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Combat Process Disturbances and Interactions:

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

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RETHINK PAPER:
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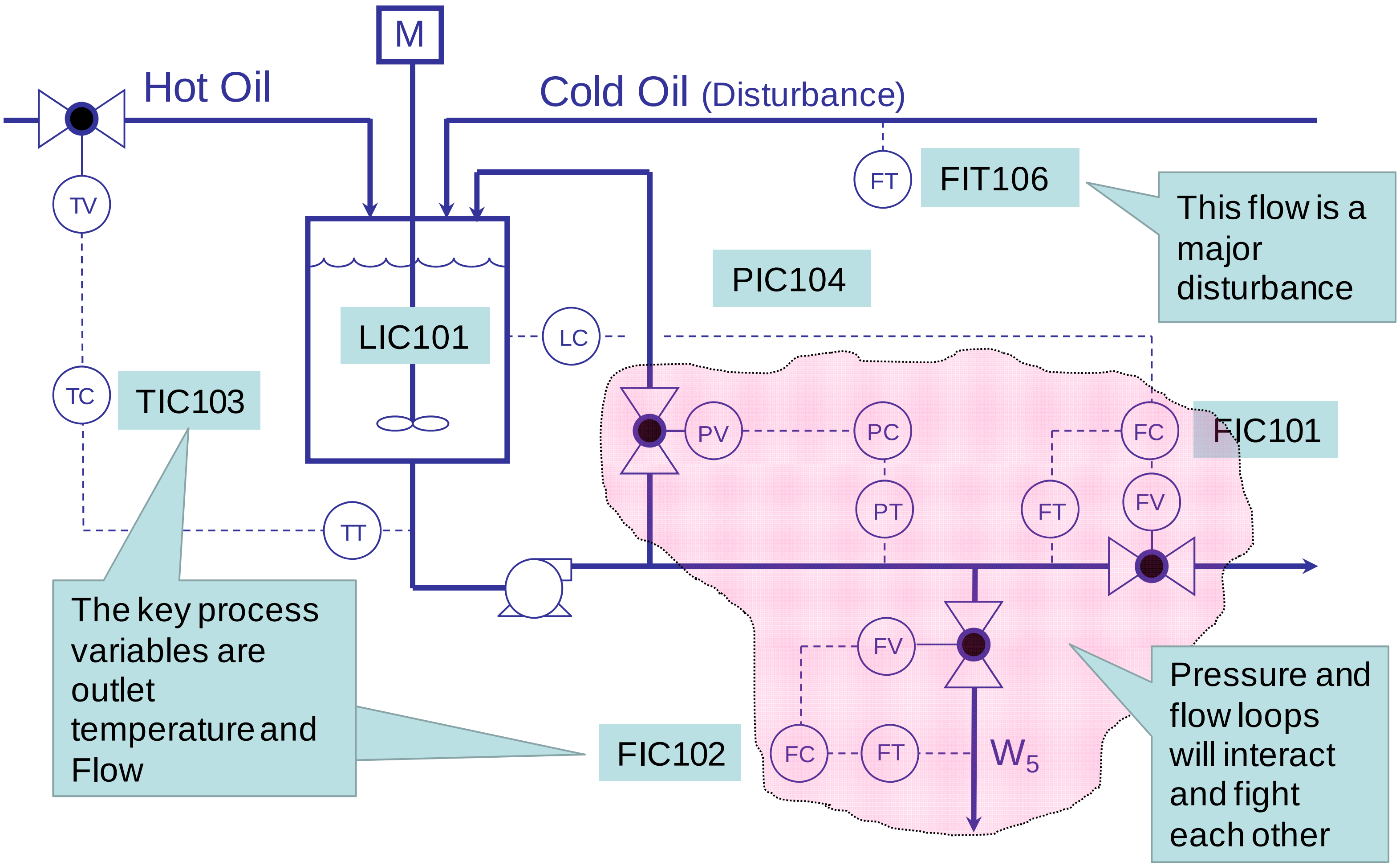
  - Measuring the effect of the disturbance
  - Implementing feedforward to *cancel the disturbance*
- Conclusions

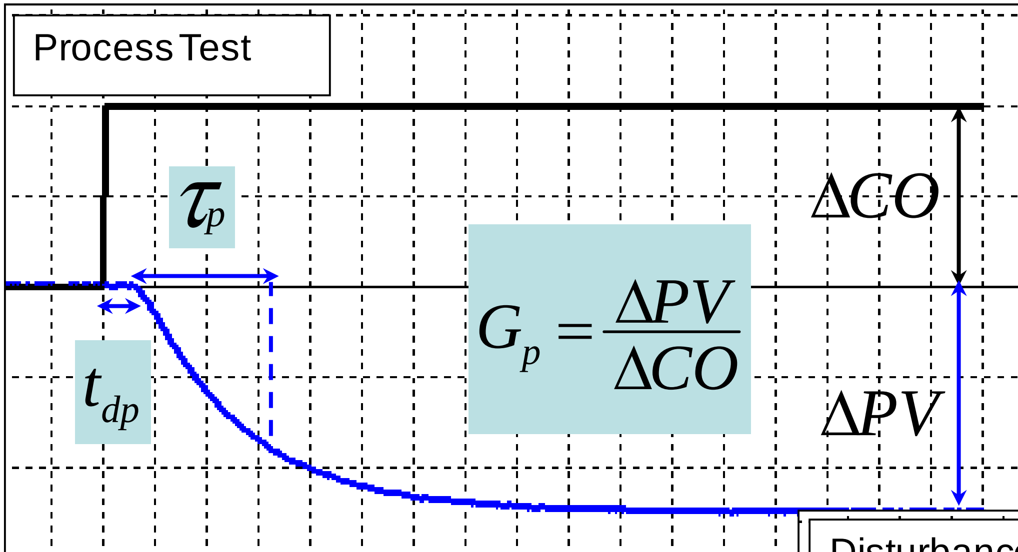
Example Process



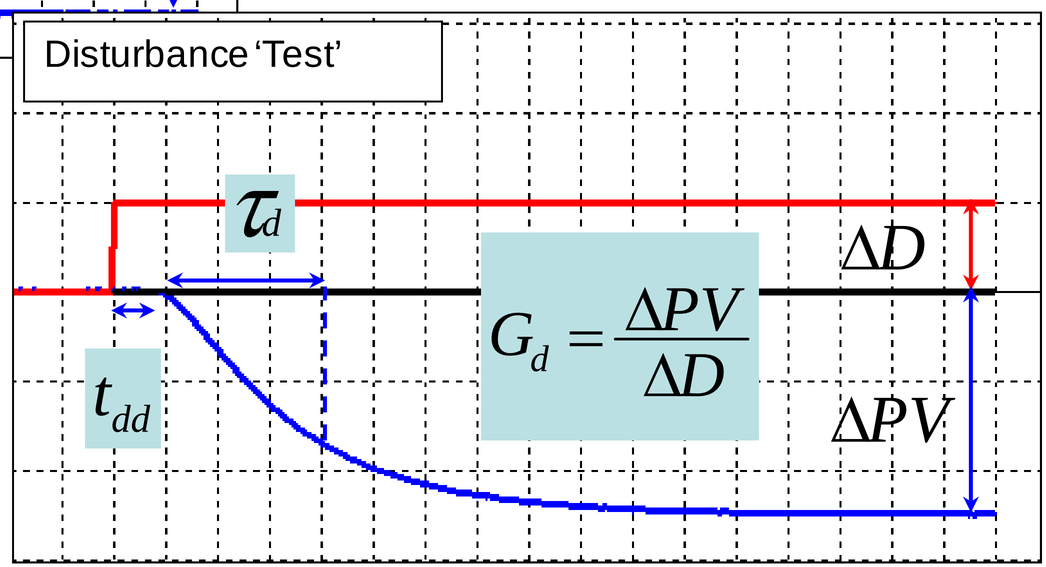
Optimization Principles and Procedures

- 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

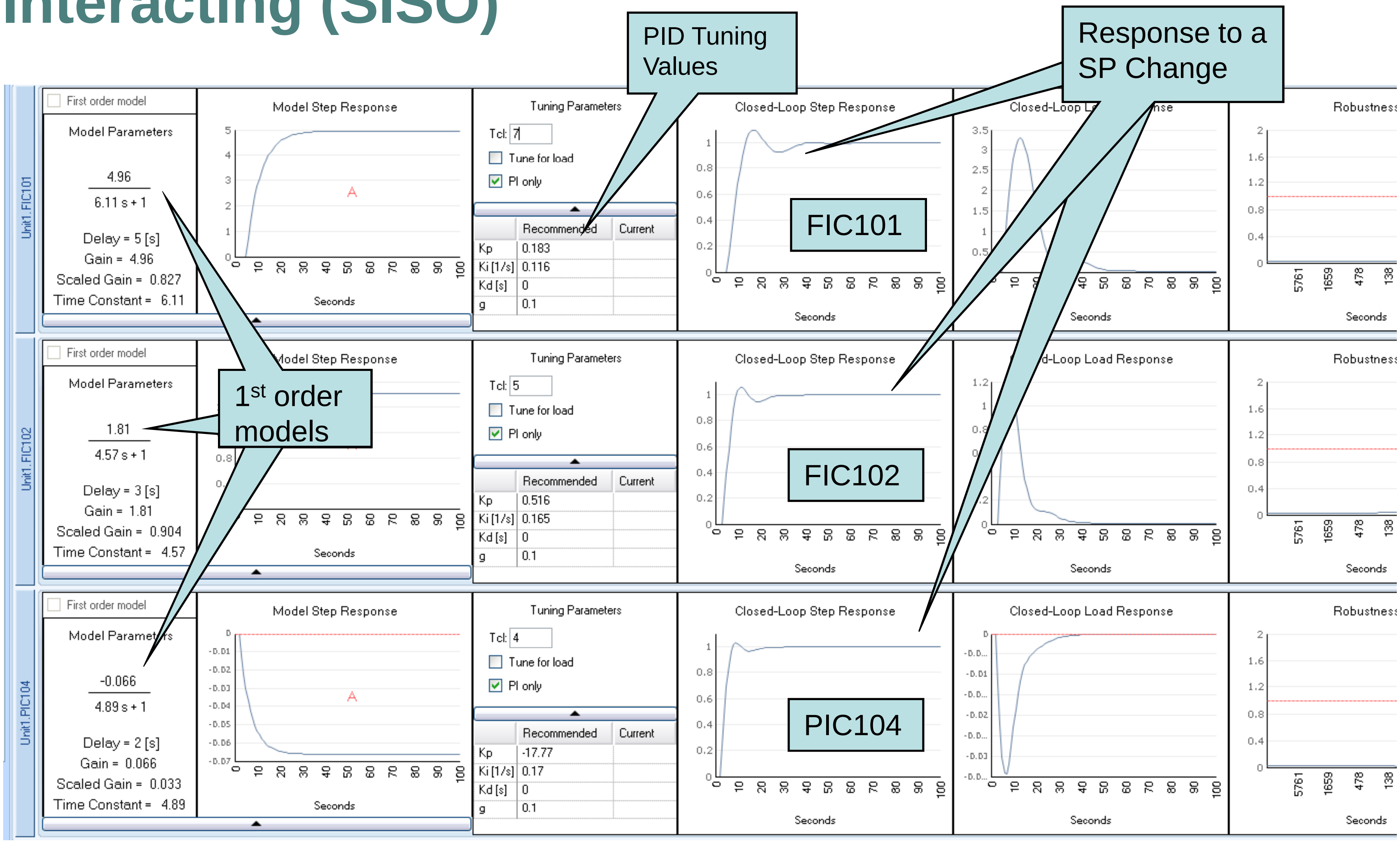
	Process Model	Disturbance Model	Compensator
Gain	G_p	G_d	$-\left[G_d / G_p \right] = \frac{\Delta CO}{\Delta D}$
Time Constant	τ_p	τ_d	$lead\,\tau_p \quad lag\,\tau_d$
Dead Time	t_{dp}	t_{dd}	$t_{dd} - t_{dp}$

Decoupling Control Background/Theory

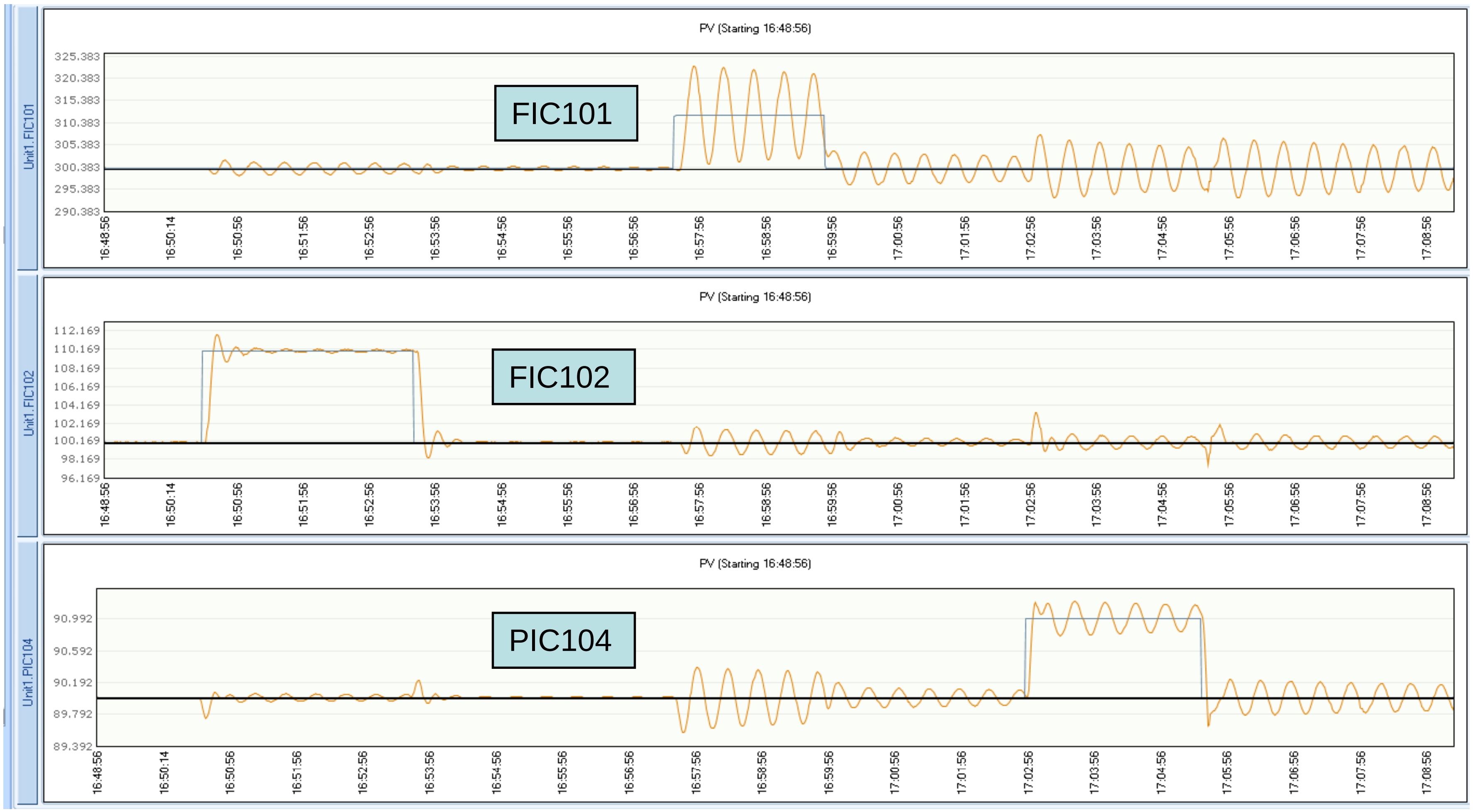
- Decoupler derived from models

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

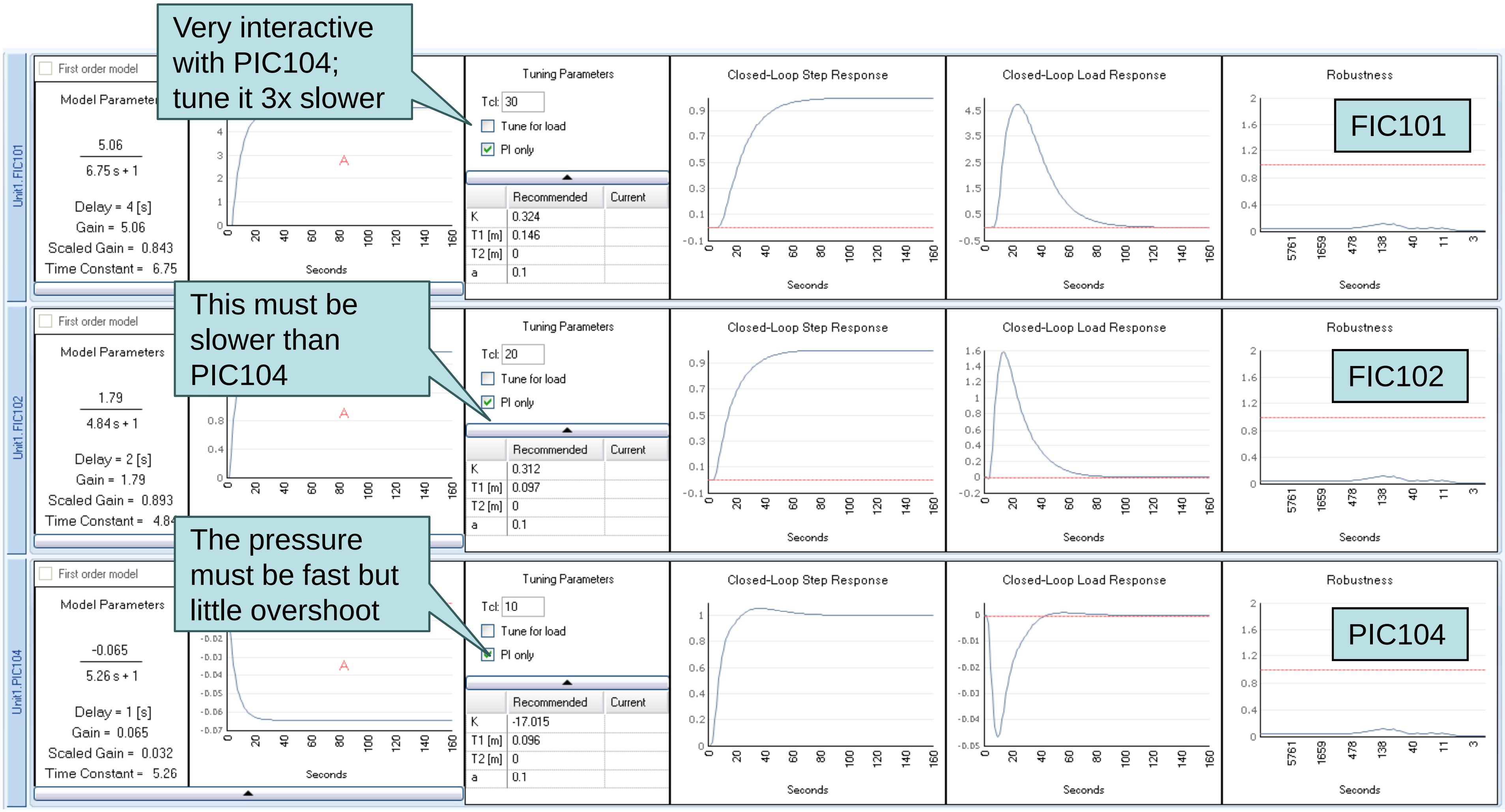
Testing and Tuning Interacting Loops as Non-Interacting (SISO)



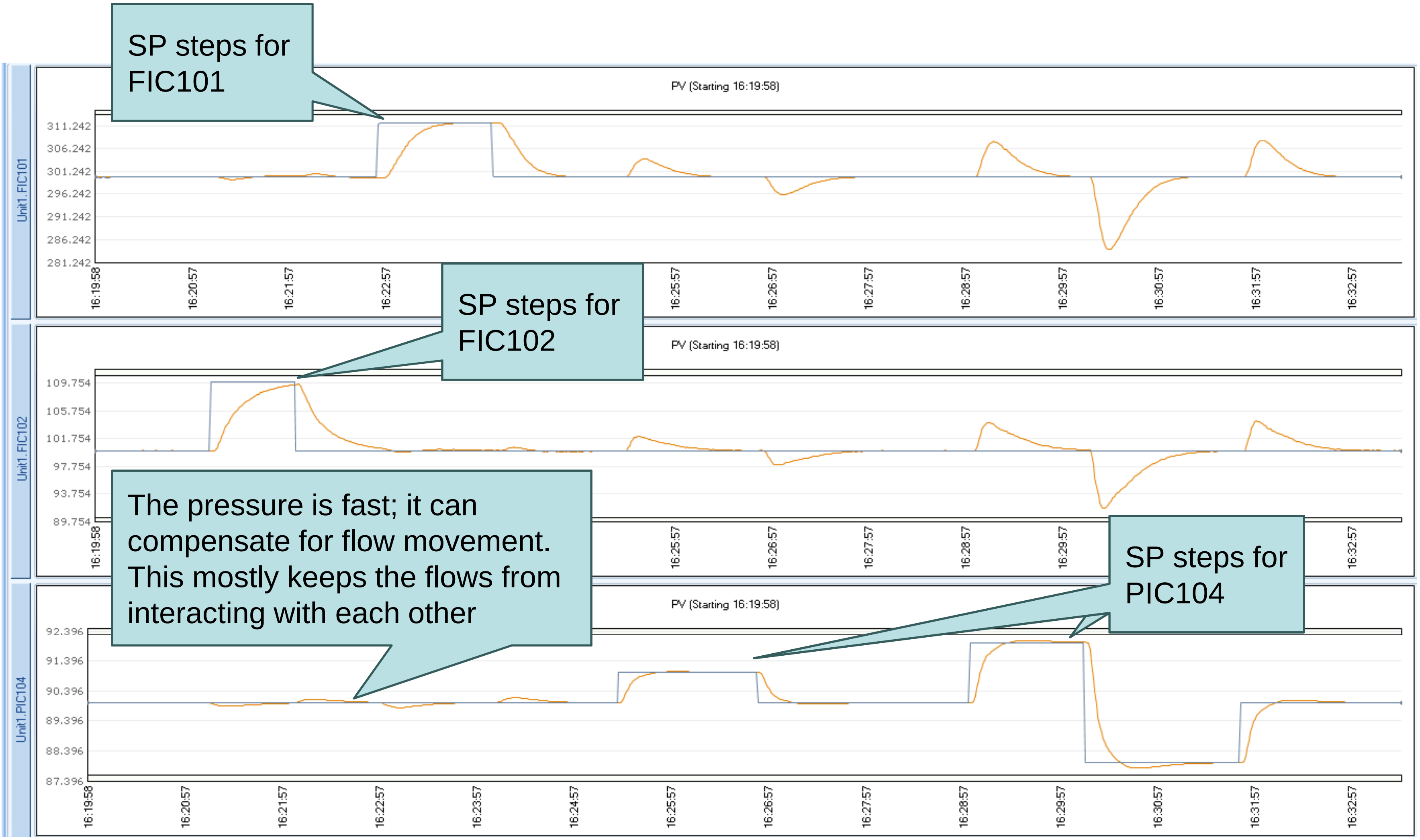
Results: Tuning Interacting Loops as Non-Interacting



De-Tuning the Loops to Reduce Interaction



Results: Detuning to Break the Interaction



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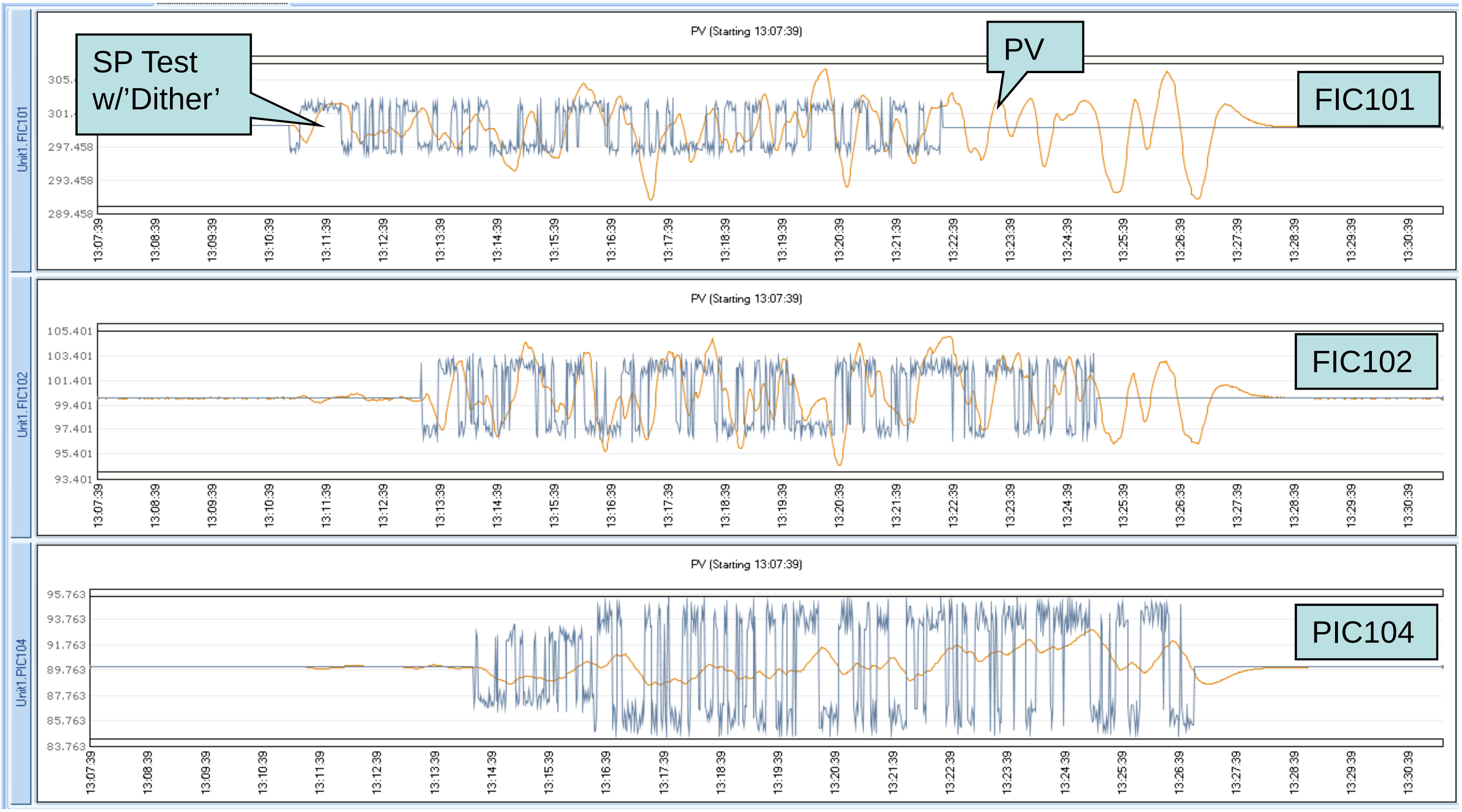
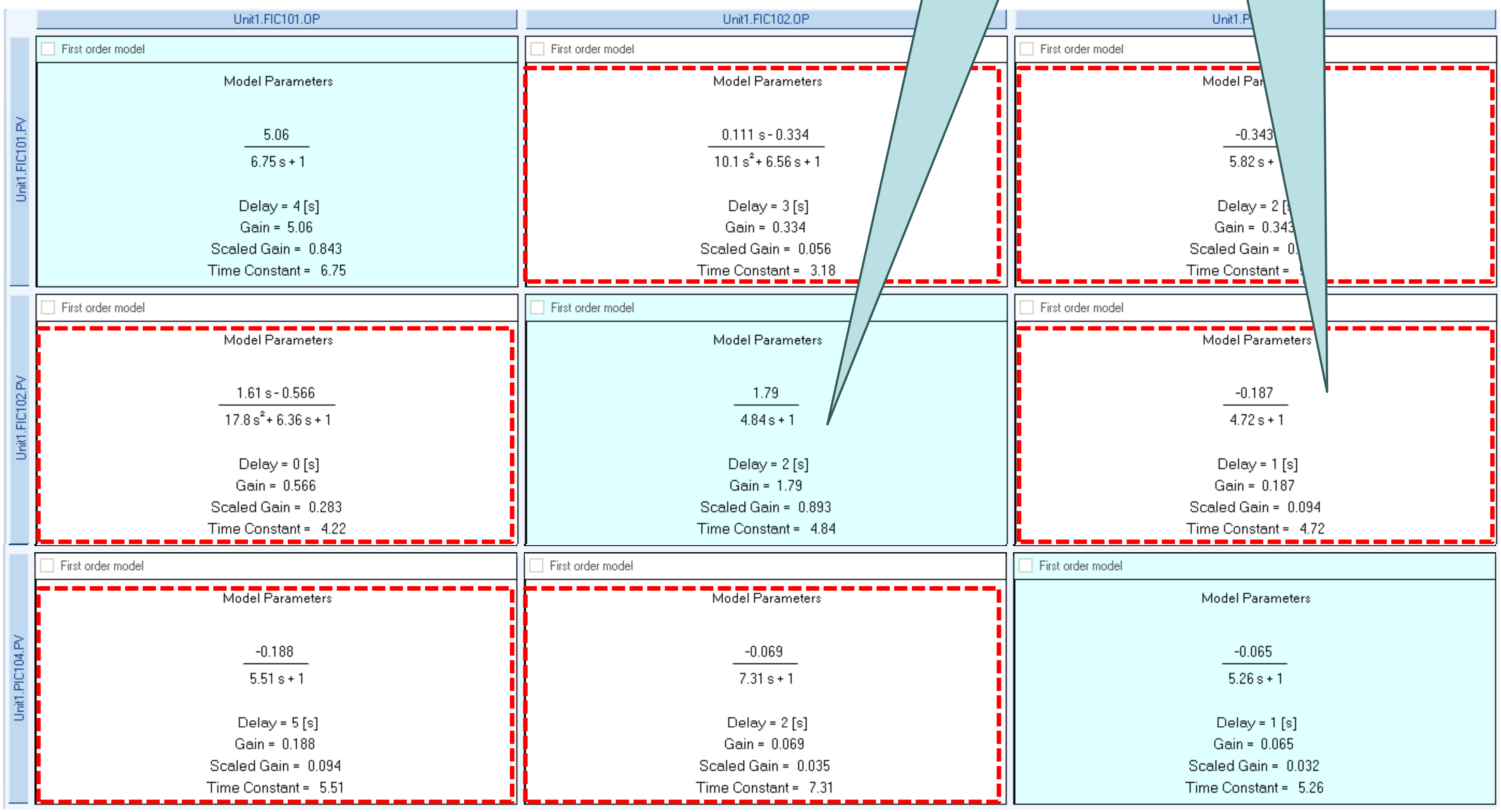
MIMO Closed Loop Testing: New Tool



MIMO Models: New Tool

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

This model shows us how FIC104.OP affects FIC102.PV



Decoupler Calculation

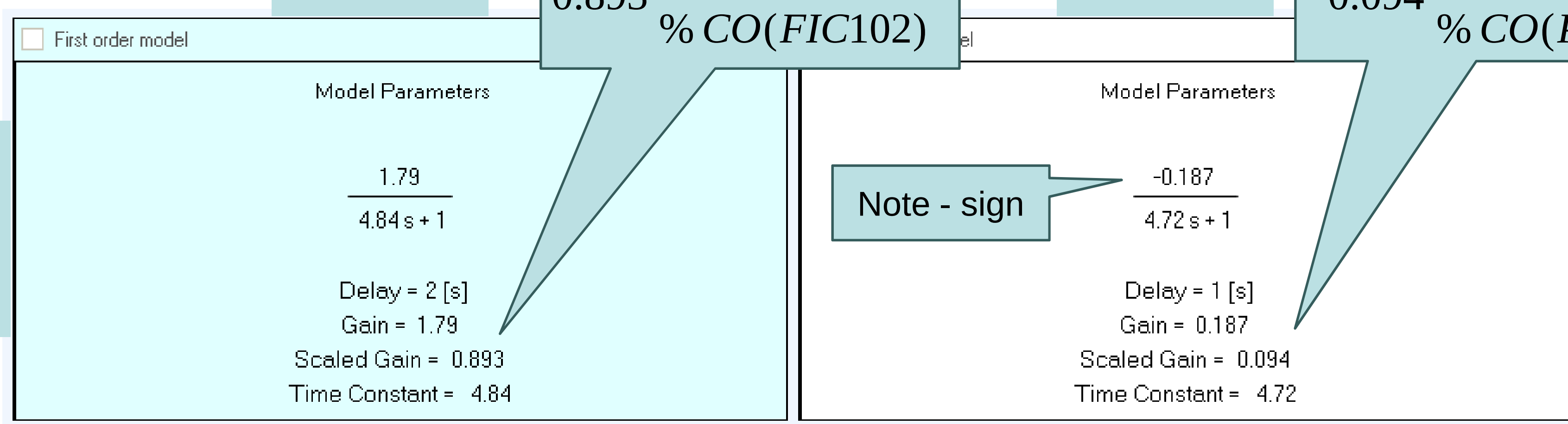
FIC102.OP

PIC104.OP

FIC102.PV

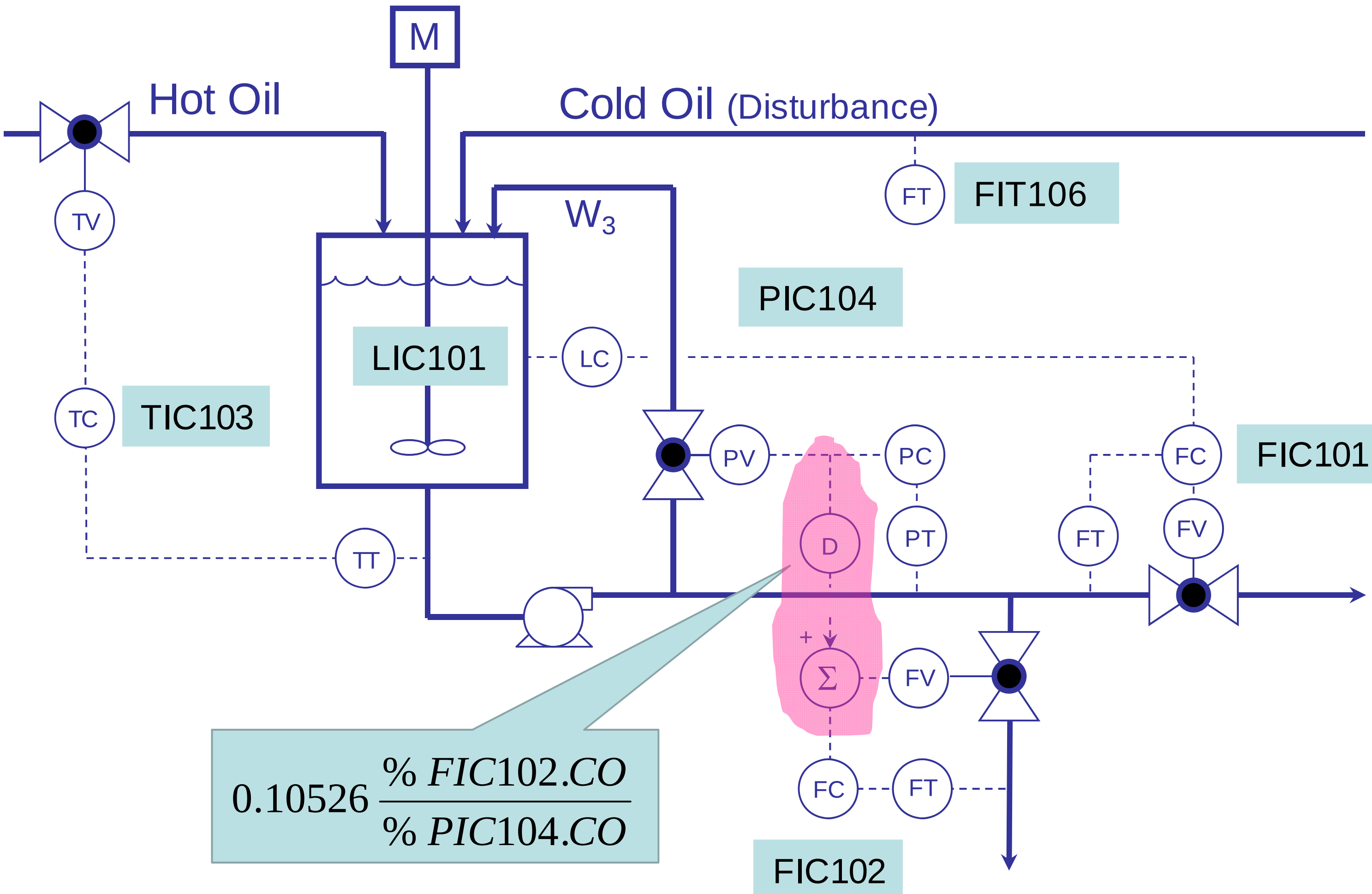
$$0.893\,\frac{\%\,PV(FIC102)}{\%\,CO(FIC102)}$$

$$-0.094\,\frac{\%\,PV(FIC102)}{\%\,CO(PIC104)}$$



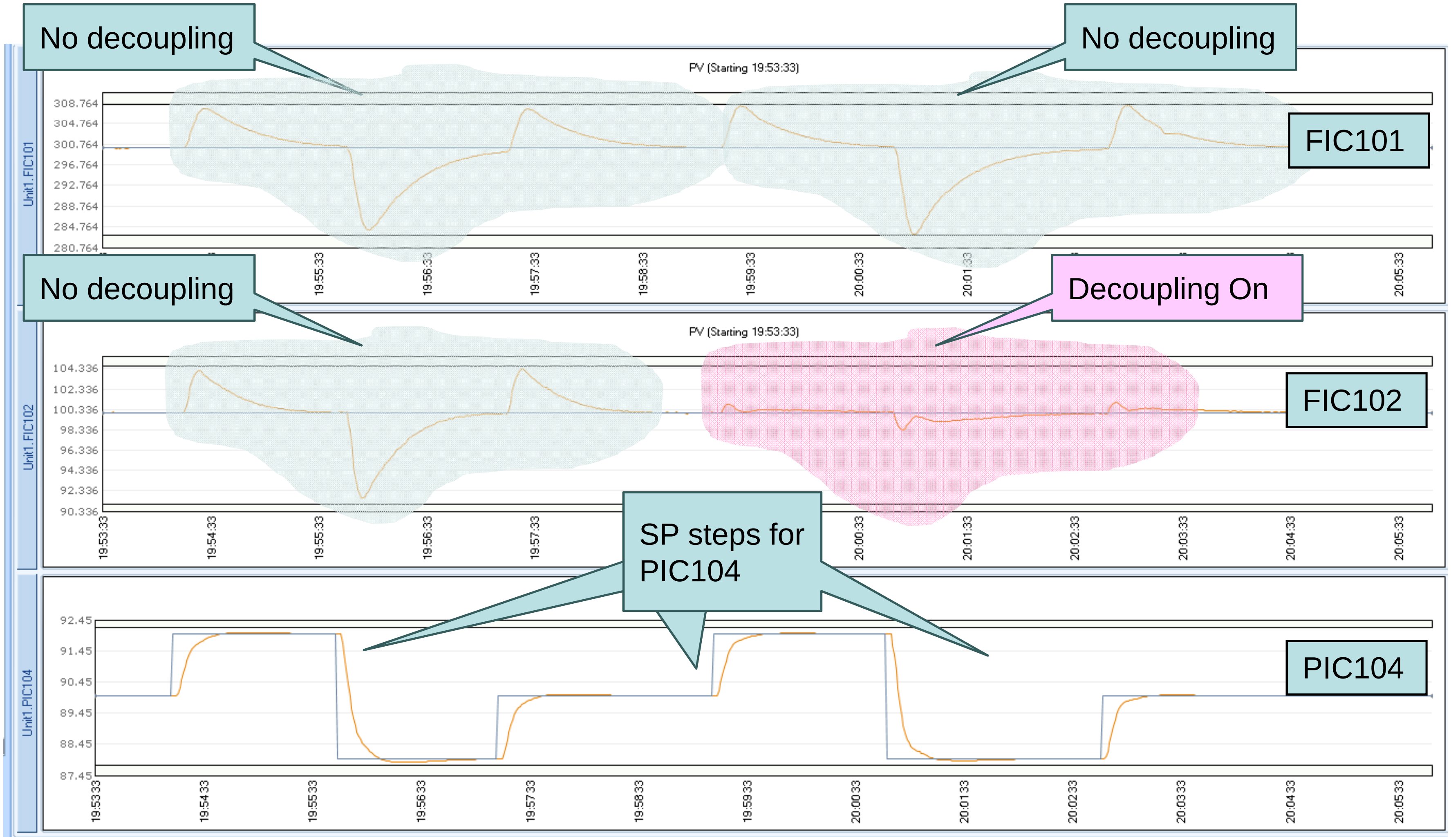
$$D_{SS} = -\frac{-0.094\,\frac{\%\,PV(FIC102)}{\%CO(PIC104)}}{0.893\,\frac{\%\,PV(FIC102)}{\%CO(FIC102)}} = 0.10526\,\frac{\%CO(FIC102)}{\%CO(PIC104)}$$

Implementing the Decoupler

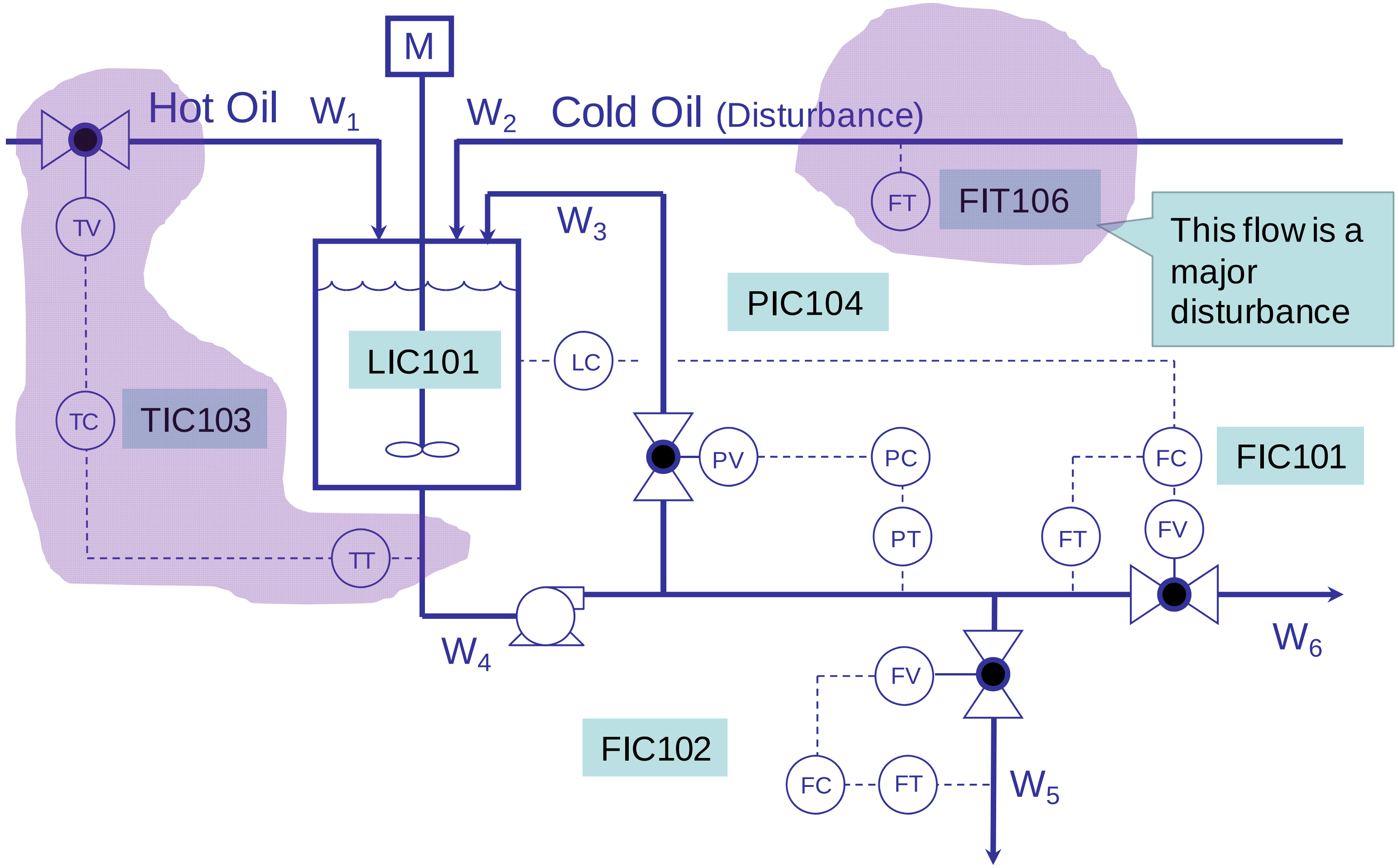


$$0.10526 \frac{\% \, FIC102.CO}{\% \, PIC104.CO}$$

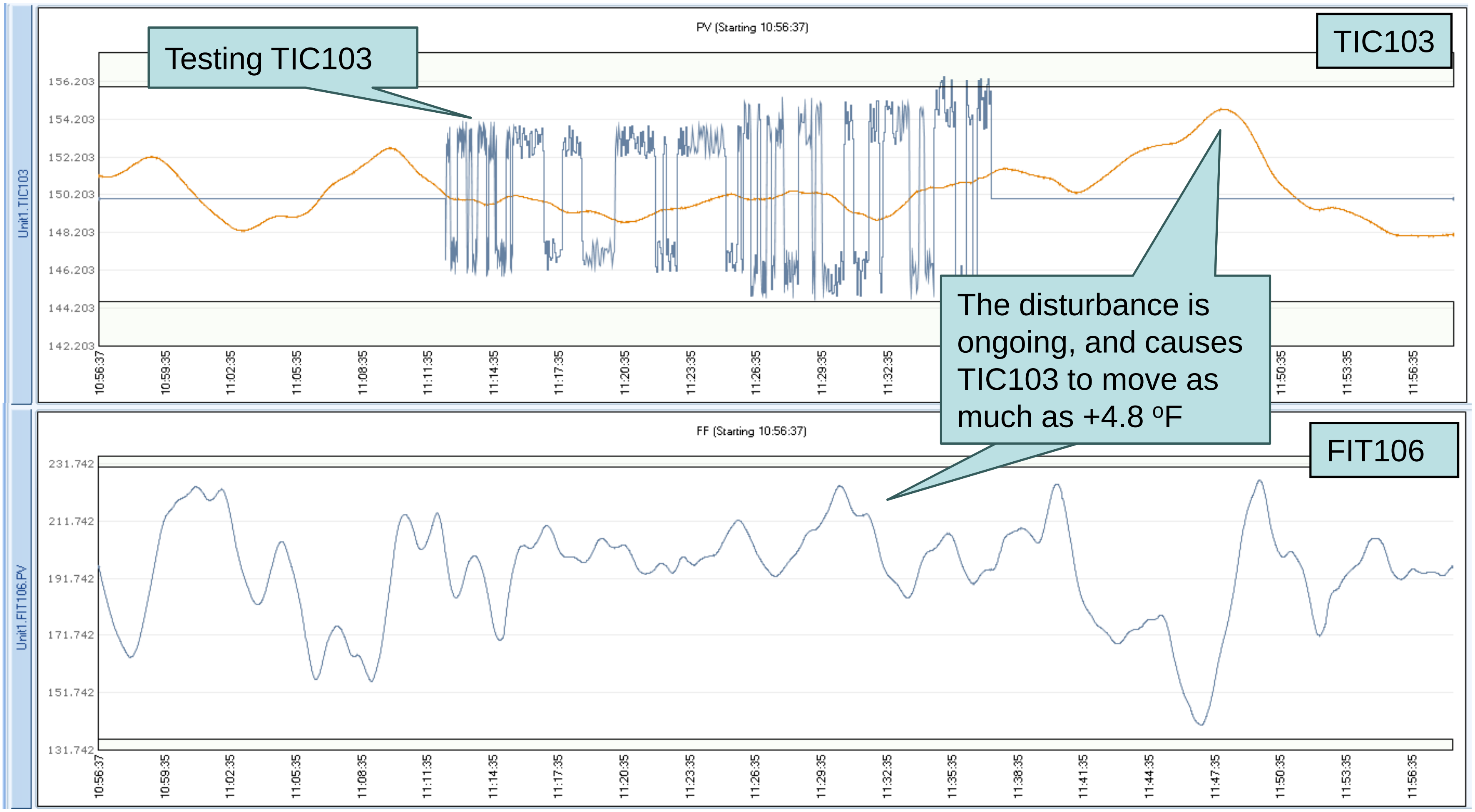
Results with Decoupler



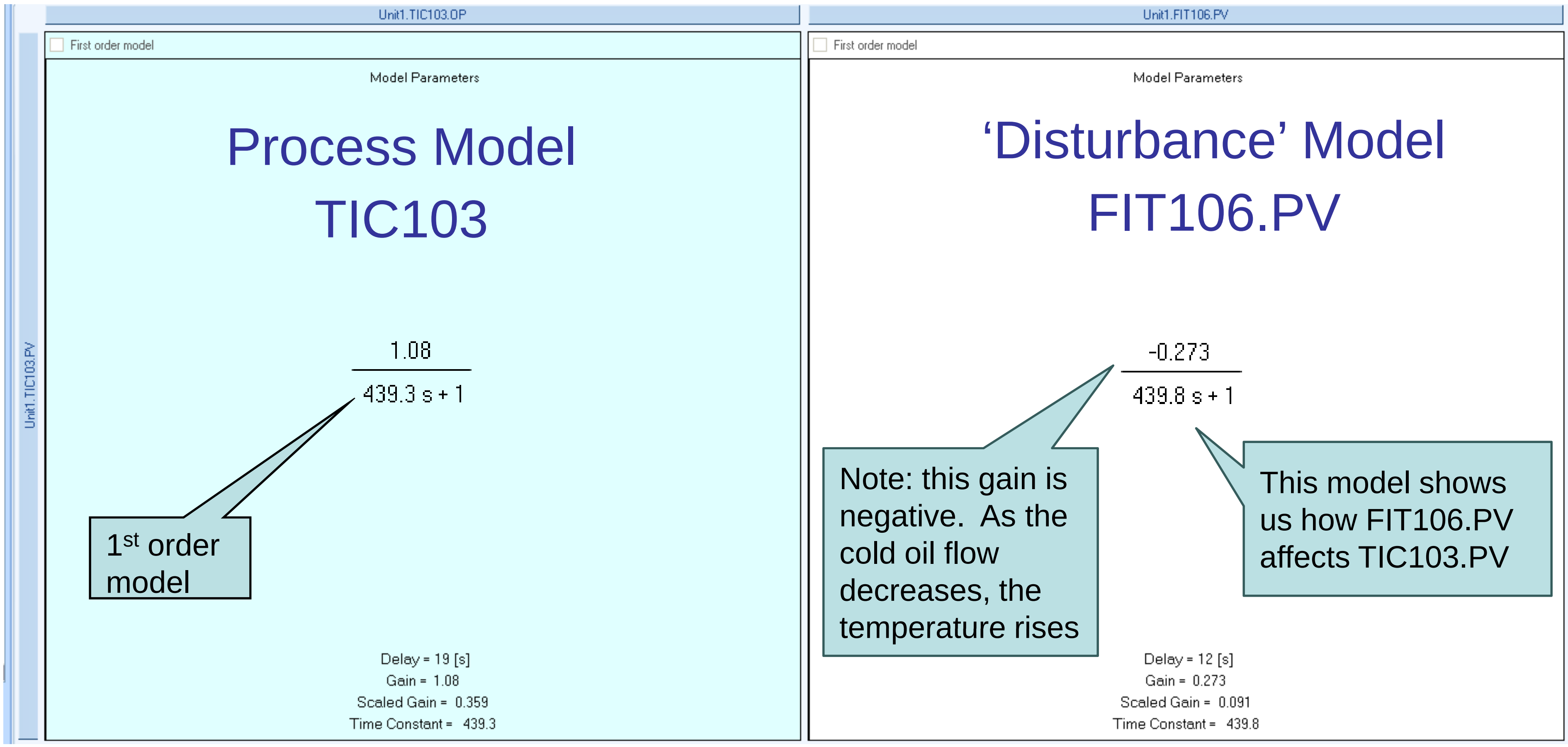
The Feedforward Solution



Modeling the Disturbance and Process: New Tool

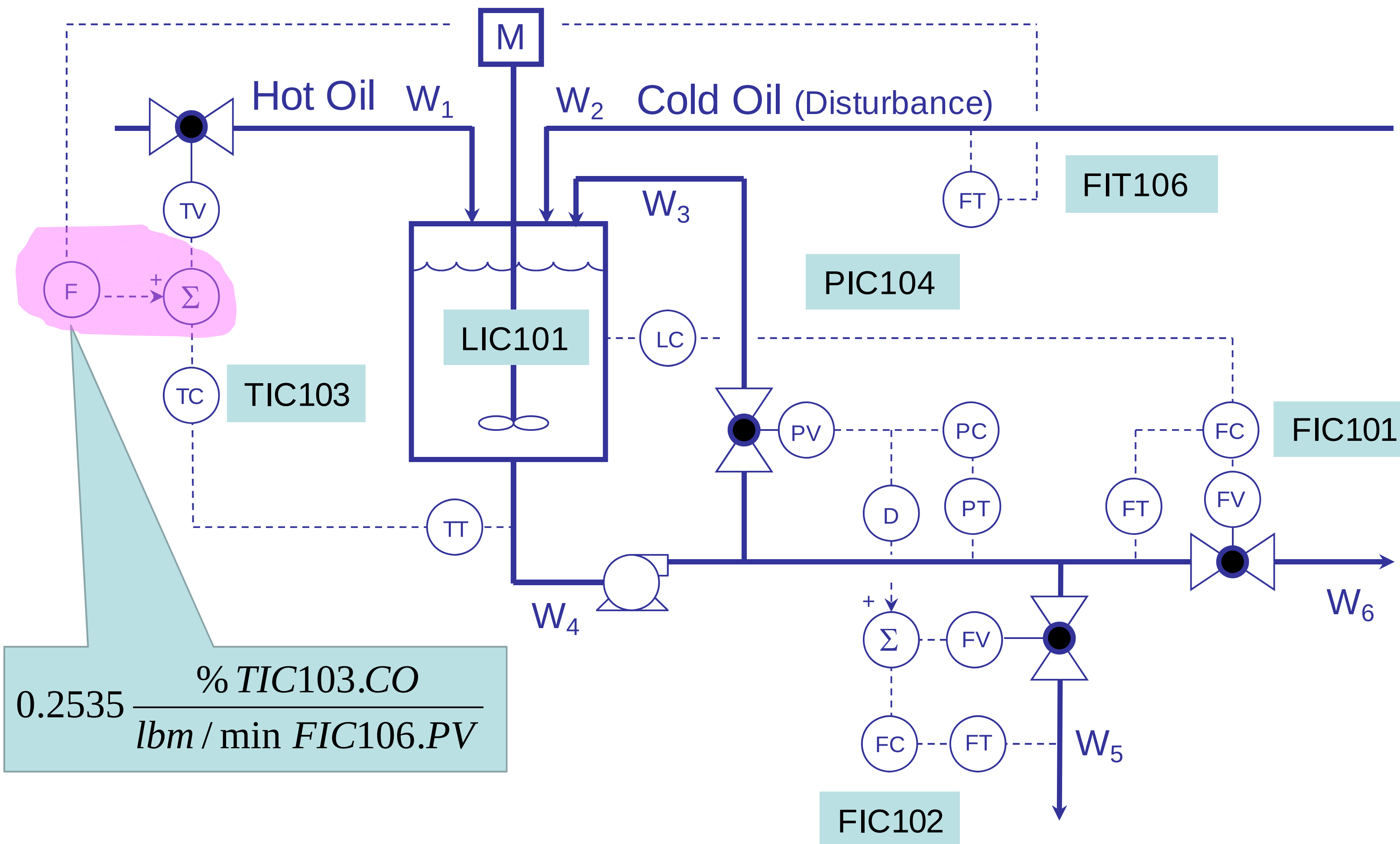


Process and Disturbance Model for Feedforward Solution



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

Implementing the Feedforward Solution



$$0.2535 \frac{\%\,TIC103.CO}{lbm/\min\, FIC106.PV}$$

Results: With Feedforward

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 feedfoward capability in your DCS or PLC
  - This can be done with minimal disruption to your process

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