller it is recommended:

$$\begin{aligned} K_{P\_optim} &= 0.75 K_{P0} \\ T_{I\_optim} &= 0.6 T_0 \\ T_{D\_optim} &= 0.1 T_0 \end{aligned} \tag{9}$$

2.2 The control system

2.2.1 Model of first order system in LabVIEW

The control system may be a system that has the form of the transfer function of the first order or second order. For the first order system we will use the first order delay element, which is described by the formula (10) [5-6].

$$\begin{aligned} & T_1 \rightarrow T x_e + x_e = K \cdot x_i \\ & T_1 \rightarrow T(sX_e(s) - x_e(0)) + X_e(s) = \\ & = KX_i(s) \\ & T_1 \rightarrow TsX_e(s) + X_e(s) = KX_i(s) \\ & T_1 \rightarrow X_e(s)(Ts+1) = KX_i(s) \\ & T_1 = \frac{X_e(s)}{X_i(s)} = \frac{K}{Ts+1} \end{aligned} \tag{10}$$

where: K – amplification factor
T – time constant

A model with first order system is presented in figure 5 and figure 6.

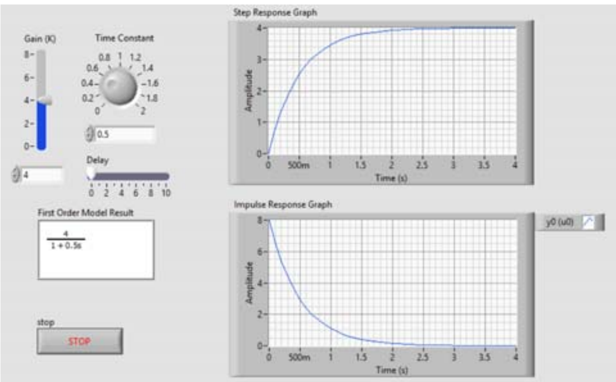

Fig. 5 Front panel for first order system

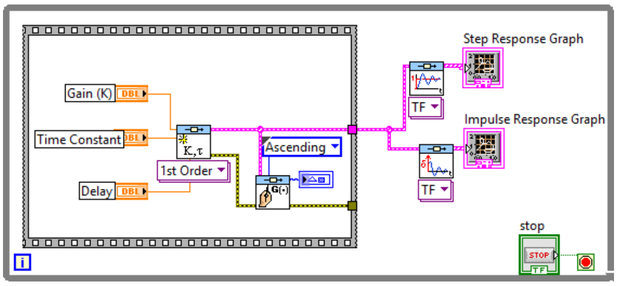

Fig. 6 Block diagram for first order system

2.2.2 Model of second order system in LabVIEW

For the second order system we will use the second order delay element, which is described by the formula (11) [7-8].

$$\begin{aligned} & T_2 \rightarrow \ddot{x}_e + 2\xi\omega_n \dot{x}_e + \omega_n^2 x_e = K\omega_n^2 x_i \\ & T_2 \rightarrow s^2 X_e(s) - sx_e(0) - \dot{x}_e(0) + \\ & + 2\xi\omega_n (sX_e(s) - yx_e(0)) + \omega_n^2 X_e(s) = \\ & = K\omega_n^2 X_i(s) \\ & T_2 \rightarrow s^2 X_e(s) + 2\xi\omega_n s X_e(s) + \\ & + \omega_n^2 X_e(s) = K\omega_n^2 X_i(s) \\ & T_2 \rightarrow X_e(s)(s^2 + 2\xi\omega_n s + \omega_n^2) = \\ & = K\omega_n^2 X_i(s) \\ & T_2 = \frac{X_e(s)}{X_i(s)} = \frac{K\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2} \end{aligned} \tag{11}$$

where: K – amplification factor
ω_n – pulsation
ξ – damping factor

A model with first order system is presented in figure 7 and figure 8.

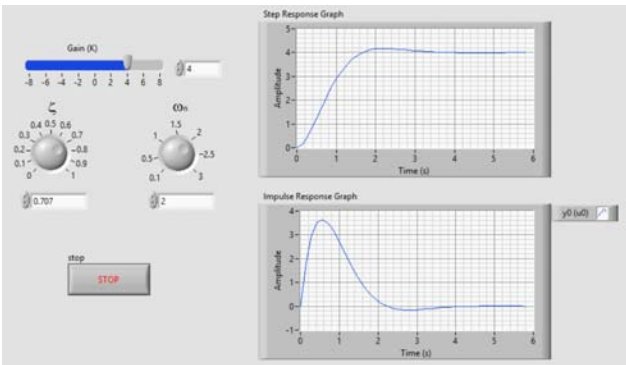

Fig. 7 Front panel for second order system

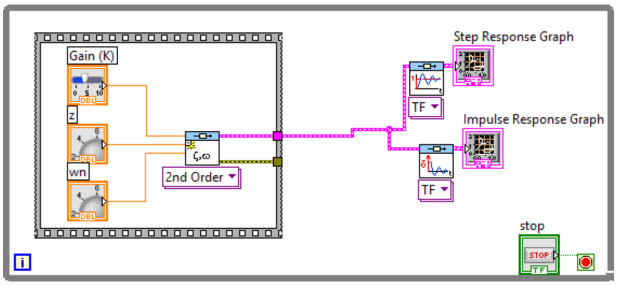

Fig. 8 Bloc diagram for second order system

To achieve the complete system we will build the block diagram in Labview with the help of the Control & Design toolkit, with the first order element and second order element.

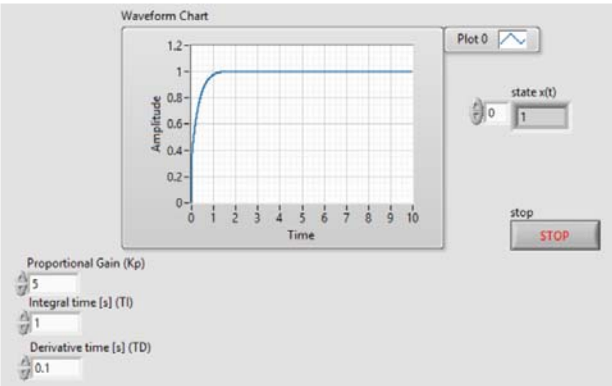

Fig. 9 Front panel for complete system with first order element

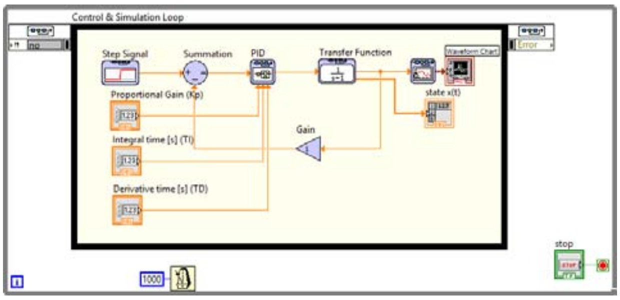

Fig. 10 Block diagram for complete system with first order element

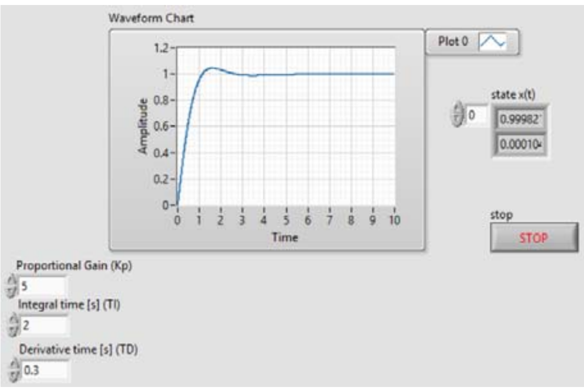

Fig. 11 Front panel for complete system with second order element

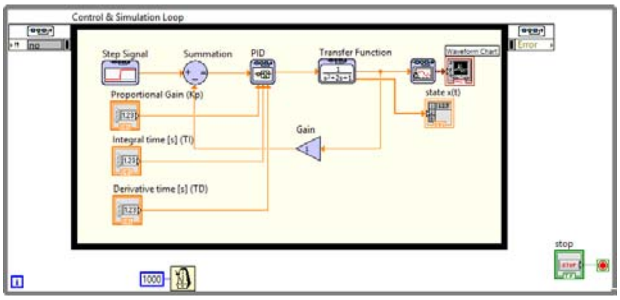

Fig. 12 Block diagram for complete system with second order element

3 Conclusion

This model can be extended and modified for a larger study, for example highlighting performance indicators in dynamic operating mode and static operating mode. The extension and modification of the system refers to the design of a more complex system, the setting of the parameters of the regulator or the behavior of the system in the time domain and in the frequency domain, etc.

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