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Journal of Scientific & Industrial Research
Vol. 78, October 2019, pp. 667-670

Azadi Controller Influentially Succeeds in the Eminent Plant Automations

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Received 4 June 2018; revised 14 February 2019; accepted 15 July 2019

This paper is devoted to present Azadi controller, which is based on a positive feedback surrounded with two negative feedbacks. This controller performs influential over the classical optimum PID controllers. Classical PID controllers have been extensively applied to the linear or nonlinear systems for many years. There are many approaches to tune these PID controllers. Among those, are Zigler-Nicols (ZN), Chien-Hrones-Reswick (CHR), Cohen–Coon (CC), and some optimum controllers such as Modulus Optimum (MO), Symmetrical Optimum (SO). However, when the plant has larger delays, Smith predictor (SP) becomes a good candidate to overcome the plant oscillations. Azadi controller actually is an adaptive controller which performs much better than those optimum classical controllers from many control features such as rise time, overshoots, settling time, or steady state errors. The simulation results confirm the ability of Azadi controller to suppress the plant oscillations. Besides, the simplicity of Azadi controller with just three parameters with its good performances suggests Azadi controller to be a good candidate for any linear, nonlinear, or time varying plants.

Keywords: Azadi, ZN, CHR, CC, Modulus Optimum, Symmetrical Optimum, Smith Predictor

Introduction

There are many classical approaches for tuning a PID controller parameters. For instance, Zigler-Nicols (ZN)[1,2] presented a systematic approach for a PID controller. Chien-Hrones-Reswick (CHR)[3], also presented a tuning approach for a PID controller. Cohen–Coon (CC)[4], tuned a PID controller based on ZN method for a faster response. Many optimal controllers have been proposed to tune a PID controllers. For instance, Modulus optimum (MO)[5,6] and Symmetrical optimum (SO)[7] are for a type I, and II plants, respectively[8]. However, when plant has a very large delay, none of those controller could overcome the plant misbehaviors. A scholar named Leo smith presented a controller, named Smith Predictor (SP)[9] for large delay plants. However, its controller is highly depended on the plant dynamics. In the case of plant uncertainties, the SP violates and cannot overcome the plant oscillations or misbehaviors. Sassan Azadi[10] presented his controller as an augmented controller to the SP which overcomes the undesirable behaviors. A PID controller may fail to control a time-varying, or nonlinear plants, so many researchers applied some other controllers such as adaptive controller, fuzzy controller, model based neural network controllers to overcome the PID controller weakness[11-16]. However, these suggested controllers may become so complicated that are not very attractive in the industrial control. In this research work, presented Azadi controller[17-21] which is based on a positive feedback with two surrounding negative feedback. Azadi controller with three parameters is simple and very adaptive to the plant variations. In the next section, this controller is presented.

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Azadi controller

Figure 1 depicts the Azadi controller which is a nonlinear gain based on two negative feedbacks and a positive feedback. This nonlinear gain is $f(v)= (\alpha_0 - \alpha_1 v + \alpha_2 v^2)/ (1+v +v^2)$, in which v is the absolute value of error divided by the error derivative ($v = |de(t)/dt \ /e(t)|$). The parameter α_1 may act as a positive feedback surrounded by the two negative feedbacks (α_0, and α_2). A compensator following the Azadi controller (figure 1) is usually a PI controller to increase the type of the system for steady state error improvement. The coefficient of α_1 is for damping of the plant and should be controlled by the two encompassing negative feedbacks of α_0, and α_2. The coefficient of α_0 is for the start-up, and also effects the positive feedback behavior. Therefore, it is usually being kept a very small value. The coefficient of α_2 is actually the steady-state velocity coefficient, and if the stability allows should be as large as possible.

Azadi controller, in fact, is a variable gain, and therefore in some special case a PID controller would

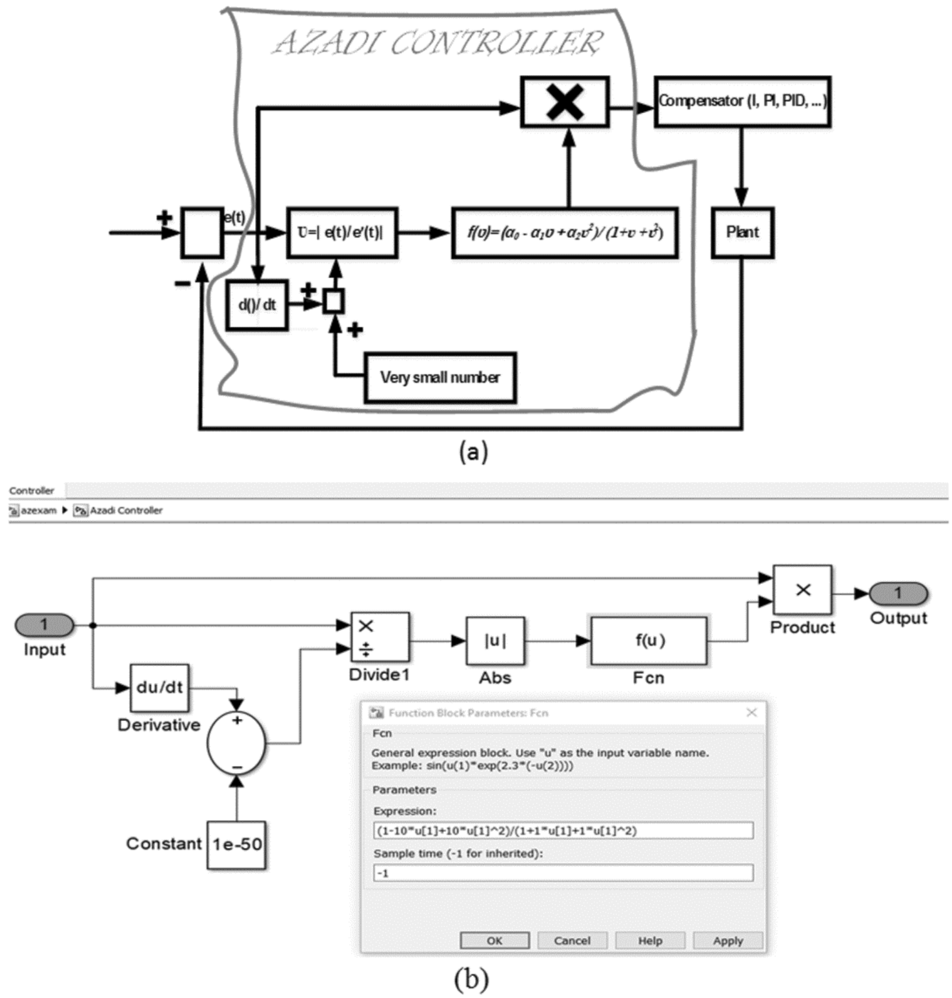

Fig. 1 — (a) Azadi controller structure, and (b) Matlab Simulink for Azadi controller

be a subset of this controller (i.e.: $\alpha 0=-\alpha 1=\alpha 2=1$). In the following section, the results obtained by Azadi controller simulations with the classical controllers are presented.

Simulation Results of Azadi Controller with Several Optimum Classical Controllers

Figure *2a* depicts the simulations for Azadi controller with ZN controller design for a first order plant T with a delay of L, i.e. $G(s)= e^{-Ls} /(Ts+1)$. The ZN PID parameters are: gain $K=T/L$, integral, and the derivative coefficients are $2L$, and $L/2$, respectively. The compensator for the Azadi controller is $(Ts+1)/s$, with $\alpha_0=0.1/L$, and $\alpha_2= \alpha_1=10\ \alpha_0$. For simulation study, the plant time constant, and delay time are considered to be: $T=1$, and $L=0.2$, and 0.5.

Figure *2b* depicts the simulations for Azadi controller with CHR controller design for the same plant parameters. The CHR controller parameters are: gain $K=0.95/(L/T)$, and the integral and derivative coefficients are $1.4L$, and $L/2$, respectively.

Figure *2c* depicts the simulations for Azadi controller with CC controller design for the same plant parameters. The controller parameters are: $r=L/T$, PID parameters are: gain $K= 1/r(4/3+r/4)$ and the integral and derivative coefficients are $L(32+6r)/(13+8r)$, $4L/(11+2r)$, respectively.

For very large delays, Azadi controller can perform well, while SP controller is highly depends on the plant parameters. The variations of the parameters are the weakness of any SP design. The Azadi controller parameters are $\alpha_0=0.1/L^{\wedge}1.15$, and $\alpha_2= \alpha_1=10\alpha_0$ for a very large delays of $L=2T=2$, and $L=5T=5$ sec. SP controller had a PI compensator of (2s+1)/2, with 20% overestimates on the gain ($K=1.2$), time delays and time constants ($L=T=2.2$, and L=T=6 seconds). Figure *2d* depicts the step responses of Azadi controller for the plants. Even in the case of delays

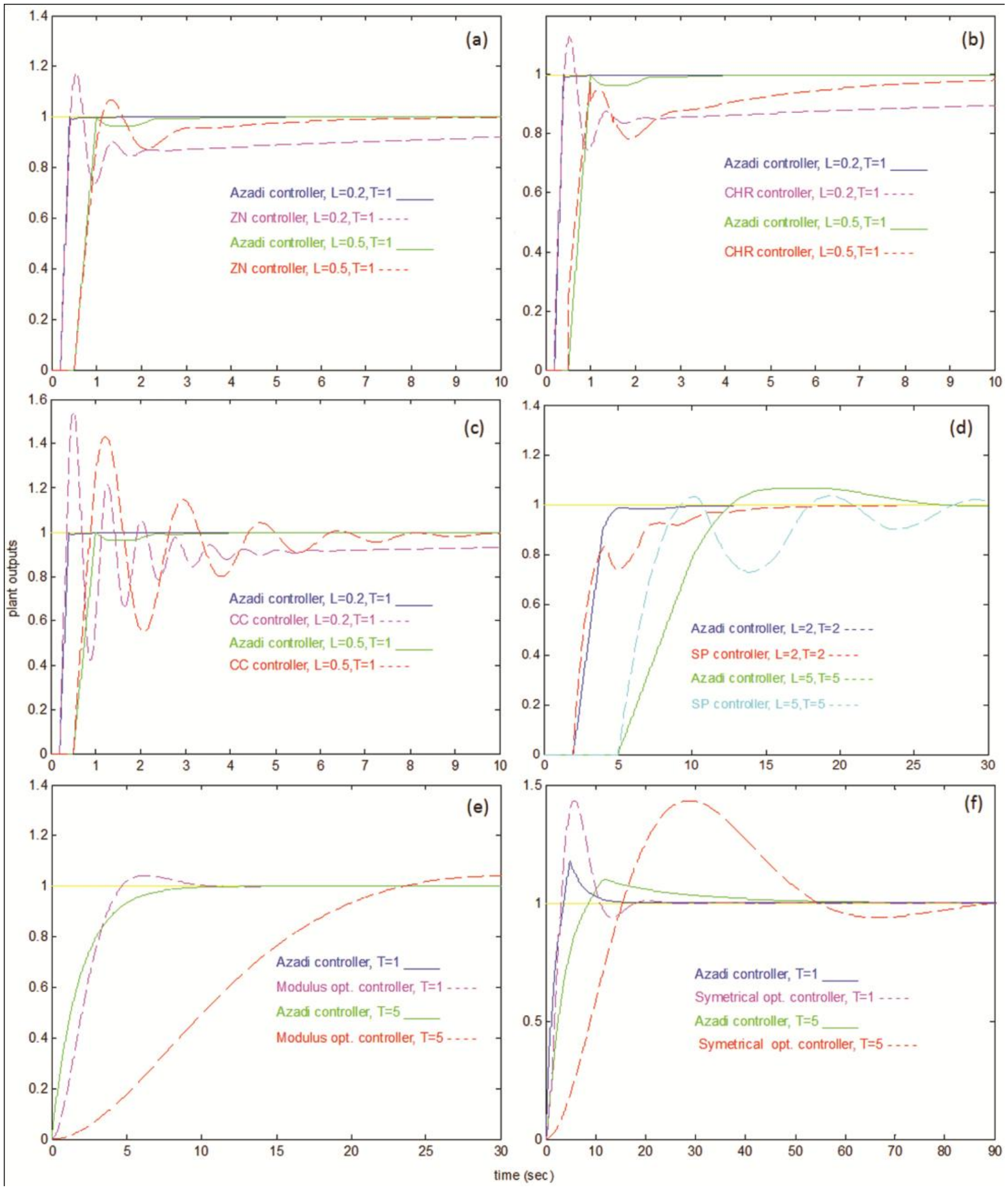

Fig. 2 — Step responses for (a) Azadi controller and ZN with different time delay of L=0.2, and L=0.5, (b) Azadi controller and CHR with different time delay of L=0. , and L=0.5, (c) Azadi controller and CC with different time delays of L=0.2, and L=0.5,(d) Azadi controller and SP (plant overestimate of 20% on the gain, time constant, and delay element) with very large time delays of L=2T=2sec and L=5T=5sec,(e) Azadi controller and modulus optimum with different time constant of T=1 and T=5sec. and (f) Azadi controller and symmetrical optimum with different time constant of T=1 and T=5sec.

five times than the time constant of the system, the plant overshoot is less than *10%*. A conventional PID controller in this case may encounter the instability or oscillations for the plants.

Figure *2e* shows Azadi controller and the MO with PID controllers. A MO is for 4% overshoot for the plant. The overall closed loop of the MO system $H(s)=1/(1+2Ts+2T^2s^2)$ in which the T is the largest plant time constant. Azadi controller parameters in this case are: $\alpha_0=0.1$, and $\alpha_2= \alpha_1=10\alpha_0$, with a PI compensator as $(Ts+1)/s$. In this case $T=1$, and $T=10$ are considered for the plant.

Figure *2f* shows Azadi controller and the SO with PID controllers. The symmetrical optimum is for zero ramp steady state error and the overall closed loop plant is in the form of $H(s)=(1+4Ts)/$

$(1+4Ts+8T^2s^2+8T^3s^3)$. A PID controller which produces this kind of transfer function for a system $G(s)=1/(Ts^2+s)$, is $K(s)=(4Ts+1)/(8T^2s)$. Due to a zero on the numerator of the closed loop plant, there is a *43%* overshoot for the step response. For Azadi controller, the same PID controller as SO is used together with a lead 1:10 as: $K_{lead}(s)=(Ts+1)/(10Ts+1)$. This lead compensator is used to reduce the large overshoot due to the zero on the plant. The Azadi controller parameters are $\alpha_0=0.5$, and $\alpha_2=\alpha_1=10\alpha_0$. In the following section, a conclusion regarding the advantages of Azadi controller with several optimum PID controllers are presented.

Conclusions

As shown in all of the figures *2a* to *2f*, Azadi controller performs admirably in any plant time delays variations or time constant variations. In addition, similar to a PID controller, design of Azadi controller is very simple because just three parameters are needed (one positive and two negative feedback gains). The controller performances are according to the percent of overshoots, rise time, and settling time. In all of the cases, Azadi controller exhibits better than all of classical controllers and therefore can be a good candidate for any linear, nonlinear, or time varying plants.

Acknowledgment

Azadi controller's initiative decision and novelty has approved through patent No. 75315 registered in Iranian industrial property office.

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