Chapter

MIMO PID Control Retuning Using the Closed-Loop Frequency Response

Anna Paula V. de A. Aguiar, George Acioli Júnior and Péricles R. Barros

Abstract

Proportional integral derivative (PID) controllers are the most used in practice for regulatory control. This is due to the good performance achieved by this controller for a variety of processes. However, about 60% have performance issue. This problem can be more evident in multivariable processes, due to the coupling between the loops. One way to improve performance is to retune the parameters. Thus, in this article, a PID control retune technique is presented. Frequency domain data are used to compute gain increments. Identification of the parametric model of the process is not necessary. The method can be applied to multivariable processes with time delay, integrative dynamics, and nonminimum phase zeros. Simulation results and the effectiveness of the method are discussed.

Keywords: PID controller, multivariable systems, frequency domain, retuning, process control

1. Introduction

The proportional integral derivative (PID) controllers are the most used in the industry [1]. Numerous tuning methods for PID parameters are found in the literature. Despite this, about 60% controllers do not reach the desired performance [2]. This occurs due to actuator wear, process changes, and mainly poorly due to tuned controllers.

Several methods of evaluation of control loops and controller tuning are found in the literature. Many of these controller evaluation and retuning methods are based on process models. In [3], process data are used to identify a model. Then, the PID controller is designed based on obtained model and desired performance is computed by output prediction. If the performance index is adequate, the PID controller is retuned using the model; otherwise, another process model must be identified.

However, identifying the model may not be an easy task. An alternative is to use data-based methods. In these methods, knowledge of the system parametric model is not necessary and time or frequency domain data are used.

In [2], a PID controller performance assessment and retuning method is proposed. The closed-loop step response data are used, and the controller is retuned so that it approximates a closed-loop reference model. The reference model is a second-order plus time delay transfer function. In [4], frequency domain constraints are inserted into the problem proposed in [2] to improve robustness and ensure stability.

Only frequency domain data are used in the method presented in [5] to retune the PID controller. In the last two, the reference model is a first order plus time delay transfer function, of which the time constant is defined according to the desired stability margins.

However, these methodologies are applied to single-input single-output (SISO) processes. On the other hand, the processes are increasingly complex due the demand for high-quality and energy-saving products is ever-increasing. Multivariable (MIMO) processes are common in the industry. PID control structures for MIMO processes are classified as decentralized control and centralized control. The decentralized control is a diagonal matrix, in which each nonzero element is a PID controller. The centralized control consists of a full matrix.

Ensuring a desired performance of the PID controller in MIMO processes is an even more difficult task, due to the coupling between the loops. The coupling represents the interactions between input and output variables. Thus, MIMO PID controller performance evaluation and retuning methods are necessary.

One way to use methods developed for SISO processes in MIMO processes is to apply them sequentially and iteratively. In [6], the method presented in [4] was used to evaluate and retune the decentralized PID controller. In [7], the PI controller retuning method presented in [5] has been extended to MIMO processes.

In this paper, the retuning method presented in [7] is reviewed and extended to PID controllers. The increments of the initial MIMO PID controllers gains are computed using only frequency domain data. The process parametric model is not required. The objective is to retune the controller so that the new closed loop is as close as possible to a given reference model. Simulation examples show that the method can be applied to multivariable process with time delay, integrative dynamics, and nonminimum phase zero.

The paper is organized as follows. In Section 2, the problem statement is presented. The frequency domain retuning method for MIMO process is proposed in Section 3. The simulation and experimental results are presented in sections 4. The conclusion is presented in Section 5.

2. Problem statement

Consider a multivariable process $\mathbf{G}(s) \in \mathbb{C}^{n \times n}$ with n inputs and n outputs and a centralized or descentralized PI/PID controller $\mathbf{C}(s) \in \mathbb{C}^{n \times n}$, respectively, given by:

$$\mathbf{C}(s) = \begin{bmatrix} C_{11}(s) & C_{12}(s) & \cdots & C_{1n}(s) \\ C_{21}(s) & C_{22}(s) & \cdots & C_{2n}(s) \\ \vdots & \vdots & \ddots & \vdots \\ C_{n1}(s) & C_{n2}(s) & \cdots & C_{nn}(s) \end{bmatrix}, \tag{1}$$

$$\mathbf{C}(s) = \begin{bmatrix} C_{11}(s) & 0 & \cdots & 0 \\ 0 & C_{22}(s) & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & C_{nn}(s) \end{bmatrix}, \tag{2}$$

where each non-null element is given by:

$$C_{ij}(s) = Kp_{ij} + \frac{Ki_{ij}}{s} + sKd_{ij}, \tag{3}$$

and Kp_{ij}, Ki_{ij}, and Kd_{ij} are the proportional, integrative, and derivative gains, respectively, and $i, j = 1, 2, \dots, n$.

The closed loop is given by:

$$\mathbf{T}(s) = (\mathbf{I} + \mathbf{G}(s)\mathbf{C}(s))^{-1}\mathbf{G}(s)\mathbf{C}(s), \tag{4}$$

where $\mathbf{T}(s) \in \mathbb{C}^{n\times n}$ must be stable, $\mathbf{I} \in \mathbb{R}^{n\times n}$ is an identity matrix. The sensitivity function is given by:

$$\mathbf{S}(s) = (\mathbf{I} + \mathbf{G}(s)\mathbf{C}(s))^{-1}. \tag{5}$$

Given a closed-loop reference model $\mathbf{T}_r(s)$ and the initial closed-loop frequency response data $\mathbf{T}_i(j\omega)$ on a finite frequency set $\Omega = [\omega_1, \omega_2, \cdots, \omega_N]$, with $\omega_1 > 0$, the problem statement is: obtain a new PID controller so that the designed closed loop is close to the desired one, without the knowledge of the parametric model of the process.

3. Frequency domain retuning

Consider an initial closed-loop $\mathbf{T}_i(s) = (\mathbf{I} + \mathbf{G}(s)\mathbf{C}_i(s))^{-1}\mathbf{G}(s)\mathbf{C}_i(s)$ with a MIMO PI/PID controller Eq. (1) and (2). The retuned controller $\overline{\mathbf{C}}(s)$ is given by:

$$\overline{\mathbf{C}}(s) = \mathbf{C}(s) + \mathbf{C}^{\Delta}(s), \tag{6}$$

where the $\mathbf{C}^{\Delta}(s)$ parameters are again increments of the initial controller gain.

The goal of the retune is to compute the $\mathbf{C}^{\Delta}(s)$ parameters, so that the new closed loop with the new controller $\overline{\mathbf{C}}(s)$ is close to the desired one. To compute the $\mathbf{C}^{\Delta}(s)$ parameters, first the frequency response $\mathbf{C}^{\Delta}(j\omega)$ is computed considering the iterations between the loops, as shown in lemma 1.1. The frequency response of the initial closed loop, the reference model, and the initial controller is the algorithm input data.

Lemma 1.1 *Given a desired reference* $\mathbf{T}_r(s)$ *and an initial* $\mathbf{T}_i(s)$ *closed loop, the* $\mathbf{C}^{\Delta}(j\omega)$ *can be computed as:*

$$\mathbf{C}^{\Delta}(j\omega) = \mathbf{C}(j\omega)\mathbf{T}_i(j\omega)^{-1}(\mathbf{T}_r(j\omega) - \mathbf{T}_i(j\omega))\mathbf{S}_r^{-1}(j\omega), \tag{7}$$

where $\mathbf{S}_r(s) = \mathbf{I} - \mathbf{T}_r(s)$ is the reference model sensitivity function.

Proof of Lemma 1.1: The proof is found in [7].

Once the $\mathbf{C}^{\Delta}(s)$ frequency response is computed, the gain increments can be obtained. By definition each element of $\mathbf{C}^{\Delta}(j\omega) \in \mathbb{C}^{n\times n}$ is of the form:

$$C^{\Delta}_{ij}(s) = Kp^{\Delta}_{ij} + \frac{Ki^{\Delta}_{ij}}{s} + Kd^{\Delta}_{ij}s. \tag{8}$$

From lemma 1.1 and matrix equality, the parameters Kp_{ij}^{Δ}, Ki_{ij}^{Δ} and Kd_{ij}^{Δ} of each element of $C_{ij}^{\Delta}(s)$ are computed as shown in lemma 1.2.

Lemma 1.2 Given the $C_{ij}^{\Delta}(s)$ frequency response, parameters Kp_{ij}^{Δ}, Ki_{ij}^{Δ}, and Kd_{ij}^{Δ} of the $\mathbf{C}^{\Delta}(j\omega)$ are computed by:

$$Kp_{ij}^{\Delta} = \left(\Phi_{r_{ij}}^{T}\Phi_{r_{ij}}\right)^{-1}\Phi_{r_{ij}}^{T}\Omega_{r_{ij}} \tag{9}$$

$$\begin{bmatrix} Ki_{ij}^{\Delta} \\ Kd_{ij}^{\Delta} \end{bmatrix} = \left(\Phi_{i_{ij}}^{T}\Phi_{i_{ij}}\right)^{-1}\Phi_{i_{ij}}^{T}\Omega_{i_{ij}}, \tag{10}$$

where

$$\Phi_{r_{ij}} = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}, \tag{11}$$

$$\Omega_{r_{ij}} = \begin{bmatrix} \Re\left(C_{ij}^{\Delta}(\, j\omega_1)\right) \\ \Re\left(C_{ij}^{\Delta}(\, j\omega_2)\right) \\ \vdots \\ \Re\left(C_{ij}^{\Delta}(\, j\omega_N)\right) \end{bmatrix}, \tag{12}$$

$$\Phi_{i_{ij}} = \begin{bmatrix} -1\ /\ \omega_1 & \omega_1 \\ -1\ /\ \omega_2 & \omega_2 \\ \vdots & \vdots \\ -1\ /\ \omega_N & \omega_N \end{bmatrix}, \tag{13}$$

$$\Omega_{i_{ij}} = \begin{bmatrix} \Im\left(C_{ij}^{\Delta}(\, j\omega_1)\right) \\ \Im\left(C_{ij}^{\Delta}(\, j\omega_2)\right) \\ \vdots \\ \Im\left(C_{ij}^{\Delta}(\, j\omega_N)\right) \end{bmatrix}, \tag{14}$$

$C_{ij}^{\Delta}(j\omega)$ is computed as shown in lemma 1.1, $\Re(.)$ and $\Im(.)$ are the real and imaginary parts, respectively, $\Omega = [\omega_1, \omega_2, \cdots, \omega_N]$ is finite frequency set, and $\omega_1 > 0$.

Proof of Lemma 1.2: As $\mathbf{C}^{\Delta}(j\omega)$ is a complex matrix so each element is given by:

$$\mathbf{C}_{ij}^{\Delta}(j\omega) = a_{ij} \quad + \quad jb_{ij}, \tag{15}$$

where $a_{ij} = \Re\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right)$ and $b_{ij} = \Im\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right)$.

For each frequency point, we have:

$$\mathbf{C}^{\Delta}(j\omega) = \begin{bmatrix} a_{11} + jb_{11} & a_{12} + jb_{12} & \cdots & a_{1n} + jb_{1n} \\ a_{21} + jb_{21} & a_{22} + jb_{22} & \cdots & a_{2n} + jb_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} + jb_{n1} & a_{n2} + jb_{n2} & \cdots & a_{nn} + jb_{nn} \end{bmatrix}, \tag{16}$$

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$$\mathbf{K}p + \frac{\mathbf{K}i}{j\omega} + j\omega\mathbf{K}d = \begin{bmatrix} a_{11} + jb_{11} & a_{12} + jb_{12} & \cdots & a_{1n} + jb_{1n} \\ a_{21} + jb_{21} & a_{22} + jb_{22} & \cdots & a_{2n} + jb_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} + jb_{n1} & a_{n2} + jb_{n2} & \cdots & a_{nn} + jb_{nn} \end{bmatrix}. \tag{17}$$

Thus, for each element:

$$Kp_{ij}^{\Delta} + \frac{Ki_{ij}^{\Delta}}{j\omega} + j\omega Kd_{ij}^{\Delta} = a_{ij} + jb_{ij}, \tag{18}$$

$$Kp_{ij}^{\Delta} + \frac{Ki_{ij}^{\Delta}}{j\omega} + j\omega Kd_{ij}^{\Delta} = \Re\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right) + j\Im\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right), \tag{19}$$

$$Kp_{ij}^{\Delta} - j\frac{Ki_{ij}^{\Delta}}{\omega} + j\omega Kd_{ij}^{\Delta} = \Re\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right) + j\Im\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right). \tag{20}$$

Separating the real and imaginary terms of each element, we have:

$$Kp_{ij}^{\Delta} = \Re\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right), \tag{21}$$

$$-\frac{Ki_{ij}^{\Delta}}{\omega} + \omega Kd_{ij}^{\Delta} = \Im\left(\mathbf{C}_{ij}^{\Delta}(j\omega)\right). \tag{22}$$

Considering a set with N points frequencies points:

$$\begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} Kp_{ij}^{\Delta} = \begin{bmatrix} \Re\left(\mathbf{C}_{ij}^{\Delta}(j\omega_1)\right) \\ \Re\left(\mathbf{C}_{ij}^{\Delta}(j\omega_2)\right) \\ \vdots \\ \Re\left(\mathbf{C}_{ij}^{\Delta}(j\omega_N)\right) \end{bmatrix}, \tag{23}$$

$$\begin{bmatrix} -1/\omega_1 & \omega_1 \\ -1/\omega_2 & \omega_2 \\ \vdots & \vdots \\ -1/\omega_N & \omega_N \end{bmatrix} \begin{bmatrix} Ki_{ij}^{\Delta} & Kd_{ij}^{\Delta} \end{bmatrix} = \begin{bmatrix} \Im\left(\mathbf{C}_{ij}^{\Delta}(j\omega_1)\right) \\ \Im\left(\mathbf{C}_{ij}^{\Delta}(j\omega_2)\right) \\ \vdots \\ \Im\left(\mathbf{C}_{ij}^{\Delta}(j\omega_N)\right) \end{bmatrix}. \tag{24}$$

A particular case, presented in [7] is given by lemma 1.3, where a PI controller is considered:

$$C_{ij}^{\Delta}(s) = Kp_{ij}^{\Delta} + \frac{Ki_{ij}^{\Delta}}{s}. \tag{25}$$

Lemma 1.3 Given the $C_{ij}^{\Delta}(s)$ frequency response, parameters Kp_{ij}^{Δ} and Ki_{ij}^{Δ} of the $\mathbf{C}^{\Delta}(j\omega)$ are computed by:

$$Kp_{ij}^{\Delta} = \left(\Phi_{r_{ij}}^{T}\Phi_{r_{ij}}\right)^{-1}\Phi_{r_{ij}}^{T}\Omega_{r_{ij}} \tag{26}$$

$$Ki^{\Delta}_{ij} = \left(\Phi^{T}_{i_{ij}}\Phi_{i_{ij}}\right)^{-1}\Phi^{T}_{i_{ij}}\Omega_{i_{ij}}, \tag{27}$$

where

$$\Phi_{r_{ij}} = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}, \tag{28}$$

$$\Omega_{r_{ij}} = \begin{bmatrix} \Re\left(C^{\Delta}_{ij}(\, j\omega_1)\right) \\ \Re\left(C^{\Delta}_{ij}(\, j\omega_2)\right) \\ \vdots \\ \Re\left(C^{\Delta}_{ij}(\, j\omega_N)\right) \end{bmatrix}, \tag{29}$$

$$\Phi_{i_{ij}} = \begin{bmatrix} -1 \ / \ \omega_1 \\ -1 \ / \ \omega_2 \\ \vdots \\ -1 \ / \ \omega_N \end{bmatrix}, \tag{30}$$

$$\Omega_{i_{ij}} = \begin{bmatrix} \Im\left(C^{\Delta}_{ij}(\, j\omega_1)\right) \\ \Im\left(C^{\Delta}_{ij}(\, j\omega_2)\right) \\ \vdots \\ \Im\left(C^{\Delta}_{ij}(\, j\omega_N)\right) \end{bmatrix}, \tag{31}$$

$C^{\Delta}_{ij}(j\omega)$ is given by Eq. (7), $\Re(.)$ and $\Im(.)$ are the real and imaginary parts, respectively, $\Omega = [\omega_1, \omega_2, \cdots, \omega_N]$ is finite frequency set and $\omega_1 > 0$.

Proof of Lemma 1.3: The proof is similar to that of lemma 1.2 and can be found in [7].

4. Simulation results

In this section, the effectiveness of the proposed PID controller retune method through simulated examples. For this, the Wood-Berry, the integrating process of the distillation column and drum boiler are considered. The initial controller can be centralized or decentralized PI or PID type. The maximum singular value of the sensitivity function ($\mathbf{S}(s)$) is used to show the closed-loop robustness property. The maximum singular value must be less than 2 to guarantee greater stability margin and robustness [8].

4.1 Example 1

Consider the Wood-Berry binary distillation column [9] given by 2×2 matrix, of which each element is a first-order plus time delay transfer function:

$$\mathbf{G}_{ex1}(s) = \begin{bmatrix} \dfrac{12.8e^{-s}}{16.7s + 1} & \dfrac{-18.9e^{-3s}}{21s + 1} \\ \dfrac{6.6e^{-7s}}{10.9s + 1} & \dfrac{-19.4e^{-3s}}{14.4s + 1} \end{bmatrix} \tag{32}$$

and the decentralized PID controller:

$$\mathbf{C}_{ex1}(s) = \begin{bmatrix} 0.34 + \dfrac{0.0198}{s} + 0.167s & 0 \\ 0 & -0.14 - \dfrac{0.0081}{s} - 0.19s \end{bmatrix}. \tag{33}$$

To obtain the closed loop as decoupled as possible, the reference model is given by the diagonal matrix given by:

$$\mathbf{T}_{rex1}(s) = \begin{bmatrix} \dfrac{1}{5.9s + 1}e^{-1s} & 0 \\ 0 & \dfrac{1}{5.8s + 1}e^{-3s} \end{bmatrix}. \tag{34}$$

The retuned controller using the lemma 1.2 is given by:

$$\overline{\mathbf{C}}_{ex1}(s) = \begin{bmatrix} 0.172 + \dfrac{0.0299}{s} + 0.204s & -0.0666 - \dfrac{0.016}{s} + 0.046s \\ -0.009 + \dfrac{0.0097}{s} - 0.0548s & -0.0512 - \dfrac{0.012}{s} + 0.106s \end{bmatrix}. \tag{35}$$

Note in **Figure 1** that the retuned closed loop is more robust than the initial one. This occurs because the peak of maximum singular value curve of the initial sensitivity function ($\mathbf{S}(s)$), Eq. (5), is above the peak of the curve corresponding to the reprojected.

In **Figure 2**, the step responses of the initial and retuned closed loop are shown. The retuned closed-loop response approaches the desired. In addition, coupling reduction is observed when the retuned controller is used. This occurs because the coupling is compensated by the off-diagonal elements of the controller matrix. Consequently, the variation of the control signal increased, as can be observed in **Figure 3**.

In this example, the decentralized PID controller was retuned so that the new closed-loop close to a diagonal reference model. As result of the proposed method, a centralized PID controller was obtained.

4.2 Example 2

Consider the integrating process of the distillation column process [10]:

$$\mathbf{G}_{ex2}(s) = \begin{bmatrix} \dfrac{3.04}{s} & \dfrac{-278.28}{s(30s + 1)(6s + 1)} \\ \dfrac{0.052}{s} & \dfrac{319.47}{s(30s + 1)(6s + 1)} \end{bmatrix} \tag{36}$$

and the decentralized PI controller:

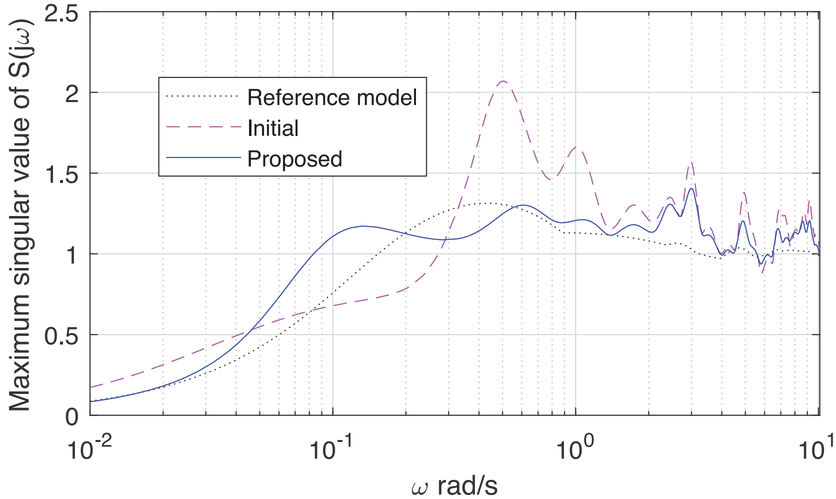

Figure 1.
Maximum singular value of sensitivity function $(\mathbf{S}(s))$ *- example 1.*

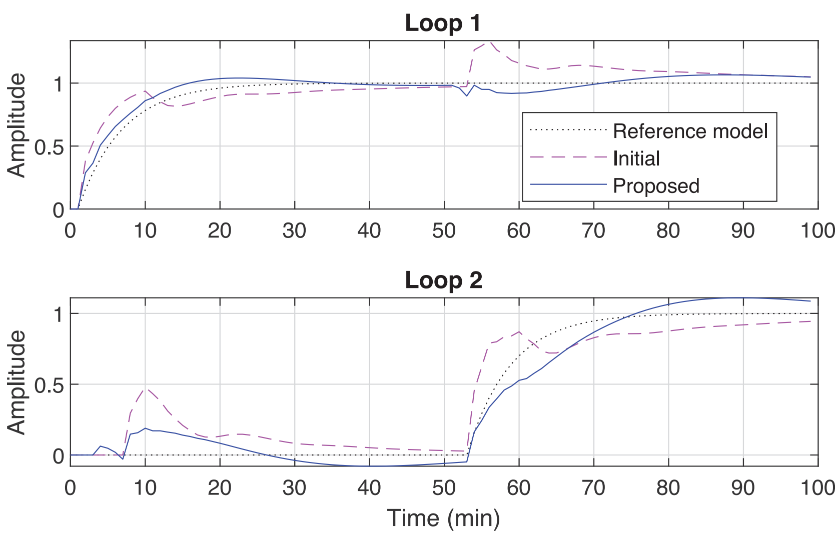

Figure 2.
Closed-loop step response - example 1.

$$\mathbf{C}_{ex2}(s) = \begin{bmatrix} 16.181 + \dfrac{202.265}{s} & 0 \\ 0 & 23.614 + \dfrac{64.926}{s} + 2.147s \end{bmatrix}. \quad (37)$$

The reference model is given by:

$$\mathbf{T}_{rex2}(s) = \begin{bmatrix} \dfrac{1}{0.05s + 1} & 0 \\ 0 & \dfrac{1}{0.2s + 1} \end{bmatrix}. \quad (38)$$

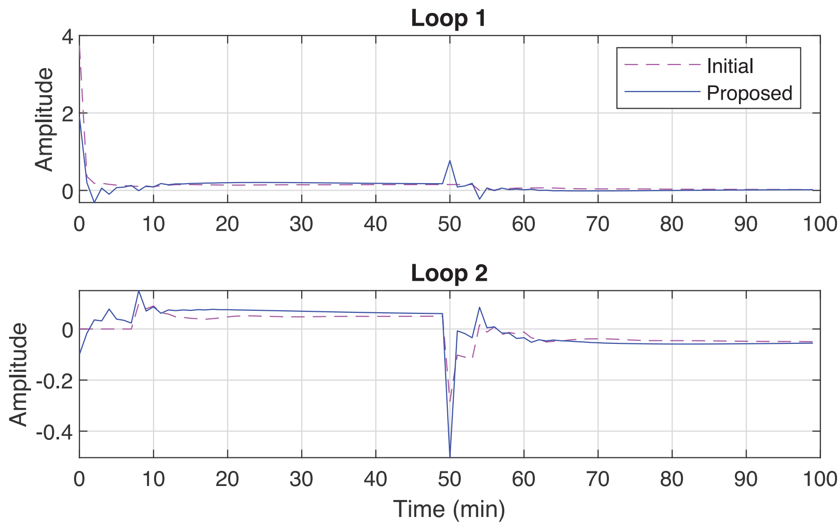

Figure 3.
Control signal - example 1.

The initial controller is decentralized and has PI-type and PID-type elements. Thus, the lemma 1.2 was used to retune the PID and for the lemma 1.3 was used to the other elements. The integral gain obtained for elements C_{11}, C_{12}, and C_{22} was approximately zero. The retuned controller is given by:

$$\overline{\mathbf{C}}_{ex2}(s) = \begin{bmatrix} 5.73 & 1.25 \\ -1.65 + \dfrac{0.0082}{s} & 2.4 + 0.49s \end{bmatrix}. \tag{39}$$

In **Figure 4**, the maximum singular value curve of the sensitivity function $(\mathbf{S}(s))$ is presented. Observe that the curve peak of the proposed loop is smaller when compared with the initial loop.

The closed-loop step response is show in **Figure 5**. The retuned loop outputs were close to the desired and slower than the initial loop. Consequently, the overshoot was reduced. Also, the control signal became smoother as shown in **Figure 6**.

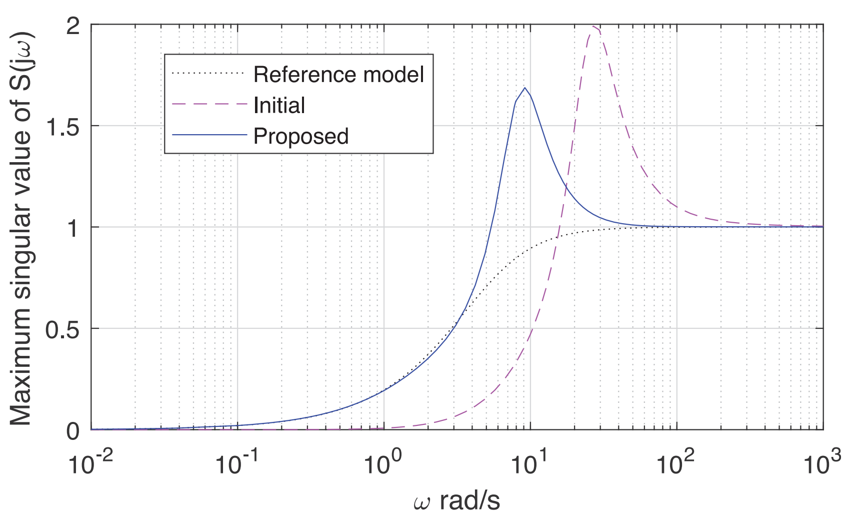

Figure 4.
Maximum singular value of sensitivity function $(\mathbf{S}(s))$ - example 2.

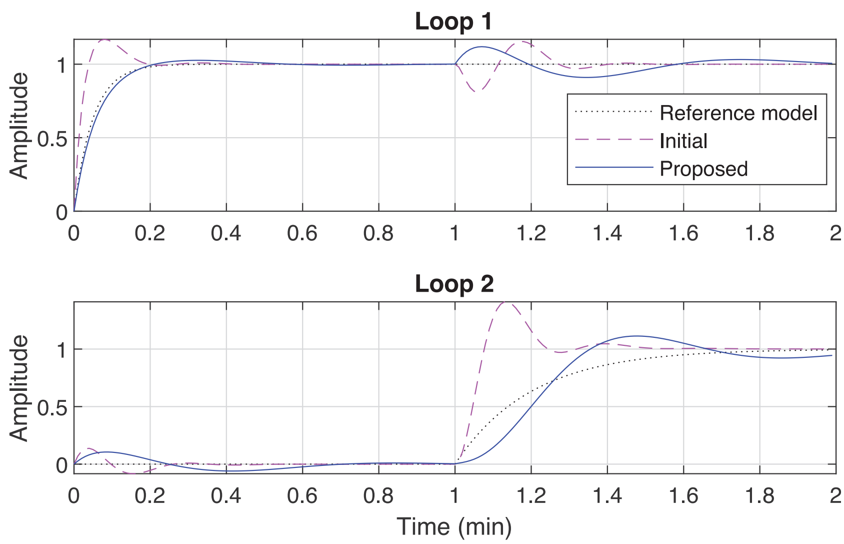

Figure 5.
Closed-loop step response - example 2.

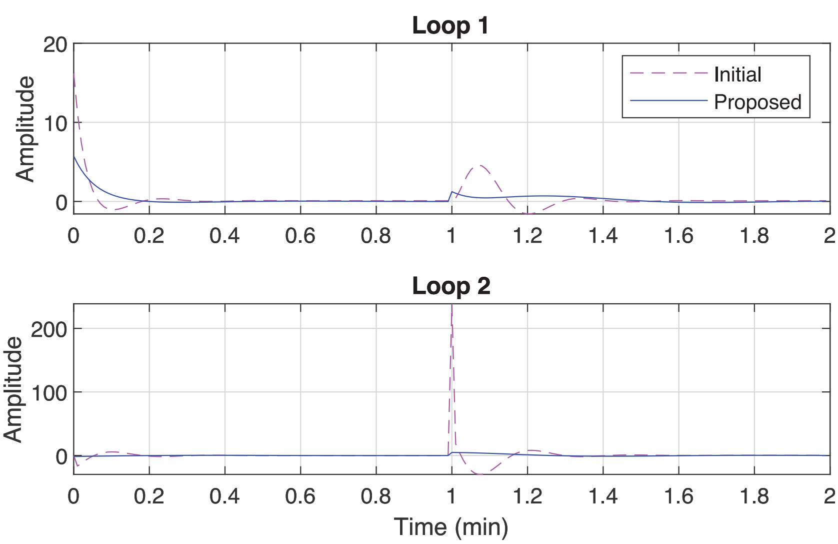

Figure 6.
Control signal - example 2.

4.3 Example 3

Consider the drum boiler integrating process [11]:

$$\mathbf{G}_{ex3}(s) = \begin{bmatrix} \dfrac{0.349}{38.19s + 1} & \dfrac{-0.1587}{203.9s + 1} \\ \dfrac{-0.0059}{s}\dfrac{1 - 401.2s}{1 + 21.15s} & \dfrac{0.01033}{s} \end{bmatrix} \tag{40}$$

and the decentralized PI controller:

$$\mathbf{C}_{ex3}(s) = \begin{bmatrix} 2.5 + \dfrac{0.05}{s} & 0 \\ 0 & 1.25 + \dfrac{0.025}{s} \end{bmatrix}. \tag{41}$$

Note the presence of a zero in the right-half plane (RHP) that affects output 2. A zero in the RHP must appear in the element of the reference model transfer matrix referring to output 2. The reference model is given by:

$$\mathbf{T}_{rex3}(s) = \begin{bmatrix} \dfrac{1}{30s + 1} & 0 \\ 0 & \dfrac{1 - 32s}{70s + 1} \end{bmatrix}. \tag{42}$$

In this case, as the process is integrative, the retune was performed using lemma 1.3 so that the retuned controller was of the PI type:

$$\overline{\mathbf{C}}_{ex3}(s) = \begin{bmatrix} 1.89 + \dfrac{0.0751}{s} & 0.198 + \dfrac{0.011}{s} \\ -17.3 + \dfrac{0.201}{s} & 2.69 + \dfrac{0.117}{s} \end{bmatrix}. \tag{43}$$

In **Figure 7**, the maximum singular value curve of the sensitivity function ($\mathbf{S}(s)$) is presented. Note that the retuned loop is significantly more robust than the initial.

The closed-loop step response is show in **Figure 8**. With the retuned controller, the interaction of input 1 with output 2 has been reduced. However, the variation of the control signal increased, as shown in **Figure 9**.

In this example, the centralized PI controller has been retuned from closed loop with a decentralized PI controller. It was possible to obtain a decoupled closed loop with a greater gain margin.

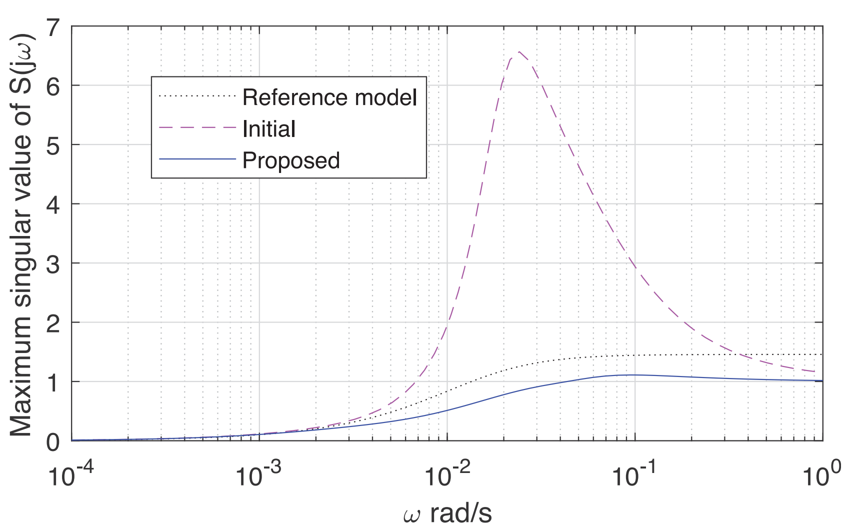

Figure 7.
Maximum singular value of sensitivity function ($\mathbf{S}(s)$) - example 3.

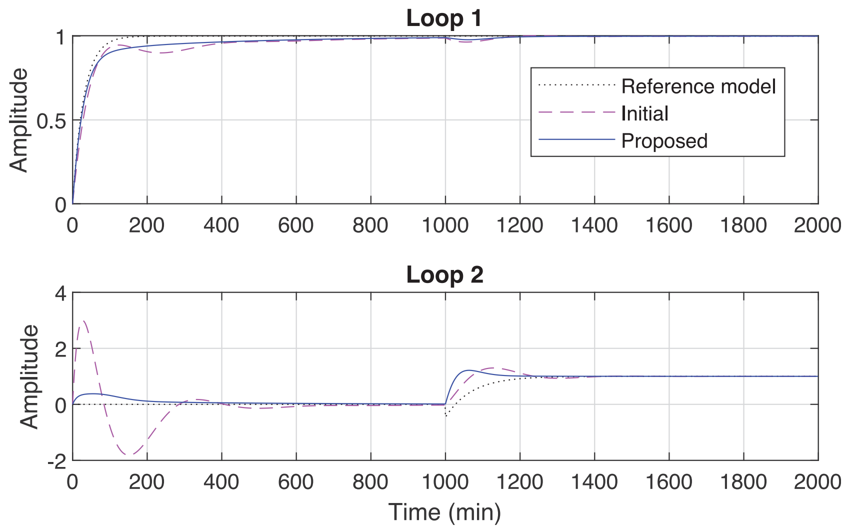

Figure 8.
Closed-loop step response - example 3.

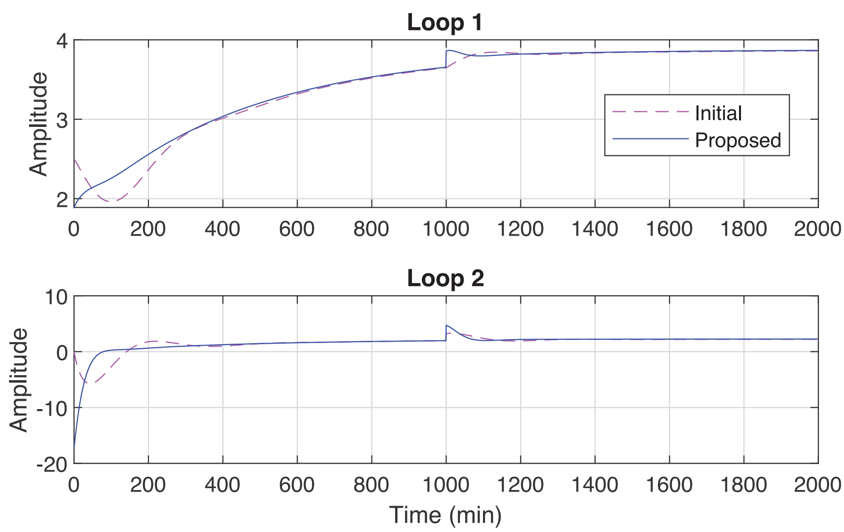

Figure 9.
Control signal - example 3.

5. Conclusions

In this article, a PID controller retuning method for multivariable processes was presented. This method is an extension of the one presented in [7]. The controller is retuned so that the closed loop approximates the desired one. The method is based on closed-loop frequency domain data. Knowledge of the parametric model of the process is not necessary.

Controller gain increments are computed from the closed-loop reference model, the initial controller, and closed-loop frequency domain data. The initial controller can be centralized or decentralized, PI or PID type.

In the simulation examples, it can be seen that the retuned controller is centralized. In example 2, it is shown that the P/PD controller can be obtained from the initial PI/PID controller. In this case, the integral gain of some controllers was approximately zero. With the redesign, it was possible to reduce the coupling between the loops and improve the robustness properties of the closed loop.

As future work, there is the application of the method to unstable processes and a methodology to define the reference model.

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