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The PIDA Controller Analysis Simulator

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Anahtar Kelimeler

Kontrol sistemi
PIDA denetleyici
Simülatör

Graphical/Tabular Abstract (Grafik Özet)

In this study; a software tool with a user-friendly interface has been designed that performs control systems simulations with different type PIDA controllers in an accurate, effective, fast and simple manner. / Bu çalışmada; farklı tipteki PIDA denetleyicilerle kontrol sistemlerinin simülasyonlarını doğru, etkili, hızlı ve basit bir şekilde gerçekleştiren, kullanıcı dostu arayüze sahip bir yazılım aracı tasarlanmıştır.

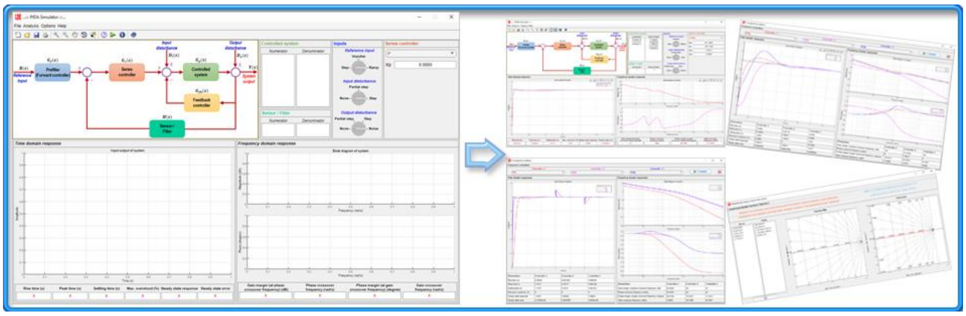

***Figure A**: The designed simulator / **Şekil A:** Tasarlanan simülatör*

Highlights (Önemli noktalar)

- *An interactive simulator was designed for the PIDA controllers in the control systems. / Kontrol sistemlerinde PIDA denetleyicileri için etkileşimli bir simülatör tasarlandı.*
- *Performance evaluations of PID and PIDA type controllers can be easily performed with time and frequency domain analysis. / PID ve PIDA tipi kontrolörlerin performans değerlendirmeleri zaman ve frekans domeni analizi ile kolayca gerçekleştirilebilir.*
- *The designed simulator has capabilities such as comparative analysis of the effects of reference and disturbance inputs and comparative analysis of some performance parameters related to time/frequency response. / Tasarlanan simülatör referans ve bozucu girişlerinin etkilerinin karşılaştırmalı analizi ve zaman/frekans cevabı ile ilgili bazı performans parametrelerinin karşılaştırmalı analizi gibi yeteneklere sahiptir.*

***Aim (Amaç):** This study aims to design of software tool to analyze effects of the PIDA controllers to the system performance. / Bu çalışma, PIDA denetleyicilerinin sistem performansına olan etkilerini analiz etmek için bir yazılım aracının tasarlanmasını amaçlamaktadır.*

***Originality (Özgünlük):** The originality of this study is the development of a new software tool (simulator) that performs comprehensive analysis for PIDA controllers. / Bu çalışmanın özgünlüğü, PIDA denetleyiciler için kapsamlı analizler gerçekleştiren yeni bir yazılım aracının (simülatör) geliştirilmesidir.*

***Results (Bulgular):** The important features of the developed simulator are demonstrated with three case studies (maglev vehicle suspension system, automatic voltage regulator, induction motor system) performed in the work. / Geliştirilen simülatörün önemli özellikleri çalışmada gerçekleştirilen üç örnek (maglev araç süspansiyon sistemi, otomatik voltaj regülatörü, endüksiyon motor sistemi) ile ortaya konmuştur.*

***Conclusion (Sonuç):** The developed interactive simulator provides effective computer support for analyzing the PIDA type controllers. / Geliştirilen etkileşimli simülatör, PIDA tipi denetleyicileri analiz etmek için etkili bilgisayar desteği sunar.*

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Abstract

The Proportional-Integral-Derivative (PID) is a traditional controller type widely used in industrial control systems. However, sometimes they may be insufficient in controlling higher degree systems. In these cases, the Proportional-Integral-Derivative-Acceleration (PIDA) controllers can be preferred. In this study; a software tool with a user-friendly interface has been designed that performs control systems simulations with different type PIDA controllers in an accurate, effective, fast and simple manner, produced single or comparative numerical and graphical results (performance parameters, time and frequency domain responses, etc.). The features and capabilities of the designed simulator have been tested with some sample systems: maglev vehicle suspension system, automatic voltage regulator and induction motor systems. The developed simulator with ease and contents is suitable for all students, engineers, and users from this area.

PIDA Denetleyici Analiz Simülatörü

Makale Bilgisi

Araştırma makalesi
Başvuru: 27/12/2024
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Anahtar Kelimeler

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Öz

Oransal-İntegral-Türev (PID), endüstriyel kontrol sistemlerinde yaygın olarak kullanılan geleneksel bir denetleyici türüdür. Ancak, bazen daha yüksek dereceli sistemlerin kontrolünde yetersiz kalabilmektedirler. Bu durumlarda Oransal-İntegral-Türev-İvme (PIDA) denetleyiciler tercih edilebilir. Bu çalışmada; farklı tip PIDA denetleyicilerle kontrol sistemleri simülasyonlarını doğru, etkili, hızlı ve basit bir şekilde gerçekleştiren, tek veya karşılaştırmalı sayısal ve grafiksel sonuçlar (performans parametreleri, zaman ve frekans alanı tepkileri vb.) üreten, kullanıcı dostu arayüze sahip bir yazılım aracı tasarlanmıştır. Tasarlanan simülatörün özellikleri ve yetenekleri bazı örnek sistemlerle test edilmiştir: maglev araç süspansiyon sistemi, otomatik voltaj regülatörü ve endüksiyon motor sistemleri. Geliştirilen simülatör, kullanım kolaylığı ve içeriği ile bu alandaki tüm öğrenciler, mühendisler ve kullanıcılar için uygundur.

1. INTRODUCTION (GİRİŞ)

The Proportional-Integral-Derivative (PID) controller is the most preferred and widely used controller type in industrial control systems due to its easy design and implementation [1-2]. However, if the degree of the controlled system is three or greater, the two zeros provided by the PID controller may be insufficient to obtain the desired response accurately. To overcome this problem and obtain the desired system response more accurately, Jung and Dorf proposed Proportional-Integral-Derivative-Acceleration (PIDA) controller and an analytical method to determine the coefficients of this controller [3-4]. The PIDA controller, also known in the literature as the PID double derivative (PIDD2 or PIDD^2) controller, has a second derivative operator in addition to the PID controller, thus adding three zeros to the system. Therefore, it provides more phase-lead to the system, further improving the transient response of the system and providing extra robustness against disturbance inputs.

The PIDA controller has attracted the attention of researchers in recent years for third order systems [3-14], fourth orders systems [15-18], integral plus dead time systems [19-22], double integrator plus dead time systems [23], first order plus dead time systems [24], second order plus dead time systems [25], second order oscillatory with time delay system [26-28], second-order oscillatory model with zero plus dead time systems [29], third order plus dead time systems [30-31], different higher order systems [32], higher order time delay systems [33-36], higher order systems with integral and dead time [37], non-minimum phase second order system [38], two-input two-output nonlinear system [39],

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uncertain time delay systems [40], nonlinear uncertain systems [41], interconnected time delay systems [10, 31, 42-44]. Some generalized PID type controllers have also been proposed by adding higher order derivative terms to PIDA controllers [45-49]. These studies also include the PIDA controller.

While there are many simulators created for PID, only a few simulators with limited features have been developed for PIDA. A few simulation tools were designed in the literature to understand the PIDA controllers [50-54]. A software tool for the disturbance analysis of PID with higher derivative degrees was developed by Bisták. Graphical results in the simulator also include performance measurements and noise characteristics with time domain responses [50]. In a different study the designed simulation tool provides a comparison of set-point and step disturbance responses in the higher derivative degree PID controller circuit with the first order time-delayed controlled system influenced by a noise [51]. In another work, Bisták and Huba developed online software tool to help with dissemination of PID controllers with higher derivative degree [52]. In the simulation tool developed by Ferrari and Visioli can modify the PIDA parameters and analyze the corresponding changes in system responses in time (reference input, step disturbance and noise rejection performance) and frequency domain [53]. In another study a simple interactive educational tool for teaching PID and PIDA control is presented [54].

The aim of this study is to design a comprehensive analysis simulator that includes different PIDA controllers in the literature. Existing simulators usually contain limited controller structures and also have limited features. In this study, an interactive simulator is designed for basic PID and PIDA controllers. This simulator, which includes P, PI, PD, PID, PIDA, I-PD, I-PDA, PID with prefilter and PIDA with prefilter controllers and can be used for educational and application purposes, can perform single and comparative analyses. As a result of the analysis of user-defined systems with selected controllers under different conditions (input disturbance, output disturbance etc.), many numerical and graphical results such as time and frequency responses, response parameters, system properties are obtained. Thus, the suitability/efficiency/performance of the relevant controllers for the defined systems under the specified conditions can be evaluated quickly, easily and effectively.

This paper is organized as follows: In Section 2, PIDA controllers are summarized. In Section 3, the designed PIDA analysis simulator is explained and some sample applications are given. Finally, Section 4 contains conclusions.

2. PIDA CONTROLLERS (PIDA DENETLEYİCİLER)

The classical PIDA controller (Figure 1) can be written as follows in time-domain and s-domain, respectively:

$$u(t) = K_p.e(t) + K_i\int_0^t e(\tau)d\tau + K_d\frac{d}{dt}e(t) + K_a\frac{d^2}{dt^2}e(t) \quad (1)$$

$$U(s) = \left(K_p + \frac{K_i}{s} + K_d s + K_a s^2\right)E(s) \quad (2)$$

If the derivative filter is used in the PIDA controller, it can be written as follows; where, a, b, c are controller zeros, and d, e are controller poles [3-4]:

$$U(s) = \left(K_p + \frac{K_i}{s} + \frac{K_d s}{(s+d)} + \frac{K_a s^2}{(s+d)(s+e)}\right)E(s) = K\frac{(s+a)(s+b)(s+c)}{s(s+d)(s+e)}E(s) \quad (3)$$

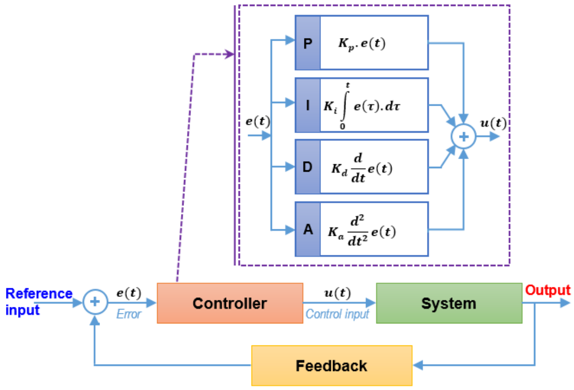


Figure 1. The feedback control system and PIDA controller (Geribeslemeli kontrol sistemi ve PIDA denetleyici)

In the PIDA controller, it can be written as follows, where α, β and γ are set-point weighting parameters for proportional, derivative and acceleration parts, respectively:

$$U(s) = K_p[\alpha R(s) - Y(s)] + \frac{K_i}{s}E(s) + K_d s[\beta R(s) - Y(s)] + K_a s^2[\gamma R(s) - Y(s)] \quad (4)$$

By taking the set-point weighting parameters as zero, I-PDA controller is obtained [55]:

$$U(s) = \frac{K_i}{s}E(s) - \left(K_p + K_d s + K_a s^2\right)Y(s) \quad (5)$$

If the set-point weighting and derivative filter are used together in the PIDA controller, the following equation can be written:

$$U(s) = K_p[\alpha R(s) - Y(s)] + \frac{K_i}{s}E(s) + \frac{K_d s}{(s+d)}[\beta R(s) - Y(s)] + \frac{K_a s^2}{(s+d)(s+e)}[\gamma R(s) - Y(s)] \quad (6)$$

3. DESIGNED TOOL and APPLICATIONS

(TASARLANAN ARAÇ VE UYGULAMALARI)

In this study, an interactive simulator was designed using MATLAB App Designer [56] for PID and PIDA controllers with different types. This simulator includes P, PI, PD, PID, PIDA, I-PD, I-PDA, PID with prefilter and PIDA with prefilter controllers. The general block diagram of the system used for analysis is seen on the simulator main screen in Figure 2. The main screen, toolbar and main menu of designed simulator with their descriptions are given in Figure 2 and Table 1-2, respectively. On the simulator main screen (Figure 2):

- The transfer function of the controlled system can be entered as numerator and denominator coefficients.
- The transfer function of the feedback system (sensor/filter) can be entered as numerator and denominator coefficients.
- Impulse, step and ramp can be selected as reference input.
- If available, user-defined step and partial step can be set as input disturbance.
- If available, user-defined step, partial step and noise can be set as output disturbance.
- The series controller is selected and its coefficients are entered. In comparative analyses, three series controllers are selected and their coefficients are entered separately.
- As a result of single analysis, time and frequency domain responses are plotted. In addition, the parameters in the relevant domains (for time domain: rise time, peak time, settling time, overshoot percentage, steady state response, steady state error; for frequency domain: gain margin, phase margin, gain crossover frequency, phase crossover frequency) are also displayed on the screen.
- As a result of the comparative analysis, the time and frequency domain responses are plotted comparatively with the adjusted controllers. In addition, the parameters in the relevant domains are given comparatively in tables.

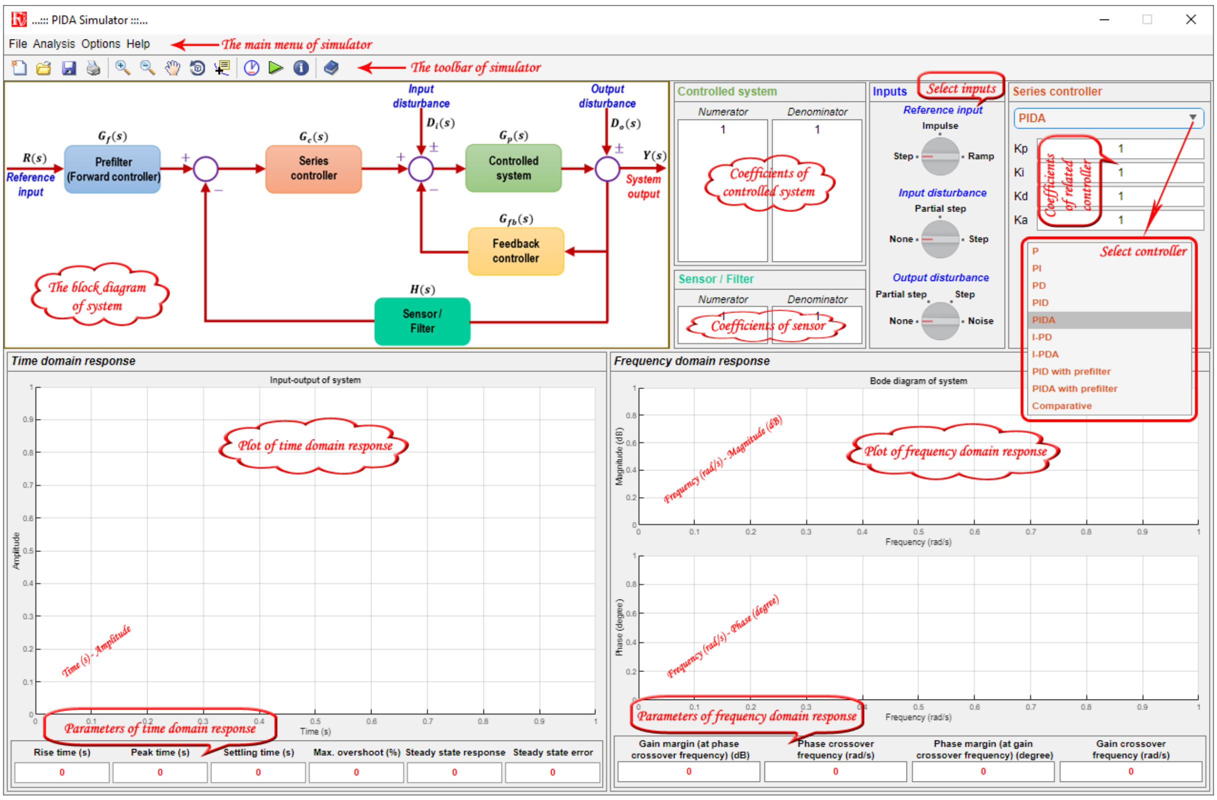


Figure 2. The main screenshot of designed simulator (Tasarlanan simülatörün ana ekranı)

Table 1. The toolbar of designed simulator (Tasarlanan simülatörün araç çubuğu)

New	Open	Save	Print	Zoom in	Zoom out	Pan	Rotate	Data cursor	Simulation time	Run	Detailed information	Help

Table 2. The main menu of designed simulator (Tasarlanan simülatörün ana menüsü)

File	Analysis	Options	Help
New Ctrl+N Open Ctrl+O Save ▸ Print Ctrl+P Exit	Single Ctrl+S Comparative Ctrl+C	Simulation range ▸ (Time, Frequency) Format Graphics	Contents Ctrl+H About
Basic operations for simulation: new, open, save (as data or image) and print	Performing single or comparative simulations/analysis	Simulation (time/frequency interval) and display (format, graphic properties, etc.) options	Simulator content/user guide

Case study-1: Maglev vehicle suspension system

The maglev vehicle can be modeled as a one-dimensional vehicle model consisting of a primary part (chassis) and a secondary part (passenger cabin). Transfer function model of the maglev suspension system from the guideway disturbance to position of the passenger cabin is given as

$$G_p(s) = \frac{b_p b_s s^2 + (b_p k_s + b_s k_p)s + k_p k_s}{m_p m_s s^4 + [m_p b_s + m_s(b_p + b_s)]s^3 + [m_p k_s + m_s(k_p + k_s) + b_p b_s]s^2 + (b_p k_s + b_s k_p)s + k_p k_s} \tag{7}$$

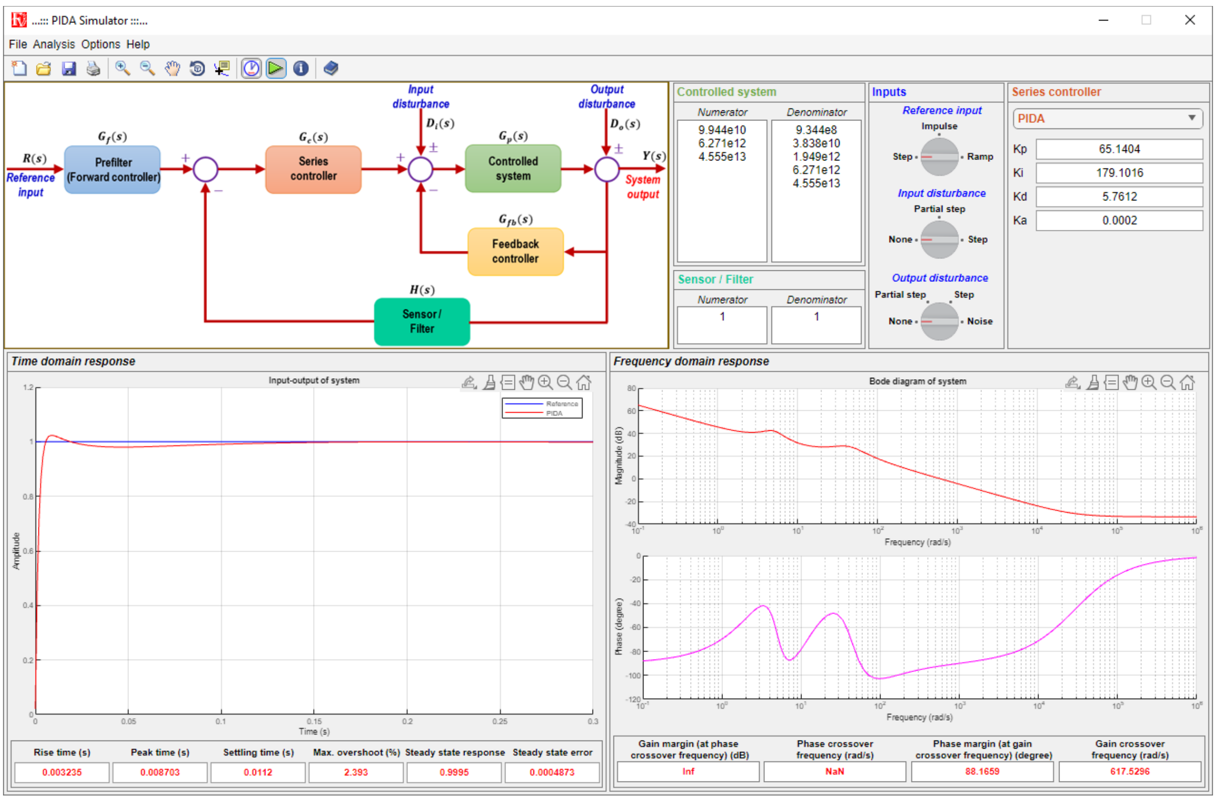
where masses m_p and m_s , stiffnesses k_p and k_s , and dampings b_p and b_s are the model parameters of the primer and seconder parts. Using the values for the model parameters given in [16], the following transfer function is obtained:

$$G_p(s) = \frac{9.944 \cdot 10^{10} s^2 + 6.271 \cdot 10^{12} s + 4.555 \cdot 10^{13}}{9.344 \cdot 10^{8} s^4 + 3.838 \cdot 10^{10} s^3 + 1.949 \cdot 10^{12} s^2 + 6.271 \cdot 10^{12} s + 4.555 \cdot 10^{13}} \tag{8}$$

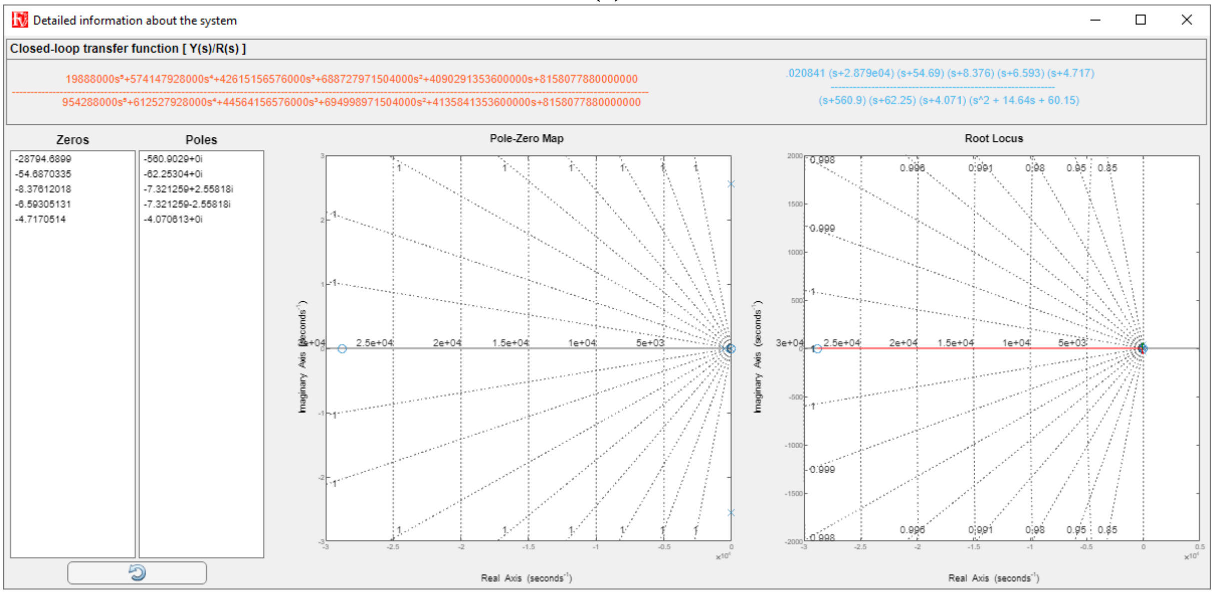
In the first simulation, the following PIDA controller given in [16] was used to control the maglev vehicle suspension system.

$$\left. \begin{aligned} G_c(s) &= 65.1404 + \frac{179.1016}{s} + 5.7612s + 0.0002s^2 \\ H(s) &= 1 \end{aligned} \right\} \tag{9}$$

The simulation result screen is shown in Figure 3a. Here, the time and frequency domain responses and related response parameters are included. Thus, the performance of the user-defined system with the specified controller can be clearly seen. If the desired specifications are not satisfied in the system response, simulations can be easily repeated by changing the controller and its coefficients. In addition, the window in Figure 3b is opened with the "Detailed information" icon. Here, the closed-loop transfer function of the system is printed in different ways, the zeros and poles of the system are listed and mapped, and the root locus curve is shown.



(a)



(b)

Figure 3. The screenshots for first application (Birinci uygulama için ekran görüntüleri)

Case study-2: Automatic voltage regulator system

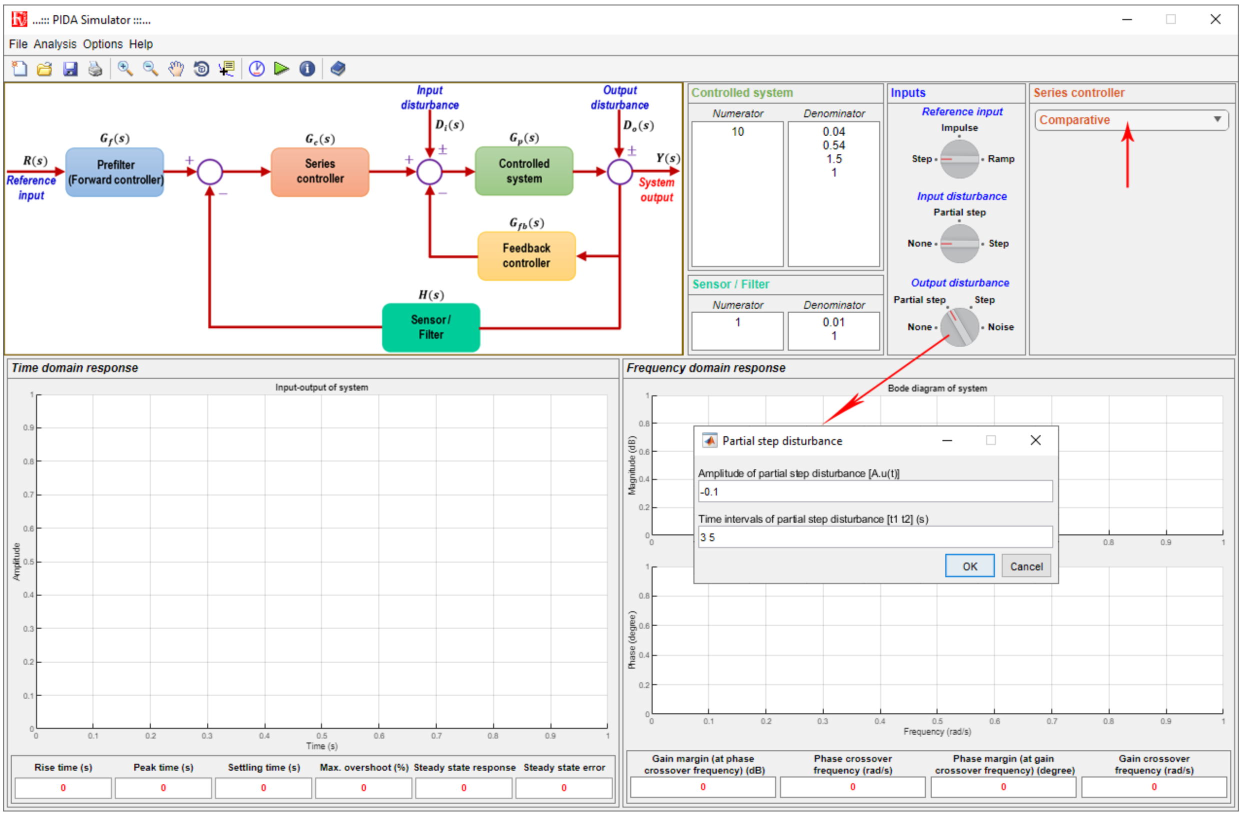
The second application is comparative control (PID, PIDA, PIDA) of automatic voltage regulator (AVR) system. An AVR system is used to regulate the generator voltage in a power system and consists of amplifier, exciter and generator blocks connected in series on forward path and a sensor on feedback path of the control system. An error information is obtained by measuring the terminal voltage of the generator with a sensor and comparing it with the reference voltage. Any designed controller processes this error signal and produces a control input that is used to excite the series-connected amplifier, exciter, generator blocks. Each block in the AVR system is modeled with a first-order system model defined by a gain and a time constant, and using the model parameters given in [15, 57-58] for each block, the following transfer function is obtained; where k_a, k_e, k_g, k_s are the gains and τ_a, τ_e, τ_g, τ_s are the time constants of the amplifier, exciter, generator and sensor blocks, respectively.

$$\left.\begin{aligned} G_p(s) &= \frac{k_a}{1+\tau_a s}\cdot\frac{k_e}{1+\tau_e s}\cdot\frac{k_g}{1+\tau_g s} \\ &= \frac{10}{0.04s^3+0.54s^2+1.5s+1} \\ H(s) &= \frac{k_s}{1+\tau_s s} = \frac{1}{0.01s+1} \end{aligned}\right\} \quad (10)$$

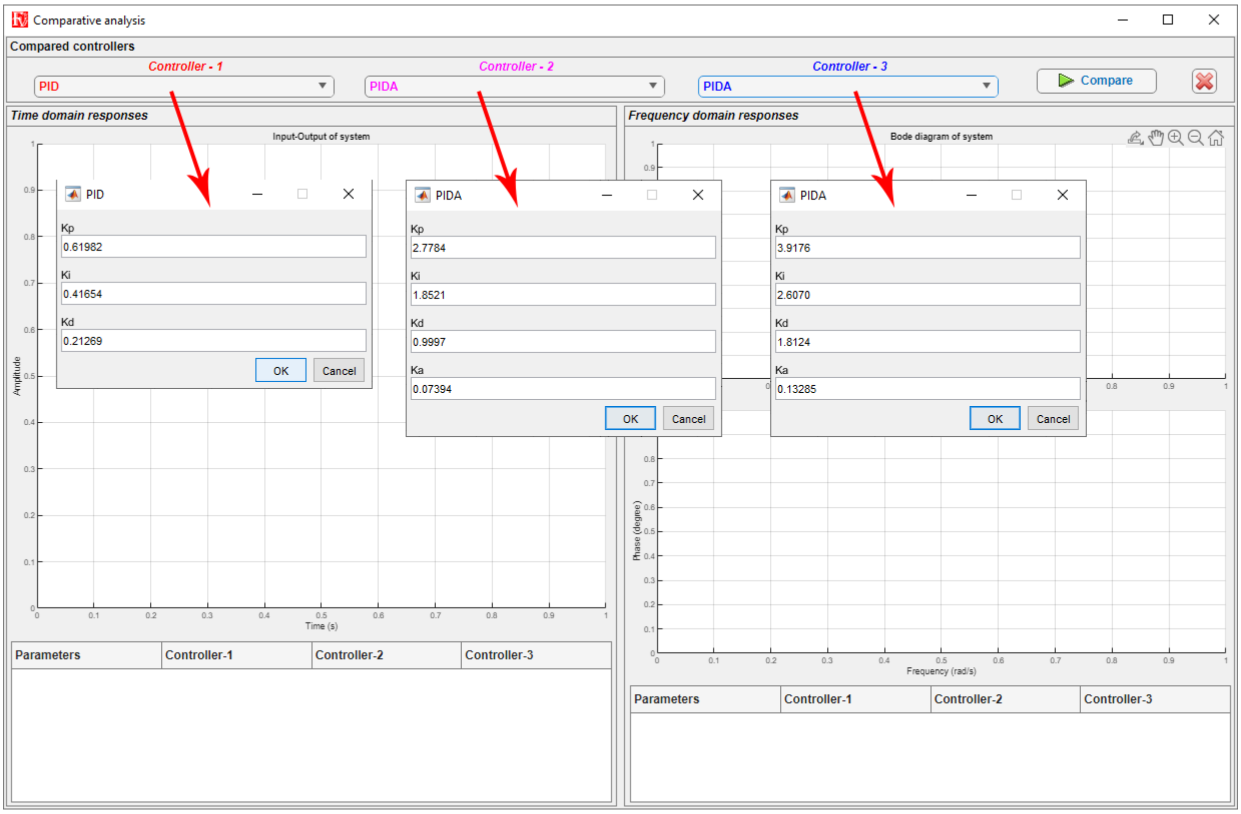
In the second simulation, the performances of the PID controller given in [57] and the PIDA controllers given in [15] and [58] were compared by using the AVR control system. Also, a step disturbance with an amplitude of 0.1 V was applied to the system output at $t = 3$ s, and removed at $t = 5$ s.

$$\left.\begin{aligned} G_{c_{PID}}(s) &= K_p + \frac{K_i}{s} + K_d s \\ &= 0.61982 + \frac{0.41654}{s} + 0.21269s \\ G_{c_{PIDA}}(s) &= K_p + \frac{K_i}{s} + K_d s + K_a s^2 \\ &= 2.7784 + \frac{1.8521}{s} + 0.9997s + 0.07394s^2 \\ G_{c_{PIDA}}(s) &= K_p + \frac{K_i}{s} + K_d s + K_a s^2 \\ &= 3.9176 + \frac{2.6070}{s} + 1.8124s + 0.13285s^2 \end{aligned}\right\} \quad (11)$$

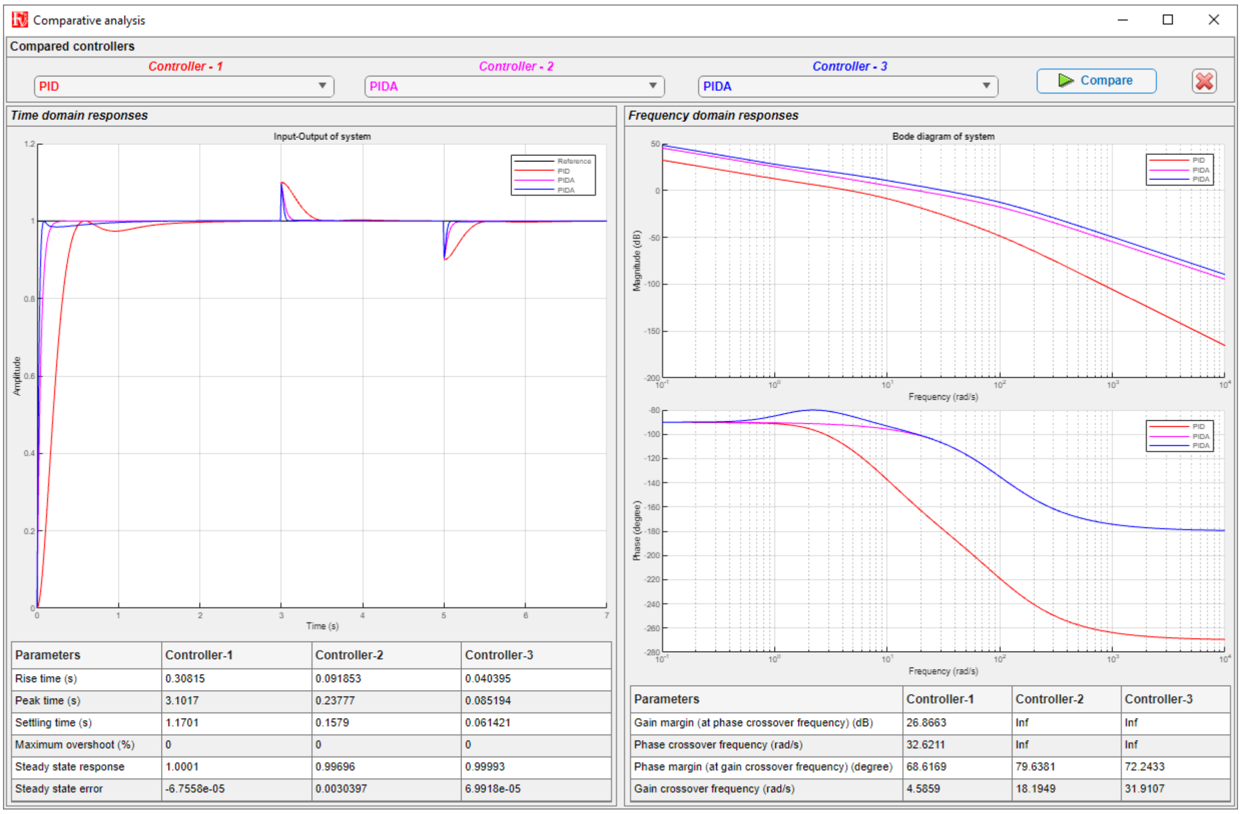
The input of the system parameters, reference input and partial step output disturbance is shown in Figure 4a. When "Comparative" is selected as the controller, the screen in Figure 4b opens and the parameters of the controllers to be compared are entered. By clicking the "Compare" button, the comparative simulation results are displayed as in Figure 4c. Here, in addition to the time and frequency domain comparative system responses, the relevant domain parameters are also displayed in tables. Thus, it is presented to the user which controller is more suitable for the defined system.


.::: PIDA Simulator :::..
File Analysis Options Help
Input disturbance
Output disturbance
$D_i(s)$
$D_o(s)$
$G_f(s)$
$G_c(s)$
$G_p(s)$
$R(s)$
Reference input
Prefilter (Forward controller)
Series controller
Controlled system
$Y(s)$
System output
$G_{fb}(s)$
Feedback controller
$H(s)$
Sensor / Filter
Controlled system
Numerator
Denominator
10
0.04
0.54
1.5
1
Sensor / Filter
Numerator
Denominator
1
0.01
1
Inputs
Reference input
Impulse
Step
Ramp
Input disturbance
Partial step
None
Step
Output disturbance
Partial step
Step
None
Noise
Series controller
Comparative
Time domain response
Input-output of system
Amplitude
Time (s)
Frequency domain response
Bode diagram of system
Magnitude (dB)
Phase (degree)
Frequency (rad/s)
Partial step disturbance
Amplitude of partial step disturbance [A.u(t)]
-0.1
Time intervals of partial step disturbance [t1 t2] (s)
3 5
OK
Cancel
Rise time (s)
Peak time (s)
Settling time (s)
Max. overshoot (%)
Steady state response
Steady state error
Gain margin (at phase crossover frequency) (dB)
Phase crossover frequency (rad/s)
Phase margin (at gain crossover frequency) (degree)
Gain crossover frequency (rad/s)

(a)


Comparative analysis
Compared controllers
Controller - 1
Controller - 2
Controller - 3
PID
PIDA
PIDA
Compare
Time domain responses
Input-Output of system
Amplitude
Time (s)
Frequency domain responses
Bode diagram of system
Phase (degree)
Frequency (rad/s)
PID
Kp
0.61982
Ki
0.41654
Kd
0.21269
OK
Cancel
PIDA
Kp
2.7784
Ki
1.8521
Kd
0.9997
Ka
0.07394
OK
Cancel
PIDA
Kp
3.9176
Ki
2.6070
Kd
1.8124
Ka
0.13285
OK
Cancel
Parameters
Controller-1
Controller-2
Controller-3

(b)



(c)

Figure 4. The screenshots for second application (İkinci uygulama için ekran görüntüleri)

Case study-3: Induction motor system

In the third application, a cascade control structure is used to control a simplified asynchronous motor model obtained by neglecting the electrical subsystem model. An Integral-Proportional (I-P) controller is used as speed controller in inner control loop, and a PIDA controller is used as position controller in outer loop. The following transfer function for the I-P controlled speed control loop is obtained by using the model parameters given in [4, 8, 55]; where k_i, k_p are the I-P controller parameters, and J, b, k_t are mechanical inertia constant, total friction coefficient, and torque constant of the motor, respectively.

$$G_p(s) = \frac{k_i k_t}{Js^2+(b+k_i k_t)s+k_i k_t} = \frac{168.0436}{s^3+25.921s^2+168.0436s} \tag{12}$$

In the third simulation, the performances of the following three PIDA controllers with $H(s) = 1$ (PIDA-Jung&Dorf, I-PDA, PIDA-Kitty) were compared.

$$\left.\begin{aligned} &G_{c_{PIDA-Jung\&Dorf}}(s) = K_p + \frac{K_i}{s} + K_d s + K_a s^2 \\ &= 11.8966 + \frac{19.5138}{s} + 2.445s + 0.1266s^2 \\ &G_{c_{I-PDA}}(s) = \begin{cases} G_c(s) = \frac{K_i}{s} = \frac{18.734}{s} \\ G_{fb}(s) = K_p + K_d s + K_a s^2 \\ = 8.842 + 0.669s + 0.0033s^2 \end{cases} \\ &G_{c_{PIDA-Kitty}}(s) = K_p + \frac{K_i}{s} + K_d s + K_a s^2 \\ &= 5.6672 + \frac{9.3764}{s} + 0.7027s + 0.0248s^2 \end{aligned}\right\} \tag{13}$$

After the data entries are completed, the comparative simulation results screen shown as in Figure 5.

The comparison of the developed simulator in this study with other simulators in the literature is summarized in Table 3.

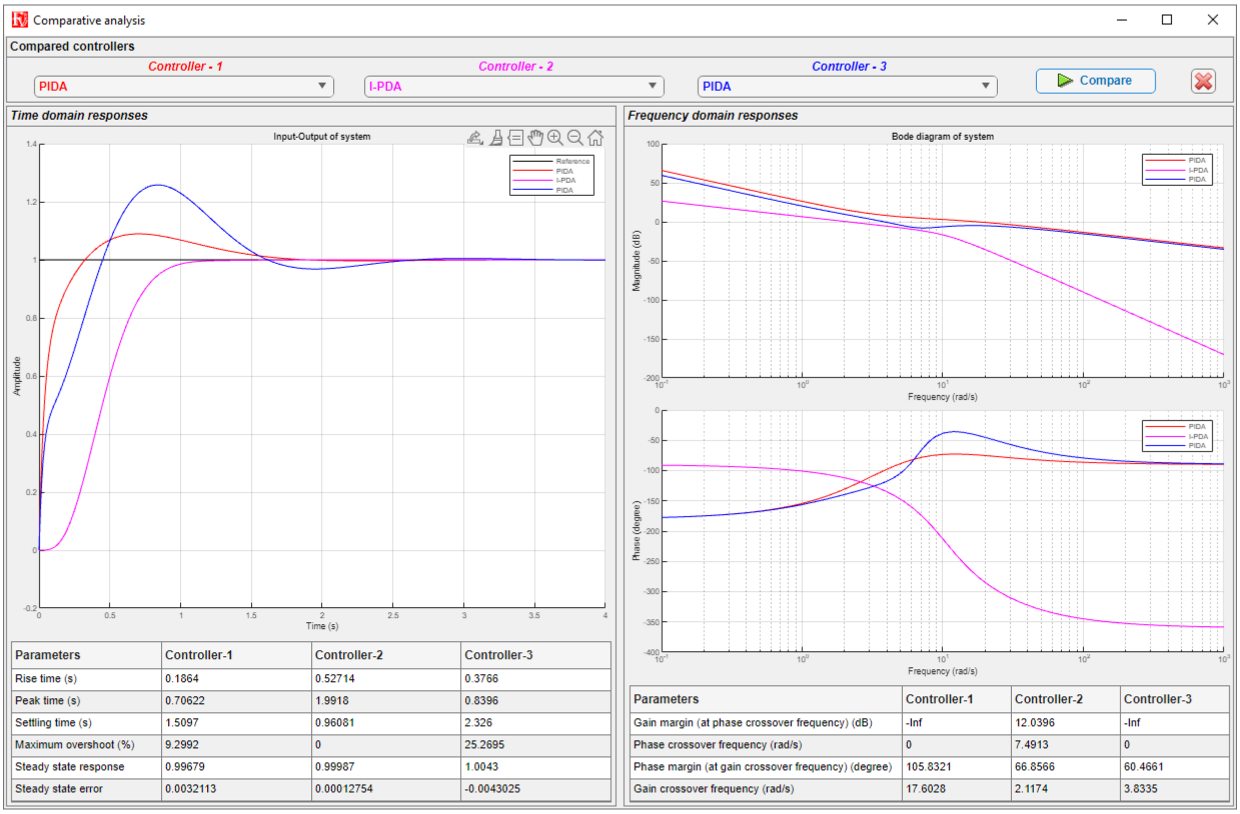


Figure 5. The screenshot for third application (Üçüncü uygulama için ekran görüntüsü)

Table 3. The comparison of simulators' properties (Simülatör özelliklerinin karşılaştırılması)

Properties			Ref. [50]	Ref. [51]	Ref. [52]	Ref. [53]	Ref. [54]	This study
Reference input	*Step*		√	√	√	√	√	√
	Impulse							√
	Ramp							√
Input disturbance	*Step*		√	√	√			√
	Delayed step				√			√
	Partial step							√
Output disturbance	*Step*							√
	Partial step							√
	Noise		√	√	√			√
Controlled system definition			√	√	√	√	√	√
Sensor / Filter definition								√
Series controller	*PID (P, PI, PD, PID)*		√	√	√	√	√	√
	PIDA		√	√	√	√	√	√
	I-PD							√
	I-PDA							√
	PID with prefilter							√
	PIDA with prefilter							√
Analysis type	*Single*		√	√	√	√	√	√
	Comparative		√	√	√	√	√	√
Responses	*Time domain plot*	*Reference tracking*	√	√	√	√	√	√
		Disturbance rejection	√	√	√	√		√
	Time domain parameters					√	√	√
	Frequency domain plot					√		√
	Frequency domain parameters					√		√
System information	*Closed-loop transfer function*							√
	Pole-zeros listing							√
	Pole-zeros mapping							√
	Root locus							√
Basic operations (save, print etc.)								√
Basic graphical operations (zoom in, zoom out, etc.)								√

4. CONCLUSIONS (SONUÇLAR)

Traditional PID controllers are used in many industrial applications. However, as the degree of the controlled system increases, the performance in the control process may decrease. This situation can be compensated by using PIDA controllers. In this study, an interactive simulator was designed for students and people who will use the relevant controllers in the control area. With this developed simulator, performance evaluations of PID and PIDA type controller systems can be easily performed with time and frequency domain analysis. In addition, the simulator has capabilities such as comparative analysis, analysis of input and output disturbance effects, and analysis of different reference input responses. In addition, it can provide detailed information about the relevant systems (closed-loop transfer functions, pole-zero mapping/listing, root locus plot, time and frequency performance parameters etc.). These features of the developed simulator are demonstrated with three case studies (maglev vehicle suspension system, automatic voltage regulator, induction motor system) performed in the work. As future work, it is planned to develop a web-based simulator and to extend by adding different controllers.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

***Metin Hatun*:** Conceptualization, Methodology, Investigation, Validation, Visualization, and Writing.

Kavramsallaştırma, Metodoloji, Araştırma, Doğrulama, Görselleştirme ve Yazma.

***Fahri Vatansever*:** Conceptualization, Methodology, Investigation, Software Development, Validation, Visualization, Writing-Reviewing and Editing.

Kavramsallaştırma, Metodoloji, Araştırma, Yazılım Geliştirme, Doğrulama, Görselleştirme, Yazma-İnceleme ve Düzenleme.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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