The single tuning rule – easily remembered

The method
Any process is approximated as first-order plus delay processes using

Integral term modified to improve disturbance rejection for integrating process

New SIMC tuning method:

• IMC PID tuning rules of Rivera, Morari, and Skogestad (1986)

Starting point:

result in good closed-loop behavior

Present analytic tuning rules which are as simple as possible and still

Objective:

Resulting model:

\[ \frac{(1 + s \tau_d)(1 + s \tau_u)}{s^2} = s \theta (s \tau_u) \]

Slope, \( \frac{1}{\tau_u} \), for slow (integrating processes):

Process with \( \tau_u < \theta \), approximately second-order time constant, \( \tau_u \) (use only for dominant second-order)

Effective time delay, \( \tau \)

Dominant time constant, \( \tau \)

Plant gain, \( k \)

**PROCESS INFORMATION**

Hano, USA, November 2001

Alicja Annual Meeting

N-7491 Tromsø, Norway

Norwegian University of Science and Technology (NTNU)

Signe Skogestad

**IN THE WORLD**

THE BEST SIMPLE PID TUNING RULES

PROBABLY
To small integral time: Slow oscillations
To large integral time: Poor disturbance rejection

\[ g = \frac{\theta + \frac{c}{2} \frac{y}{T}}{1} = \frac{c}{2} \]

which is a cascade form PID-controller with

\[ \frac{s(\theta + \frac{c}{2})}{1} \frac{y}{1} = (s)c \]

To get a PID-controller use \( \omega \) and derive:

\[ \frac{y}{1} \]

Gives a „Smith Predictor“ controller:

\[ \frac{y}{1} = (s)\delta \]

Consider second-order with delay block:

\[ \frac{1}{1 + \frac{\tau}{\theta}} \]

Controller:

\[ \frac{(1 + \frac{\tau}{\theta})}{1} \]

IMC TUNING = DIRECT SYNTHESIS

\[ \text{or to \( \tau \), use second-order model.} \]

The „other half“ of the largest neglected time constant is added to \( \tau \)

\[ \alpha \] all smaller high-order time constants

This is to avoid being too conservative.

\[ \text{half of the largest neglected time constant (the „half rule“)} \]

\[ \text{Inverse response time constant(s) „time delay“} \]

Effective delay

\[ \frac{s\theta + 1}{\theta} \approx \frac{s\theta^2}{1} \text{ and } \theta \delta - 1 \approx s\theta - \delta \]

Basic (Taylor approximation):

\[ \theta \]

Example
\[
\frac{(1 + s)(1 + s^2 + s^3)(1 + s^3)(1 + s)}{1} = (s)^0 \theta \\
\]

EXAMPLE: Process from Astrom et al. (1998)

\[
\frac{(1 + s^2 + s^3)(1 + s^3)(1 + s)}{(1 + s)(1 + s^3)^3} \theta = (s)^0 \theta 
\]

EXAMPLE

<table>
<thead>
<tr>
<th>Table 1: Robustness to load changes and uncompensated input showing slight divergence in (a) and (b) (c) (d) (e). The same criteria applied to</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
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<tr>
<td>3.5</td>
</tr>
<tr>
<td>4.0</td>
</tr>
</tbody>
</table>

I. First-order system response with response time \( t_r \) (IMC-tuning) = Gain margin about 3

\[
\bar{z}_d = \sigma \underline{L} \\
(\theta + 0.5) \bar{L} \underline{L} \max = \sigma \underline{L} \\
\theta \bar{L} \underline{L} = \sigma \underline{L} \\
\theta = \sigma \underline{L} \quad \text{SINC} \\
\]

TUNING FOR FAST RESPONSE WITH GOOD ROBUSTNESS

SIM-C PID TUNING RULES

\[
\bar{z}_d = \sigma \underline{L} \\
\{\theta + 0.5\} \bar{L} \underline{L} \max = \sigma \underline{L} \\
\theta \bar{L} \underline{L} = \sigma \underline{L} \\
\theta + 0.5 \bar{L} \underline{L} = \sigma \underline{L} \\
= \sigma \underline{L}
\]
Application: Retuning for Integrating Process

\[ \theta < \tau \] (approximately)

Conclusions: Use second-order model (and derivative action) only when

\[ \text{Derivative action (solid line) has only a minor effect.} \]

First order with delay plant (\( \theta = \tau \)) with \( \theta < \tau \)