



Building Leadership Excellence



Combat Process Disturbances and Interactions:

New Tools and a Practical Guide to Implementing Feedforward and Decoupling Control

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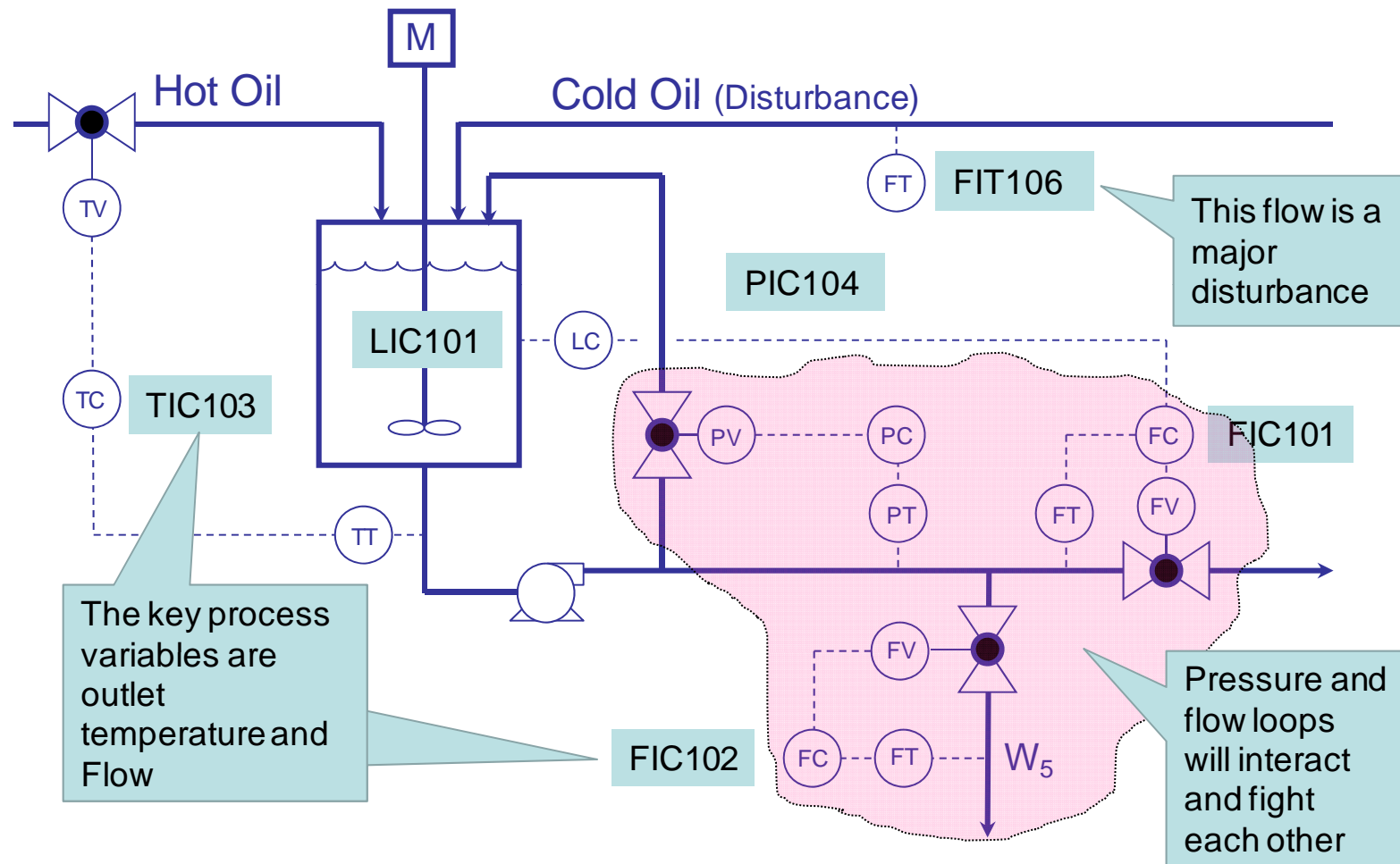
RETHINK PAPER:
Lean and Green

Contents

- Example Process and Control Objectives
 - Optimization Principles and Procedures
- Background and Theory
- Decoupling Control
 - De-tuning interacting loops (a quick fix)
 - Implementing decoupling to *cancel loop interaction*
- Feedforward Control
 - Measuring the effect of the disturbance
 - Implementing feedforward to *cancel the disturbance*
- Conclusions



Example Process

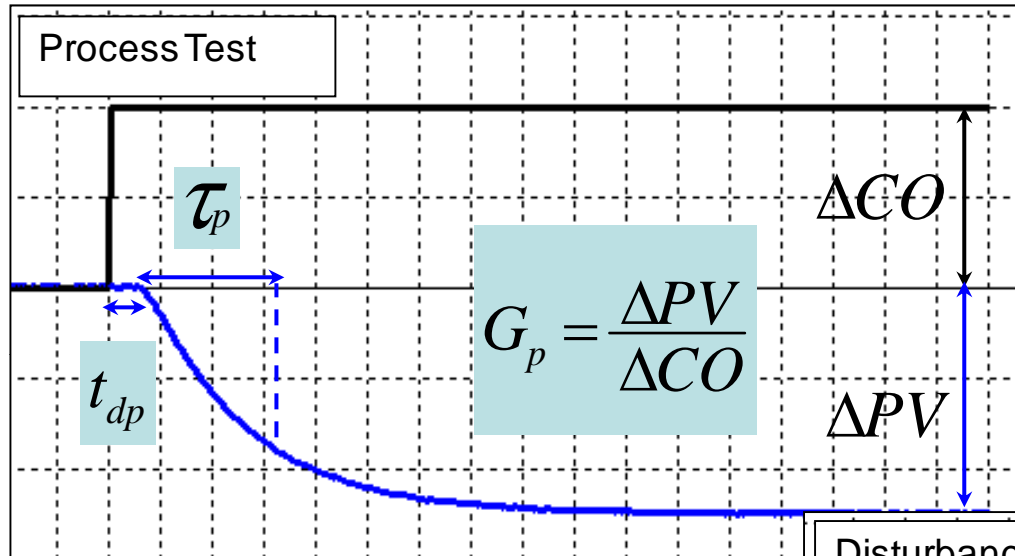


Optimization Principles and Procedures

- Fast loops must be tuned first
 - Always! No exceptions
 - Pressure and flows tested as non-interacting (SISO)
 - Pressure and flows tested for interaction (MIMO)
 - De-tuned if possible to break the interaction
 - Decoupled if de-tuning is not acceptable
- Slow loops will be tuned last
 - Temperature and the Disturbance
 - Tested for feedforward

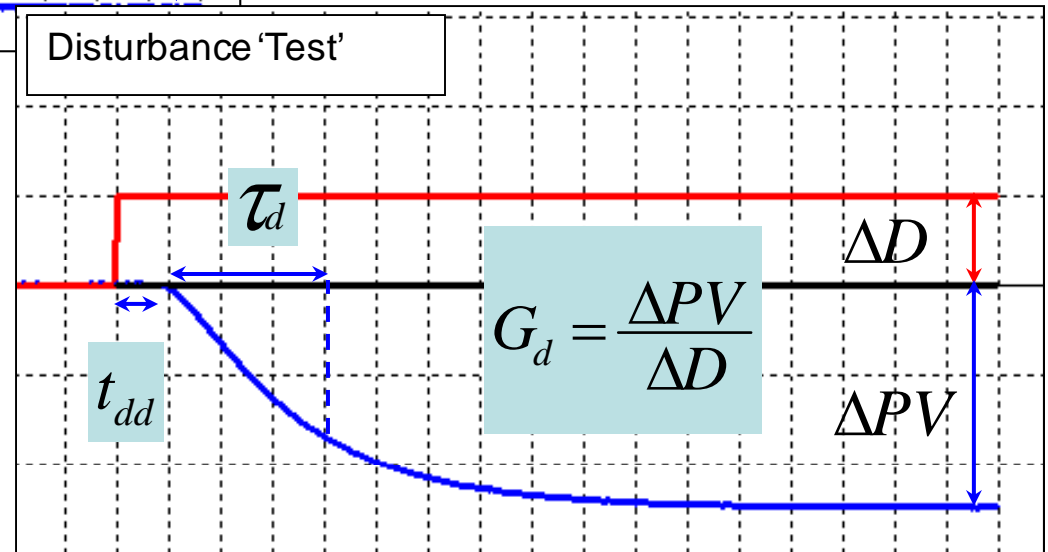


FeedForward Control Background/Theory



Theory: Place control loop in manual, step output, and find the process model.

Theory: With control loop in manual, step disturbance, and find the disturbance model.



FeedForward Control Background/Theory

- Compensator derived from models

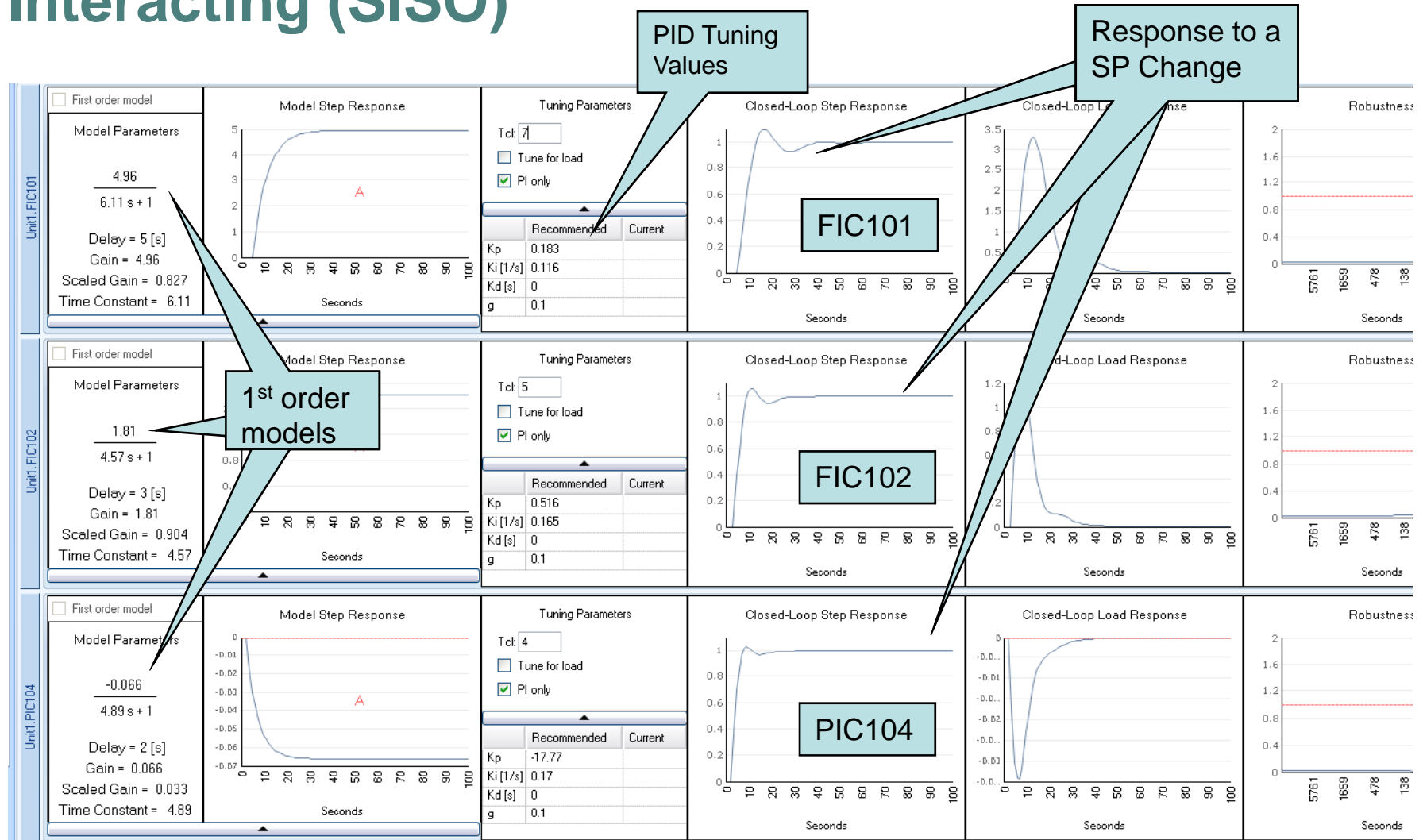
	Process Model	Disturbance Model	Compensator
Gain	G_p	G_d	$-\left[\frac{G_d}{G_p} \right] = \frac{\Delta CO}{\Delta D}$
Time Constant	τ_p	τ_d	$lead \tau_p \quad lag \tau_d$
Dead Time	t_{dp}	t_{dd}	$t_{dd} - t_{dp}$

Decoupling Control Background/Theory

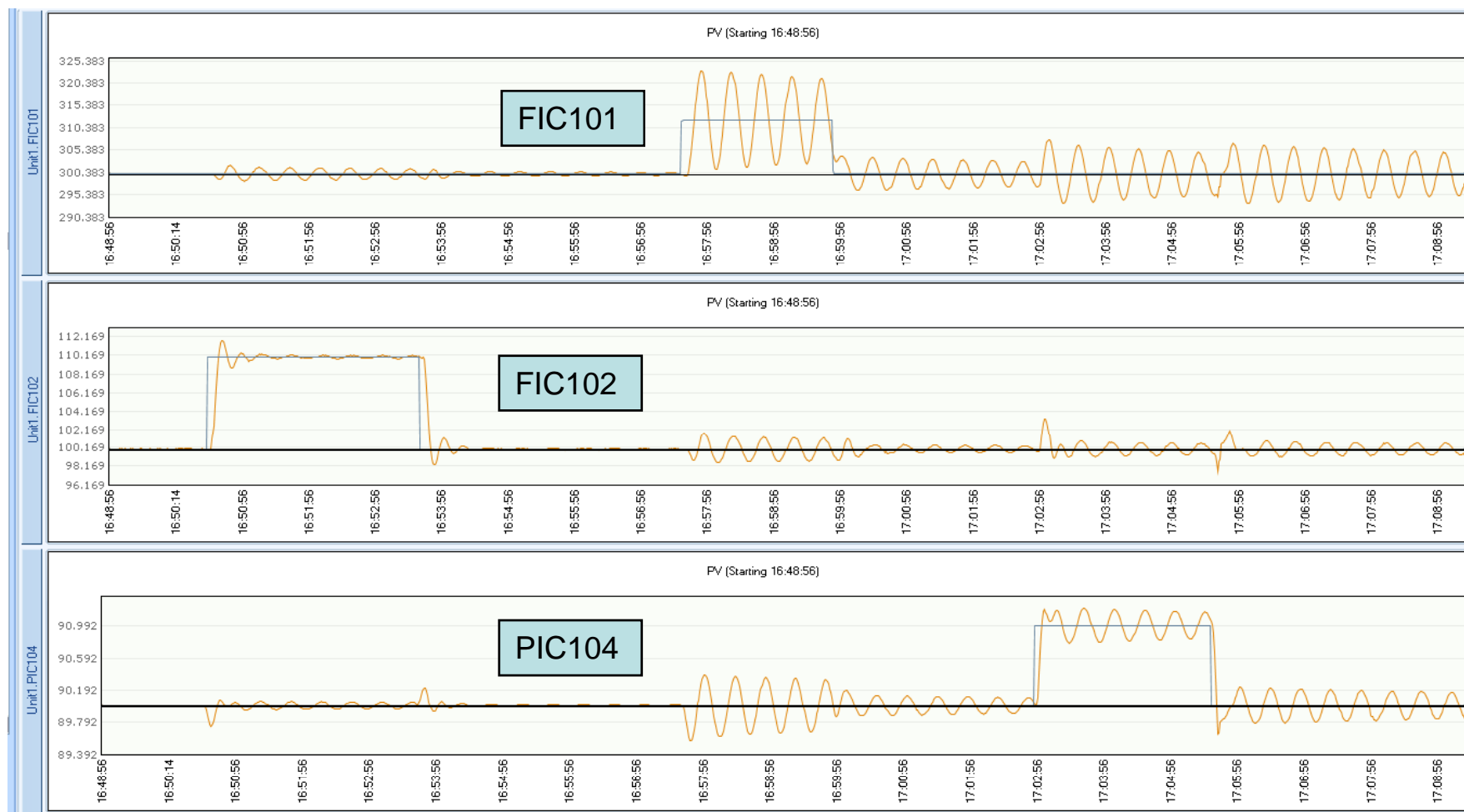
- Decoupler derived from models

	Process 1 Model	Process 2 Effect on Process 1	Decoupler
Gain	G_{p11}	G_{p12}	$-\left[\frac{G_{p12}}{G_{p11}} \right] = \frac{\Delta CO_1}{\Delta CO_2}$
Time Constant	τ_{11}	τ_{12}	<i>lead</i> τ_{11} <i>lag</i> τ_{12}
Dead Time	t_{d11}	t_{d12}	$t_{d12} - t_{d11}$

Testing and Tuning Interacting Loops as Non-Interacting (SISO)



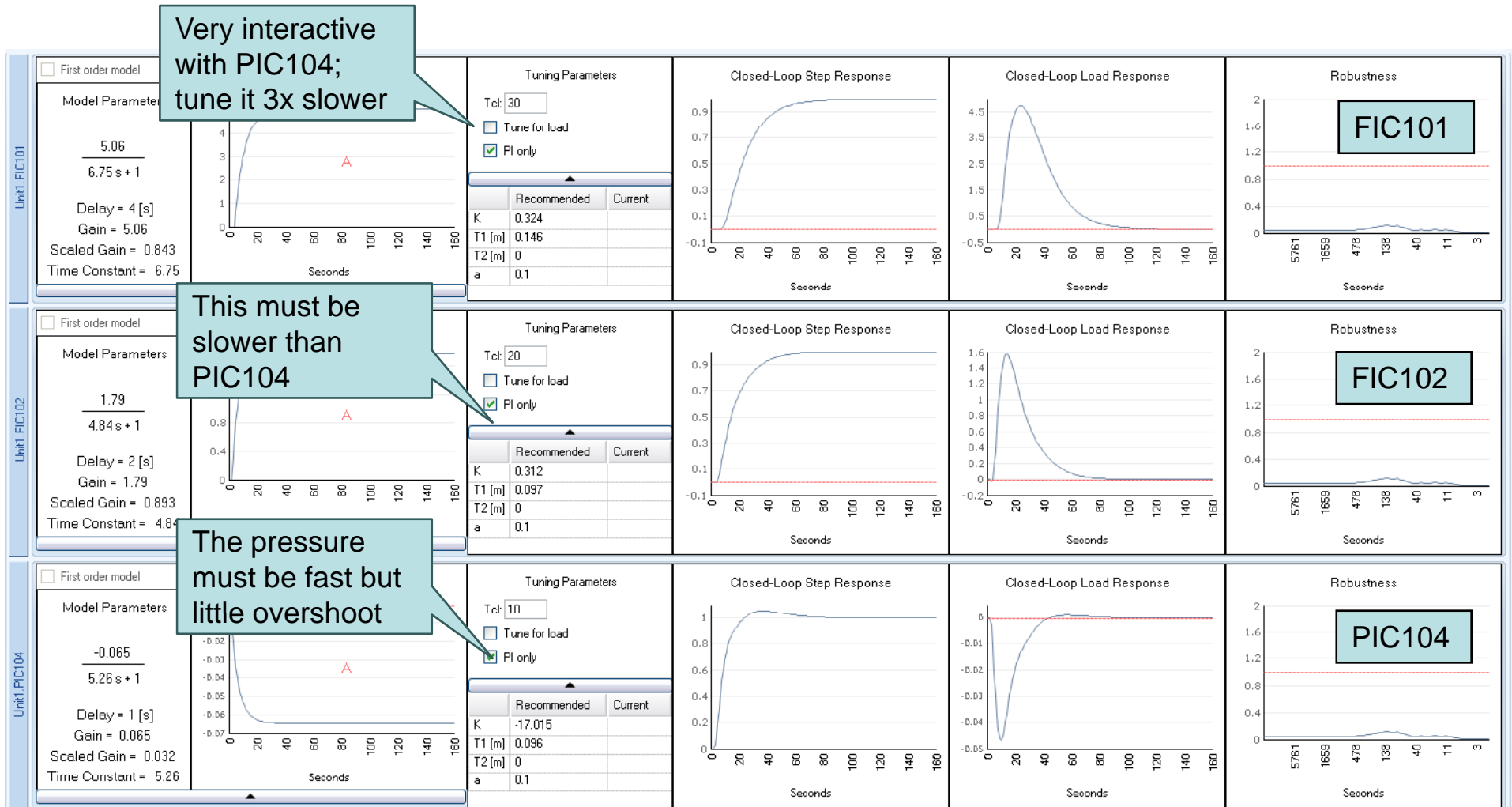
Results: Tuning Interacting Loops as Non-Interacting



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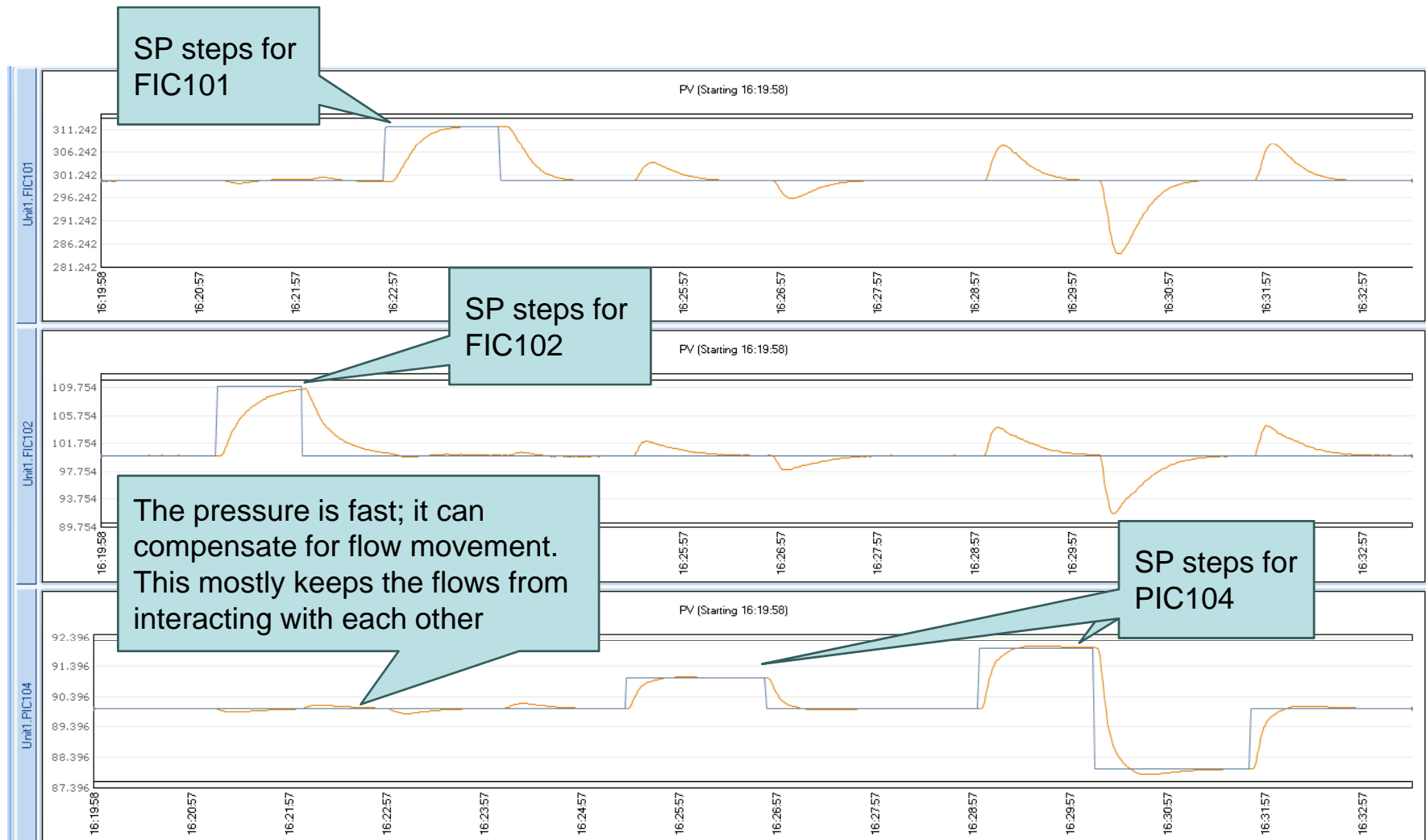
De-Tuning the Loops to Reduce Interaction



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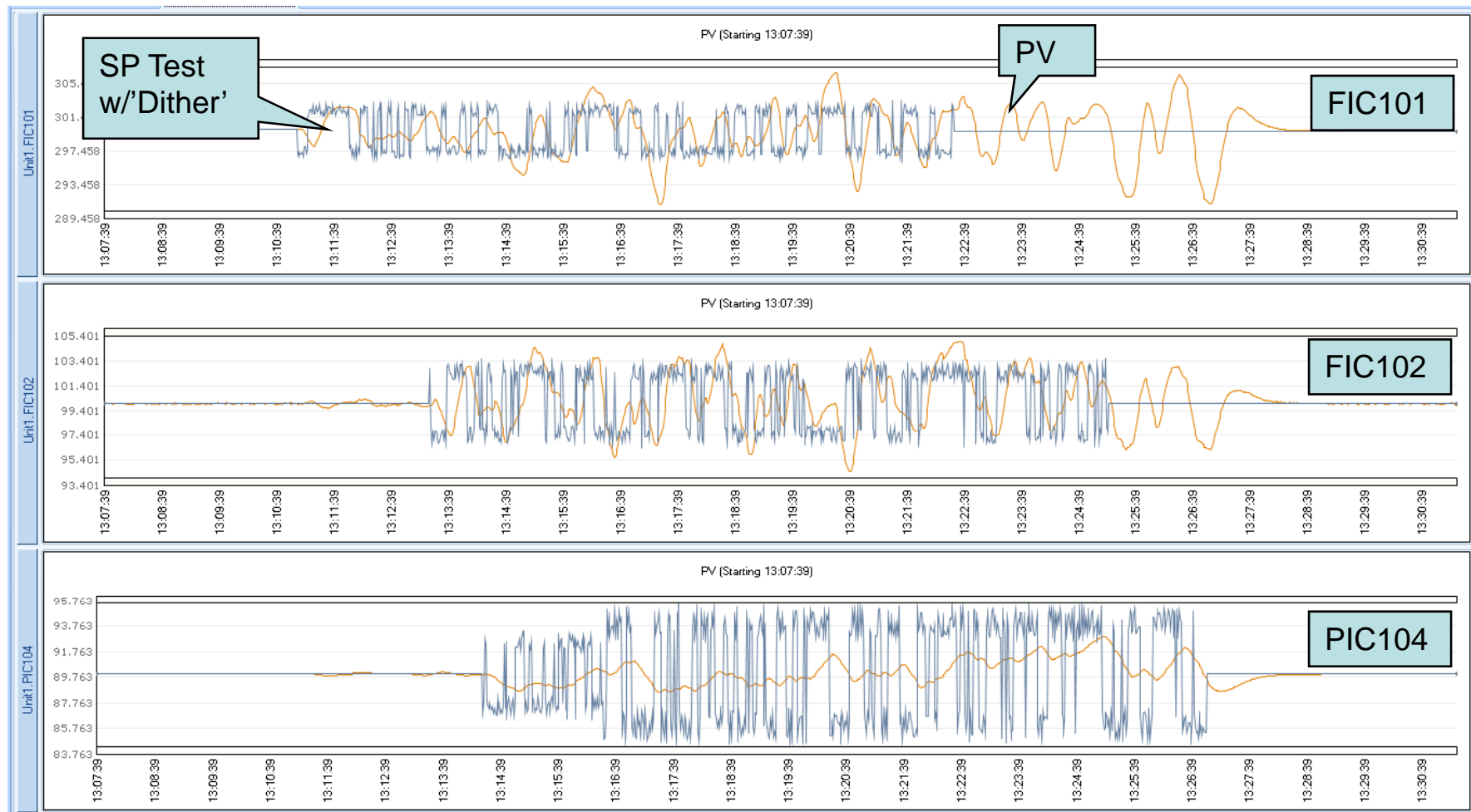
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Results: Detuning to Break the Interaction



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MIMO Closed Loop Testing: New Tool



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MIMO Models: New Tool

This model shows us how FIC102.OP affects FIC102.PV

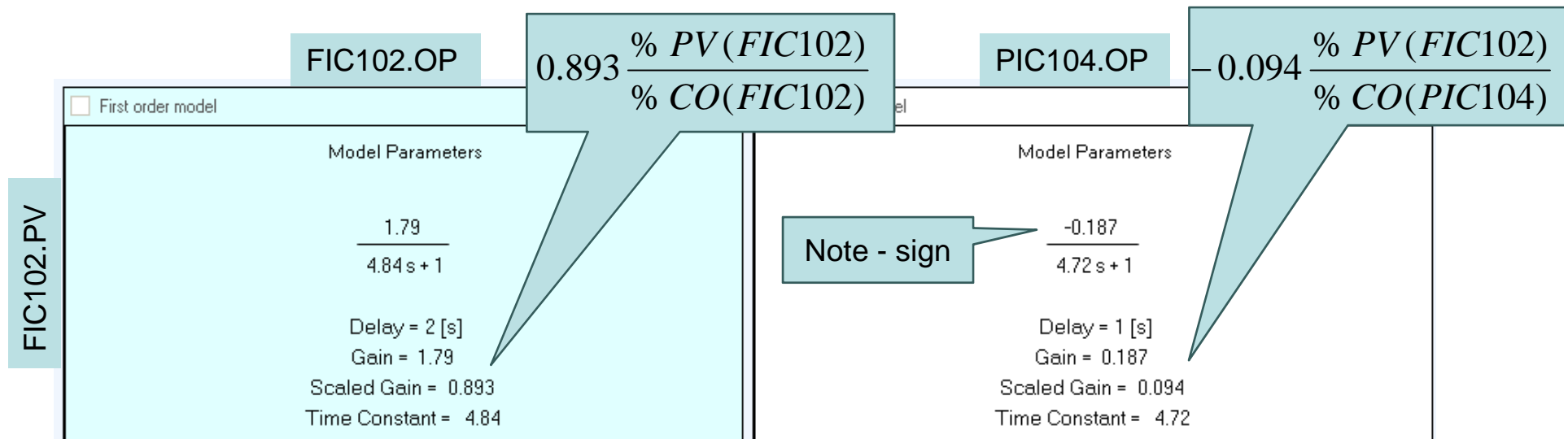
This model shows us how PIC104.OP affects FIC102.PV

	Unit1.FIC101.OP	Unit1.FIC102.OP	Unit1.PIC104.OP
Unit1.FIC101.PV	<input type="checkbox"/> First order model Model Parameters $\frac{5.06}{6.75s + 1}$ Delay = 4 [s] Gain = 5.06 Scaled Gain = 0.843 Time Constant = 6.75	<input type="checkbox"/> First order model Model Parameters $\frac{0.111s - 0.334}{10.1s^2 + 6.56s + 1}$ Delay = 3 [s] Gain = 0.334 Scaled Gain = 0.056 Time Constant = 3.18	<input type="checkbox"/> First order model Model Parameters $\frac{-0.343}{5.82s + 1}$ Delay = 2 [s] Gain = 0.343 Scaled Gain = 0.058 Time Constant = 5.82
Unit1.FIC102.PV	<input type="checkbox"/> First order model Model Parameters $\frac{1.61s - 0.566}{17.8s^2 + 6.36s + 1}$ Delay = 0 [s] Gain = 0.566 Scaled Gain = 0.283 Time Constant = 4.22	<input type="checkbox"/> First order model Model Parameters $\frac{1.79}{4.84s + 1}$ Delay = 2 [s] Gain = 1.79 Scaled Gain = 0.893 Time Constant = 4.84	<input type="checkbox"/> First order model Model Parameters $\frac{-0.187}{4.72s + 1}$ Delay = 1 [s] Gain = 0.187 Scaled Gain = 0.094 Time Constant = 4.72
Unit1.PIC104.PV	<input type="checkbox"/> First order model Model Parameters $\frac{-0.188}{5.51s + 1}$ Delay = 5 [s] Gain = 0.188 Scaled Gain = 0.094 Time Constant = 5.51	<input type="checkbox"/> First order model Model Parameters $\frac{-0.069}{7.31s + 1}$ Delay = 2 [s] Gain = 0.069 Scaled Gain = 0.035 Time Constant = 7.31	<input type="checkbox"/> First order model Model Parameters $\frac{-0.065}{5.26s + 1}$ Delay = 1 [s] Gain = 0.065 Scaled Gain = 0.032 Time Constant = 5.26



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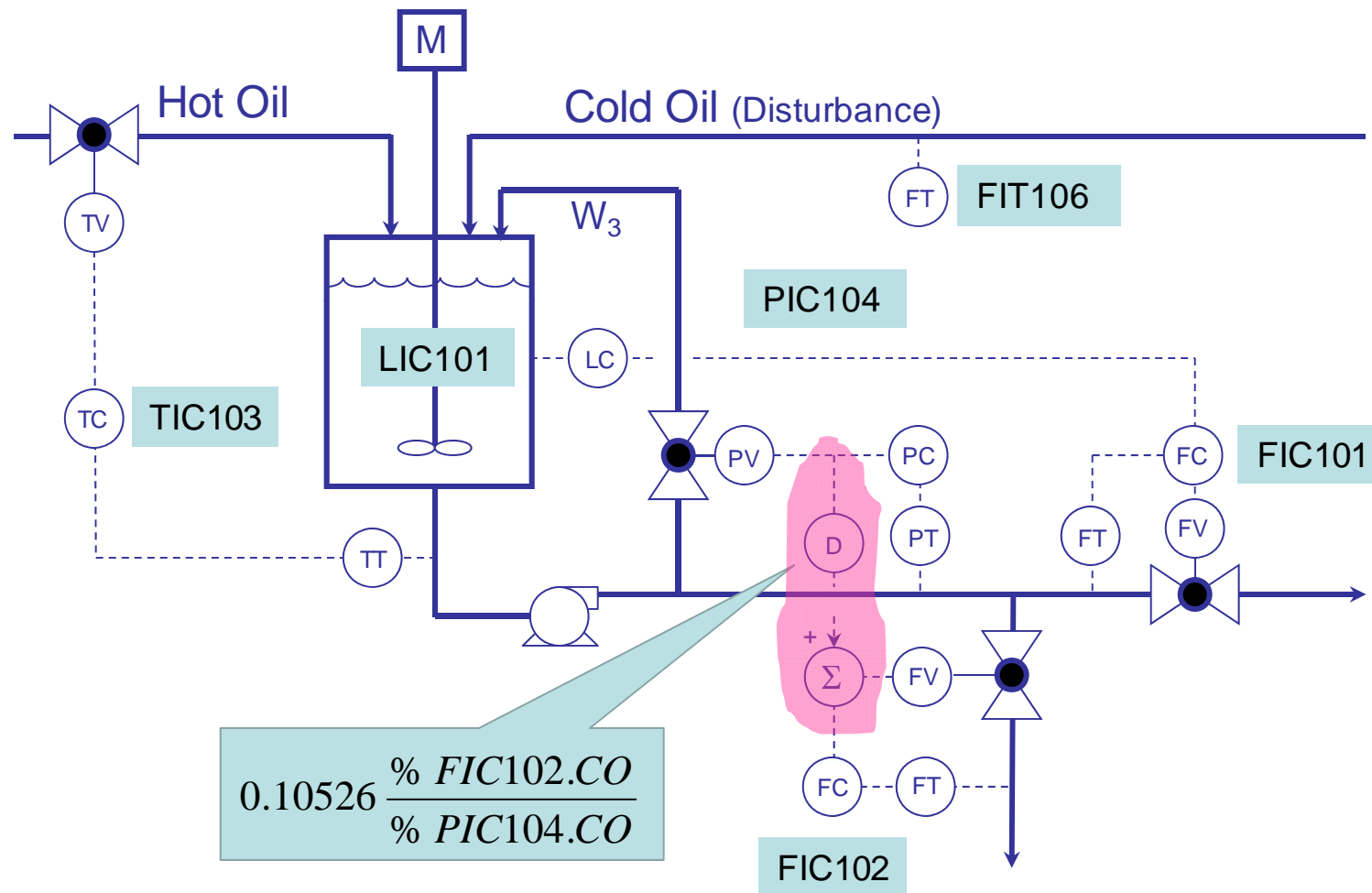
Decoupler Calculation



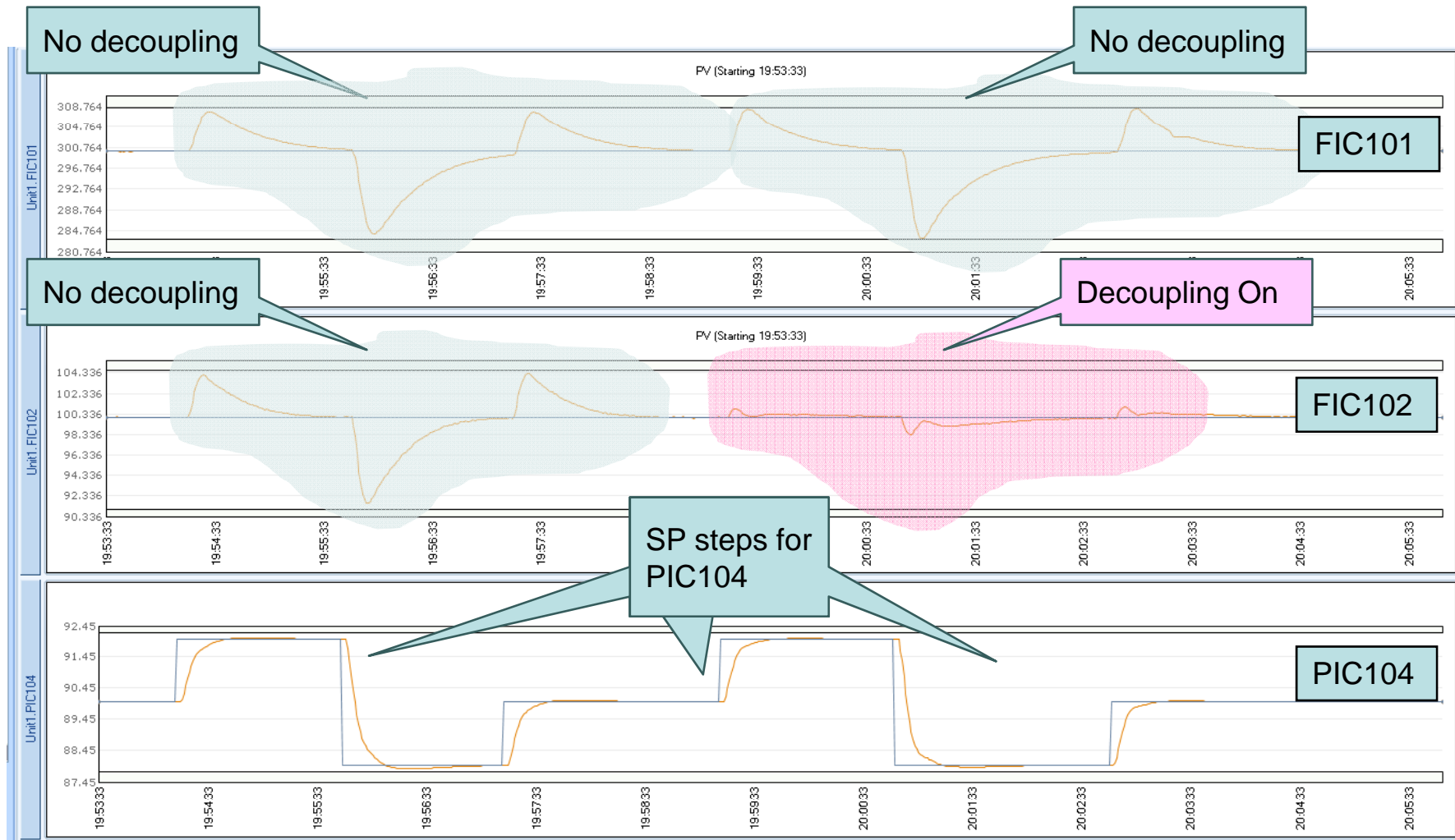
$$D_{SS} = - \frac{-0.094 \frac{\% PV(FIC102)}{\% CO(PIC104)}}{0.893 \frac{\% PV(FIC102)}{\% CO(FIC102)}} = 0.10526 \frac{\% CO(FIC102)}{\% CO(PIC104)}$$



Implementing the Decoupler



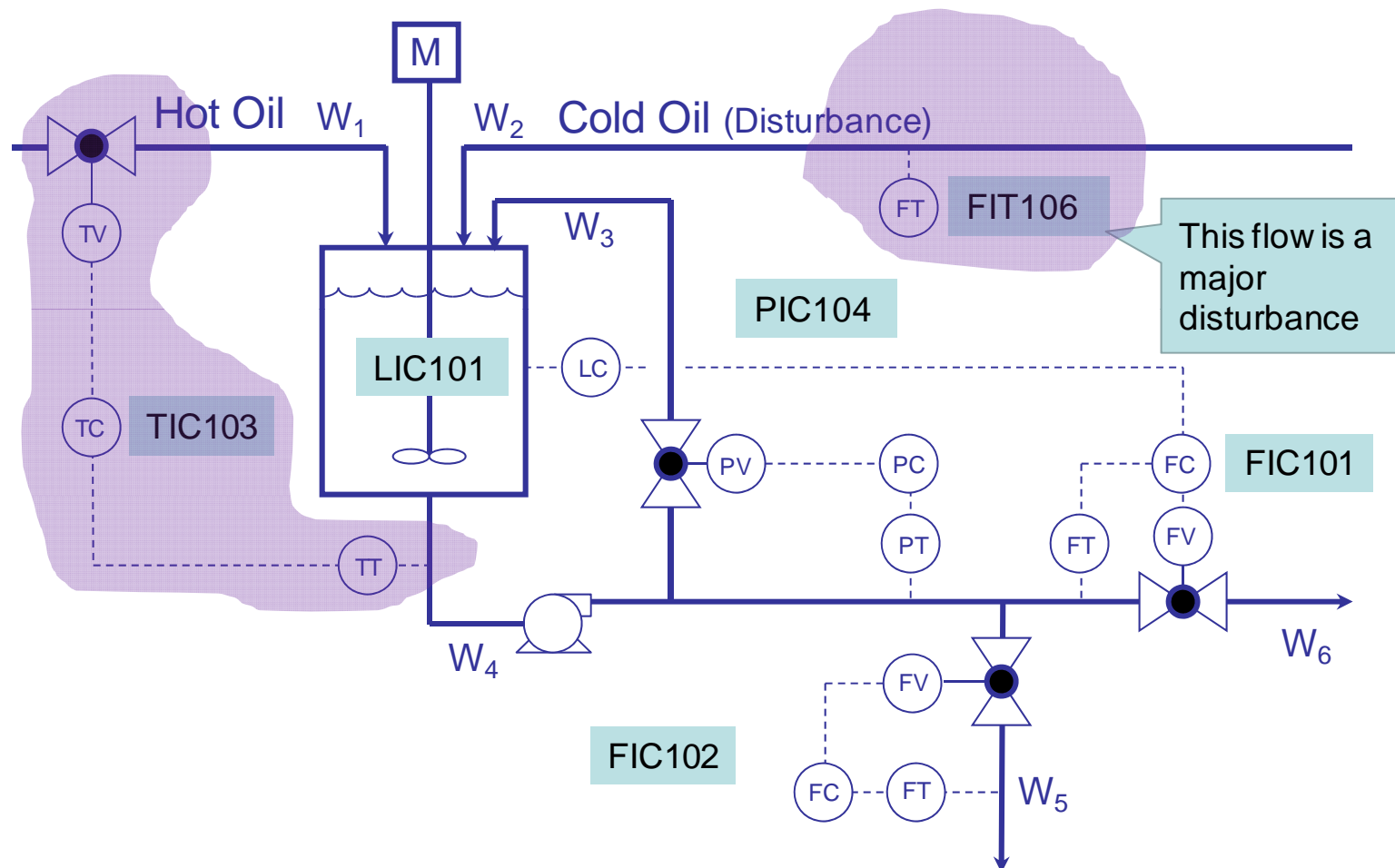
Results with Decoupler



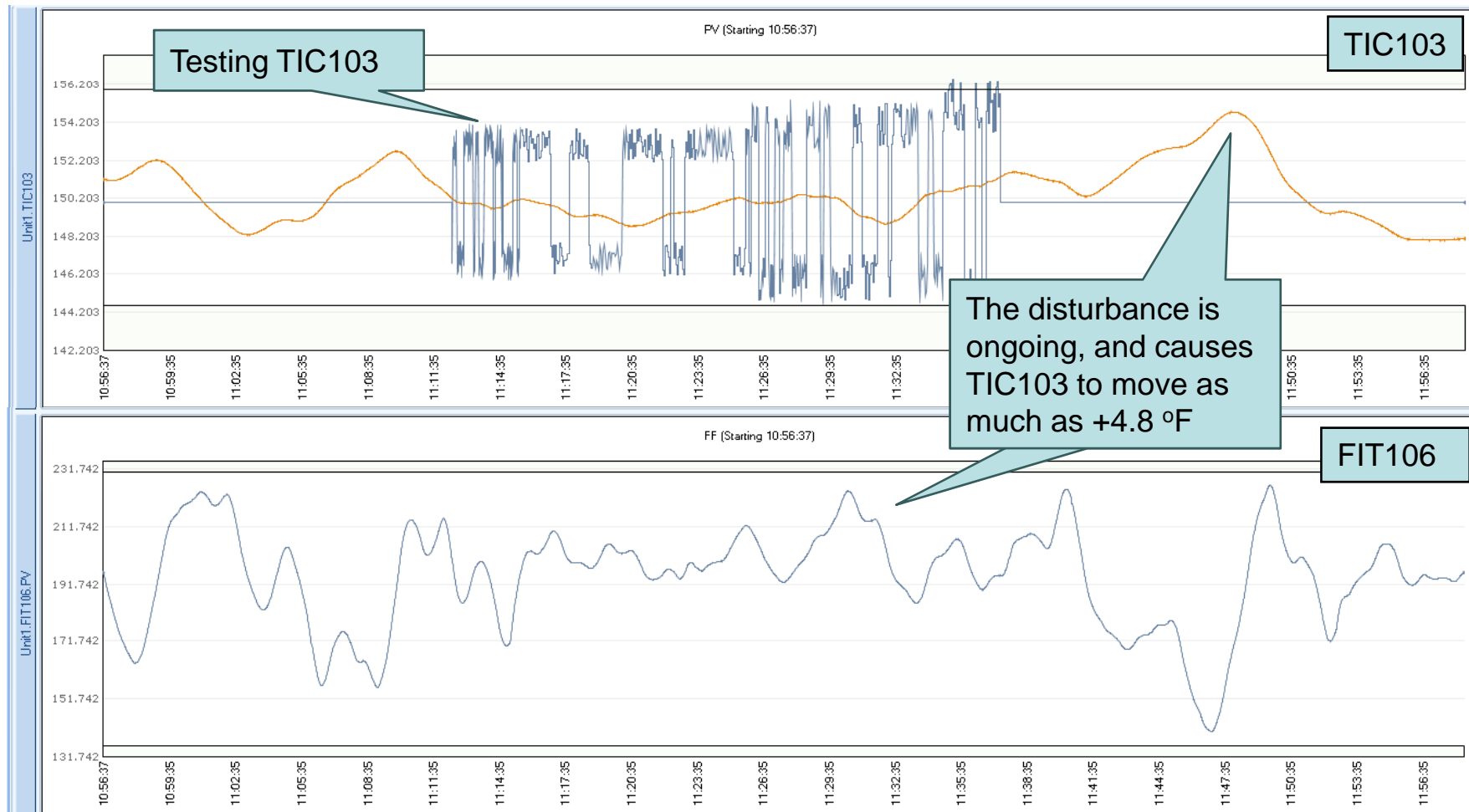
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The Feedforward Solution



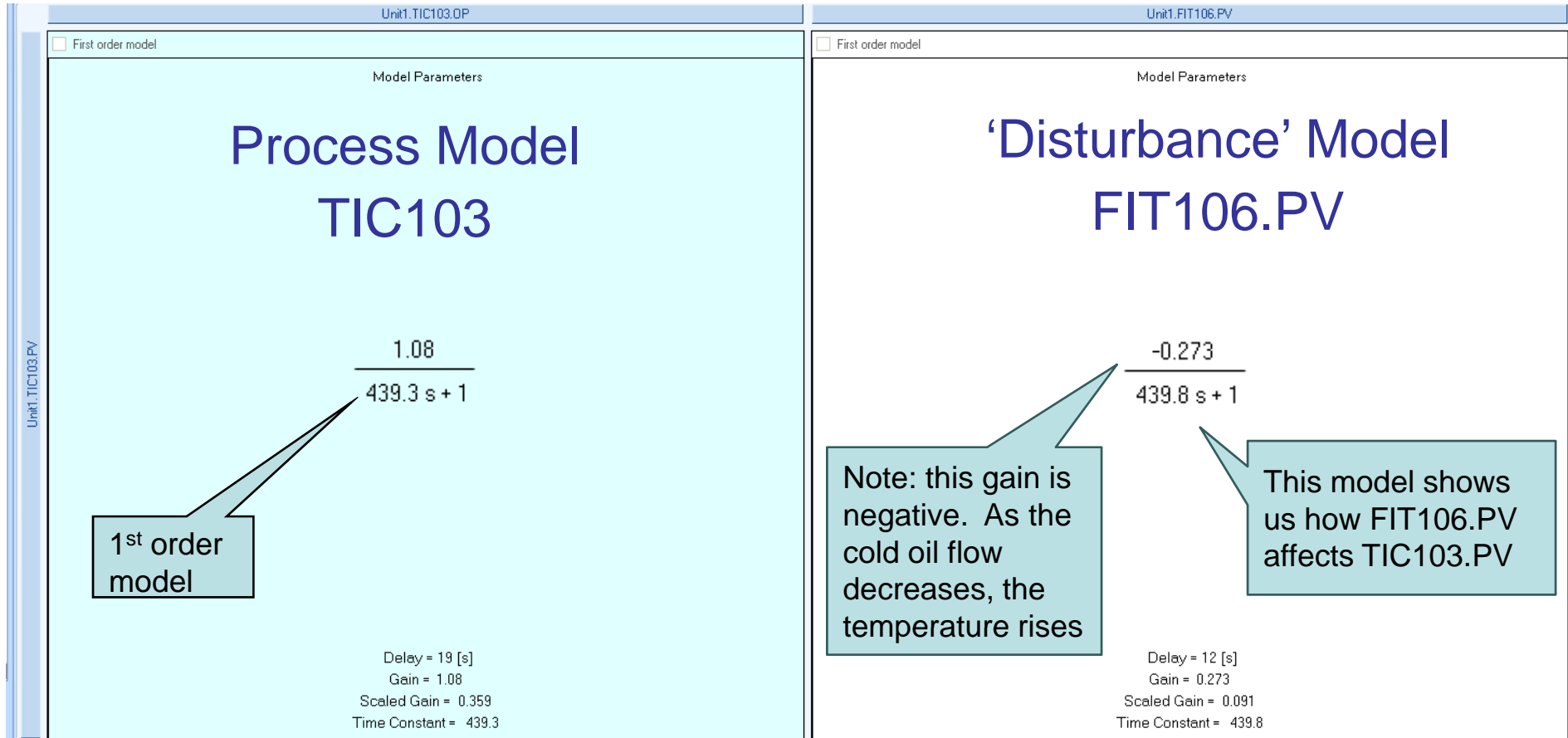
Modeling the Disturbance and Process: New Tool



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Process and Disturbance Model for Feedforward Solution



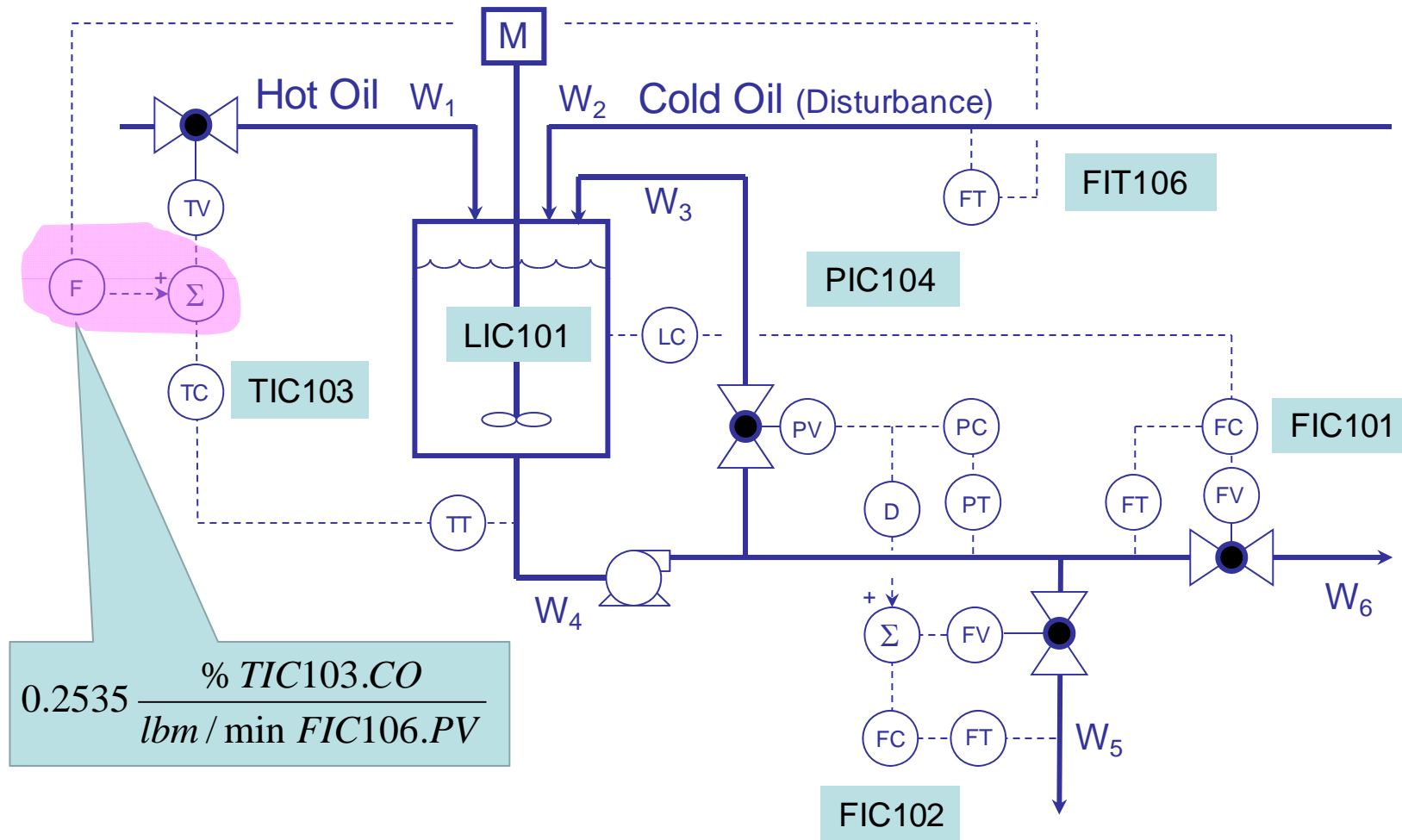
$$FF_{SS} = - \frac{-0.273 \text{ } ^\circ\text{F/lbm/min FIT106}}{1.08 \text{ } ^\circ\text{F/\%CO TIC103}} = 0.2528 \frac{\%CO(TIC103)}{\text{lbm / min}(FIT106)}$$



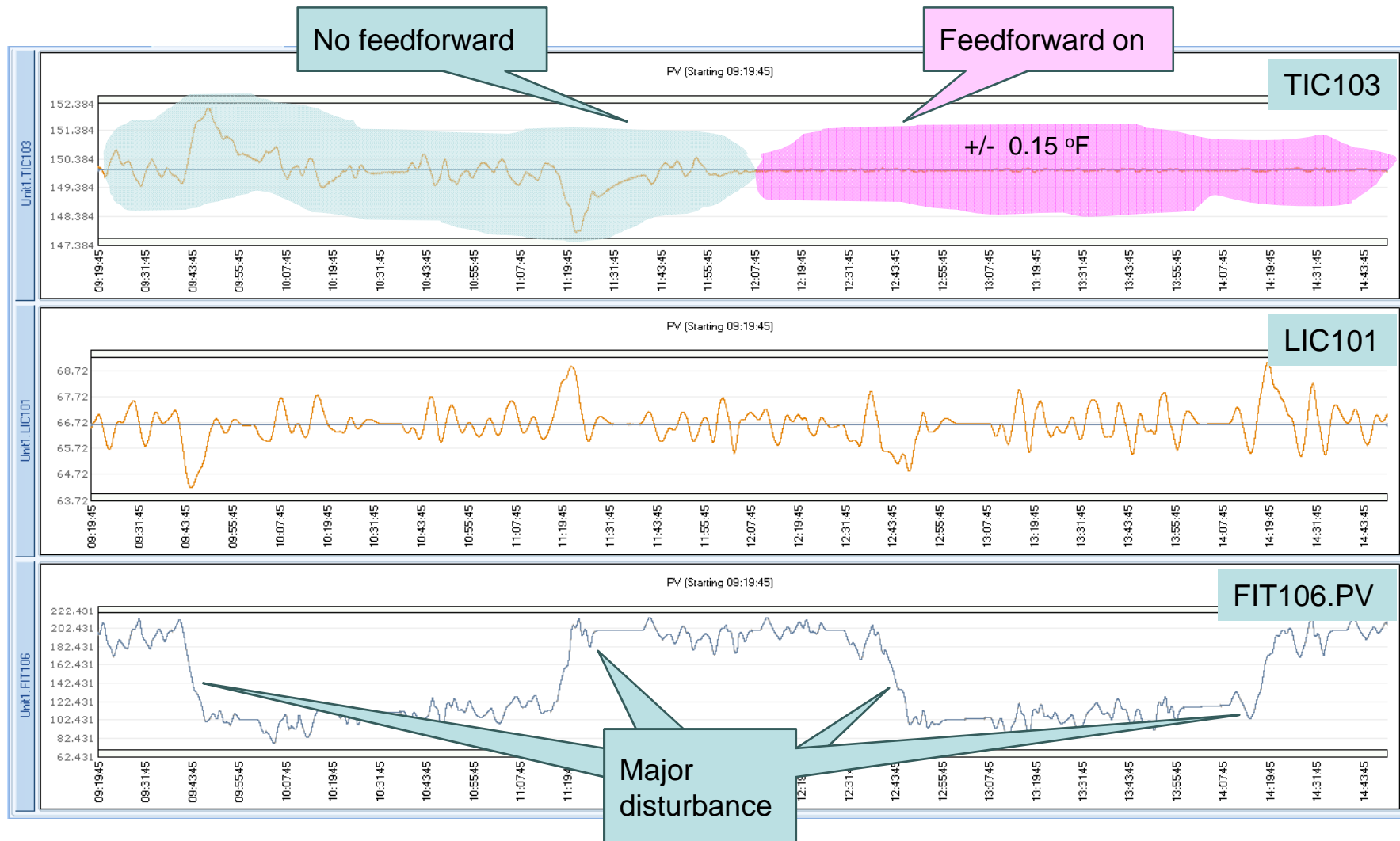
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Implementing the Feedforward Solution



Results: With Feedforward



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Conclusions

- Interacting loops and disturbances negatively impact your process
- Implementing Feedforward and Decoupling has been difficult in the past
 - Step testing the process as in theory is not practical
- New Tools
 - Make it possible to utilize the decoupling and feedforward capability in your DCS or PLC
 - This can be done with minimal disruption to your process

