Unleash the Power of FREE DeltaV Model Predictive Control (MPC)

Session ID: 6-14908

POWERING COLLABORATION

DISCLAIMER

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Presenters

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  DeltaV Product Manager

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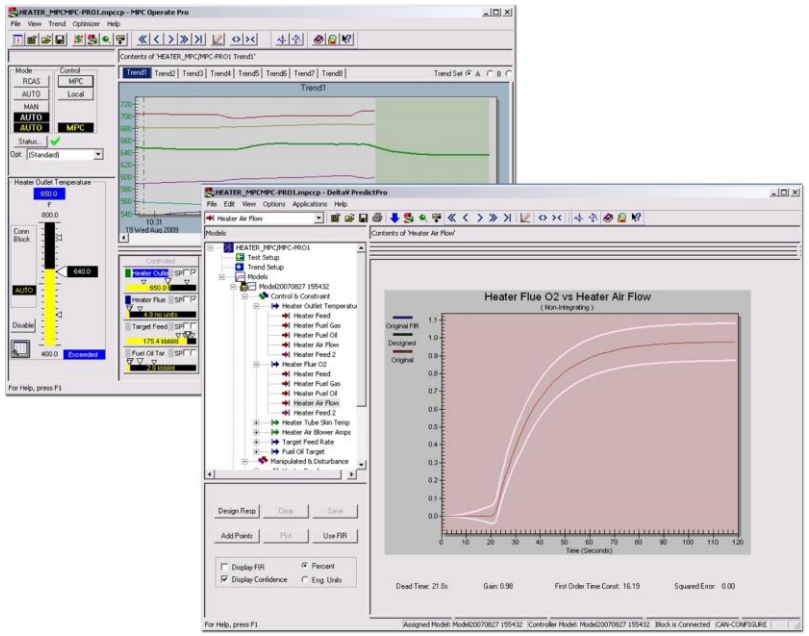
  APC Consultant

Agenda

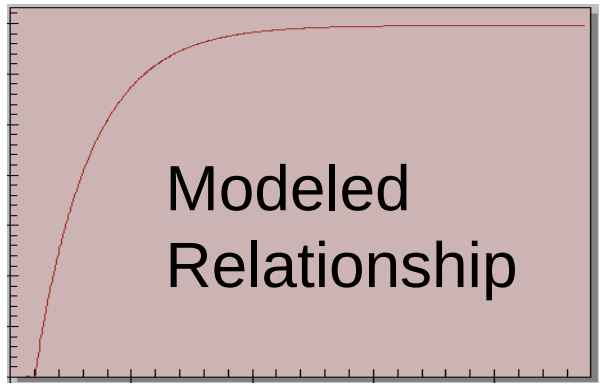
- What is Model Predictive Control (MPC)?
- What is DeltaV's FREE MPC product?
- Where would I use a single MV MPC controller?
- How to add MPC to existing PID control?
  - Live Demonstration
- Where to find more information

What is Model Predictive Control?

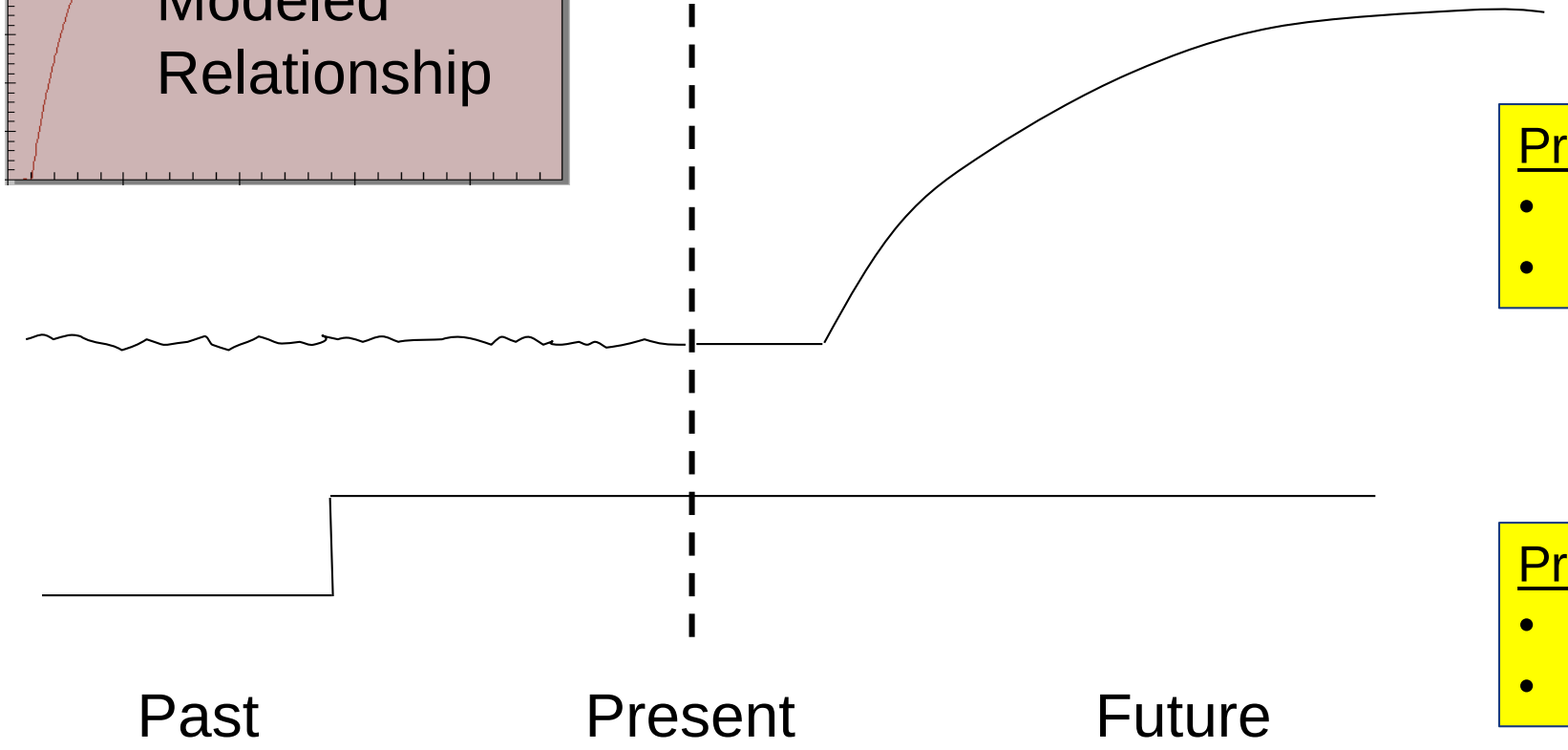


- Control method which is good at handling difficult process dynamics to reduces variability and protects constraints
  - Multiple process interactions decoupling
  - Disturbance rejection
  - Constraint protection
  - Deadtime compensation
- Optimizes process manipulated variables within unit constraints
  - Maximize throughput
  - Minimize energy
  - Increase yields of most valuable product

Model Predictive Control



Learns From The Past
To Predict The Future



Process Outputs
- Control Variables
- Constraint Variables

Process Inputs
- Manipulated Variables
- Disturbance Variables

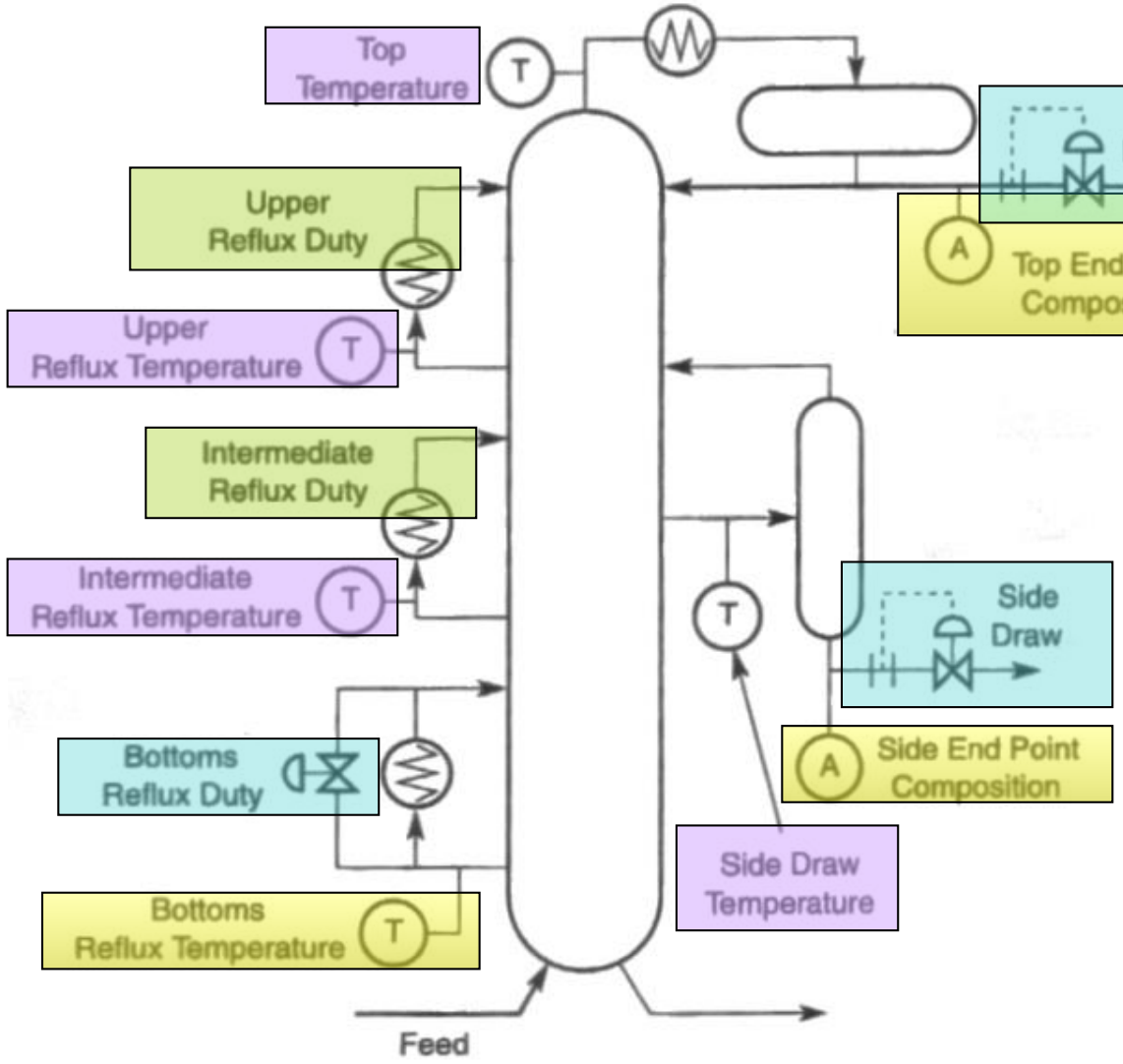
MPC – Example

- Consider the standard cruise control for an auto
  - Control Variable = Speed
  - Manipulated Variable – Accelerator pedal
- Enhanced Cruise Control
  - Control Variable = Speed
  - Constraint variable = Fuel Economy (mpg)
  - Manipulated Variable – Accelerator
  - Manipulated Variable – Brake
  - Disturbance Variable – Forward looking slope detection
  - Optimizer (fastest speed, best economy, highest profit, etc.)

MPC Example for Distillation Control

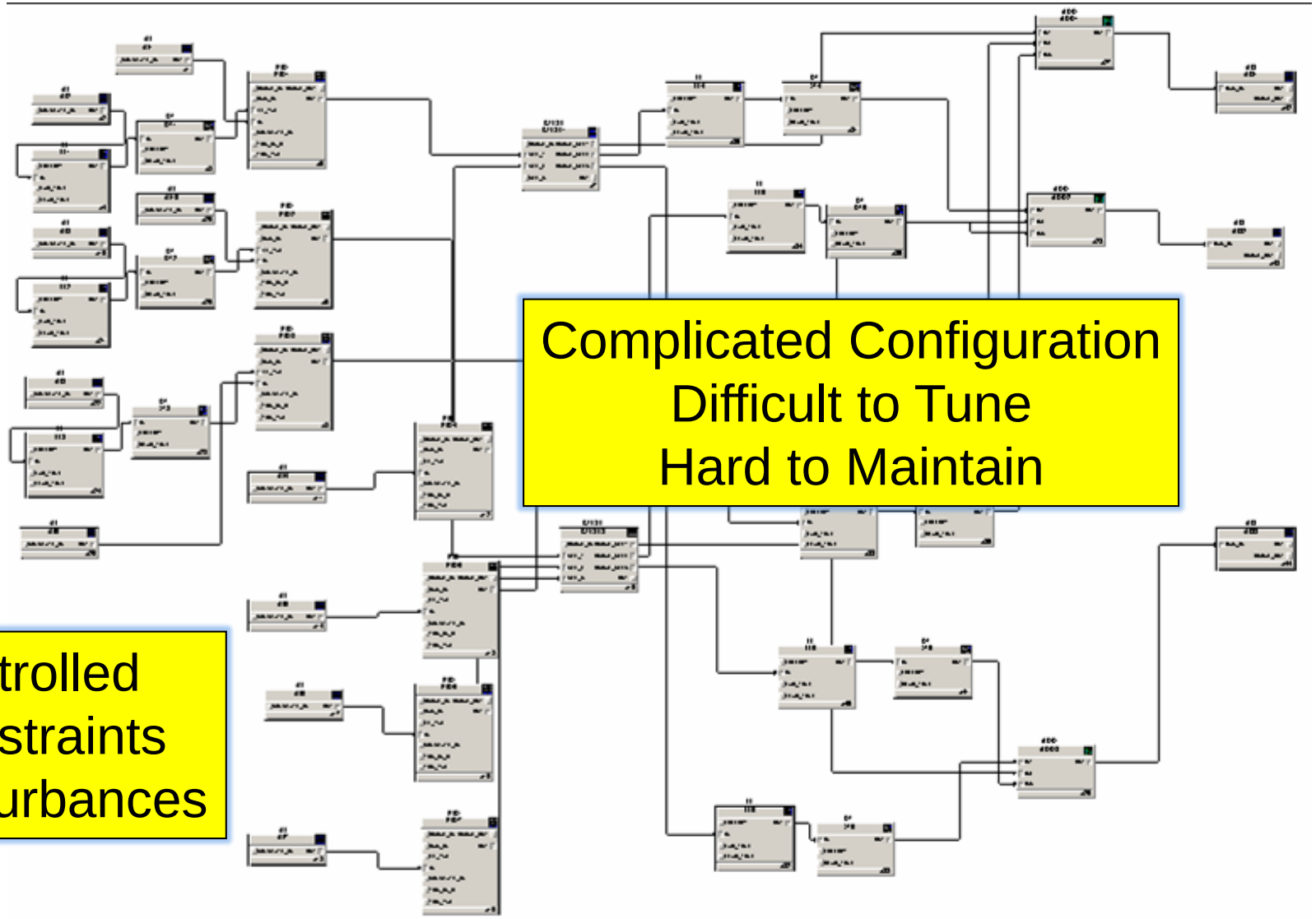
- Many Interactions
- Many Constraints
- Many Disturbances
- Long Delay Times
- Economic Optimization Opportunity

Distillation Example



Controlled
Manipulated
Constraints
Disturbances

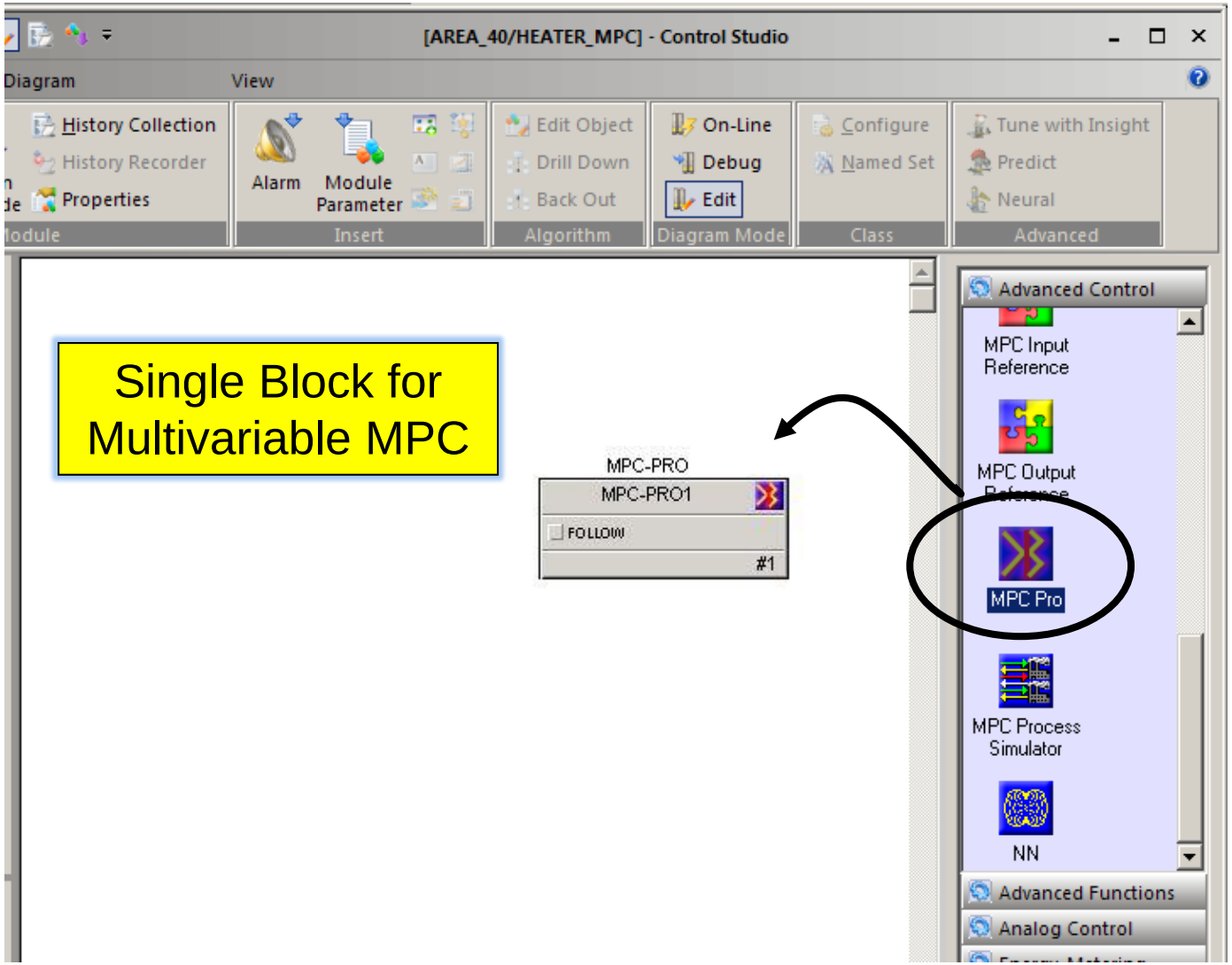
Traditional Control with PID and Feedforward



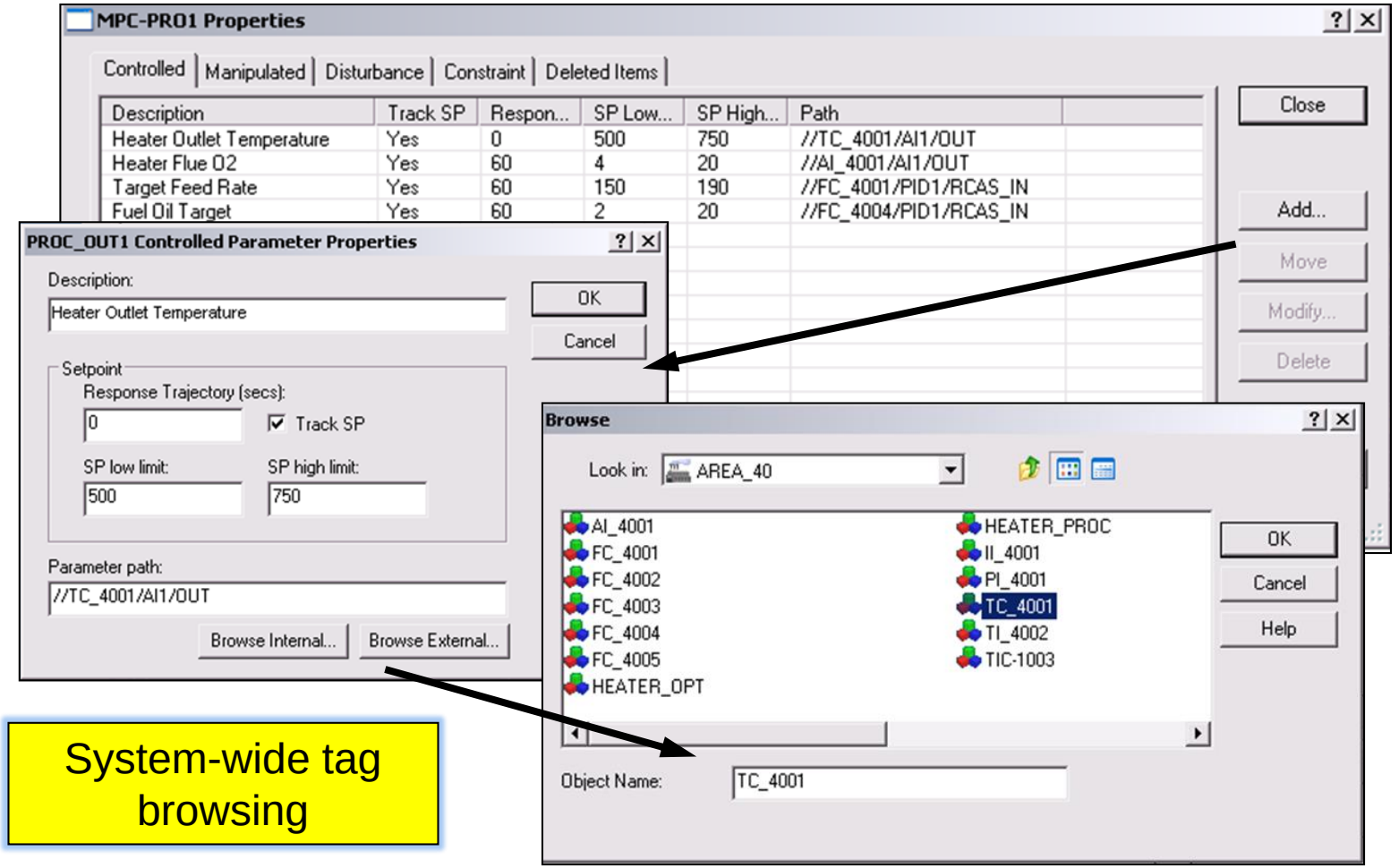
Complicated Configuration
Difficult to Tune
Hard to Maintain

3 Controlled
4 Constraints
3 Disturbances

DeltaV MPC Configuration



DeltaV MPC Configuration

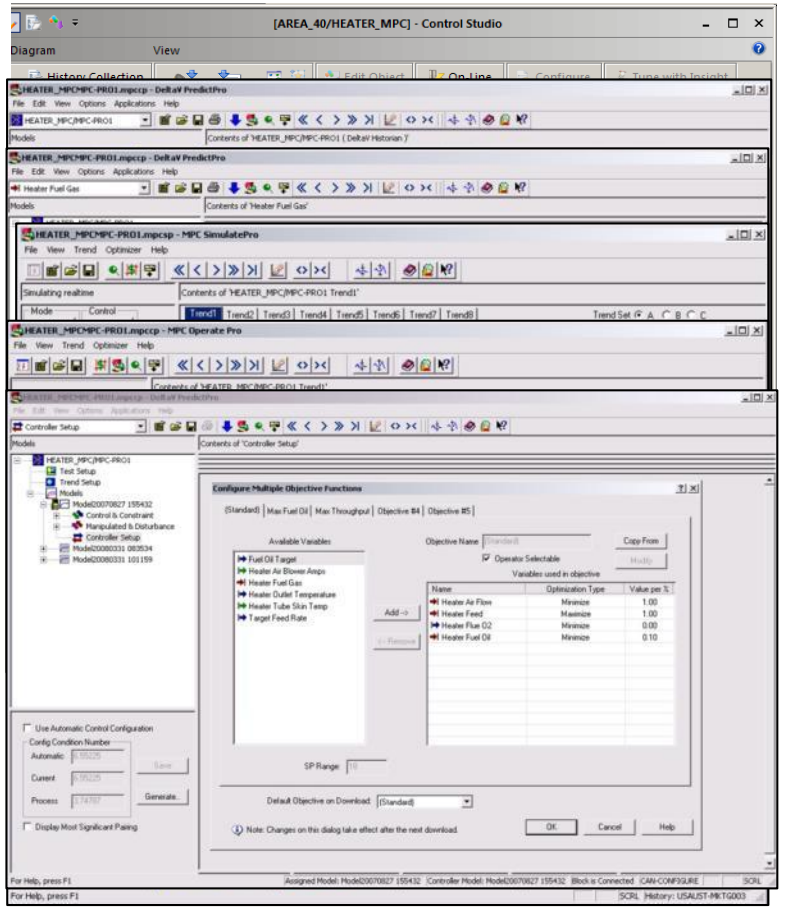


System-wide tag browsing

… all in the DCS database

DeltaV PredictPro – Key Features

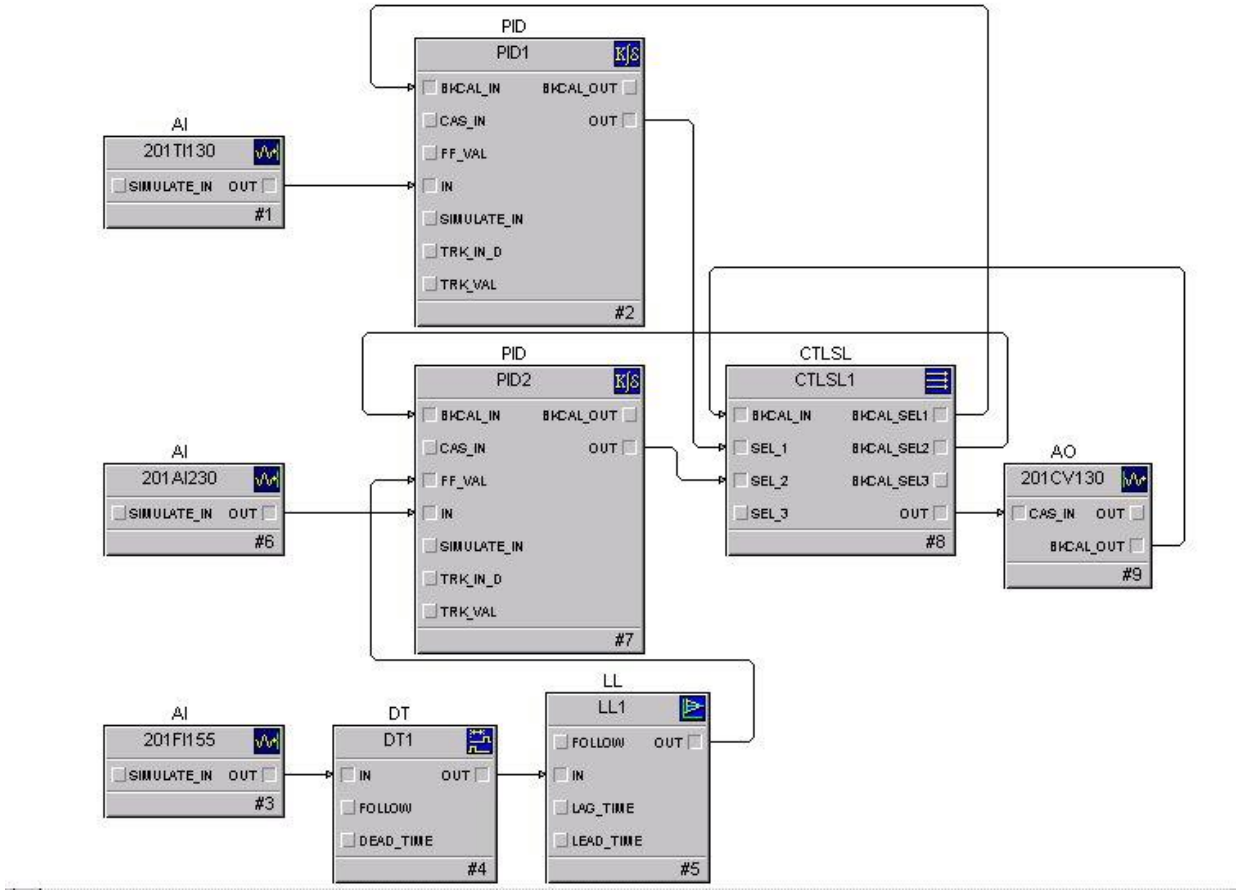
- Easy Configuration with DeltaV Control Studio
- Integrated with DeltaV Database and Historian
- Automated Plant Testing and Model ID
- Off-line Simulator for Testing and Training
- Standard Operator Displays
- Embedded Flexible LP Optimization
- Scalable, Practical, Easy to Use
  - – Licensed by # MVs



What is DeltaV FREE MPC?

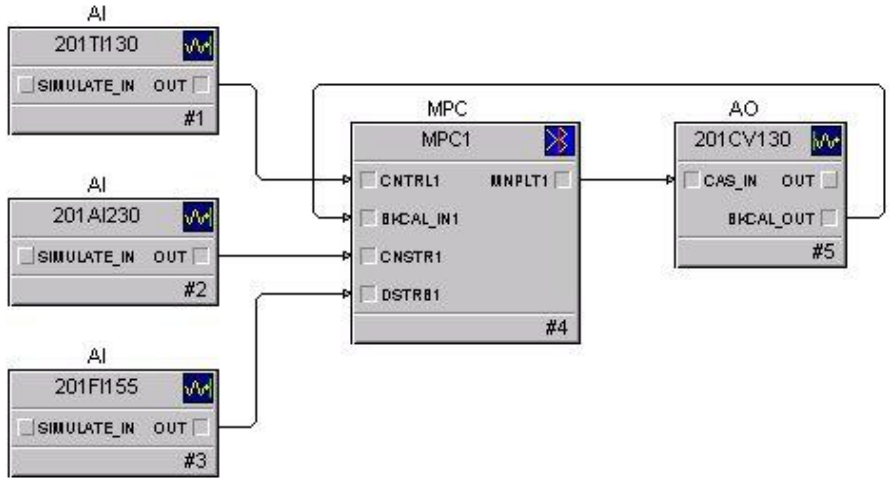
- All single MV MPC applications are FREE
  - No license required
- What single MV MPC can do well:
  - Constraint override
  - Deadtime compensation
  - Disturbance rejection
- What single MV MPC cannot do:
  - Optimization for multiple MVs
  - Process interaction decoupling for multiple MVs

Single MV MPC Example



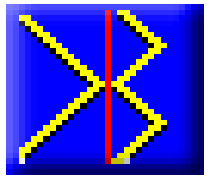
Traditional Approach

Example: Control loop with one manipulated variable, one disturbance and one constraint



MPC

Which MPC block should I use?



MPC

MPC Pro

MPC Plus

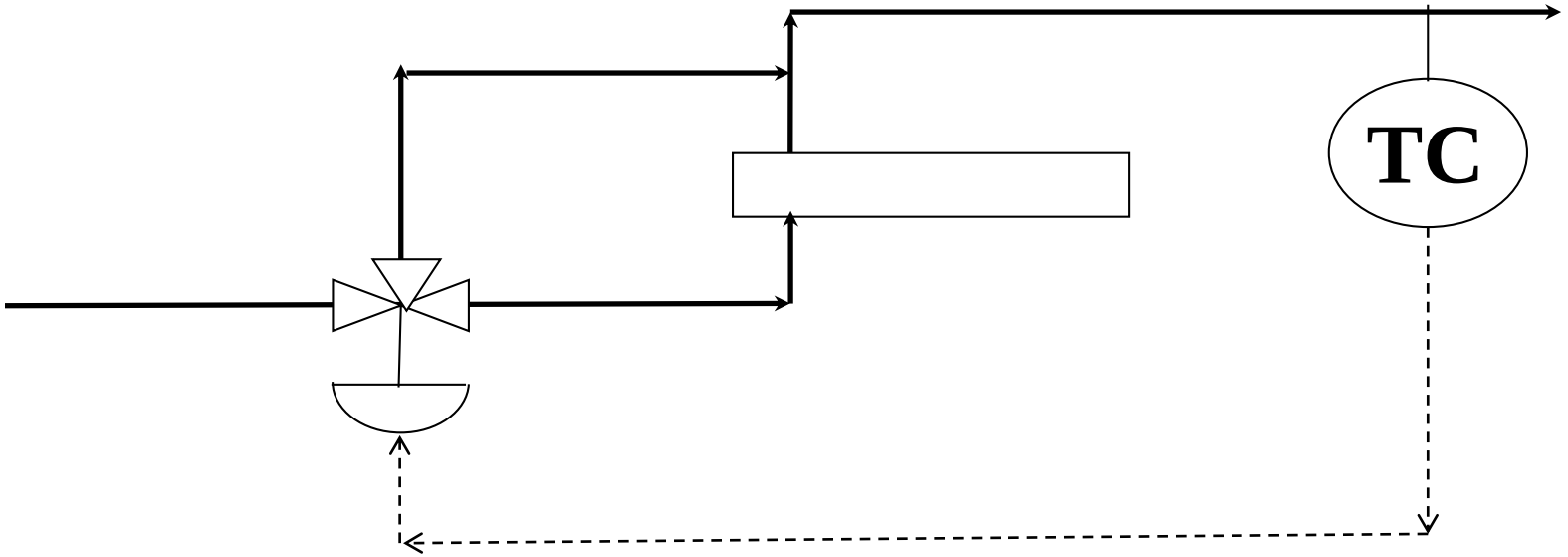
- MPC block
  - MPC without optimization
  - Smaller applications, runs in controller or workstation
  - Simple implementation
- MPCPro
  - MPC with optimization
  - Larger applications, runs in controller or workstation
  - Fixed models, fixed control configuration only
- MPCPlus
  - MPC with optimization
  - Larger applications / runs in workstation only
  - Supports non-linear models, flexible configuration

✓ Simplest for Single MV MPC

Demonstration - Adding MPC To Existing Control

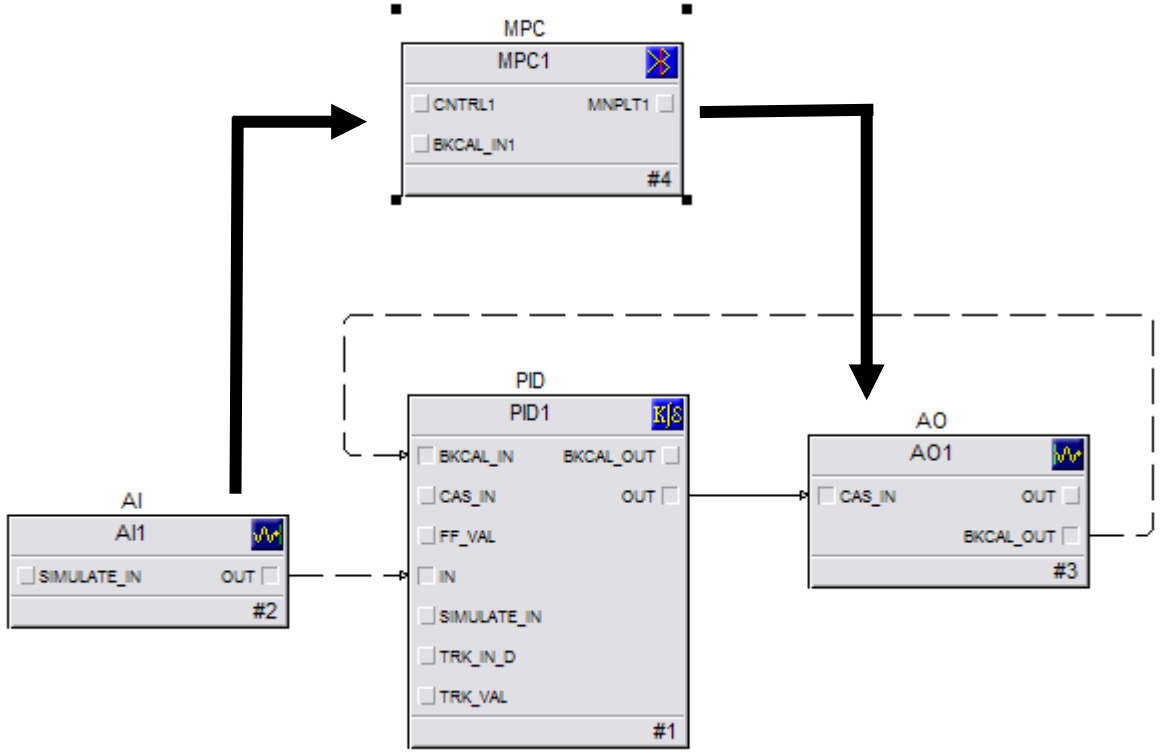
- The following slides demonstrate typical steps required to implement an MPC controller as an alternative (not necessarily a replacement) to an existing PID controller
- The presentation included a live demonstration. These slides are for reference.

Deadtime Compensation with MPC



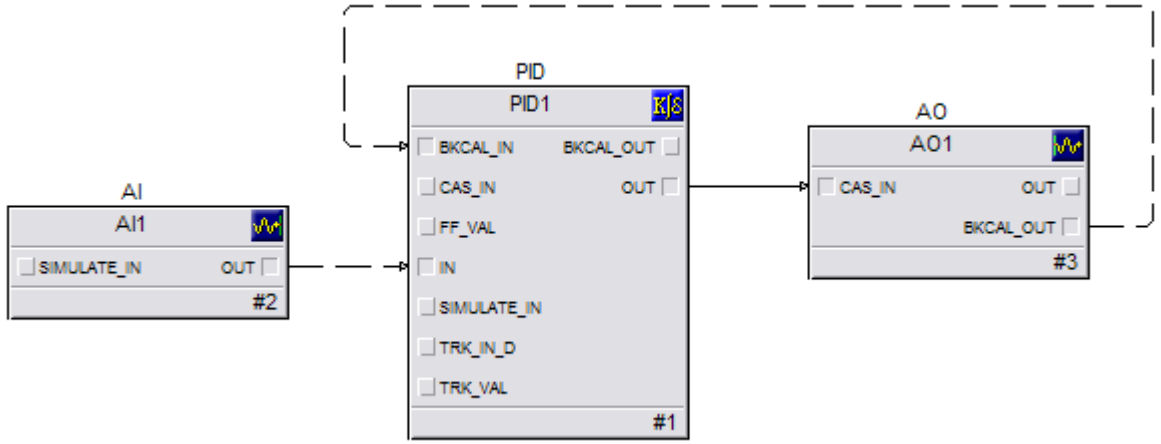
- Gasoline feed preheater for sulfur removal
- “Mixing” temperature response fast (Tau=5-10 seconds)
- Step test revealed 9 minutes of dead time!
- Temperature measurement ~500 ft downstream!

MPC for PID Replacement

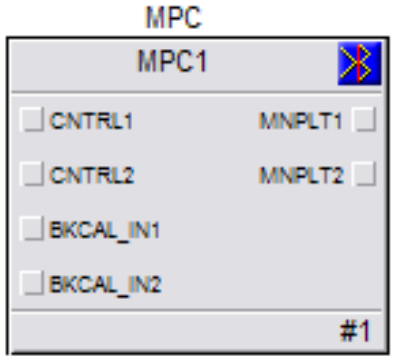


Recommend implementing MPC in a separate module.

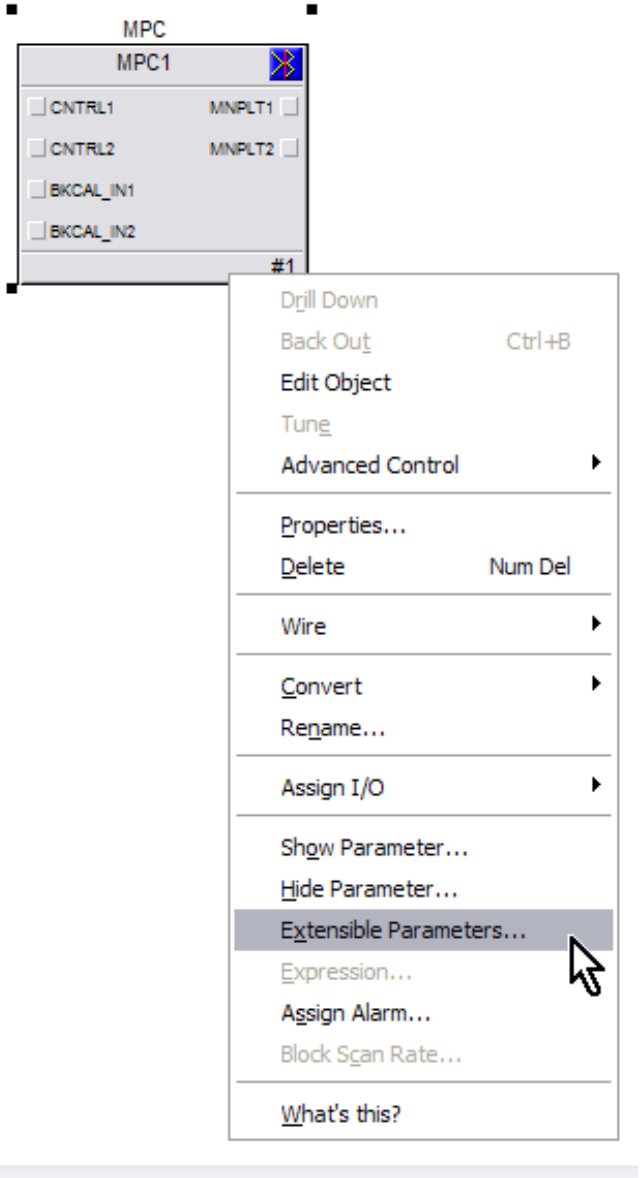
No changes to existing PID module



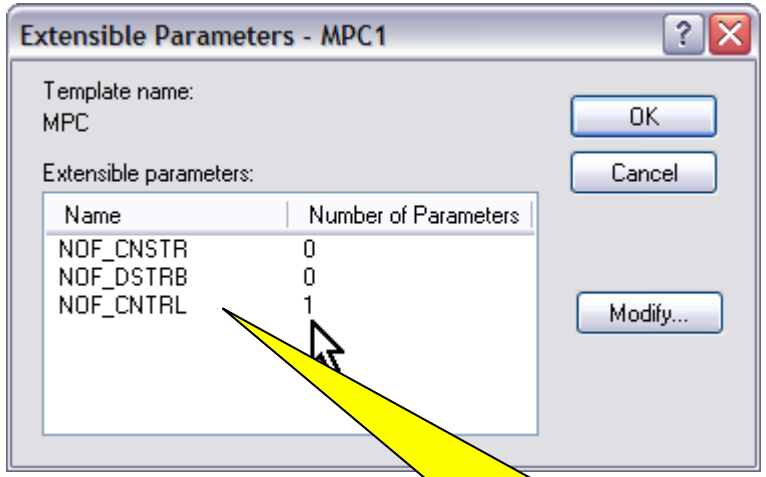
Create A New MPC Module



Specify Single MV MPC (1 in x 1 out)

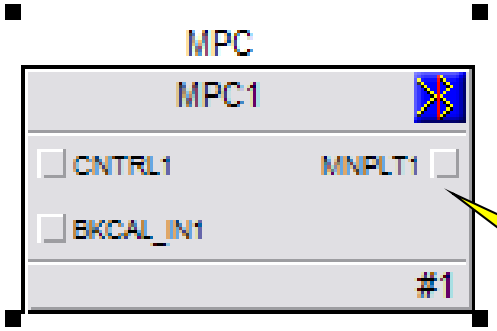


Change The Number Of Controlled Variables



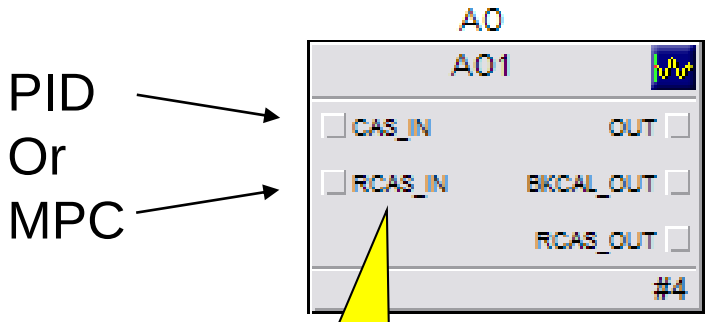
Change Your Number Of Controlled Variables to One (which activates 1 MV)

Single MV MPC



Now It's The Right Size For Your FREE MPC application.

Did You Know?.....



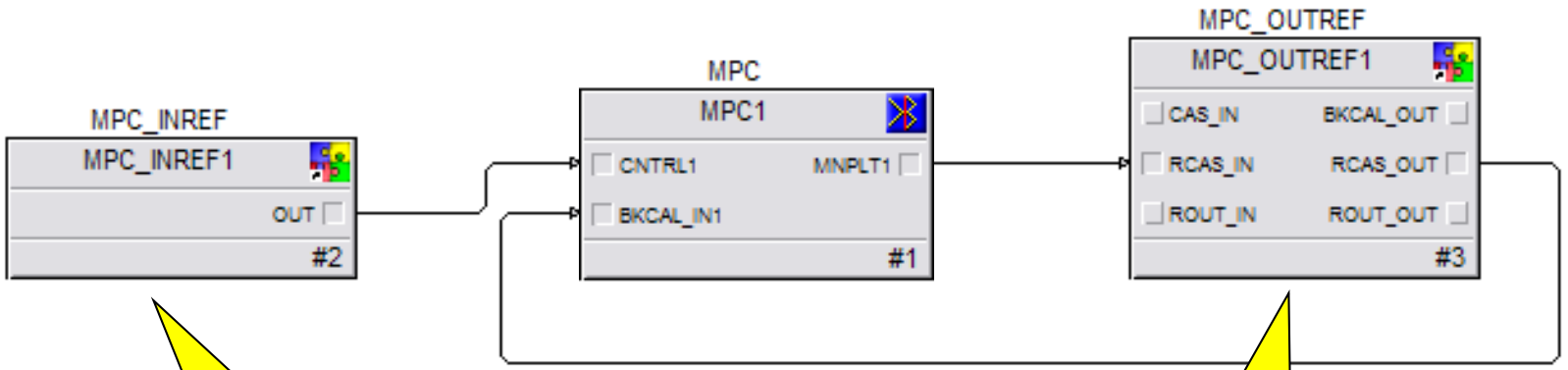
The AO Block Supports RCAS Mode

This Is How We'll Write To The Analog Out Block In The PID Module

Note: You do not have to expose the RCAS for this method to work.

Connect With The Existing PID In Other Module

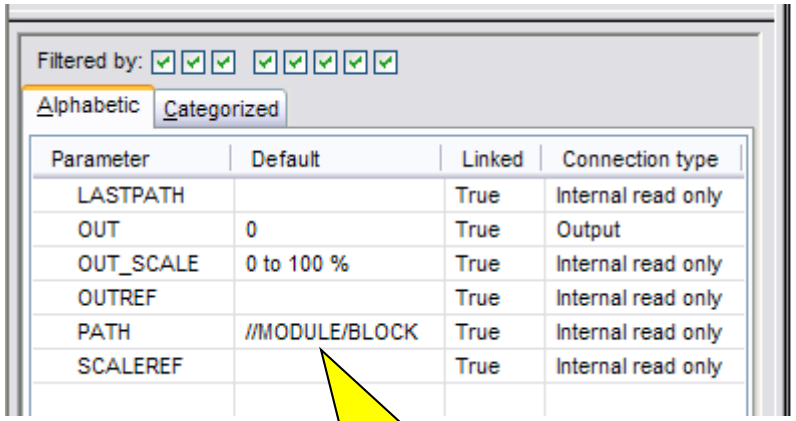
Use MPC_INREF and MPC_OUTREF to connect MPC block to signals in other modules! Not required for MPCPro and MPCPlus (more later).

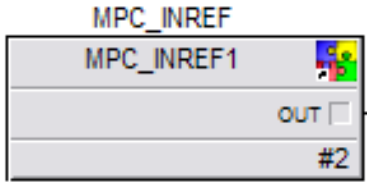


Now Connect This Block To The AI Block In The PID Module

Connect This One To The AO Block In The PID Module

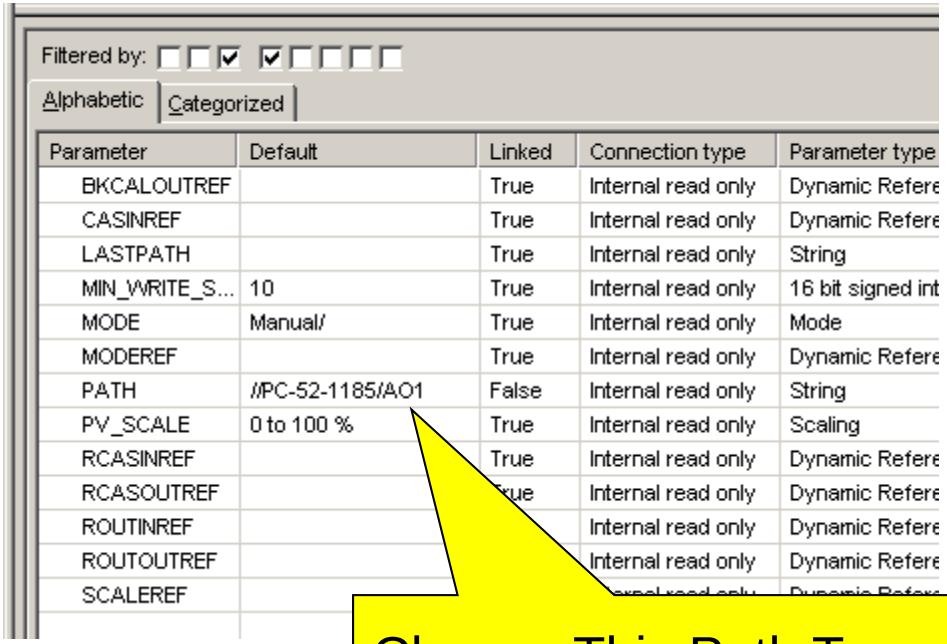
Define AI path for MPC_INREF

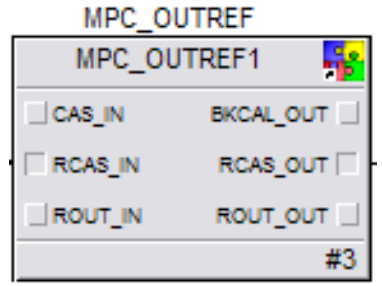




Change This Path To Your PID Module And Block. Example; //PC-52-1185/AI1

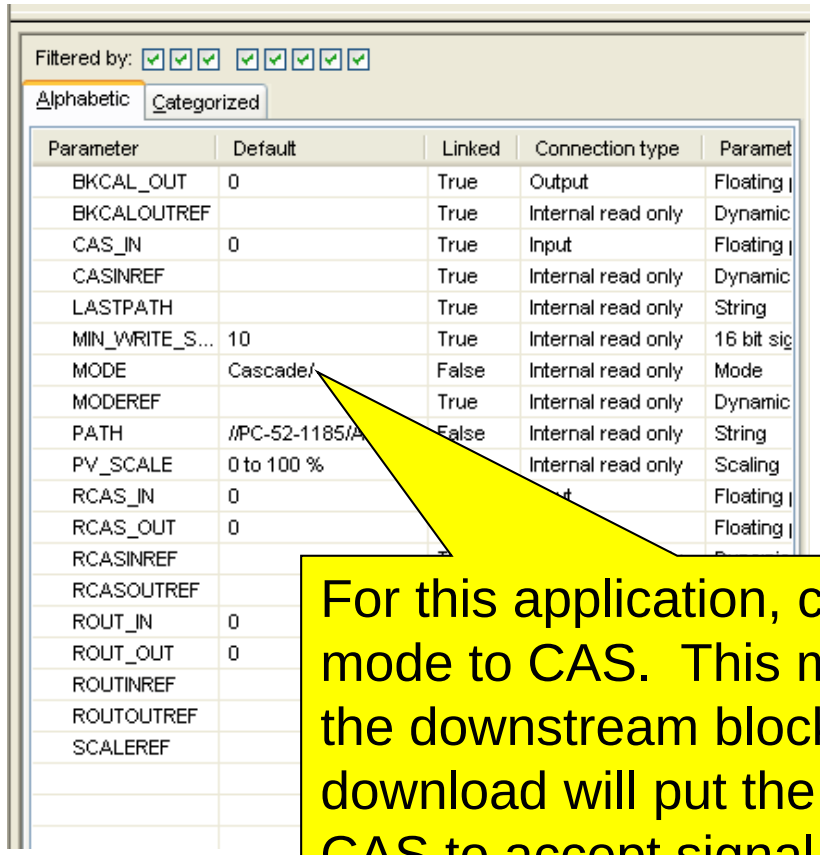
Define AO path for MPC_OUTREF

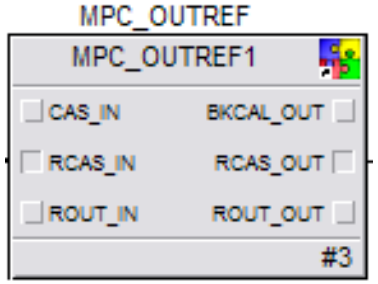




Change This Path To Your PID Module And AO Block. Example; //PC-52-1185/AO1

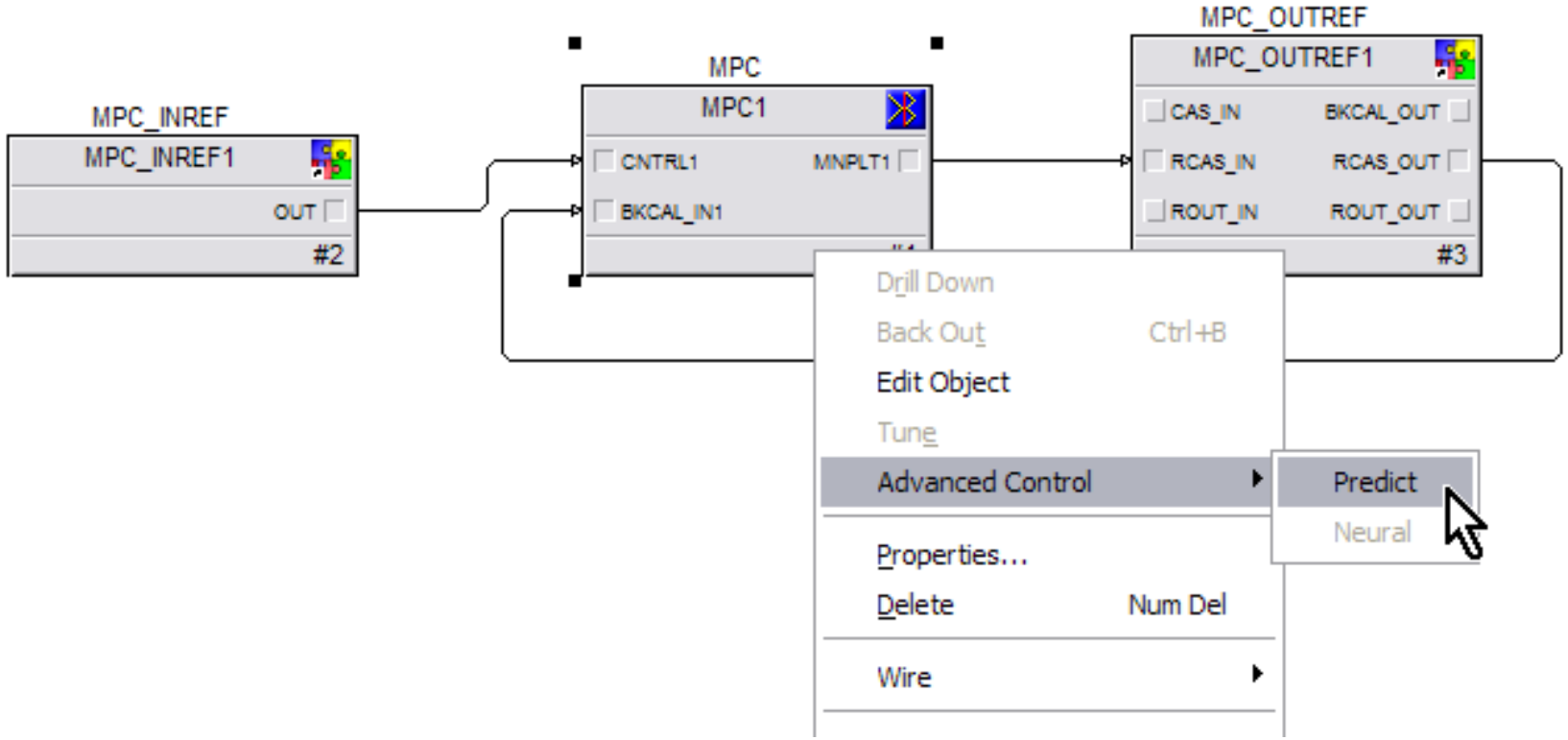
Specify CAS Mode for OUTREF Block

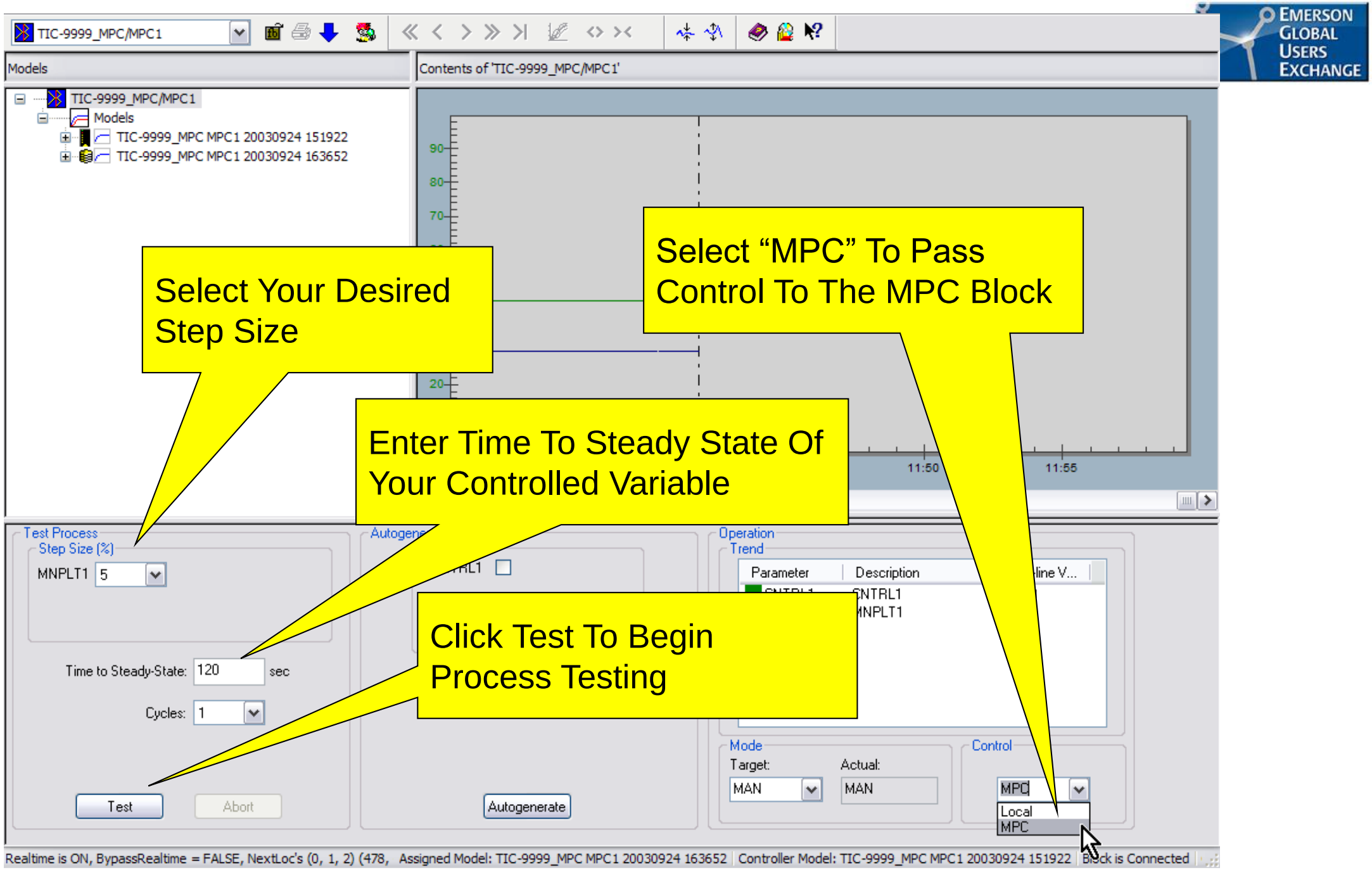


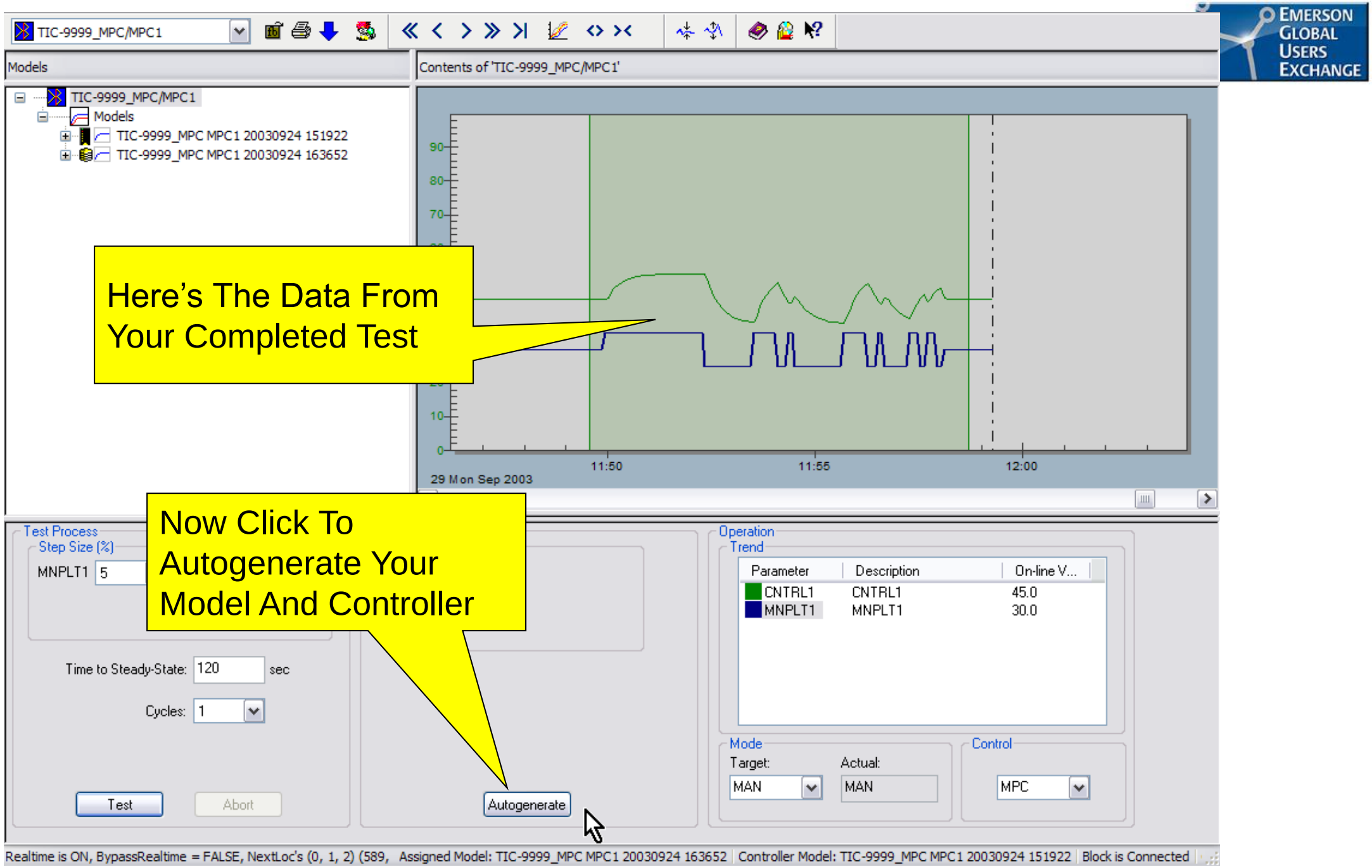


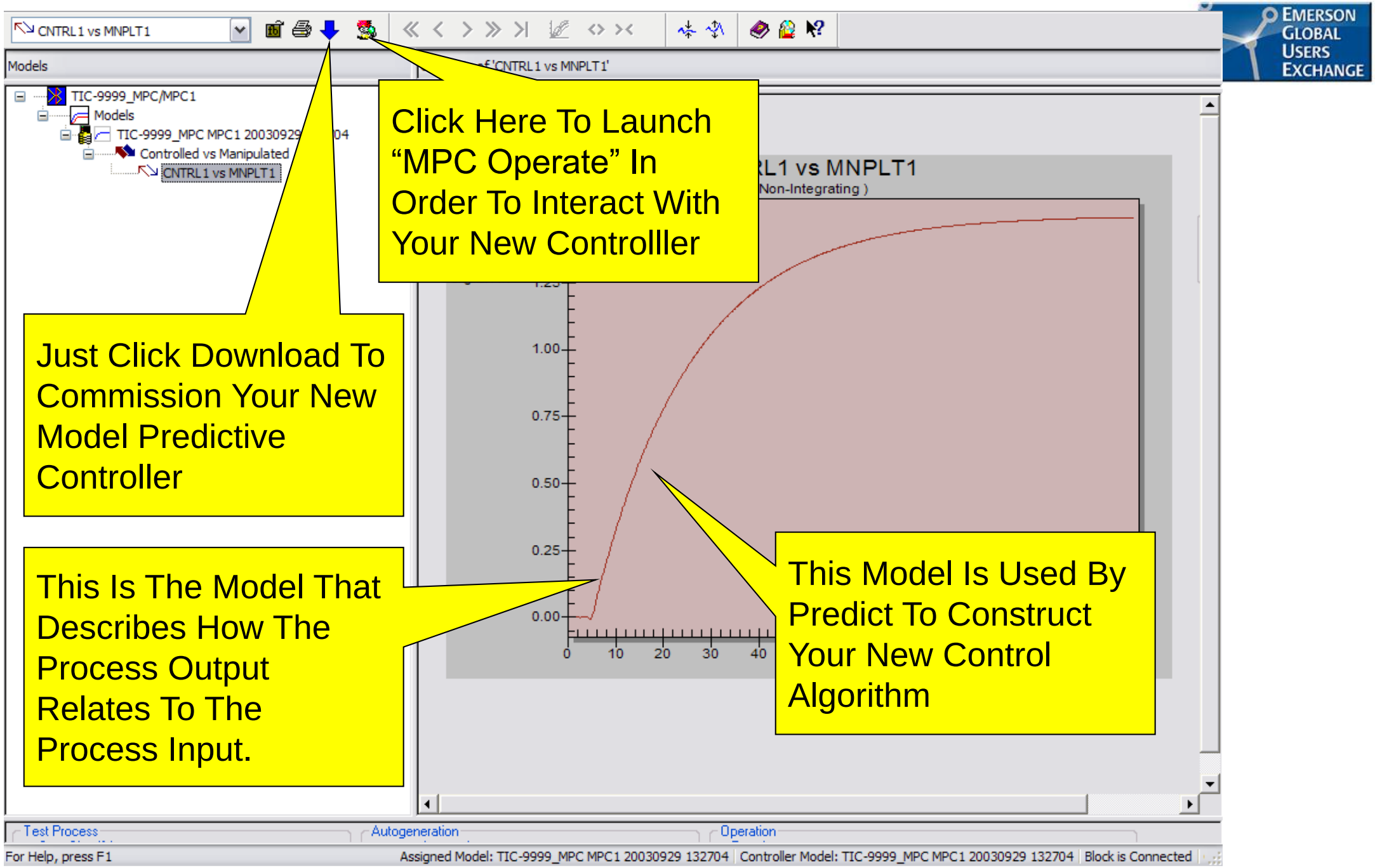
For this application, change the mode to CAS. This mode applies to the downstream block. Thus, a download will put the AO block in CAS to accept signal from PID. (Default is MAN when the downstream block is a PID.)

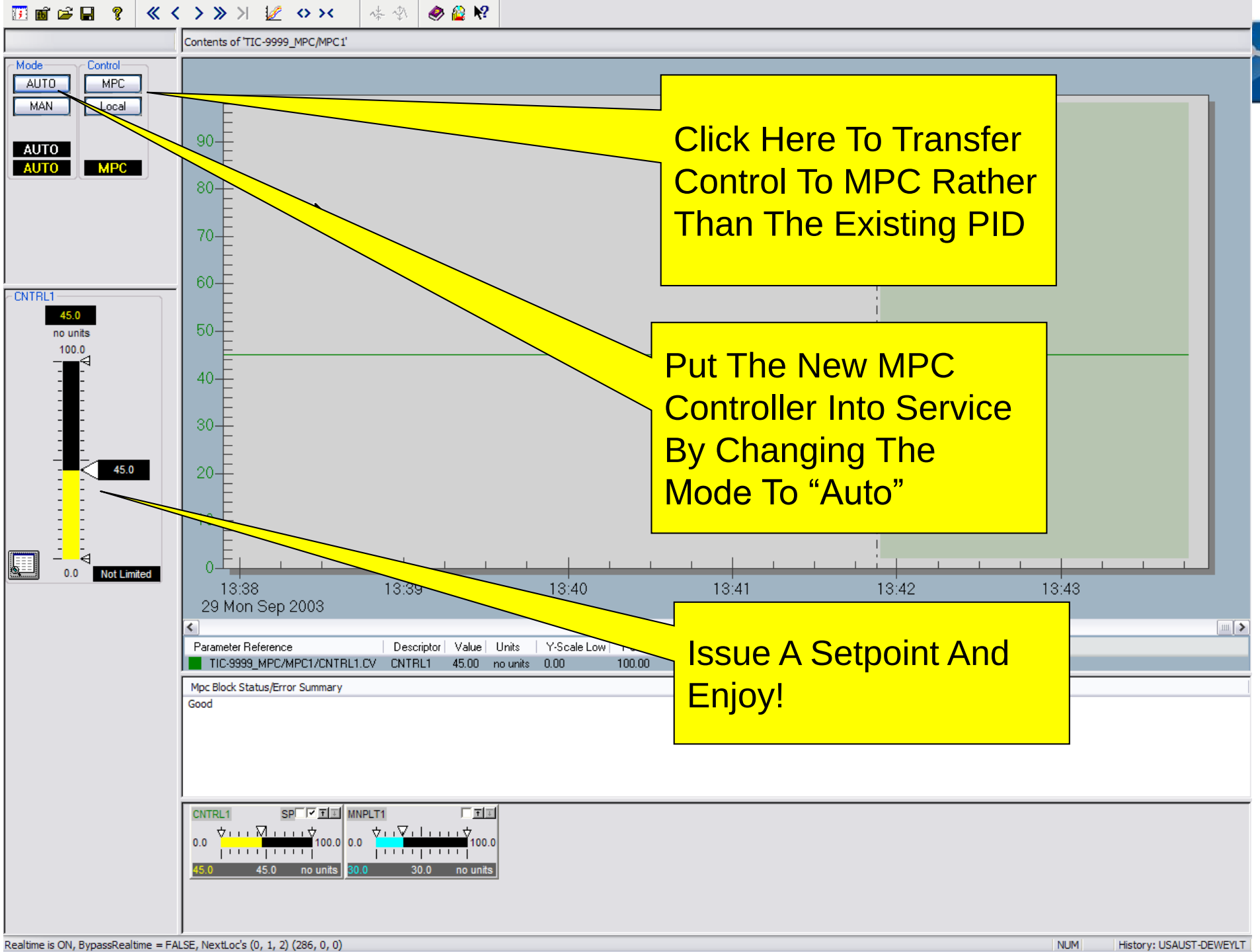
Save, Download, Test The Process - Predict




TIC-9999_MPC/MPC1
Models
Contents of 'TIC-9999_MPC/MPC1'
TIC-9999_MPC/MPC1
Models
TIC-9999_MPC MPC1 20030924 151922
TIC-9999_MPC MPC1 20030924 163652
90
80
70
20
11:50
11:55
Select Your Desired Step Size
Select “MPC” To Pass Control To The MPC Block
Enter Time To Steady State Of Your Controlled Variable
Click Test To Begin Process Testing
Test Process
Step Size (%)
MNPLT1
5
Time to Steady-State:
120
sec
Cycles:
1
Test
Abort
Autogenerate
Operation
Trend
Parameter
Description
CNTRL1
MNPLT1
Mode
Target:
Actual:
MAN
MAN
Control
MPC
Local
MPC
Realtime is ON, BypassRealtime = FALSE, NextLoc's (0, 1, 2) (478,
Assigned Model: TIC-9999_MPC MPC1 20030924 163652
Controller Model: TIC-9999_MPC MPC1 20030924 151922
Block is Connected


TIC-9999_MPC/MPC1
Models
Contents of 'TIC-9999_MPC/MPC1'
TIC-9999_MPC/MPC1
Models
TIC-9999_MPC MPC1 20030924 151922
TIC-9999_MPC MPC1 20030924 163652
90
80
70
10
0
11:50
11:55
12:00
29 Mon Sep 2003
Here's The Data From Your Completed Test
Now Click To Autogenerate Your Model And Controller
Test Process
Step Size (%)
MNPLT1 5
Time to Steady-State: 120 sec
Cycles: 1
Test
Abort
Autogenerate
Operation
Trend
Parameter
Description
On-line V...
CNTRL1
CNTRL1
45.0
MNPLT1
MNPLT1
30.0
Mode
Target:
Actual:
MAN
MAN
Control
MPC
Realtime is ON, BypassRealtime = FALSE, NextLoc's (0, 1, 2) (589, Assigned Model: TIC-9999_MPC MPC1 20030924 163652 | Controller Model: TIC-9999_MPC MPC1 20030924 151922 | Block is Connected


CNTRL1 vs MNPLT1
Models
TIC-9999_MPC/MPC1
Models
TIC-9999_MPC MPC1 20030929
Controlled vs Manipulated
CNTRL1 vs MNPLT1
Click Here To Launch "MPC Operate" In Order To Interact With Your New Controlller
Just Click Download To Commission Your New Model Predictive Controller
This Is The Model That Describes How The Process Output Relates To The Process Input.
This Model Is Used By Predict To Construct Your New Control Algorithm
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
Test Process
Autogeneration
Operation
For Help, press F1
Assigned Model: TIC-9999_MPC MPC1 20030929 132704
Controller Model: TIC-9999_MPC MPC1 20030929 132704
Block is Connected



Click Here To Transfer Control To MPC Rather Than The Existing PID

Put The New MPC Controller Into Service By Changing The Mode To “Auto”

Issue A Setpoint And Enjoy!

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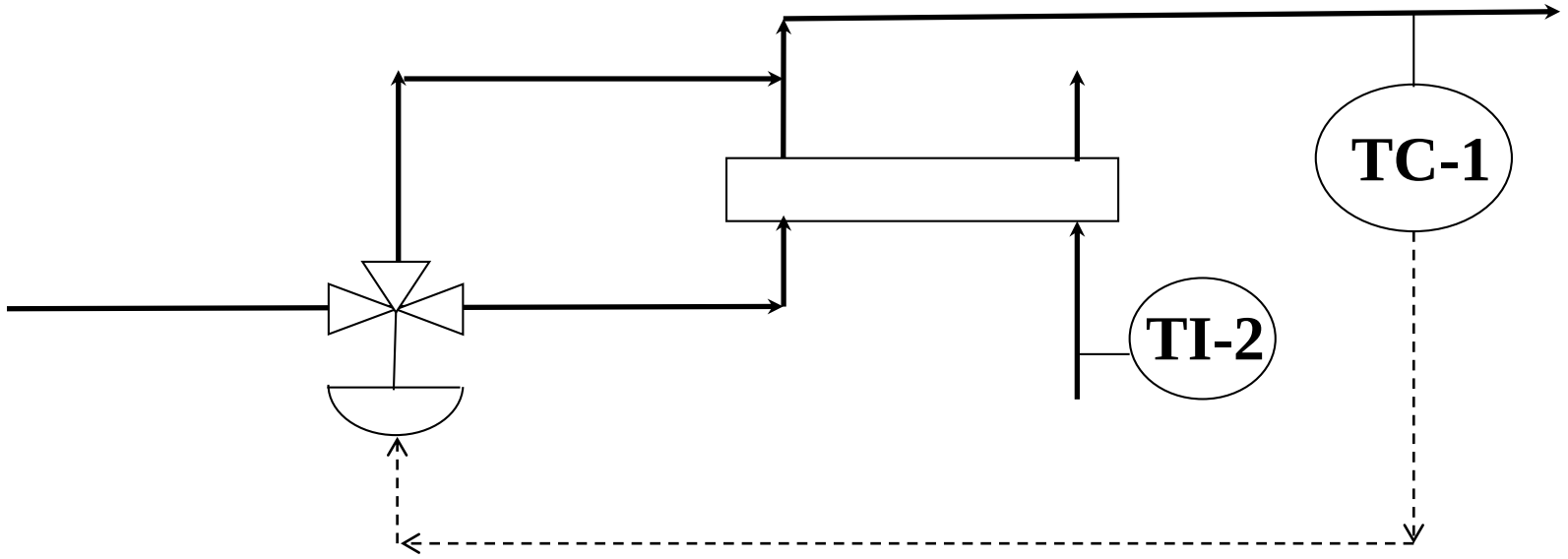
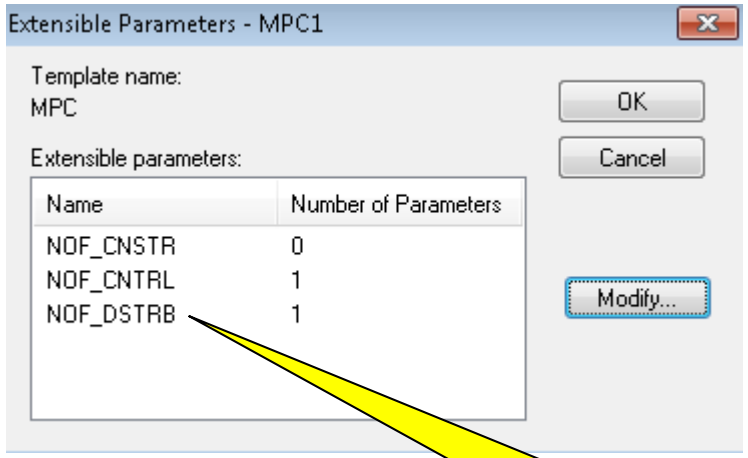
Disturbance Rejection with MPC



- Temperature of heating stream impacts outlet temp
- Typically implemented as feedforward to PID (calculate FFWD Gain, dead time, lead-lag
- Use TI-2 as a Disturbance Variable with MPC-simple model

Add a Disturbance Variable



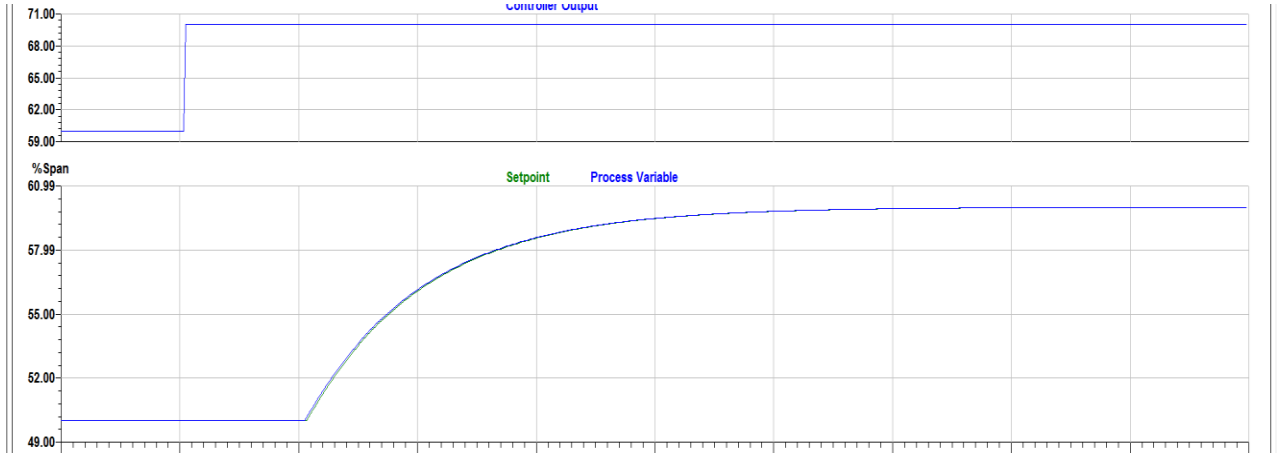
Change Your Number Of Disturbance Variables to One

Feed Forward with MPC

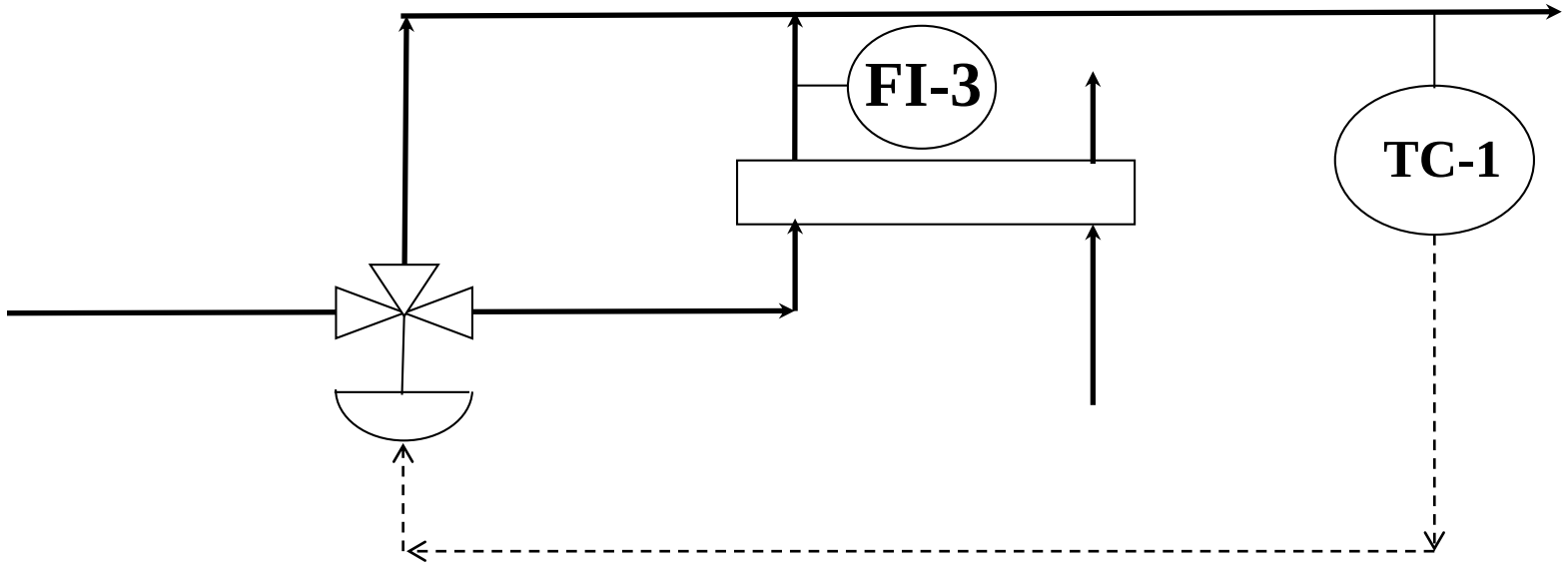
- Add a model from the DV to the CV
  - Analyze changes of DV with Predict (or PredictPro for MPCPro, MPCPLus)
  - Calculate model
  - May also calculate model from a loop tuning package such as InSight or Entech Toolkit

Loop Overview

Area0:	
Area1:	
Area2:	
Tag:	PV
Desc:	Process Variable
Process:	*Unknown*
Response:	1st Order
Parameters:	Kp=0.5300 %Span/%Out, Td=536.0 Sec, Tau1=248.0 Sec

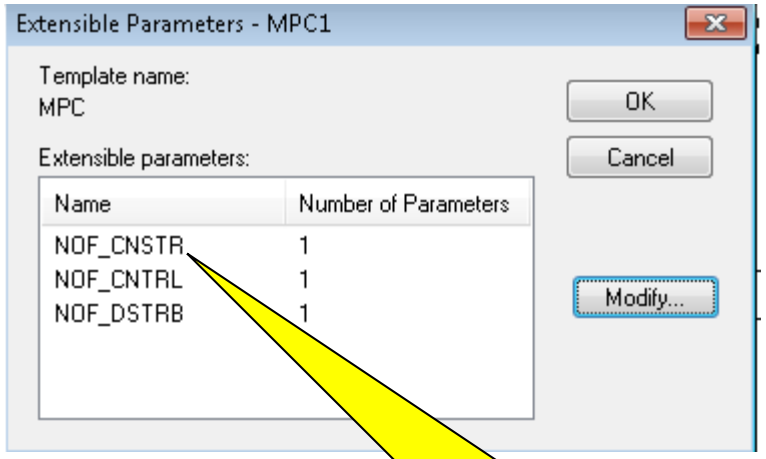


Constraint Override with MPC



- Suppose there is a minimum flow through exchanger tubes, FI-3, to avoid fouling
- Typically done with 2 PID's and a hi/lo selector
- Implement as a Constraint Variable (LV) with MPC

Add a Constraint Variable

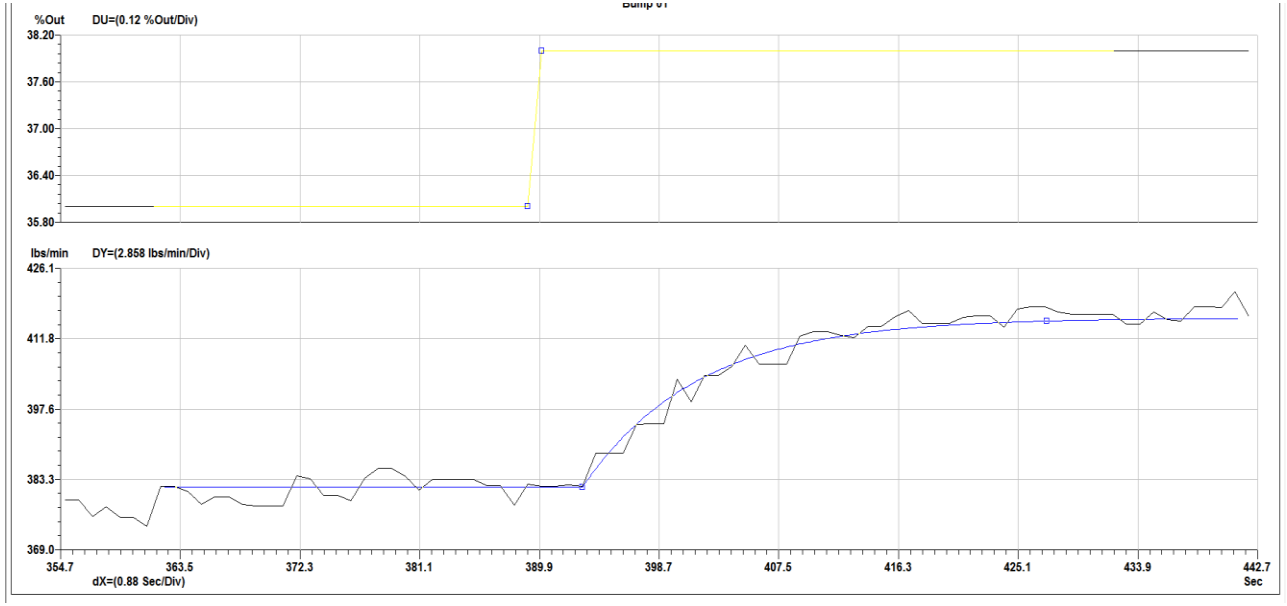


Change Your Number Of Constraint Variables to One

Constraint Control with MPC

- Add a model from the MV to the Constraint Variable
  - Analyze steps of MV with Predict (or PredictPro for MPCPro, MPCPLus)
  - Calculate model
  - May also calculate model from a loop tuning package such as InSight or Entech Toolkit

Process:	*Unknown*
Response:	1st Order
Parameters:	Kp=0.8596 %Span/%Out, Td=4.000 Sec, Tau1=8.538 Sec
Actuator:	*Unknown*, Class: 1 (Poor)



Where To Get More Information

- **Published Advanced Control Books**
  - **Control Loop Foundation – Batch and Continuous Processes**
  - **Advanced Control Foundation – Tools, Techniques, and Applications**
  - May be purchase through the ISA web site - http://www.isa.org/
- **Control Loop Foundation Web Site**
  - Includes book workshops - http://www.controlloopfoundation.com/
- **Contact your local Emerson business partner**
- Additional questions:
  - John.Caldwell@Emerson.com
  - James.Beall@Emerson.com

Summary

- Model Predictive Control Fundamentals
- FREE Single MV DeltaV MPC
- Demonstrations
- Questions?

Thank You for Attending!

Enjoy the rest of the conference.

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