Showcase of Advanced Regulatory Control in the Sugar Industry

James Caws MEng CEng MIChemE

Senior Automation & Control Engineer, British Sugar

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Agenda

- Control Challenges
- Simple Soft Sensors
- Smith Predictor Dynamic Compensation
- Dynamic Mass Balance
- Dynamic Feedforward

Introduction to British Sugar

8 million tonnes

1.2 million tonnes + co-products

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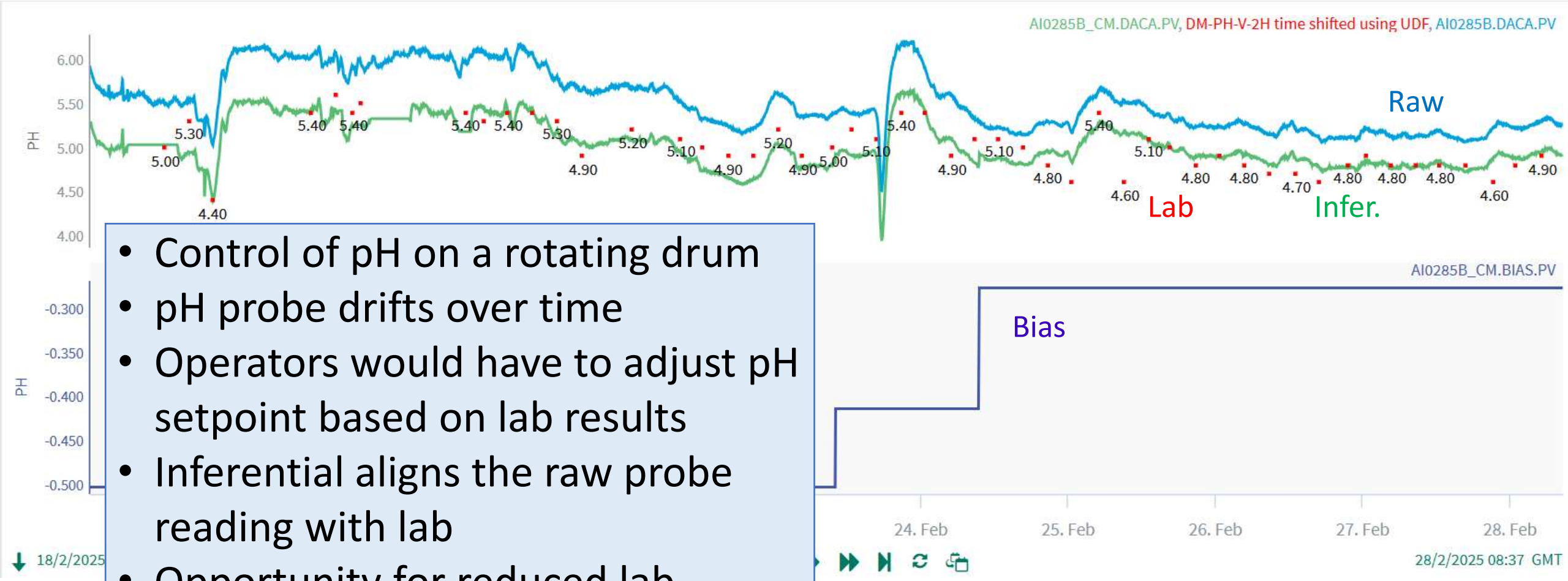
Control Challenges

- Unmeasured disturbances – variable raw material
- Long process dynamics
- Mix of continuous and batch unit operations
- Harsh environment for instrumentation – scaling/abrasion
- Lack of operator familiarity with more complex control strategies

Advanced Regulatory Control (ARC) we have found, in general, a good compromise between and the simplicity of base control (such as PID) and the complexity and cost of Multivariable Predictive Control

Soft Sensors



- Control of pH on a rotating drum
- pH probe drifts over time
- Operators would have to adjust pH setpoint based on lab results
- Inferential aligns the raw probe reading with lab
- Opportunity for reduced lab sampling frequency

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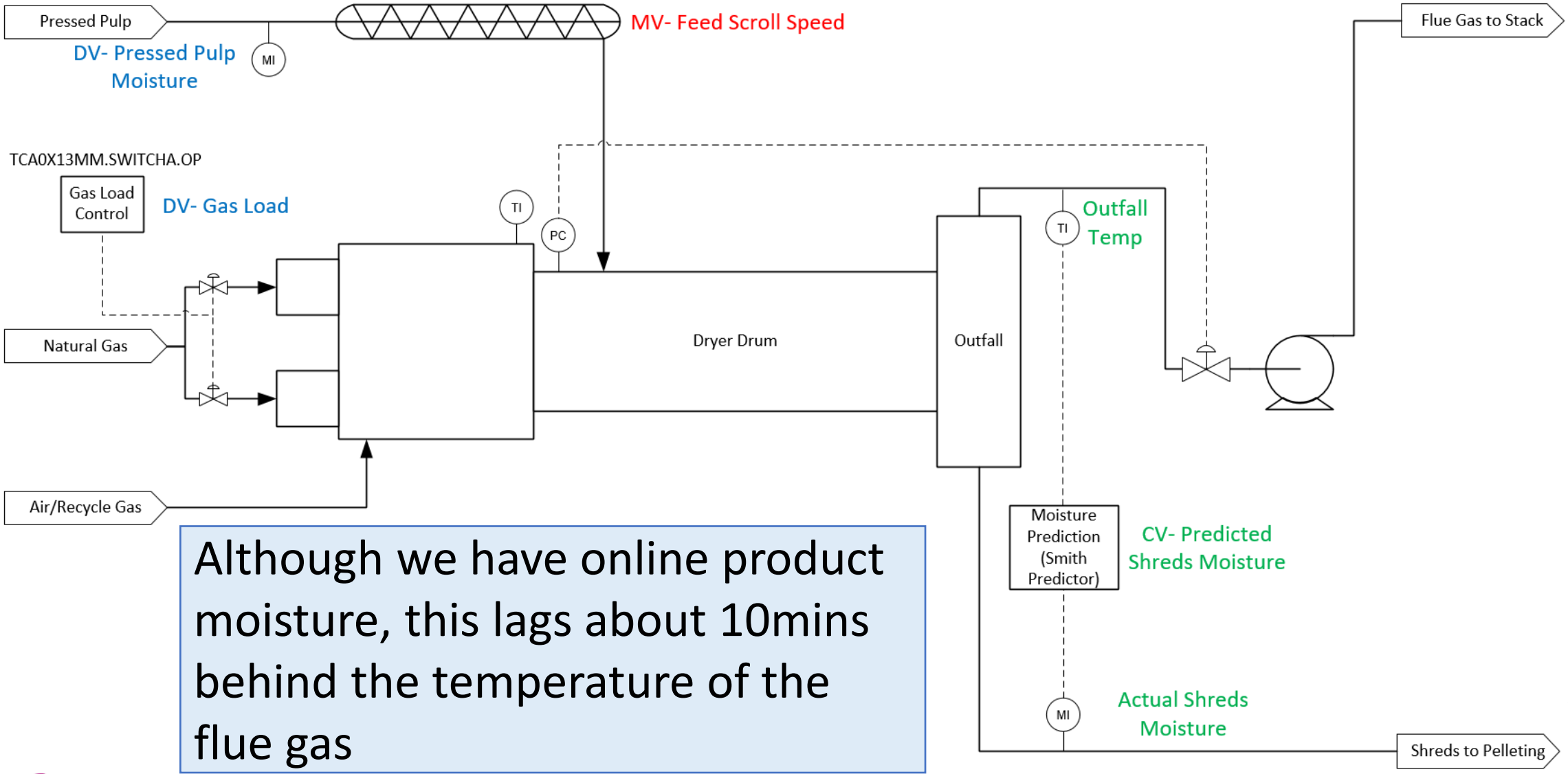
Smith Predictor - Dynamic Compensation



Although we have online product moisture, this lags about 10mins behind the temperature of the flue gas

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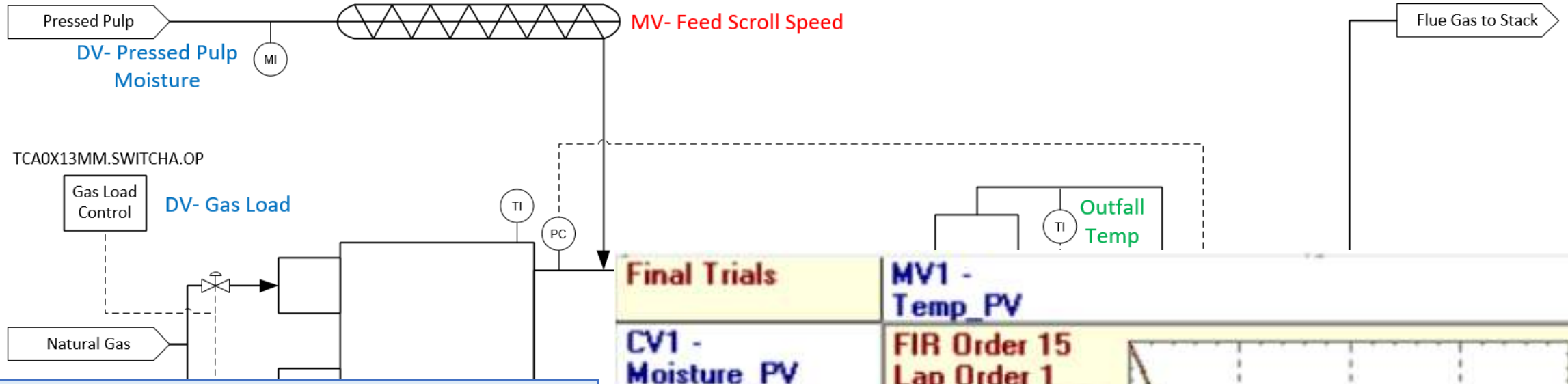
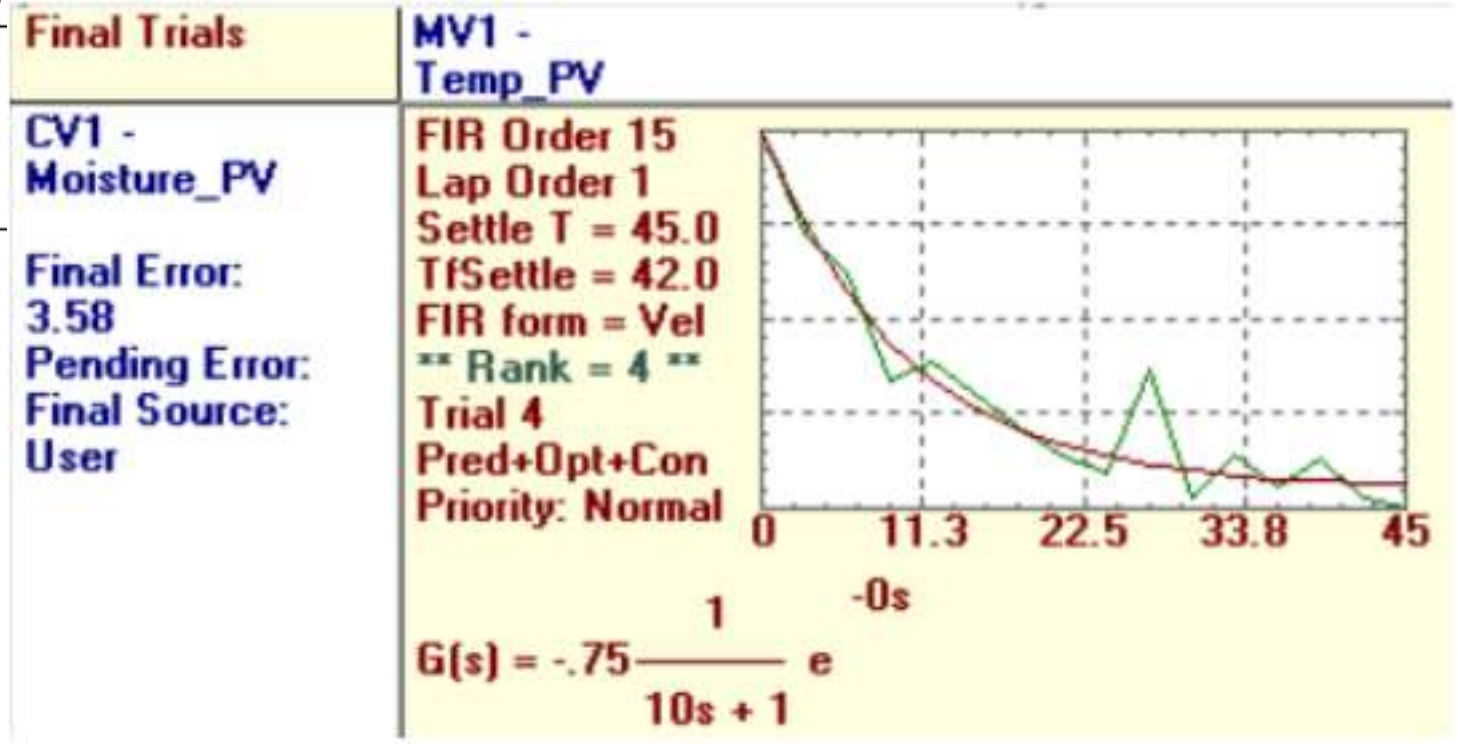
Smith Predictor - Dynamic Compensation



Use temperature to predict moisture and control to the predicted moisture.

Actual moisture is used to correct the prediction bias.



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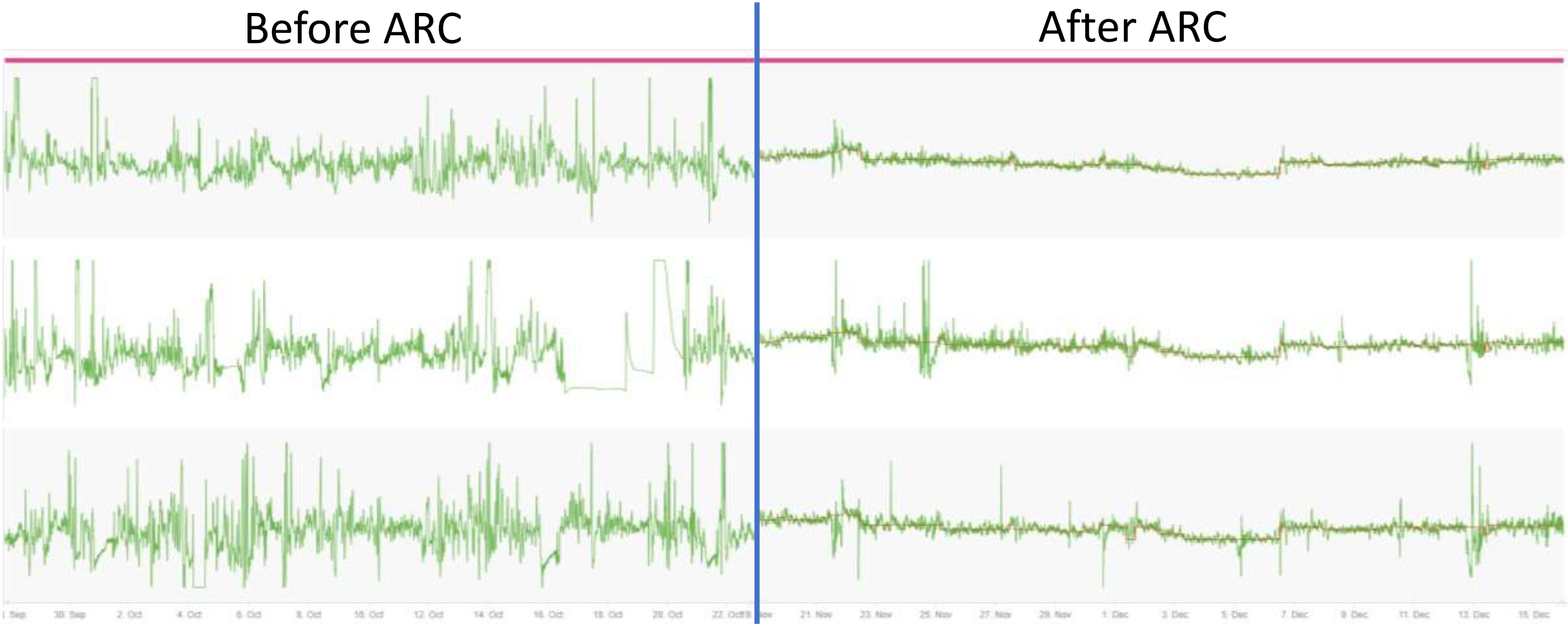
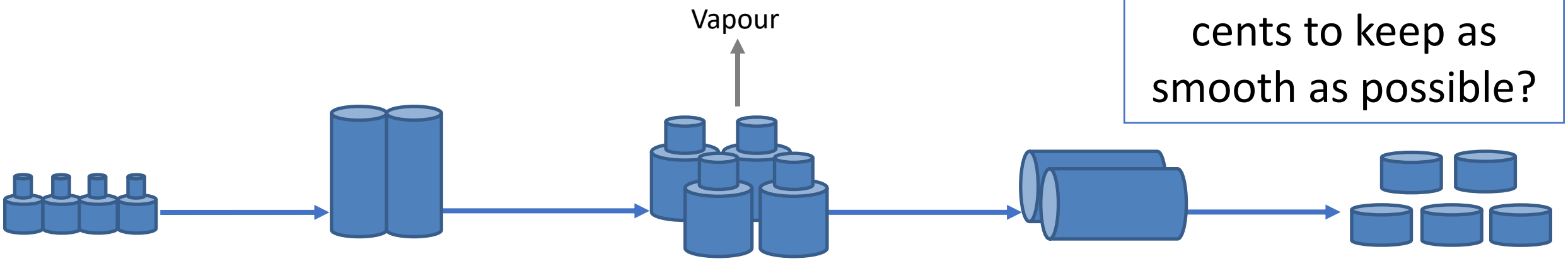
Smith Predictor - Dynamic Compensation



Mix of Continuous & Batch – Dynamic Mass Balance

How to determine the setpoint for raw cents to keep as smooth as possible?



White Centrifuges (Batch Centrifugation)

High Green Syrup Tanks

Raw Pans (Semi-batch Crystallisation)

5 hour batch cycle time (discharge every 60-90mins)

Receivers

Raw Centrifuges (Continuous Centrifugation)

Low-grade sugar recycled

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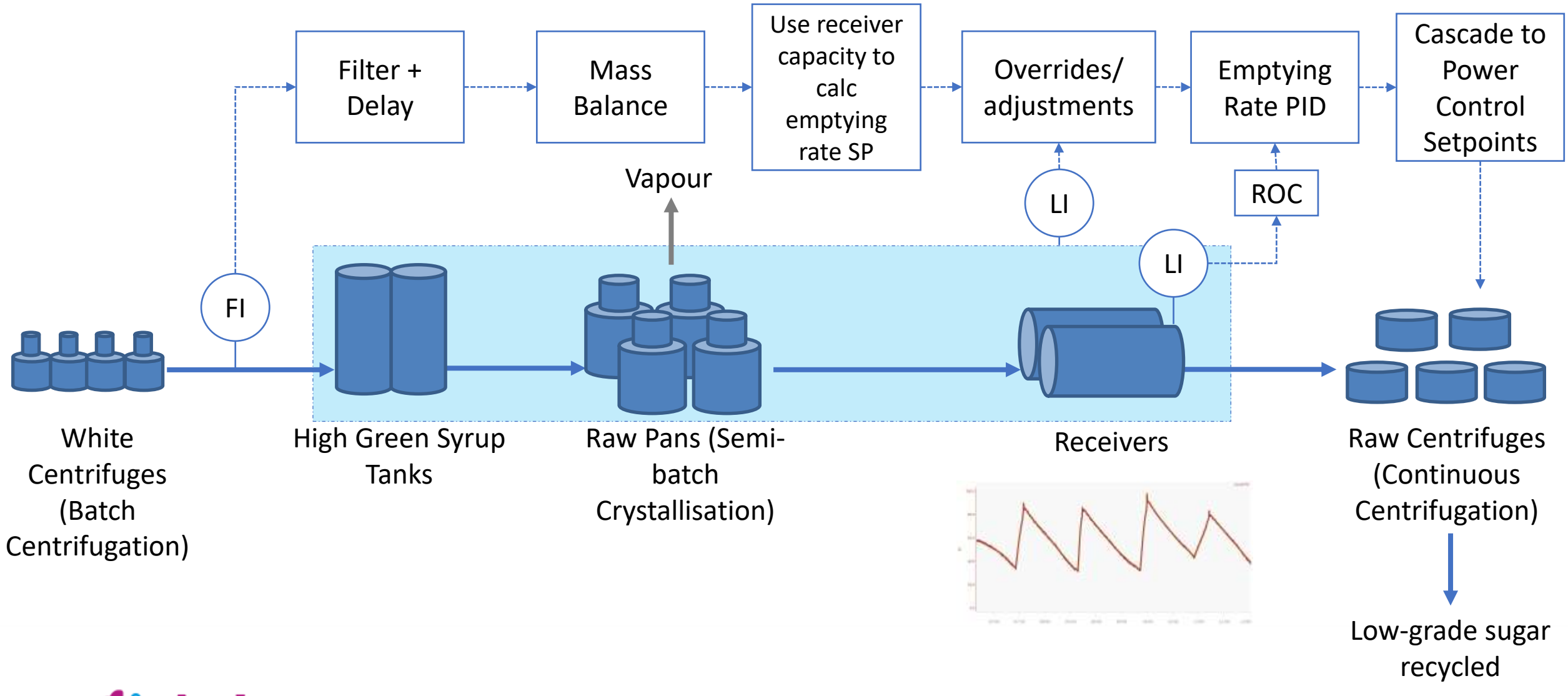
Mix of Continuous & Batch – Dynamic Mass Balance



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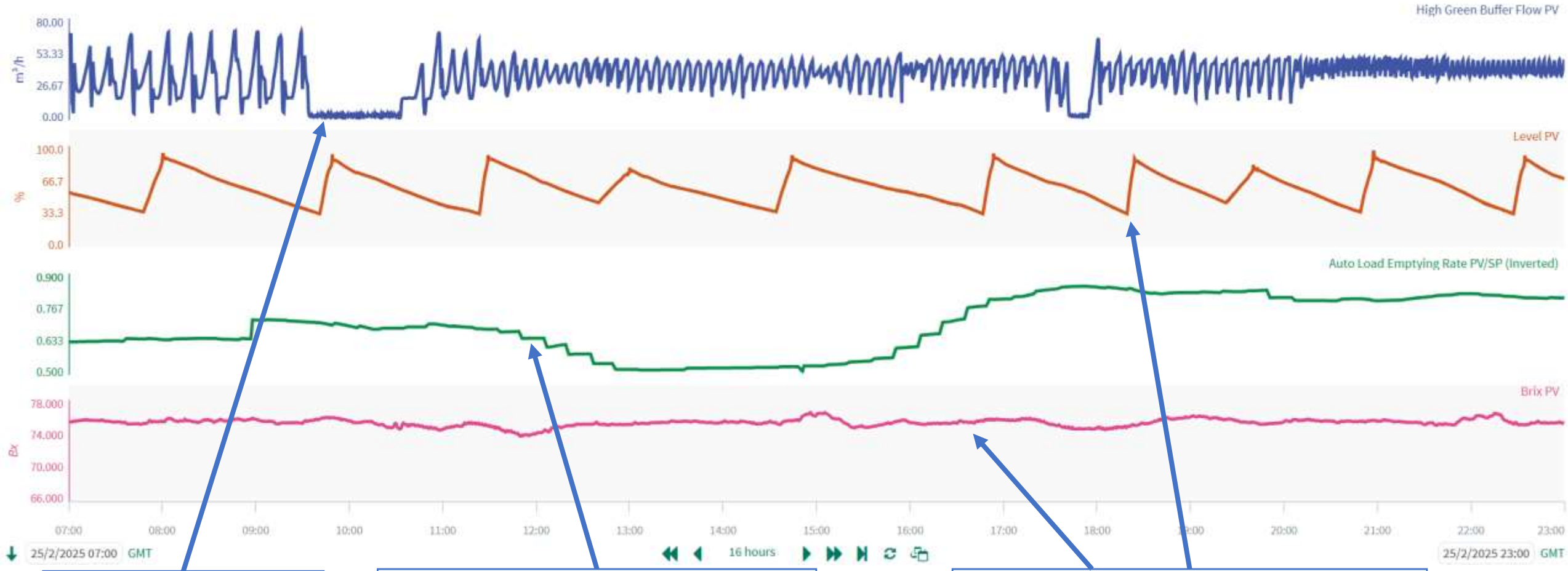
Mix of Continuous & Batch – Dynamic Mass Balance

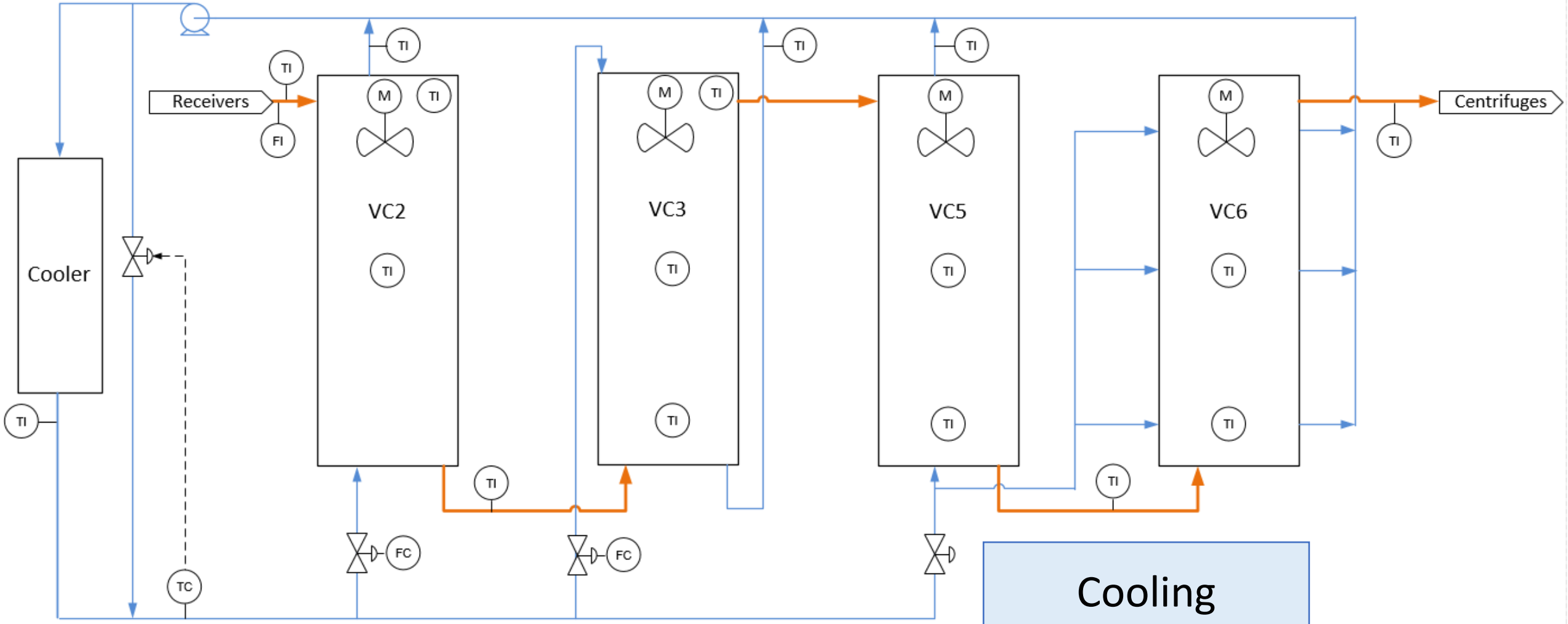


Downtime in upstream process

About 2 hours after stop, control starts to reduce throughput of centrifuge station

Tank level stays in control and impact on downstream density is minimised

Long Dynamics – Dynamic Feedforward



Cooling Crystallisation Process

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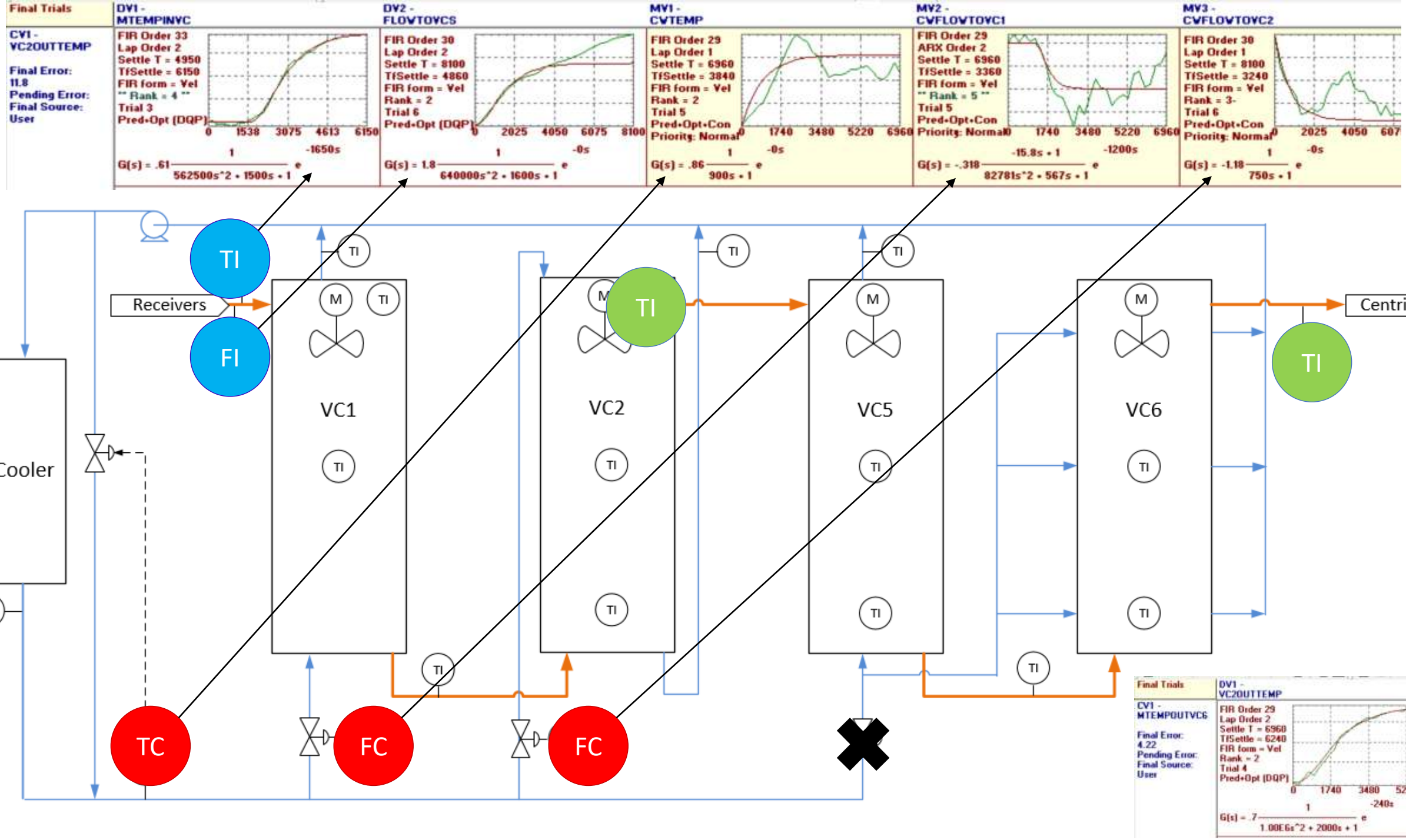
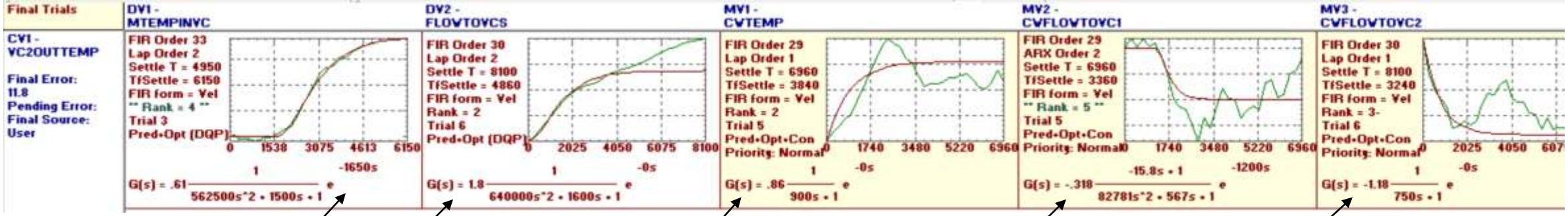

Final Trials
CV1 - VC2OUTTEMP
Final Error: 11.8
Pending Error:
Final Source: User
DV1 - MTEMPINVC
FIR Order 33
Lap Order 2
Settle T = 4950
TfSettle = 6150
FIR form = Vel
** Rank = 4 **
Trial 3
Pred+Opt (DQP)
0 1538 3075 4613 6150
G(s) = .61 / 562500s^2 + 1500s + 1 e -1650s
DV2 - FLOWTOVCS
FIR Order 30
Lap Order 2
Settle T = 8100
TfSettle = 4860
FIR form = Vel
Rank = 2
Trial 6
Pred+Opt (DQP)
0 2025 4050 6075 8100
G(s) = 1.8 / 640000s^2 + 1600s + 1 e -0s
MV1 - CVTEMP
FIR Order 29
Lap Order 1
Settle T = 6960
TfSettle = 3840
FIR form = Vel
Rank = 2
Trial 5
Pred+Opt+Con
Priority: Normal
0 1740 3480 5220 6960
G(s) = .86 / 900s + 1 e -0s
MV2 - CVFLOWTOVC1
FIR Order 29
ARX Order 2
Settle T = 6960
TfSettle = 3360
FIR form = Vel
** Rank = 5 **
Trial 5
Pred+Opt+Con
Priority: Normal
0 1740 3480 5220 6960
G(s) = -.318 / 82781s^2 + 567s + 1 e -1200s -15.8s + 1
MV3 - CVFLOWTOVC2
FIR Order 30
Lap Order 1
Settle T = 8100
TfSettle = 3240
FIR form = Vel
Rank = 3-
Trial 6
Pred+Opt+Con
Priority: Normal
0 2025 4050 607
G(s) = -1.18 / 750s + 1 e -0s
TI
FI
Receivers
VC1
VC2
VC5
VC6
Centrifuges
Cooler
TC
FC
FC
M
Final Trials
CV1 - MTEMPOUTVC6
Final Error: 4.22
Pending Error:
Final Source: User
DV1 - VC2OUTTEMP
FIR Order 29
Lap Order 2
Settle T = 6960
TfSettle = 6240
FIR form = Vel
Rank = 2
Trial 4
Pred+Opt (DQP)
0 1740 3480 5220 6960
G(s) = .7 / 1.00E6s^2 + 2000s + 1 e -240s


Final Trials
CV1 - VC2OUTTEMP
Final Error: 11.8
Pending Error:
Final Source: User
DV1 - MTEMPINVC
FIR Order 33
Lap Order 2
Settle T = 4950
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DV2 - FLOWTOVCS
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Lap Order 2
Settle T = 8100
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Trial 6
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G(s) = 1.8 / 640000s^2 + 1600s + 1 e -0s
MV1 - CVTEMP
FIR Order 29
Lap Order 1
Settle T = 6960
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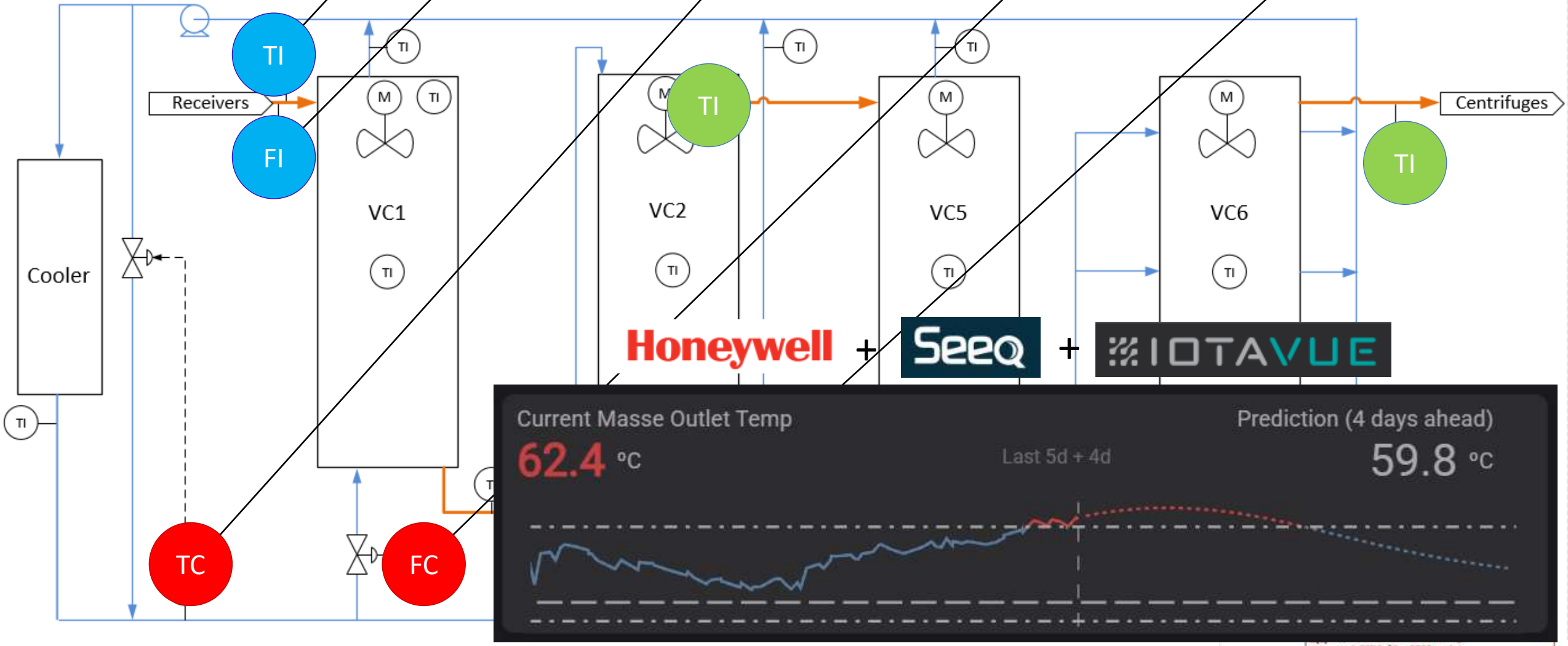
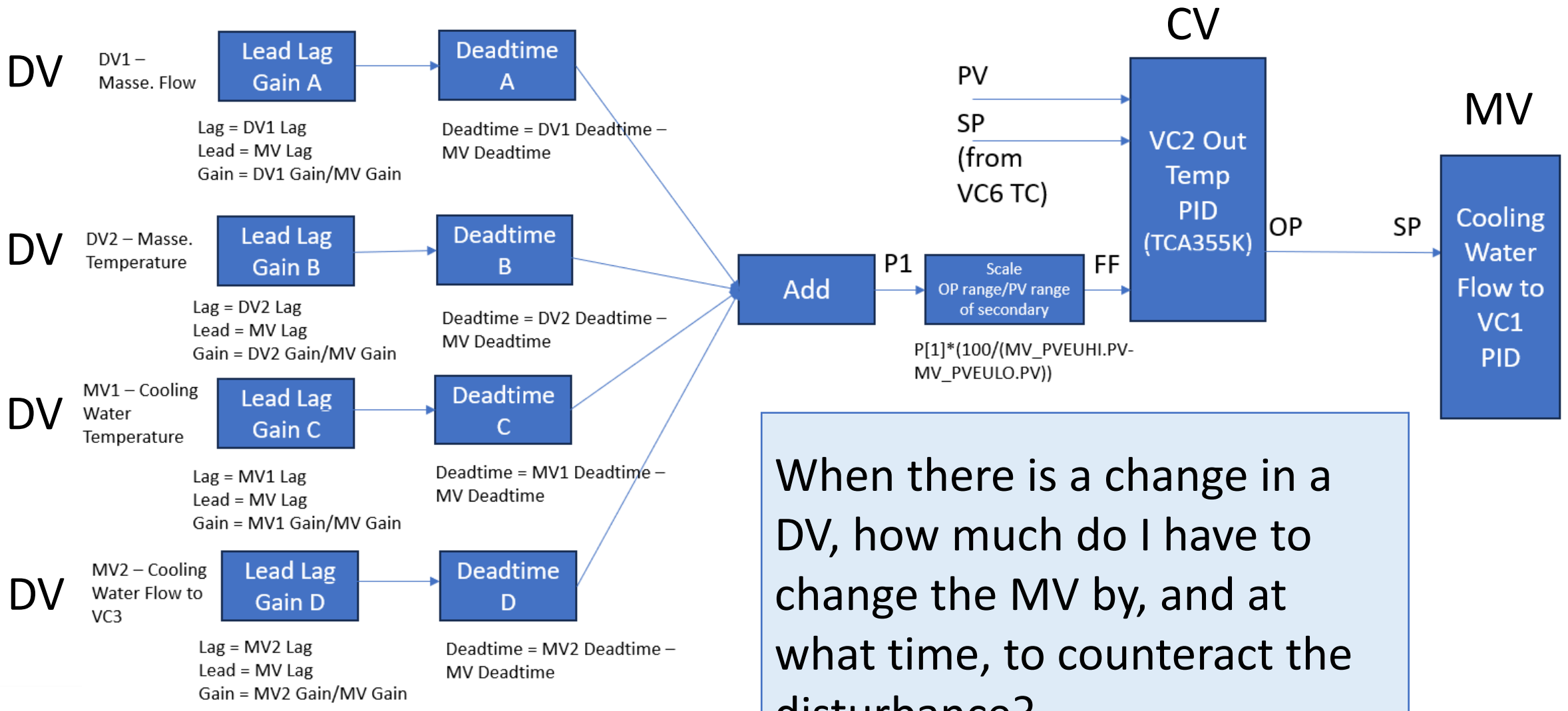
FIR form = Vel
Rank = 2
Trial 5
Pred+Opt+Con
Priority: Normal
G(s) = .86 / 900s + 1 e -0s
MV2 - CVFLOWTOVC1
FIR Order 29
ARX Order 2
Settle T = 6960
TfSettle = 3360
FIR form = Vel
** Rank = 5 **
Trial 5
Pred+Opt+Con
Priority: Normal
G(s) = -.318 / 82781s^2 + 567s + 1 e -15.8s + 1 -1200s
MV3 - CVFLOWTOVC2
FIR Order 30
Lap Order 1
Settle T = 8100
TfSettle = 3240
FIR form = Vel
Rank = 3-
Trial 6
Pred+Opt+Con
Priority: Normal
G(s) = -1.18 / 750s + 1 e -0s


TI
FI
Receivers
VC1
VC2
VC5
VC6
Centrifuges
Cooler
TC
FC
Honeywell
Seeq
IOTAVUE
Current Masse Outlet Temp
62.4 °C
Last 5d + 4d
Prediction (4 days ahead)
59.8 °C

Long Dynamics – Dynamic Feedforward



When there is a change in a DV, how much do I have to change the MV by, and at what time, to counteract the disturbance?

Other MVs treated like DVs

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"Everything should be made as simple as possible, but not simpler." – Albert Einstein

Thank you!

Thank you also to Gemma Sainty, Control Engineer, British Sugar and Howard Boder, NewLand Control

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