Int. J. Nonlinear Anal. Appl. In Press, 1–8
ISSN: 2008-6822 (electronic)
http://dx.doi.org/10.22075/ijnaa.2025.35721.5312

Azadi controller, the particular idea for the plant automations; illustrative models direct the nature-designed approach

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(Communicated by Madjid Eshaghi Gordji)

Abstract

This article is devoted to illustrating the distinctive, exclusive, and unique functioning and management of the Azadi controller for automations. The system dynamics may vary, so a PID or many direct or indirect adaptive controllers were suggested for it. In all cases, the controller parameters must always be re-adjusted to overcome the plant oscillations or instabilities. These adjustments usually yield many undesirable plant responses. The Azadi controller does not need to be re-adjusted for stable plant control since the plant response is pre-determined through the controller's special shape, i.e. a hyperbolic function with a specific factor. In addition, this response is always at the optimum designed purpose, i.e. no oscillations or overshoots at all, with a pleasant and nice rise time. Furthermore, this hyperbolic function looks like the natural cell activities, which are expressed through the Goldman equation. This cell behaviour passes three distinguished stages as negative, positive, and then negative feedback, exactly the same approach as the Azadi controller does. Because the nature power and handling are independent of the input parameter deviations, or the plant dynamic varieties, and always sink at the optimum response, a great nature matching to the Azadi controller is realised. Nature always suggests the finest design approach without any vital challenges. Therefore, this nature matching suggests that the Azadi controller be the crucial controller design. The simulation plant outcomes support this great clue and impression.

Keywords: Azadi controller, nature design, positive feedback, optimum response
2020 MSC: 00A06, 62P30

1 Introduction

For automations, various direct and indirect adaptive control design approaches have been suggested for time-varying or nonlinear plant automations. When the plant encounters disturbances, a re-adjustment of the controller parameters is required. Furthermore, these disturbances have many influences on the controller parameters, which unavoidably deteriorate the plant responses. The Azadi controller [1, 2, 3, 4, 5, 6, 7] design approach overcomes the disturbances on the plant. The idea comes from the action potential in the cell membrane [9, 8, 10, 11, 12, 13] which has positive feedback surrounded by two negative feedbacks. This controller is actually a variable gain which automatically adjusts itself to yield the optimum plant response. Figure 1 depicts the Azadi controller, which is a nonlinear gain as:

$$f(\vartheta) = \frac{\alpha_0 - \alpha_1\vartheta + \alpha_2\vartheta^2}{1 + \vartheta + \vartheta^2}. \tag{1.1}$$

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Received: October 2024 *Accepted:* April 2025

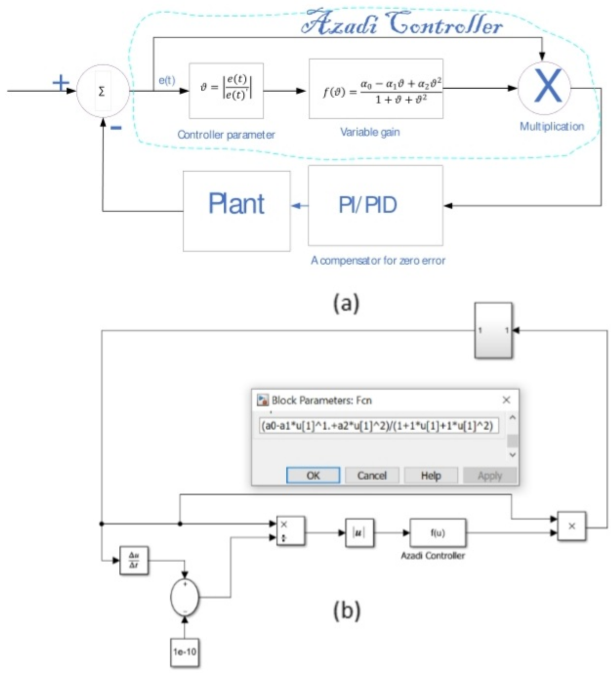

Figure 1: a) Azadi controller schematic, and b) MATLAB Simulink.

The parameter of ϑ is:

$$c = \left| \frac{e(t)}{e(t)'} \right|. \tag{1.2}$$

The values of the plant error $e(t)$ and its derivative $de(t)/dt$, respectively.

A compensator such as PI or PID is usually utilized just to ensure zero steady-state error for a step input, since the Azadi controller is a variable gain. If the plant is unstable, these compensators are used to ensure the plant's stability and do not play a major role in the overall plant responses. As seen in Figure 1, the Azadi controller has just three parameters: α_0, α_1, and α_2. These three parameters yield negative, positive, and negative feedback, respectively. The simplicity of this controller, which is just a variable gain, facilitates the plant stability studies. In the following section, to illustrate this controller's behaviour, two different plants are studied. In the first one, a very wide range of time-varying stable plants is examined, and in the second one, a delayed plant with a variable time constant is examined. Also, to illustrate the Azadi controller's performance, a PID controller is introduced.

2 Model simulation results

In this section, two cases of a time-varying sensitive stable plant and a delayed system are presented.

2.1 Case A: A Time-Varying Sensitive Stable Plant

Consider the plant under controller:

$$G(s) = \frac{\mu = 1 \dots 1000}{s^2 + (2 + \sin t)(1 + \text{rand}(0.1))s + 1}. \tag{2.1}$$

Although this plant is always stable, it is very hard to achieve satisfactory responses using any well-known controllers. Its dynamics vary both in a sinusoidal and a random manner. Besides, its sensitivity or gain varies across a very wide range. The simulation result of a PID controller (tuned $K_{PID}(s)$) based on two sensitive gains is depicted in Figure 2.

$$K_{PID}(s) = 2 + \frac{1.42}{s} + 0.65s. \tag{2.2}$$

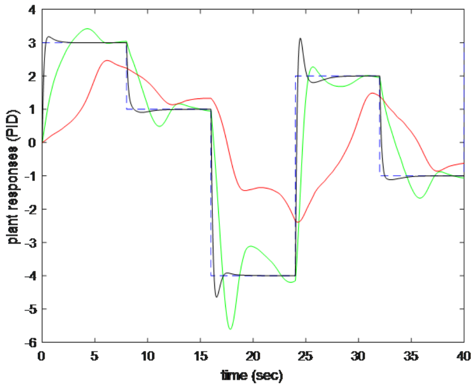

Figure 2: The time-varying plant with a tuned PID controller: the plant input (blue line), and the plant gains are: $\mu = 0.1$ (red line), $\mu = 1$ (green line), and $\mu = 10$ (black line).

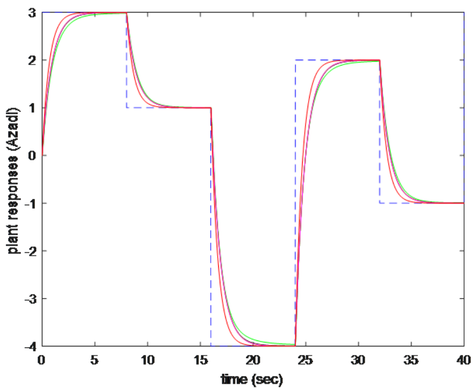

Figure 3: Azadi controller with different plant sensitives, and Azadi controller parameters: $\alpha_0 = 1$, $\alpha_1 = 10$, and $\alpha_2 = 10$ with sensitive gains as: $\mu = 1$ (green line), $\mu = 10$ (black line), $\mu = 100$ (yellow line), $\mu = 1000$ (magenta line), and also having different Azadi controller parameters $\alpha_0 = 30$ $\alpha_1 = 700$, $\alpha_2 = 1000$ with a sensitive gain of $\mu = 1$ (red line).

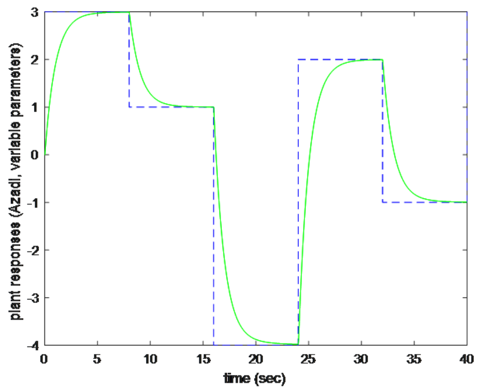

Figure 4: Azadi controller with variable parameter does not have any effects on the plant response, while any variations on PID controller violates the plant response.

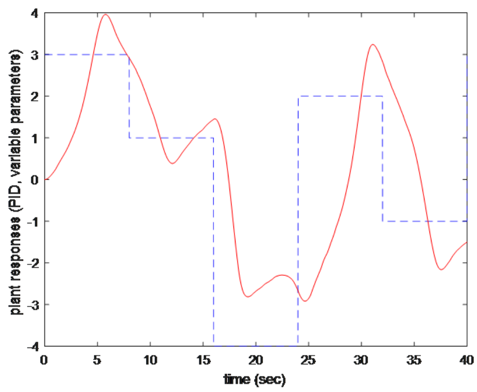

Figure 5: PID controller with the time-varying plant with a time-varying PID parameters.

Now, the Azadi controller output responses for different Azadi controller parameters using a PI compensator (for zero steady-state error) are depicted in Figure 3.

$$K_{PID}(s) = \frac{10s+1}{s}. \tag{2.3}$$

As seen in Figure 3, the Azadi control parameter does not have any vital effect on the responses. To elaborate on this strength, consider the Azadi controller parameters vary sinusoidally and random variables similar to the plant dynamics as:

$$\begin{cases} \alpha_0 = 1.5 + 0.1(\sin(0.5t) + \text{rand}_{0.1}) \\ \alpha_1 = 20 + 0.1(\sin(0.5t) + \text{rand}_{0.1}) \\ \alpha_2 = 20 + 0.1(\sin(0.5t) + \text{rand}_{0.1}) \end{cases} \tag{2.4}$$

These noisy control parameters for both the Azadi and the PID controllers are considered. The outputs for both controllers are depicted in Figure 4 and Figure 5, respectively. In both cases, the plant is time-varying, and the controller parameters are also varying sinusoidally and randomly.

Figure 6 shows the plant input and the α_1 parameter for Azadi controller. As can be seen in Figure 4, the Azadi plant output is optimum, and the plant variations as well as control parameter variations do not have any effect on the results. In other words, the controller compensates for both the plant dynamics and its own variations to ensure the optimum response. In the following section, another vital case of plant automation, i.e., a time-delayed plant with variable time constant is considered.

2.2 Case B) A Time-Delayed Plant with Variable Time Constant

In this section, a variable time constant with a time-delayed $G(s)$ is considered as follows:

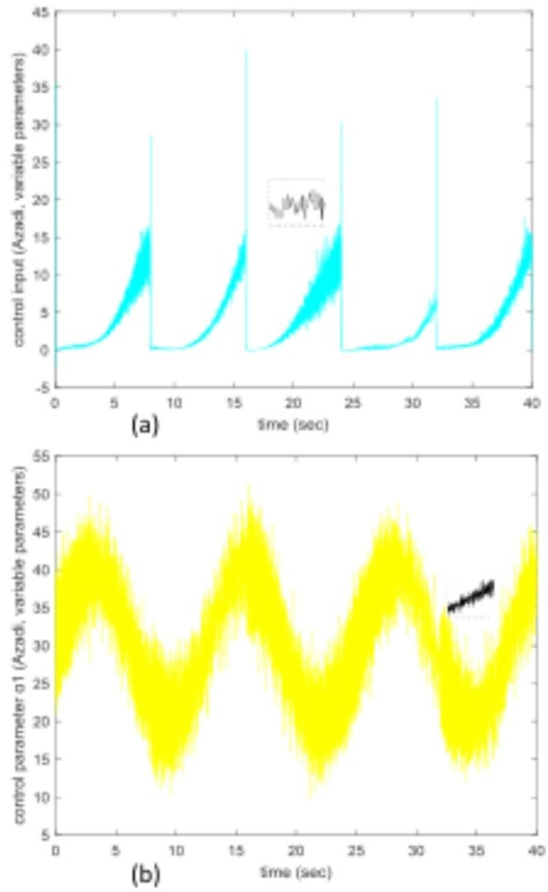

Figure 6: Azadi controller in the presence of the time-varying plant: a) the plant input, and b) the time-varying α_1 parameter.

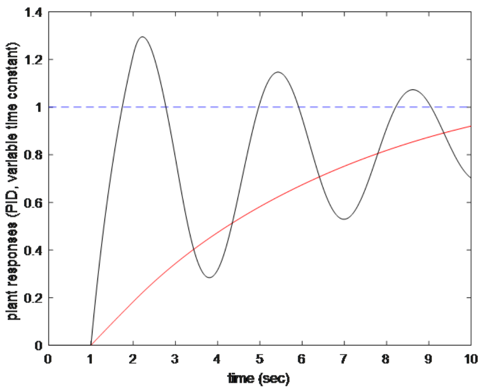

Figure 7: The PID controller for the plant step response for $T = 10$ sec (red line), and $T = 1$ sec (black line).

$$G(s) = \frac{e^{-s\tau}}{1 + Ts} \quad (2.5). \tag{2.4}$$

In order to simulate the Azadi controller, a noisy PI controller with variance of 5% of the plant time constant is also considered. To establish a comparison with a PID, $T = 10$ sec, and $T = 1$ sec with the delay of $\tau = 1$ sec is considered.

Tuning the PID controller for $T = 10$ sec, results:

$$K_{\text{PID}}(s) = 1.54 + \frac{0.16}{s} + 0.35s. \tag{2.5}$$

Figure 7 shows the plant output response for the PID case. Now, the Azadi controller with the parameters $\alpha_0 = 0.09$, $\alpha_1 = 0.9$, and $\alpha_2 = 0.9$ is considered for both time constants of $T = 10$ sec and $T = 1$ sec. Figure 8a and Figure 8b depict the plant outputs and inputs for the Azadi controller, respectively. In the following section, a brief conclusion based on these simulation results is presented.

3 Conclusions

Simulation results for the sensitive time-varying plants, together with the variable Azadi control parameters indicate that all of the plant responses are at the optimum behavior with no shift in responses. In fact, noises and disturbances on the stable plant and control parameters do not influence the output results. Also, simulation results for the time-delayed systems show that the optimum responses are lost due to the strong action behavior of Azadi controller. Azadi controller reduces its gain (Figurer 8b) to avoid any oscillations or instabilities. A comparison with the PID controller indicates that the PID control is disturbed by the delay component (Figure 7). While Azadi controller behavior can be deeply admirable. Therefore, based on the simulation results one can conclude that:

1. The stable time-varying plant responses are independent of both plant and Azadi control designed parameters.
2. All of the plant responses are at the optimum points.
3. There are no oscillations or overshoots for the time-varying stable plant or delayed systems.
4. In the case of delayed systems, Azadi controller sacrifices the optimum response to avoid any oscillations or sluggish behaviors. Protecting the plant from oscillations or instability is more crucial than just an optimum response.
5. Azadi controller behaves similar to the cell action potential activity, i.e., one positive feedback surrounded by two negative feedbacks.
6. The hyperbolic function of Azadi controller is similar to the Goldman equation of the cell membranes.
7. Physiological data from nature indicate that disturbances on the plant or controller parameters are all bypassed by a strong and great reaction. Similarly, Azadi controller sinks at the optimum responses despite every disturbance on the plant or controller parameters.

Based on all of the above seven outcomes, one can conclude that Azadi controller is a remarkable and unchallenged controller.

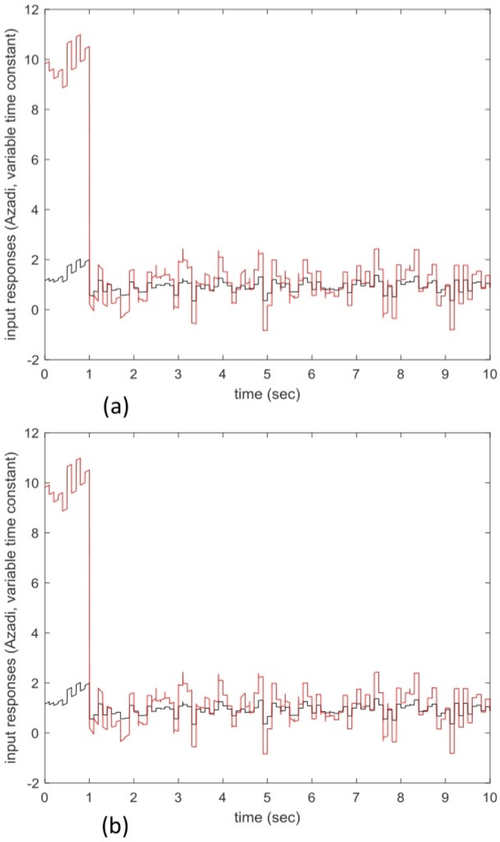

Figure 8: Azadi controller for the input step response for $T = 10$ sec (red line), and $T = 1$ sec (black line): a) outputs b) inputs.

Acknowledgment

Azadi controller's initiative decision and novelty has been approved through patent No. 75315 registered in Iranian Industrial Property Office.

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