DOI: https://doi.org/10.36910/6775-2524-0560-2023-53-08
UDC 004.415.3
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# SIMULATION OF TWO-STAGE TEMPERATURE REGULATION SYSTEM

**Pekh P., Khrystynets N., Gubysh R., Shulgach V. Simulation of two-stage temperature regulation system** The article presents the results of the development of the PID controller setting technology using Matlab Simulink tools and the study of the operation process of a closed two-cascade temperature control system based on such controllers. The structural diagrams of the model and the simulation results of the two-cascade system are given.
**Keywords**: closed regulation system, PID regulator. Matlab Simulink

**Пех П.А., Христинець Н.А.. Губиш Р.А., Шульгач В.В. Моделювання двоступінчастої системи регулювання температури.** В статті наведені результати розроблення засобами Matlab Simulink технології налаштування ПІД-регуляторів та дослідження процесу роботи замкнутої двокаскадної системи регулювання температури на базі таких регуляторів. Наведені структурні схеми моделі та результати моделювання двокаскадної системи.
**Ключові слова:** замкнута система регулювання, ПІД-регулятор. Matlab Simulink

**Formulation of the problem.** It is known [1, 2, 3] that a typical functional diagram of a closed temperature control system, which is shown in Figure 1, contains the following elements: a device that sets the signal level, the value of which is actually regulated by the system; control (regulating) device; executive mechanism; object of management; feedback subsystem, an integral component of which are temperature sensors.

The setting device supplies the totalizer with the temperature value x(t), which should be provided by the facility management system. The actual value of the temperature y(t) measured by the sensor is also fed to the adder, but with a minus sign. At the output of the adder, we have the difference of these signals ε(t)=x(t)-y(t). Depending on the magnitude and sign of this signal, the regulating device generates a control signal u(t), which, after amplification, is fed to the executive mechanism. In turn, the executive mechanism produces a signal γ(t), which directly affects the control object. The control object (for example, a room of a smart house) forms the output signal of the system y(t), which is measured by the sensor and fed back to the adder. In the case of a positive value of the signal ε(t)=x(t)-y(t), the system will try to increase the supply of heat to the house, and, conversely, if the signal ε(t) is negative, the system will try to decrease the supply of heat to the house .

The task of a closed system of automatic temperature regulation (SAR) is to maintain it at a given level.

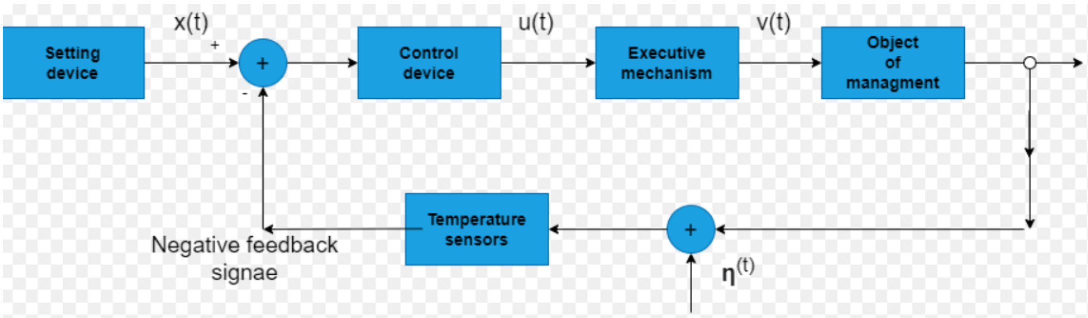


Fig. 1. Functional diagram of a closed temperature control system

As we can see from the description of the temperature control system, its central link is the control device, which in most cases uses PID controllers [5]. The structure of the PID controller is shown in Fig. 2. The PID controller actually combines proportional (P), integral (I) and differential (D) controllers, so the total output signal of the PID controller will depend on the integrated effect of each of these controllers.

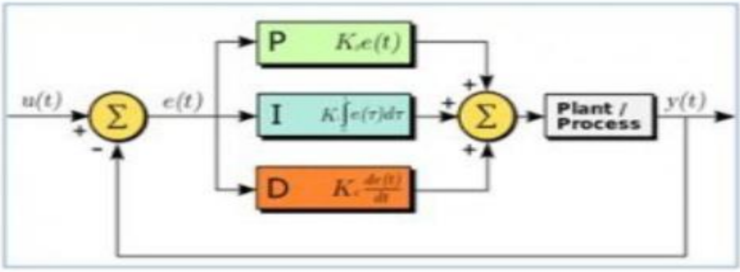



Fig. 2. Structural diagram of the PID controller

**The purpose of the research** is to develop a technology for adjusting the parameters of PID controllers using Matlab Simulink and to study the process of operation of a closed two-cascade temperature control system based on such controllers.

**The novelty of the research** consists in the use of Matlab Simulink tools for optimal adjustment of the parameters of PID controllers and the study of the operation of a closed two-cascade temperature control system based on such controllers [4, 5].

**Main part**. Figure 4 shows the stages of building a two-stage temperature control system. For this, blocks from various Matlab Simulink libraries were used (Fig 3).

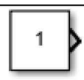
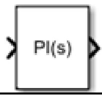
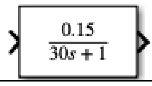
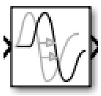
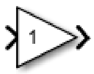
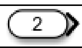
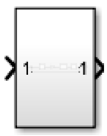
| Block name | Library name | Graphic representation of the block |
|---|---|---|
| Constant | Sources |  |
| Scope | Sinks |  |
| PID Controller | Continues |  |
| Transfer Fcp | Continues |  |
| Transport Delay | Continues |  |
| Gain | Math Operations |  |
| Sum | Math Operations |  |
| In | Ports And Subsystems |  |
| Out | Ports And Subsystems |  |
| Mux | Signal Routing |  |
| Variant Subsystem | Ports And Subsystems |  |

Fig. 3. Blocks used to build a model of the temperature control system

First of all, the model of the first stage of the two-cascade system was developed (Fig. 4a). The parameters of the blocks of this model were taken as they were offered by the Matlab Simulink program itself. Surprisingly, the results of its modeling (Fig. 5a) showed that it provides a given value of a given temperature over time. However, a stable model created in this way does not take into account the parameters of a real physical object, and therefore is inherently formal, that is, one that is not related to a specific object.

We configure the model so that it takes into account the parameters of a real physical object. This is achieved by setting such parameters that would correspond to a real object - a room in a smart house. For this purpose, we set the following parameters of the model: the temperature value that the system must maintain, constant value = 20 (Constant block); parameters of the transfer function (block Transfer Fcn) set the parameters of the object numerator coefficients = 0.15, denominator coefficients = [30 1]; the inertia of the object (Transport Value block) sets such a parameter as the delay time Time Delay = 25. The parameters of the PID controller itself remain the previous ones: P = I = 1.

As soon as we set the real parameters of the physical object (rooms of a smart house), the simulation results (Fig. 5, b) become disappointing - the system loses stability. The question arises, how to adjust the parameters of the PID controller so that the system becomes stable and best copes with the task of maintaining the temperature at a given level?

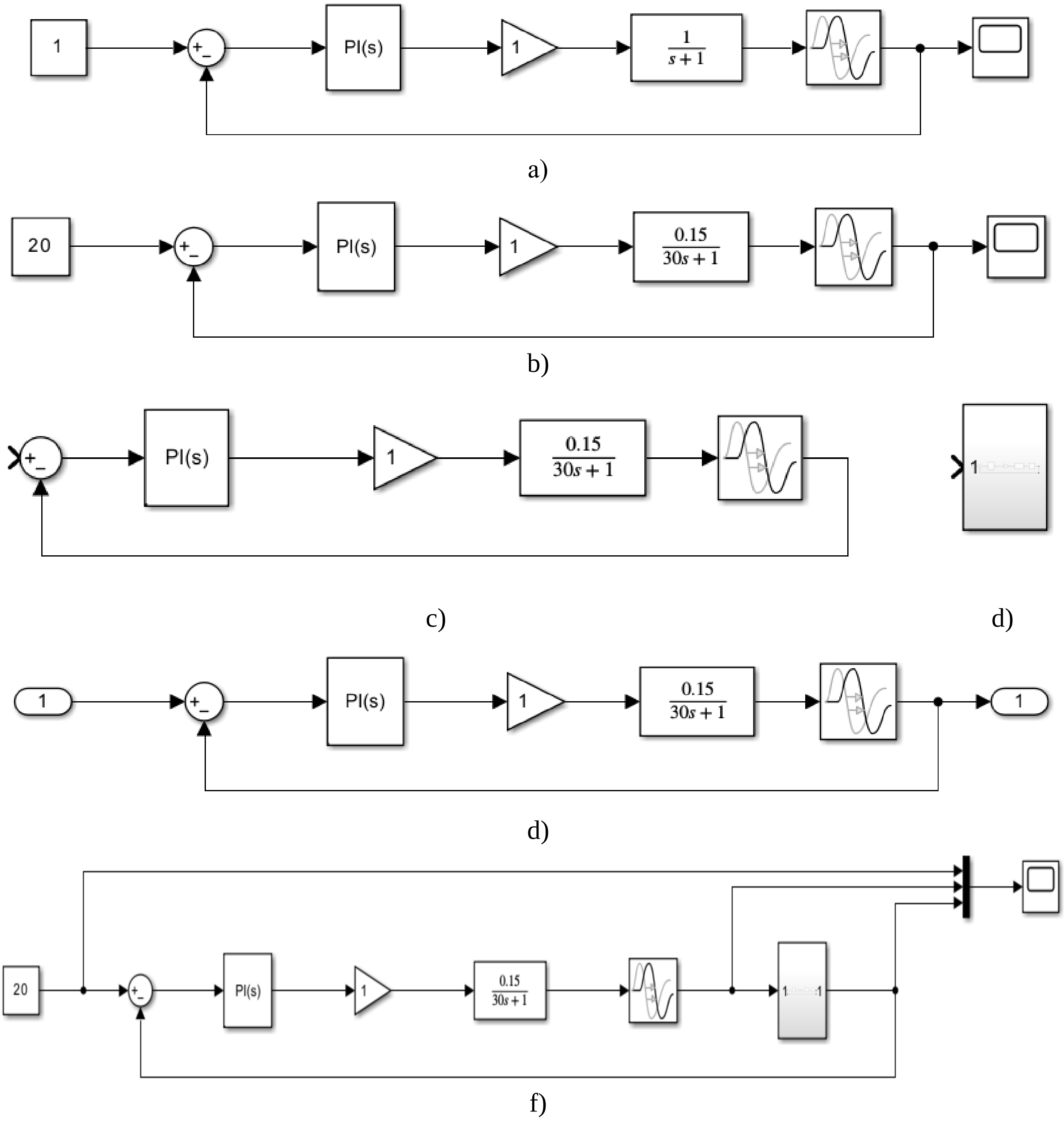
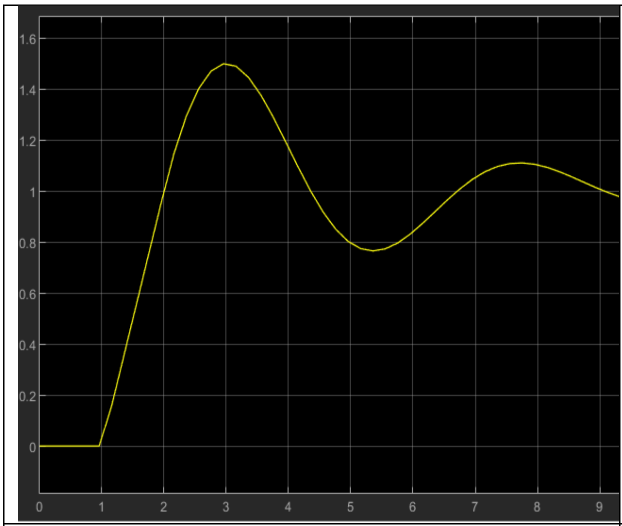
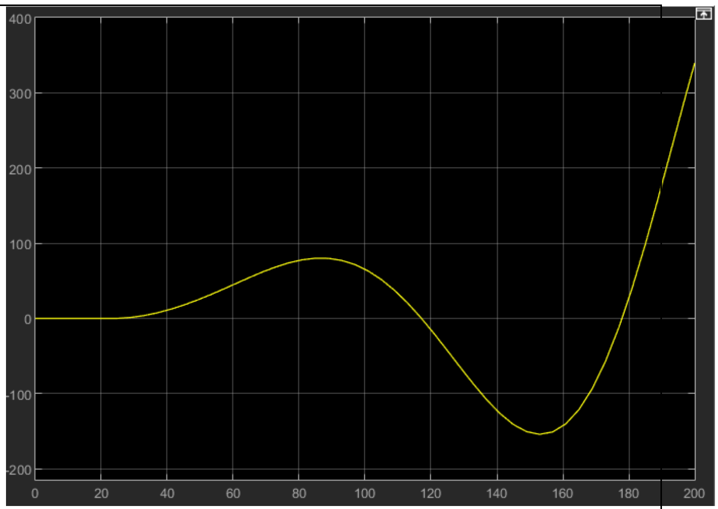



Fig. 4. Stages of construction of a closed two-cascade temperature control system:

a) One-stage closed temperature control system with standard block parameters.
b) One-stage closed temperature control system with changed block parameters.
c) The first stage of the temperature regulation system.
d) Temperature control subsystem with adjusted parameters.
e) Internal structure of the temperature control subsystem with adjusted parameters.
f) Two-stage temperature control system.

For this purpose, we call up the window for setting the parameters of the PID controller (Fig. 6), and press the button Tune... Matlab Simulink offers the approximate parameters of the PID controller (including the parameters of the proportional P = 5.925 and integral I = 0.1546 components) and demonstrates the corresponding these parameters are the results of simulation (Fig. 7) of system operation.




| a) | б) |
|---|---|

Fig. 5. Simulation results of a single-stage temperature control system:
a) with standard parameters. b) with changed parameters.

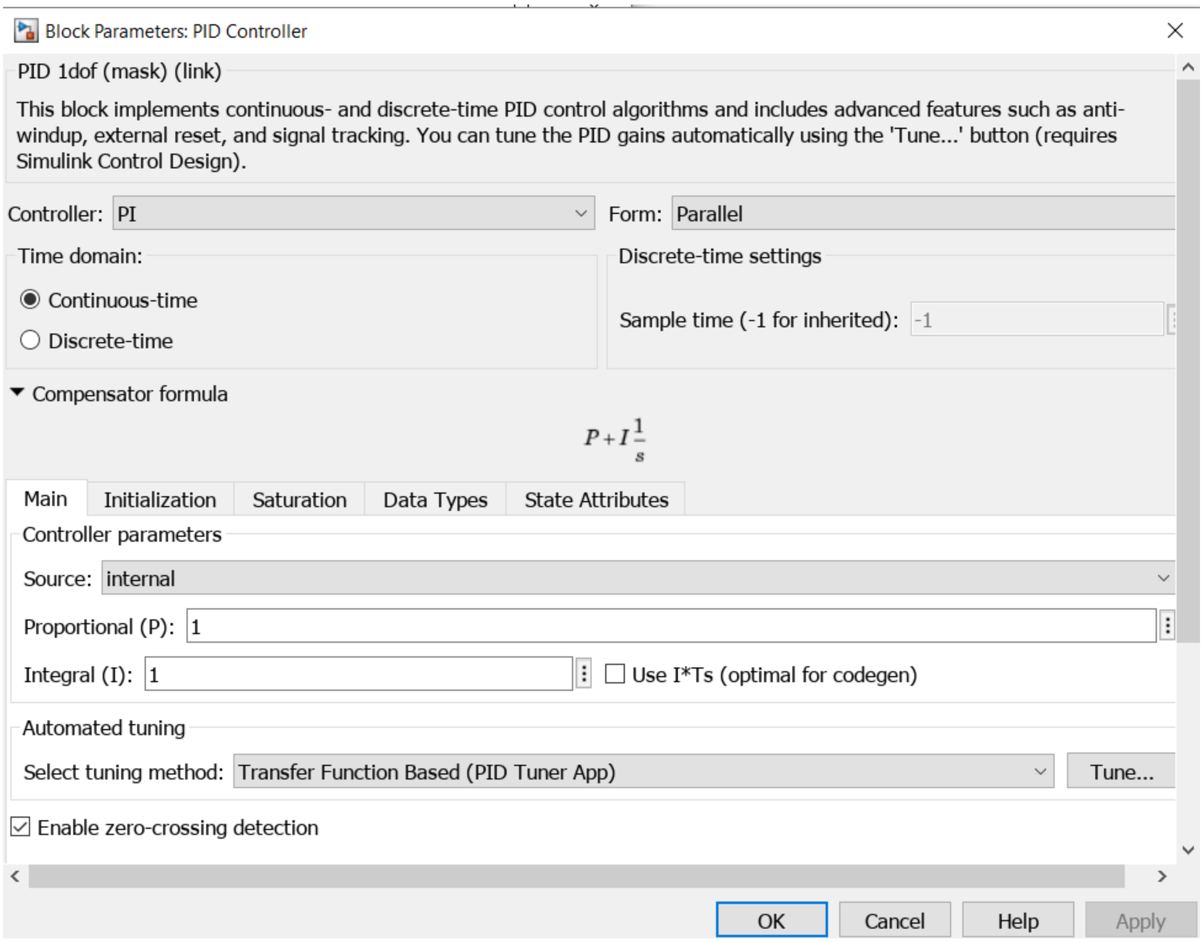



Fig. 6. The window for setting the parameters of the PID regulator

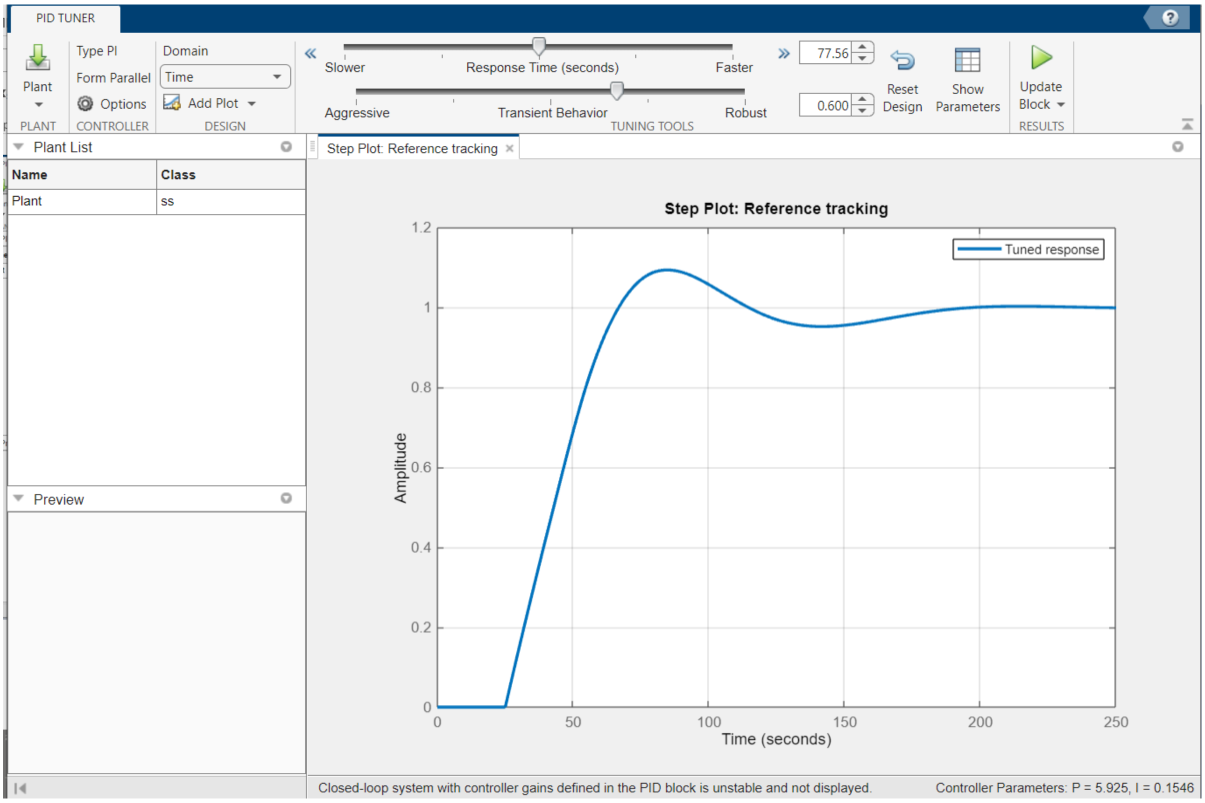
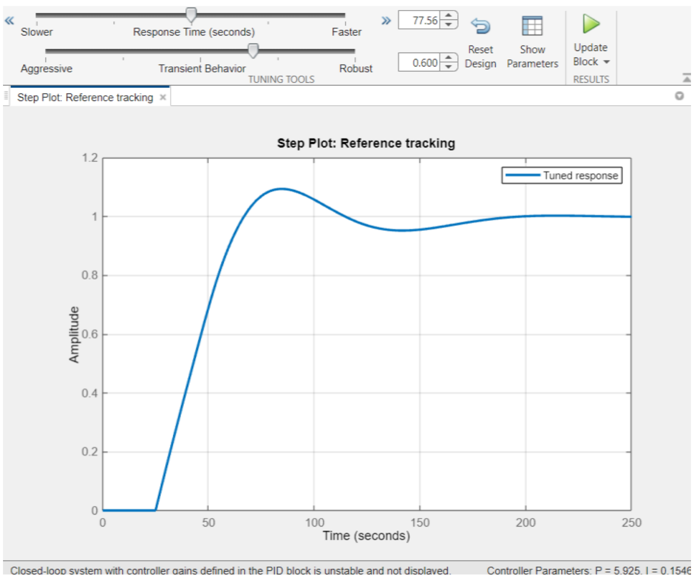


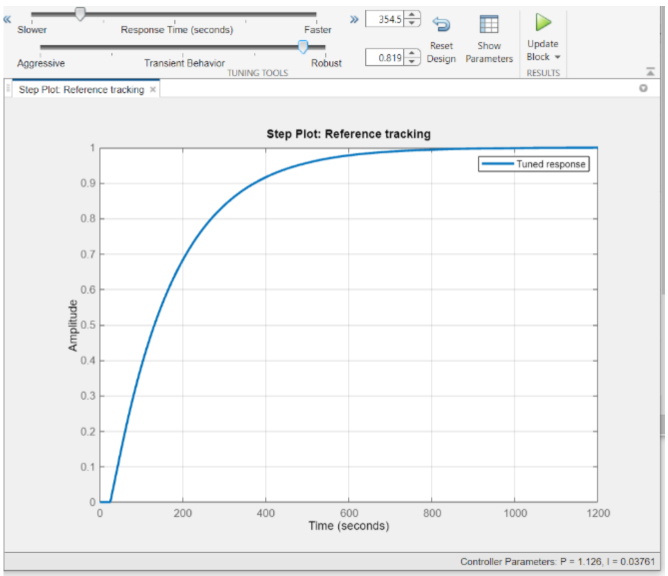

Fig. 7. Window with optimal parameters of the PID regulator and tools for adjustment

With the help of the window (Fig. 6), you can try to set other parameters of the PID controller by moving the Slower and Aggressive sliders to one or another position, but the simulation results of the corresponding systems (Fig. 8 ,a - 8, d) testify in favor of exactly that option offered by Matlab Simulink. In particular:

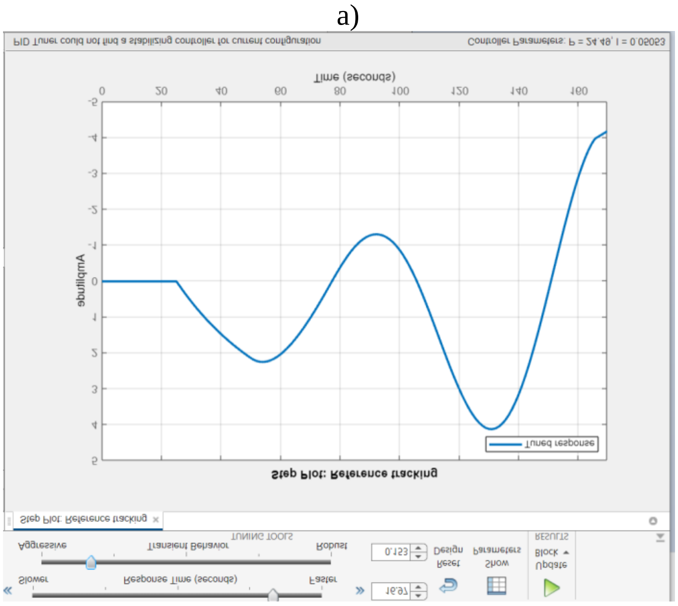
- Option 1 (Fig. 8, a). The error of temperature regulation and the time of the transition process are close to the optimal values; but also the parameters of the PID controller are close to the optimal values.
- Option 2 (Fig. 8, b). The system has a transition time that is significantly longer than the optimal value.
- Option 3 (Fig. 8, c). The system loses stability.
- Option 4 (Fig. 8, d). The error of temperature regulation and the time of the transition process are slightly larger than the optimal values.



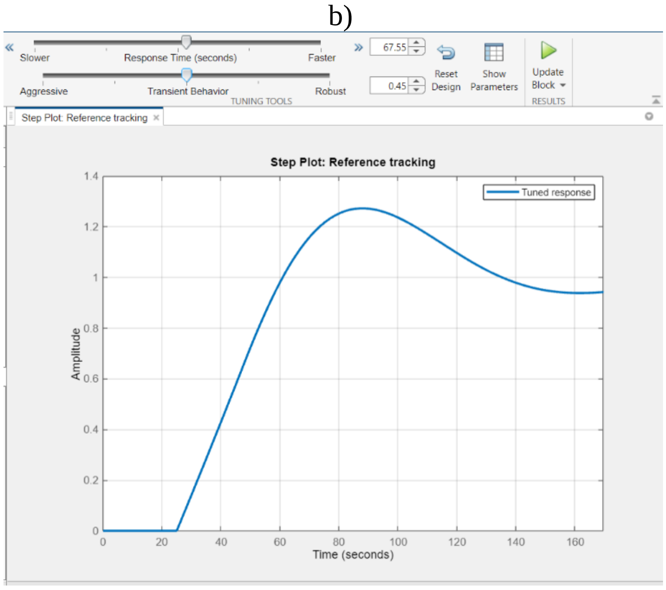

a)




b)



c)




d)

Fig. 8. Results of manual selection of PID controller parameters:
a) PID temperature controller with parameters: P=5.925; I=0.154;
b) PID temperature controller with parameters: P=1.126; I=0.038;
c) PID temperature controller with parameters: P=24.490; I=0.050;
d) PID temperature controller with parameters: P=67.555; I=0.045.

Therefore, returning to the Block Parameters: PID Controller window (Fig. 6), click the Apply button, agreeing that the proposed Matlab Simulink parameters of the PID controller will be applied to our model. So, the first stage of the model is configured optimally.

Let's move on to the creation of the second level of the system. To do this, we turn the first level of the system into a subsystem (Fig. 4, c - 4, e). We create the second stage of the system in the same sequence as the first stage was created. At the output of the second stage, we place the subsystem we created. We feed the output of the subsystem to the Sum block with a minus sign. We display graphs of signals from the master device, from the second stage of the system and the subsystem created by us on the display.

The optimal parameters of the PID controller of the second subsystem are adjusted using the same technology as the parameters of the PID controller of the first subsystem (Fig. 9).

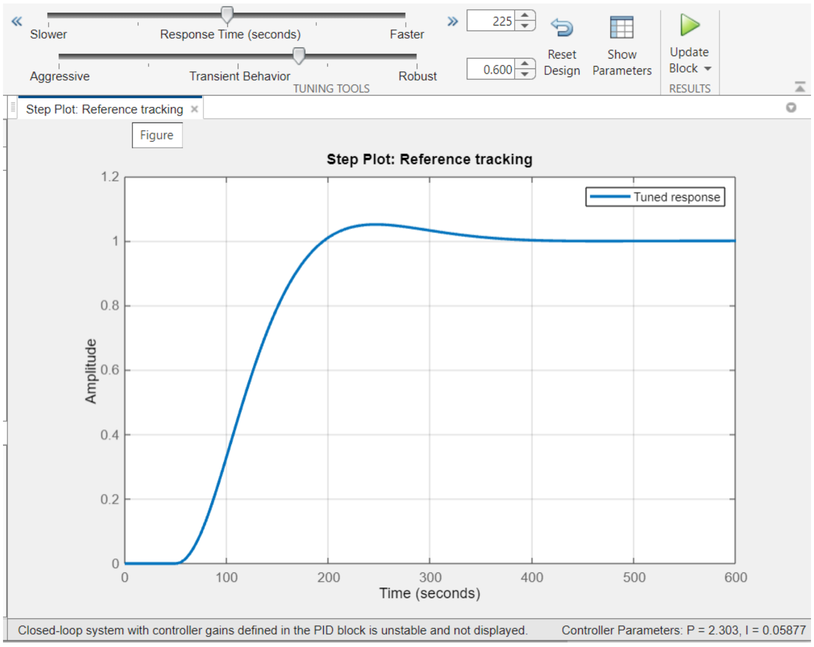



Fig. 9. Results of the optimal selection of the parameters of the PID controller of the second stage

The results of modeling the operation of a closed two-cascade temperature control system with optimal parameters are shown in Figure 10. Analyzing these results, we conclude that the system is stable and efficient, which indicates the successful adjustment of the parameters of its regulators.

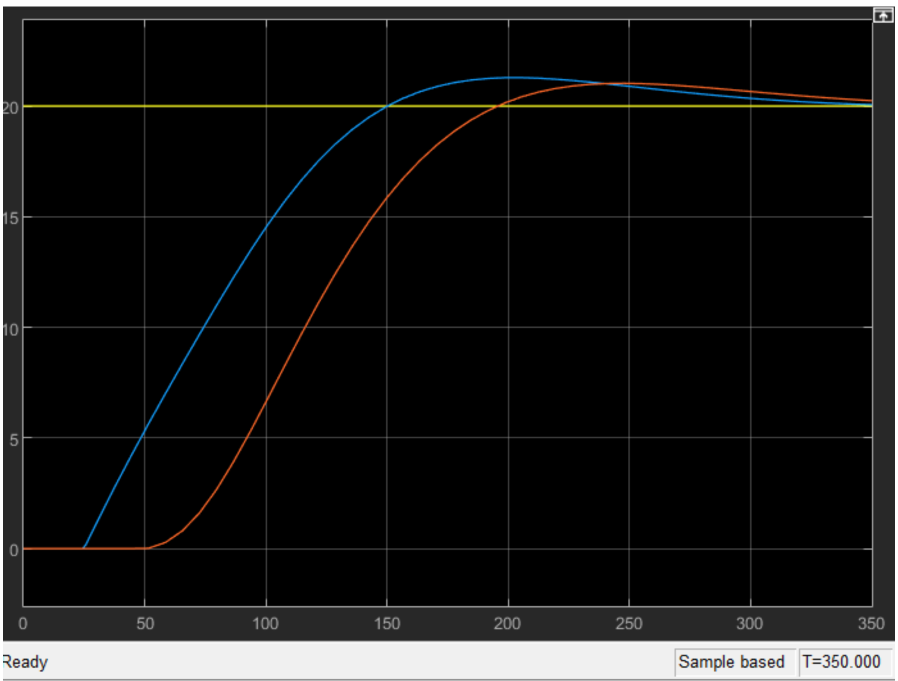


Fig. 10. Results of modeling the operation of a closed two-stage system with optimal parameters

**Conclusions.** In this article:

1. The proposed technology for setting parameters of PID controllers using Matlab Simulink.
2. Analyzed results of simulation of the operation process of a closed two-cascade temperature control system based on PID controllers

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