

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

Session ID: 6-14908

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Presenters



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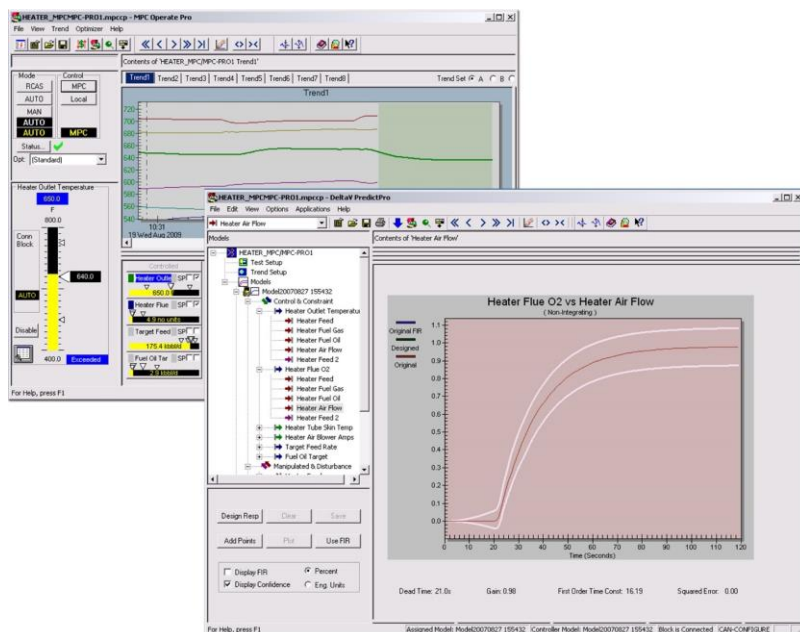


Agenda

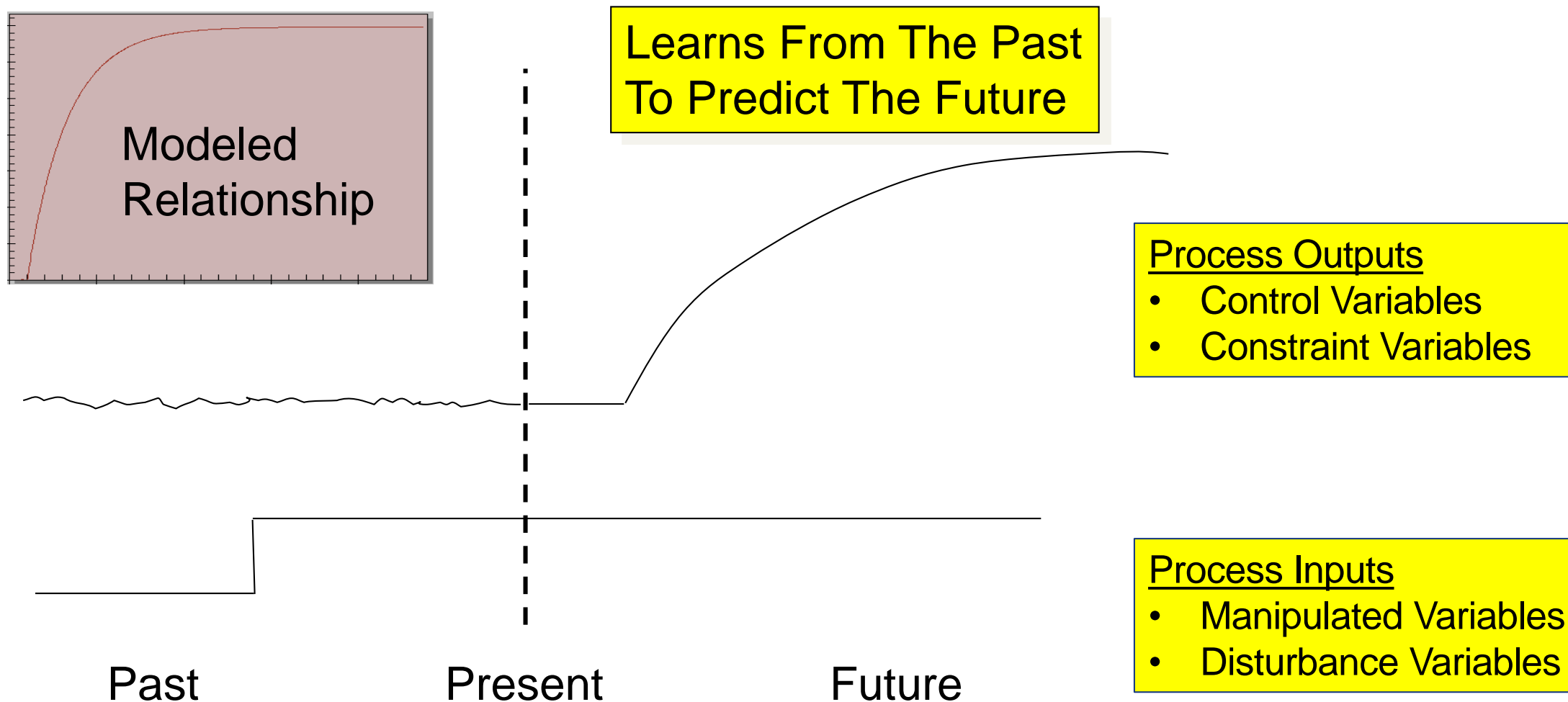
- What is Model Predictive Control (MPC)?
- What is DeltaV's FREE MPC product?
- Where would I use a single MV MPC controller?
- How to add MPC to existing PID control?
 - Live Demonstration
- Where to find more information

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



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.)

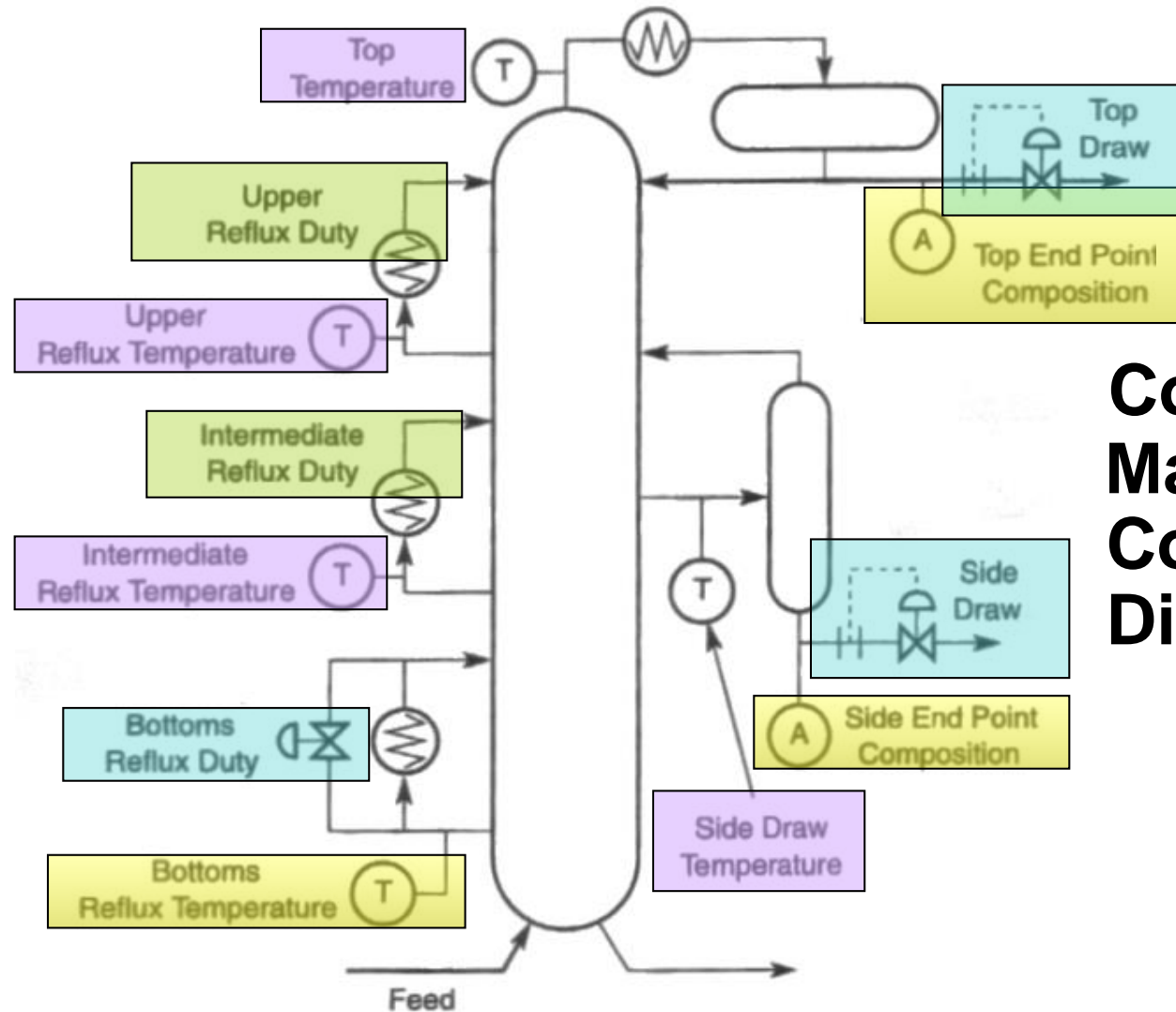


MPC Example for Distillation Control



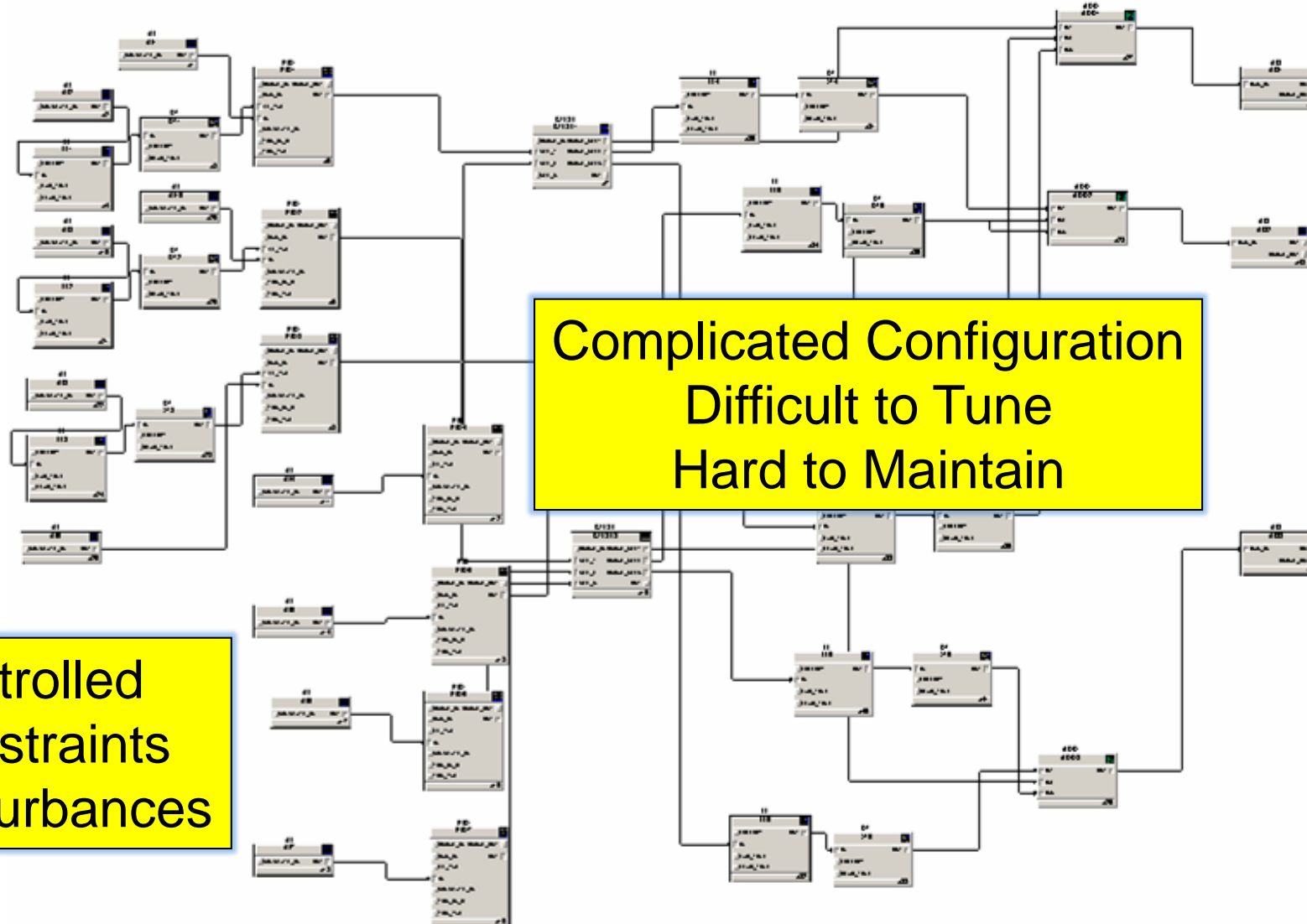
- Many Interactions
- Many Constraints
- Many Disturbances
- Long Delay Times
- Economic Optimization Opportunity

Distillation Example



Controlled
Manipulated
Constraints
Disturbances

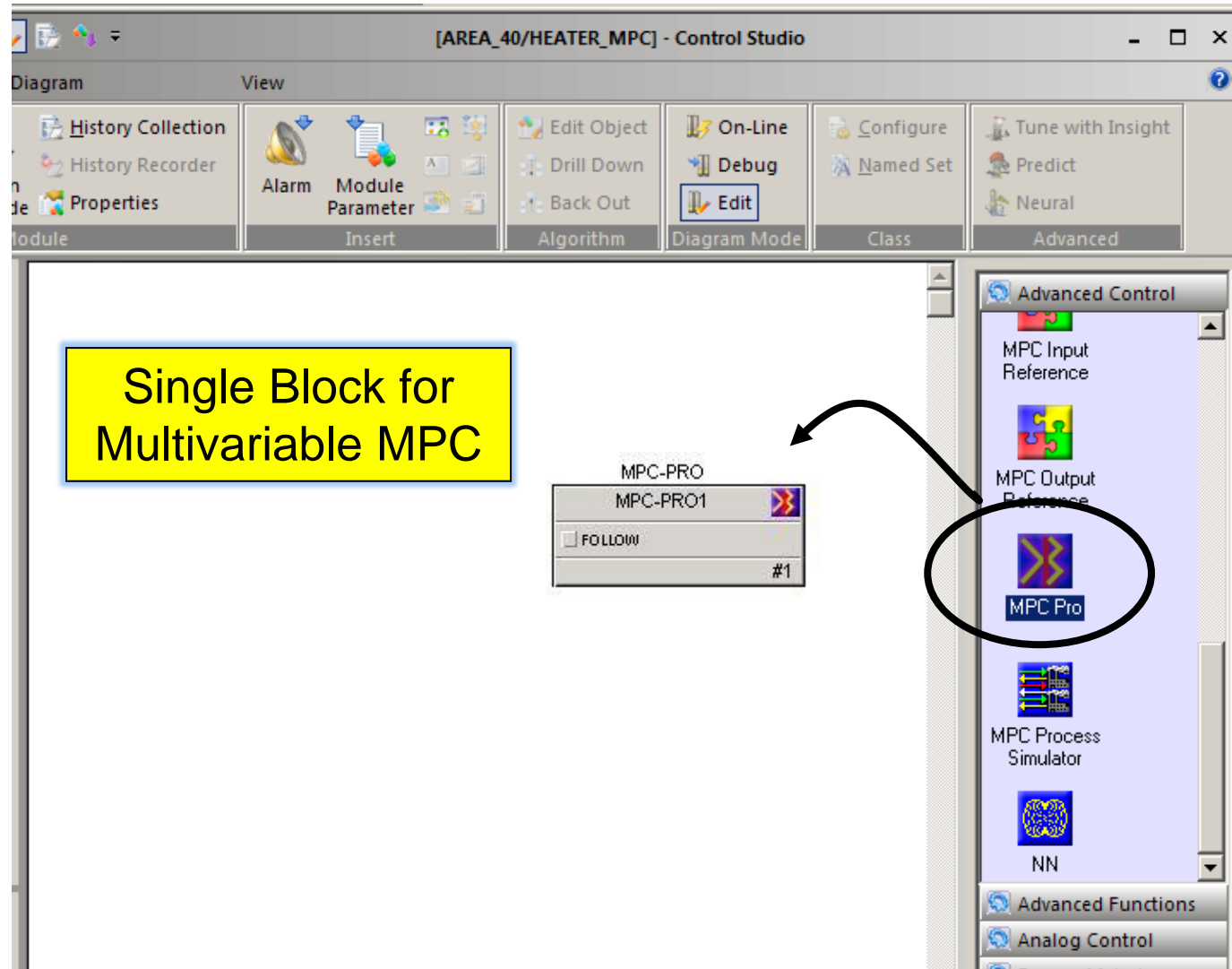
Traditional Control with PID and Feedforward



Complicated Configuration
Difficult to Tune
Hard to Maintain

3 Controlled
4 Constraints
3 Disturbances

DeltaV MPC Configuration

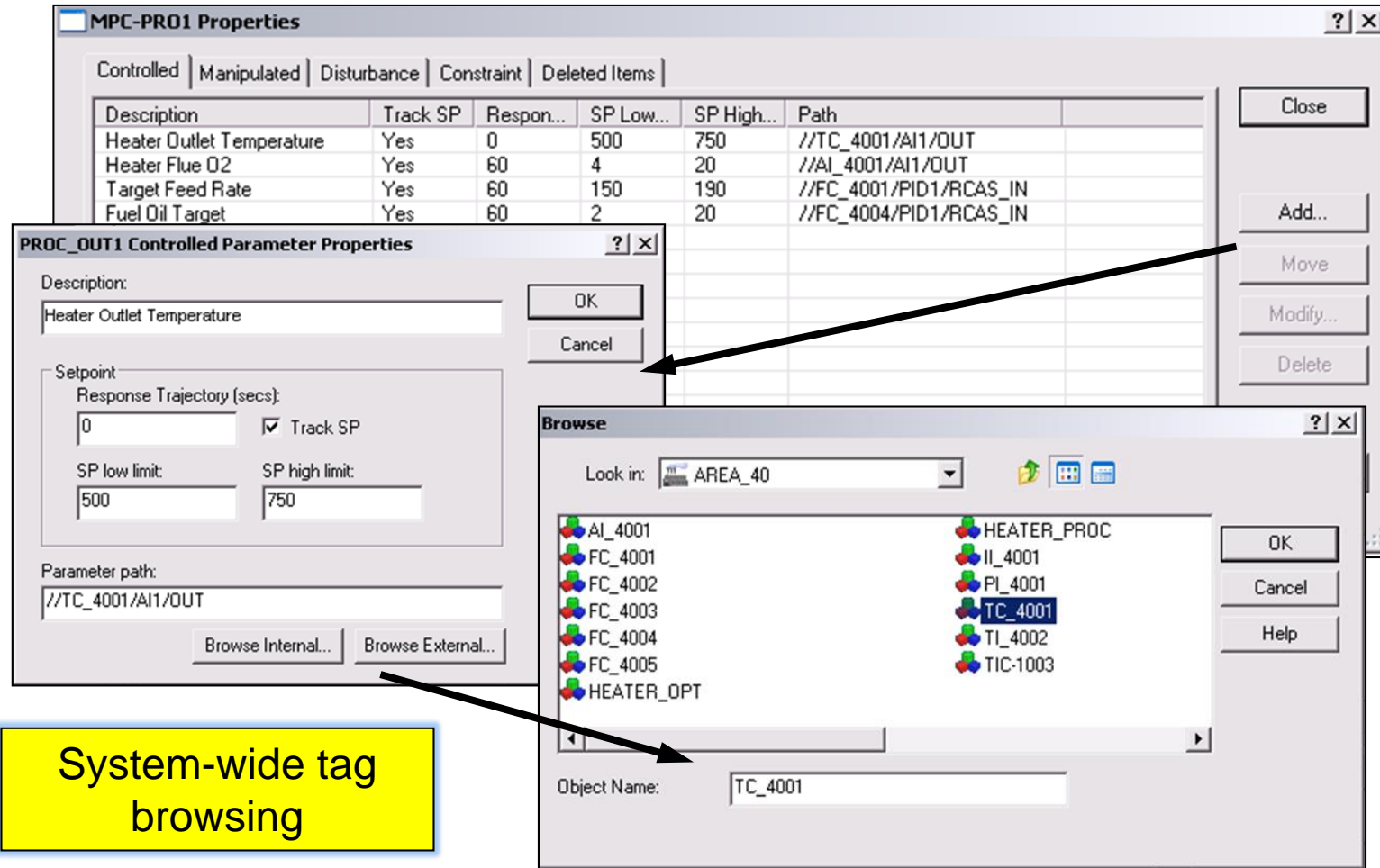


The screenshot displays the DeltaV Control Studio interface for configuring an MPC system. The window title is "[AREA_40/HEATER_MPC] - Control Studio". The top menu bar includes "Diagram" and "View". Below the menu bar is a toolbar with various icons for "History Collection", "History Recorder", "Properties", "Alarm", "Module Parameter", "Edit Object", "Drill Down", "Back Out", "On-Line", "Debug", "Edit", "Configure", "Named Set", "Tune with Insight", "Predict", and "Neural".

In the center of the workspace, a yellow box contains the text "Single Block for Multivariable MPC". Below this box is a block diagram element labeled "MPC-PRO" with the instance name "MPC-PRO1". The block has a "FOLLOW" checkbox and is identified as "#1".

On the right side, a vertical palette titled "Advanced Control" lists several control blocks. The "MPC Pro" block is circled in black, and a curved arrow points from this circle to the "MPC-PRO1" block in the workspace. Other blocks in the palette include "MPC Input Reference", "MPC Output Reference", "MPC Process Simulator", and "NN".

DeltaV MPC Configuration



The screenshot displays the DeltaV MPC configuration interface. The main window is titled "MPC-PRO1 Properties" and contains a table of controlled parameters. Overlaid on this are two smaller dialog boxes: "PROC_OUT1 Controlled Parameter Properties" and "Browse".

Description	Track SP	Respon...	SP Low...	SP High...	Path
Heater Outlet Temperature	Yes	0	500	750	//TC_4001/AI1/OUT
Heater Flue O2	Yes	60	4	20	//AI_4001/AI1/OUT
Target Feed Rate	Yes	60	150	190	//FC_4001/PID1/RCAS_IN
Fuel Oil Target	Yes	60	2	20	//FC_4004/PID1/RCAS_IN

The "PROC_OUT1 Controlled Parameter Properties" dialog shows the following fields:

- Description: Heater Outlet Temperature
- Response Trajectory (secs): 0
- Track SP:
- SP low limit: 500
- SP high limit: 750
- Parameter path: //TC_4001/AI1/OUT

The "Browse" dialog shows a tree view of the DCS database with the following objects listed:

- AI_4001
- FC_4001
- FC_4002
- FC_4003
- FC_4004
- FC_4005
- HEATER_OPT
- HEATER_PROC
- II_4001
- PI_4001
- TC_4001
- TI_4002
- TIC-1003

The "Object Name" field in the "Browse" dialog is set to "TC_4001".

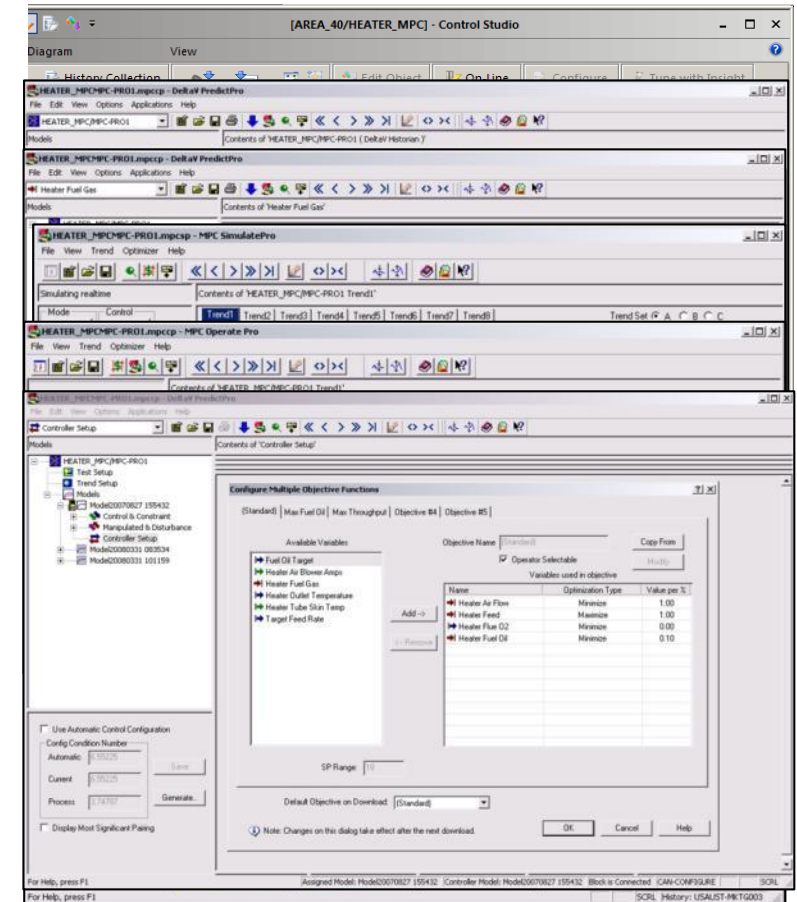
System-wide tag browsing

... 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



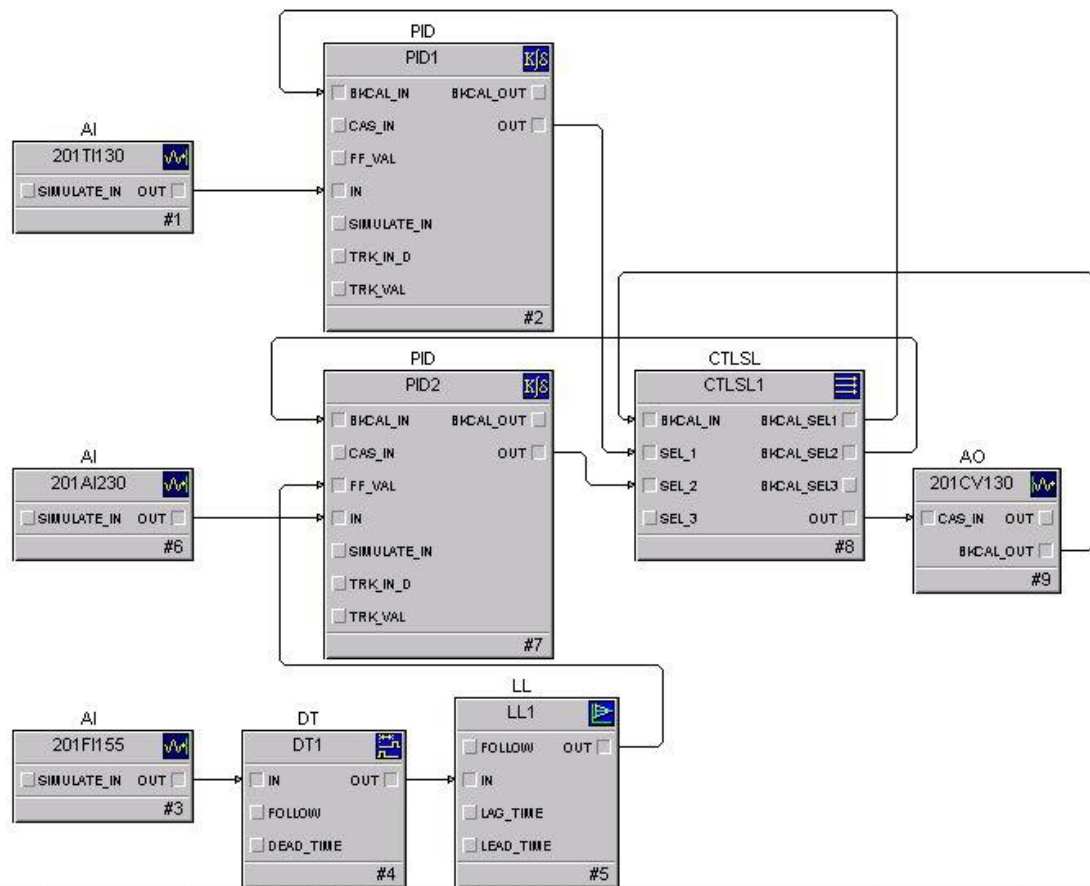
What is DeltaV FREE MPC?

- 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

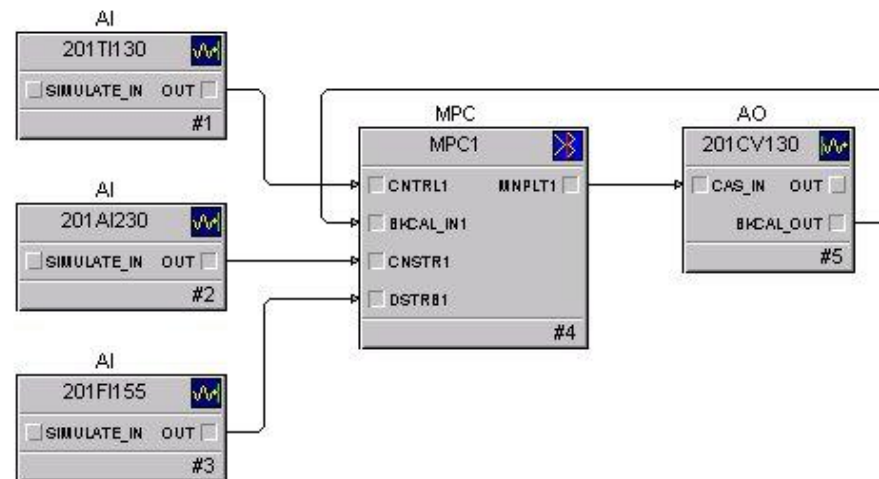


Single MV MPC Example

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

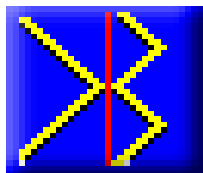


Traditional Approach



MPC

Which MPC block should I use?



MPC

- MPC block
 - MPC without optimization
 - Smaller applications, runs in controller or workstation
 - Simple implementation



Simplest
for Single
MV MPC



MPC Pro

- MPCPro
 - MPC with optimization
 - Larger applications, runs in controller or workstation
 - Fixed models, fixed control configuration only



MPC Plus

- MPCPlus
 - MPC with optimization
 - Larger applications / runs in workstation only
 - Supports non-linear models, flexible configuration

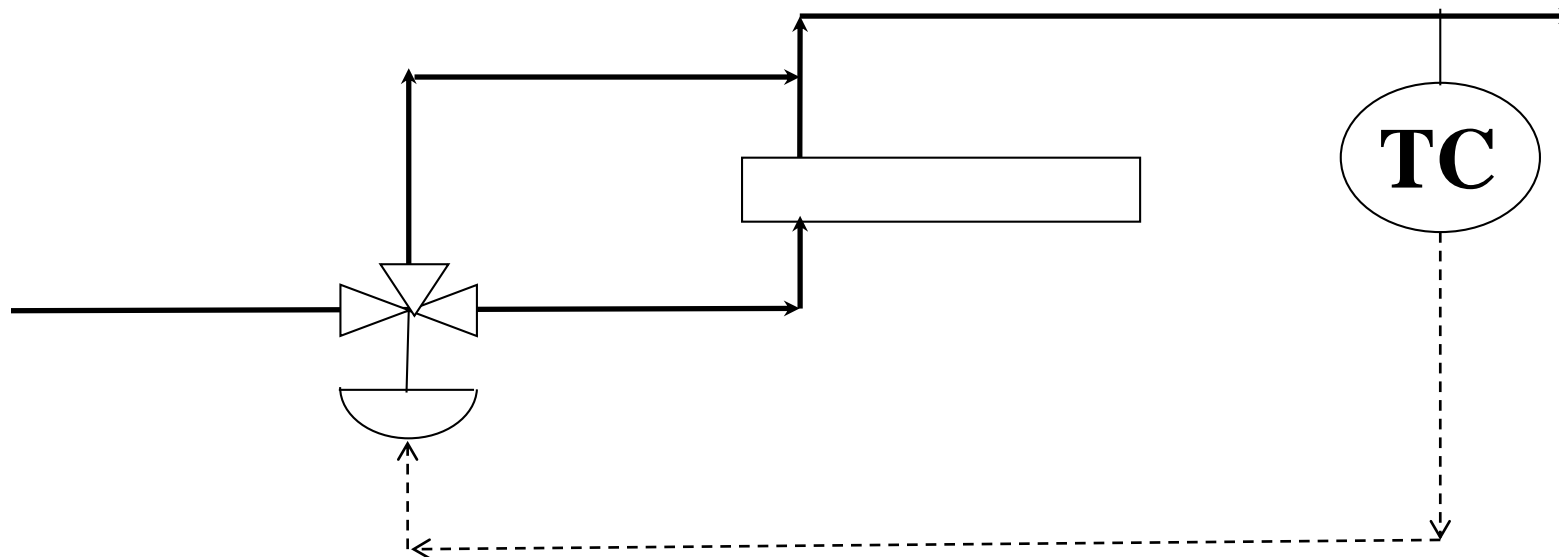
Demonstration - Adding MPC To Existing Control



- 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.

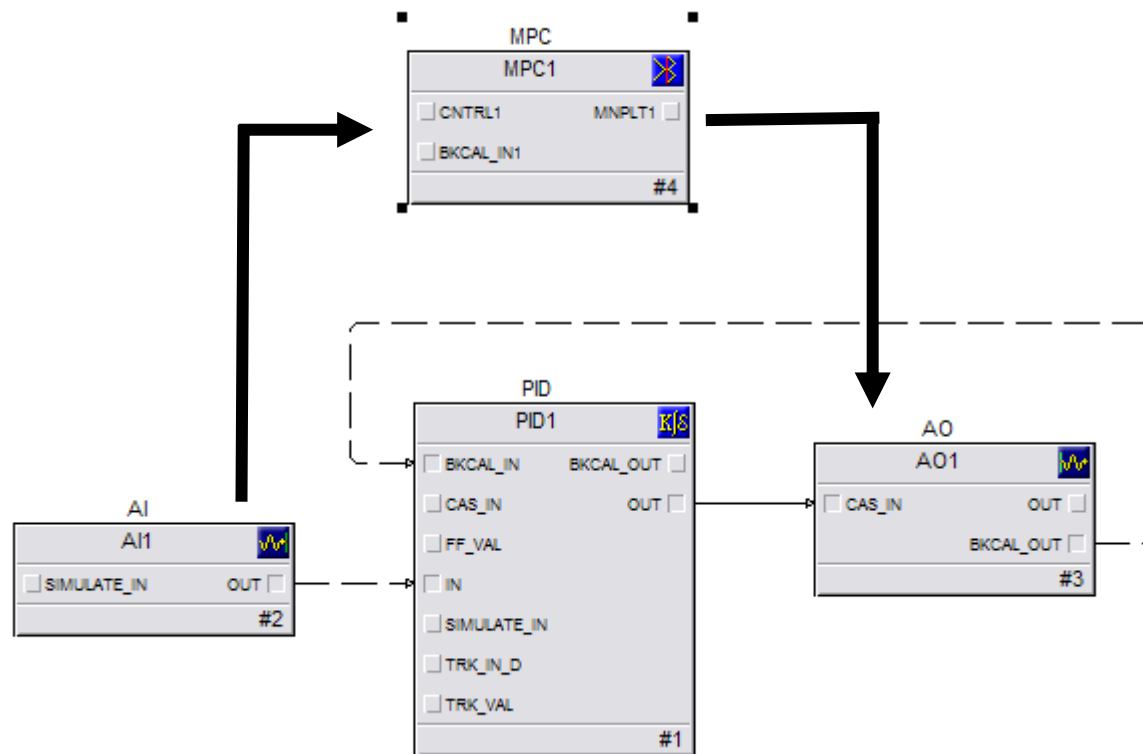


Deadtime Compensation with MPC



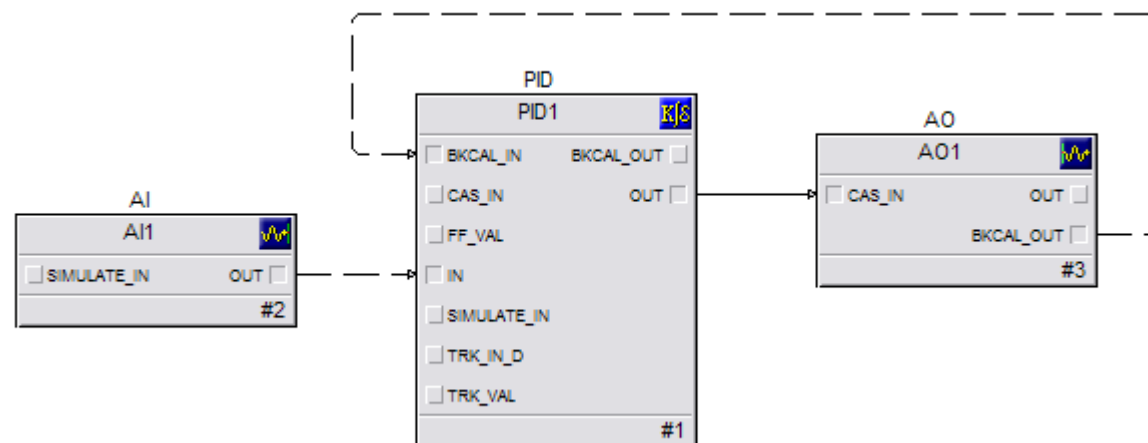
- Gasoline feed preheater for sulfur removal
- “Mixing” temperature response fast ($\tau=5-10$ seconds)
- Step test revealed 9 minutes of dead time!
- Temperature measurement ~500 ft downstream!

MPC for PID Replacement




Recommend implementing MPC in a separate module.

No changes to existing PID module



Create A New MPC Module

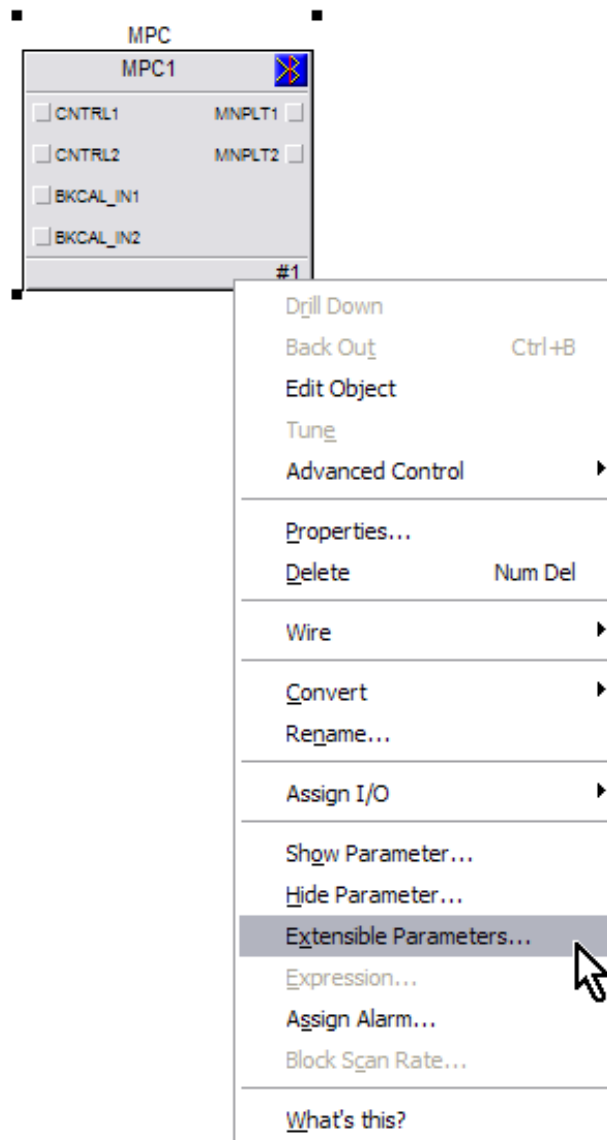
MPC

MPC1 

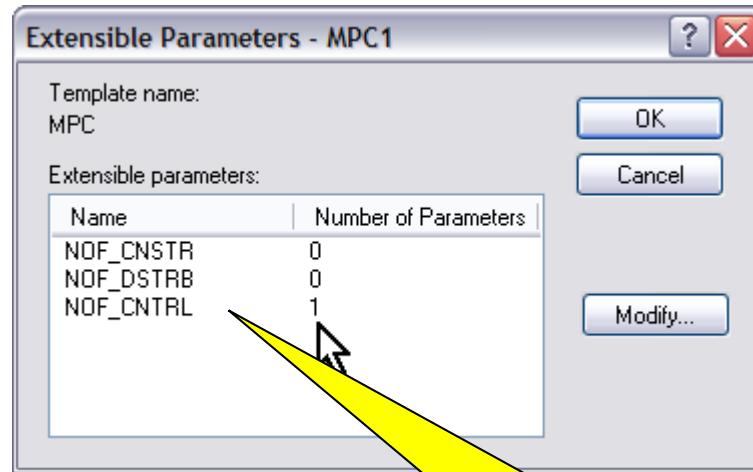
<input type="checkbox"/> CNTRL1	MNPLT1	<input type="checkbox"/>
<input type="checkbox"/> CNTRL2	MNPLT2	<input type="checkbox"/>
<input type="checkbox"/> BKCAL_IN1		
<input type="checkbox"/> BKCAL_IN2		

#1

Specify Single MV MPC (1 in x 1 out)

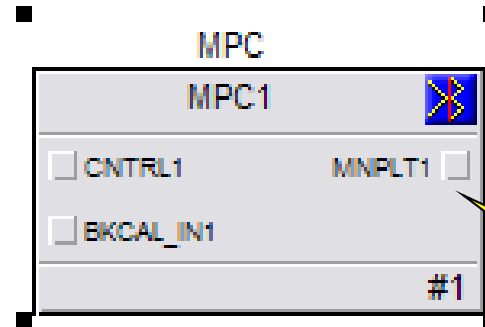


Change The Number Of Controlled Variables



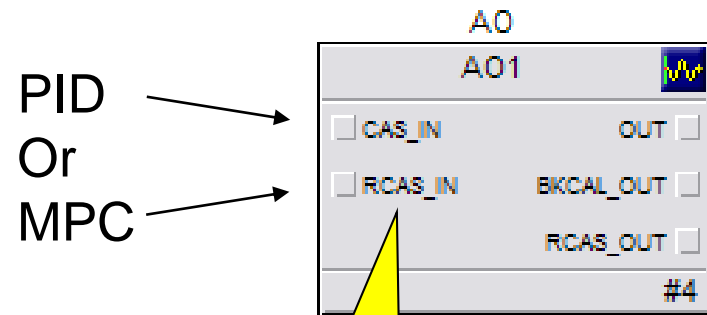
Change Your Number Of
Controlled Variables to One
(which activates 1 MV)

Single MV MPC



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

Did You Know?.....



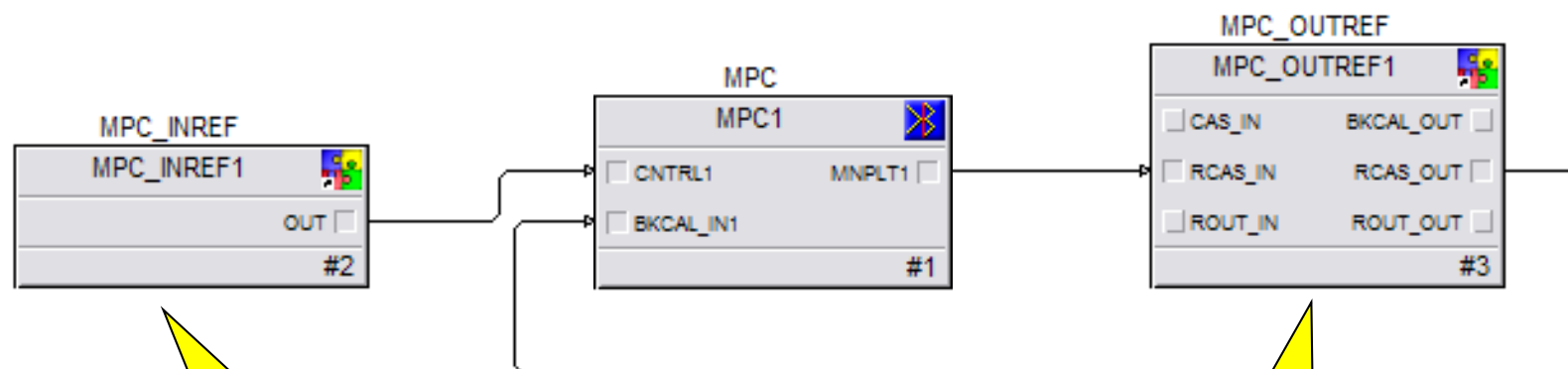
The AO Block
Supports RCAS
Mode

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

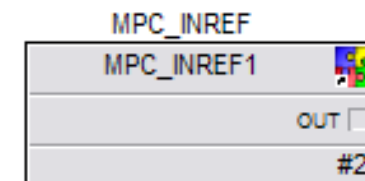
Connect This One To The AO Block In The PID Module

Define AI path for MPC_INREF

Filtered by:

Alphabetic Categorized

Parameter	Default	Linked	Connection type
LASTPATH		True	Internal read only
OUT	0	True	Output
OUT_SCALE	0 to 100 %	True	Internal read only
OUTREF		True	Internal read only
PATH	//MODULE/BLOCK	True	Internal read only
SCALEREF		True	Internal read only



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

Define AO path for MPC_OUTREF

Filtered by:

Alphabetic | Categorized

Parameter	Default	Linked	Connection type	Parameter type
BKCALOUTREF		True	Internal read only	Dynamic Refer
CASINREF		True	Internal read only	Dynamic Refer
LASTPATH		True	Internal read only	String
MIN_WRITE_S...	10	True	Internal read only	16 bit signed int
MODE	Manual/	True	Internal read only	Mode
MODEREF		True	Internal read only	Dynamic Refer
PATH	//PC-52-1185/AO1	False	Internal read only	String
PV_SCALE	0 to 100 %	True	Internal read only	Scaling
RCASINREF		True	Internal read only	Dynamic Refer
RCASOUTREF		True	Internal read only	Dynamic Refer
ROUTINREF		True	Internal read only	Dynamic Refer
ROUTOUTREF		True	Internal read only	Dynamic Refer
SCALEREF		True	Internal read only	Dynamic Refer

MPC_OUTREF

MPC_OUTREF1

CAS_IN BKCAL_OUT

RCAS_IN RCAS_OUT

ROUT_IN ROUT_OUT

#3

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


Specify CAS Mode for OUTREF Block

Filtered by:

Alphabetic Categorized

Parameter	Default	Linked	Connection type	Paramet
BKCAL_OUT	0	True	Output	Floating
BKCALOUTREF		True	Internal read only	Dynamic
CAS_IN	0	True	Input	Floating
CASINREF		True	Internal read only	Dynamic
LASTPATH		True	Internal read only	String
MIN_WRITE_S...	10	True	Internal read only	16 bit sig
MODE	Cascade/	False	Internal read only	Mode
MODEREF		True	Internal read only	Dynamic
PATH	/MPC-52-1185/A	False	Internal read only	String
PV_SCALE	0 to 100 %		Internal read only	Scaling
RCAS_IN	0			Floating
RCAS_OUT	0			Floating
RCASINREF				
RCASOUTREF				
ROUT_IN	0			
ROUT_OUT	0			
ROUTINREF				
ROUTOUTREF				
SCALEREF				

MPC_OUTREF

MPC_OUTREF1 

CAS_IN BKCAL_OUT

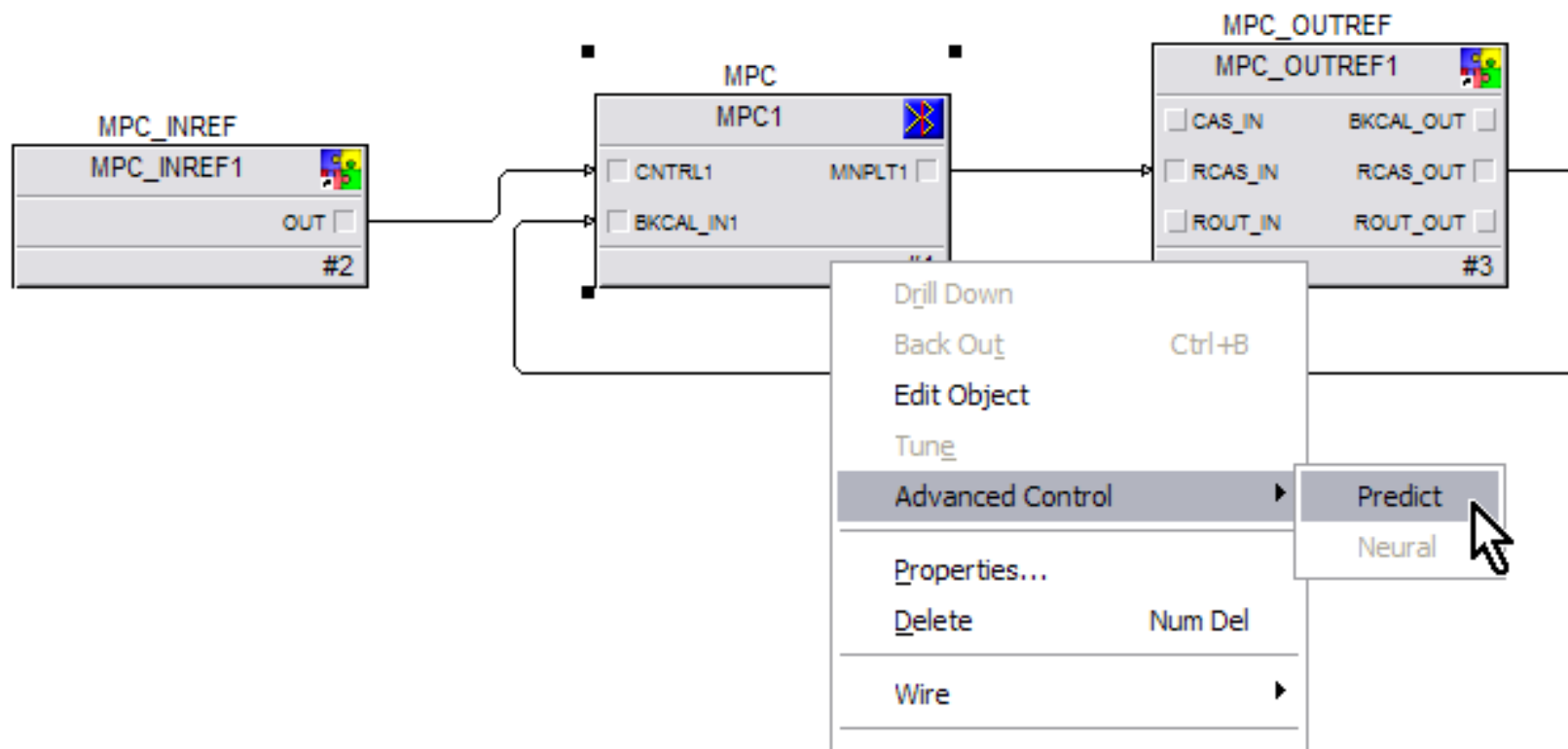
RCAS_IN RCAS_OUT

ROUT_IN ROUT_OUT

#3

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



The screenshot shows the Emerson MPC control software interface. At the top, the window title is 'TIC-9999_MPC/MPC1'. The left pane shows a tree view of models. The main area contains a graph and a control panel. The control panel includes a 'Test Process' section with a dropdown for 'Step Size (%)' set to 5, a 'Time to Steady-State' input set to 120 sec, and a 'Cycles' dropdown set to 1. There are 'Test', 'Abort', and 'Autogenerate' buttons. A 'Control' section shows 'Mode' set to 'MAN' and 'Actual' set to 'MAN'. A dropdown menu is open, showing 'MPC' selected, with 'Local' and 'MPC' as options. A status bar at the bottom provides system information.

Select Your Desired Step Size

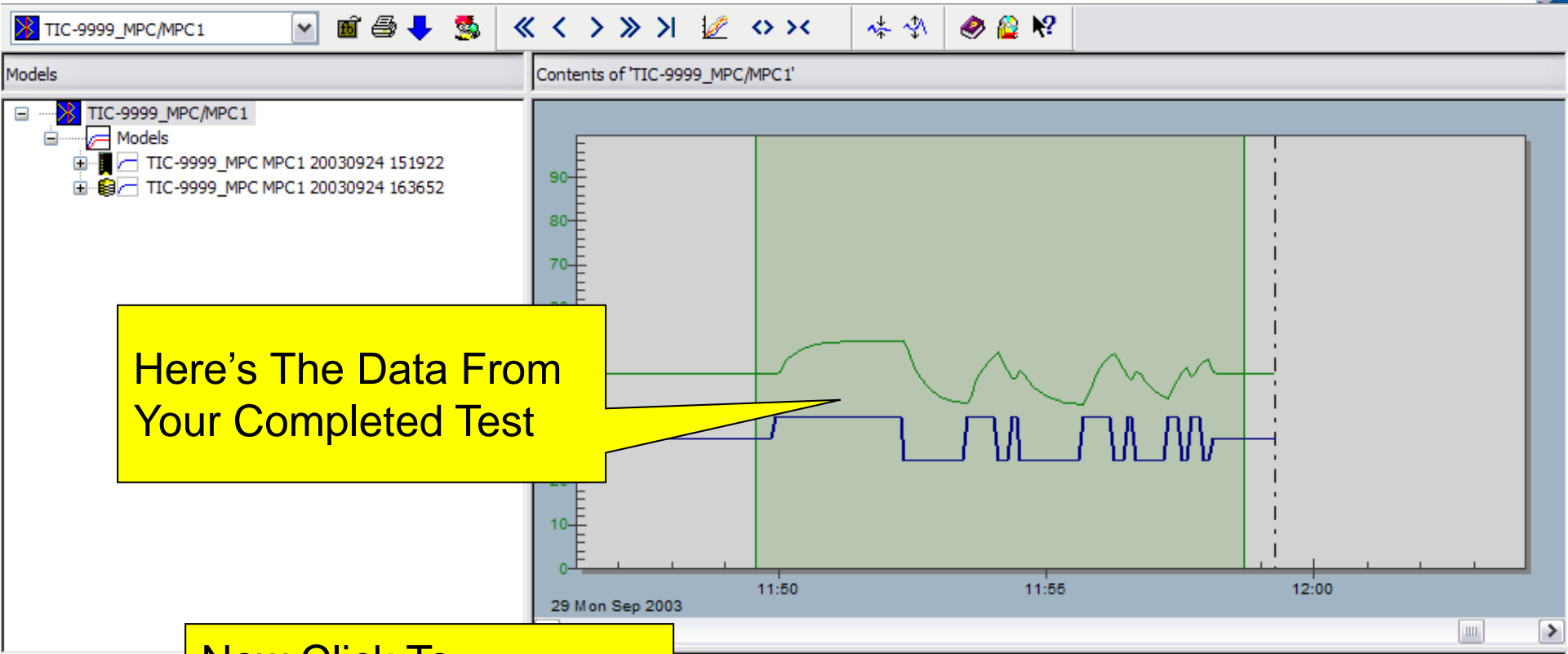
Select "MPC" To Pass Control To The MPC Block

Enter Time To Steady State Of Your Controlled Variable

Click Test To Begin Process Testing

Parameter	Description	Value
CONTROL1	CONTROL1	MPC
MNPLT1	MNPLT1	5

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



Here's The Data From Your Completed Test

Test Process
Step Size (%)
MNPLT1 5

Time to Steady-State: 120 sec
Cycles: 1

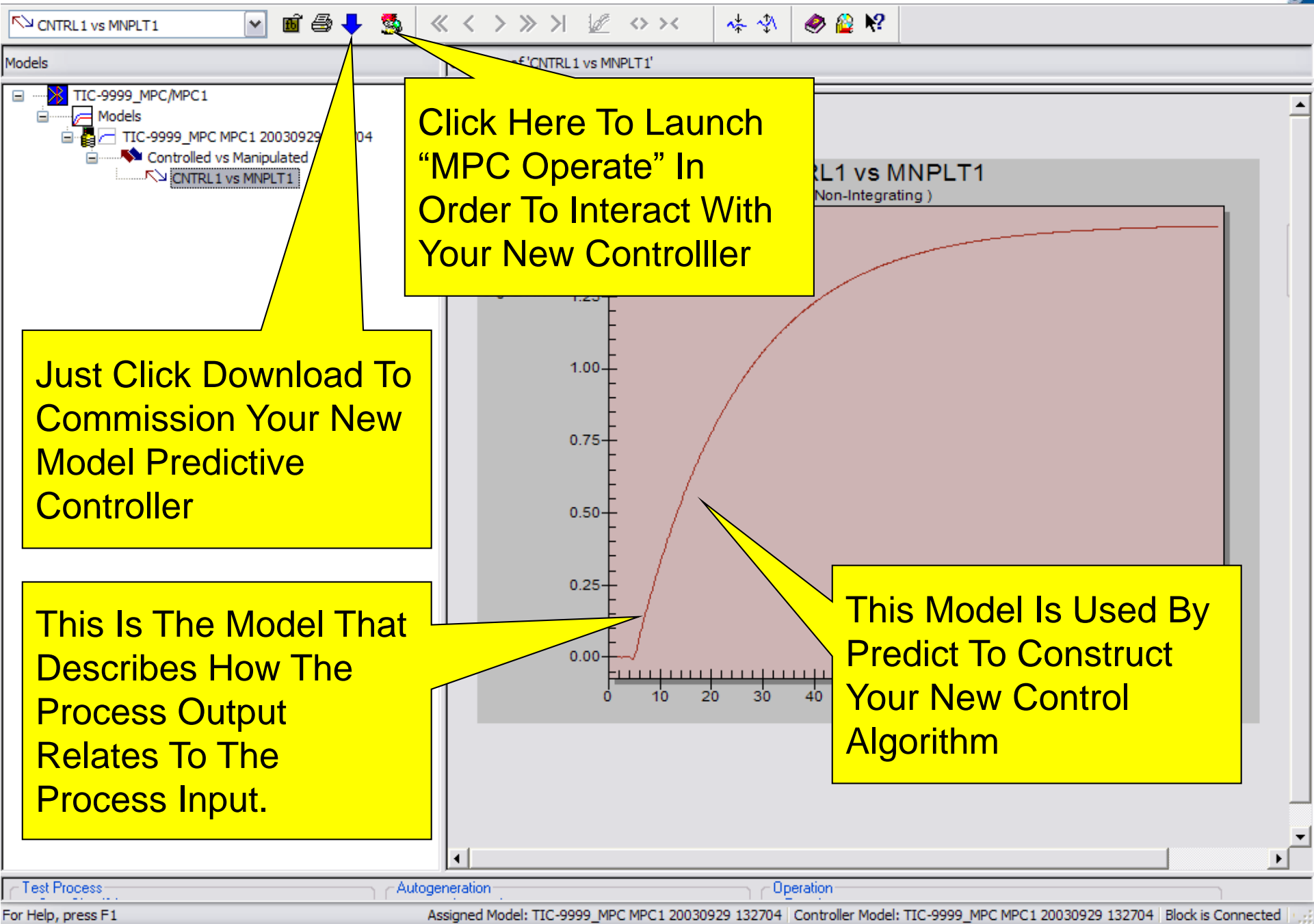
Test Abort Autogenerate

Operation Trend

Parameter	Description	On-line V...
CNTRL1	CNTRL1	45.0
MNPLT1	MNPLT1	30.0

Mode
Target: MAN Actual: MAN Control: MPC

Now Click To Autogenerate Your Model And Controller

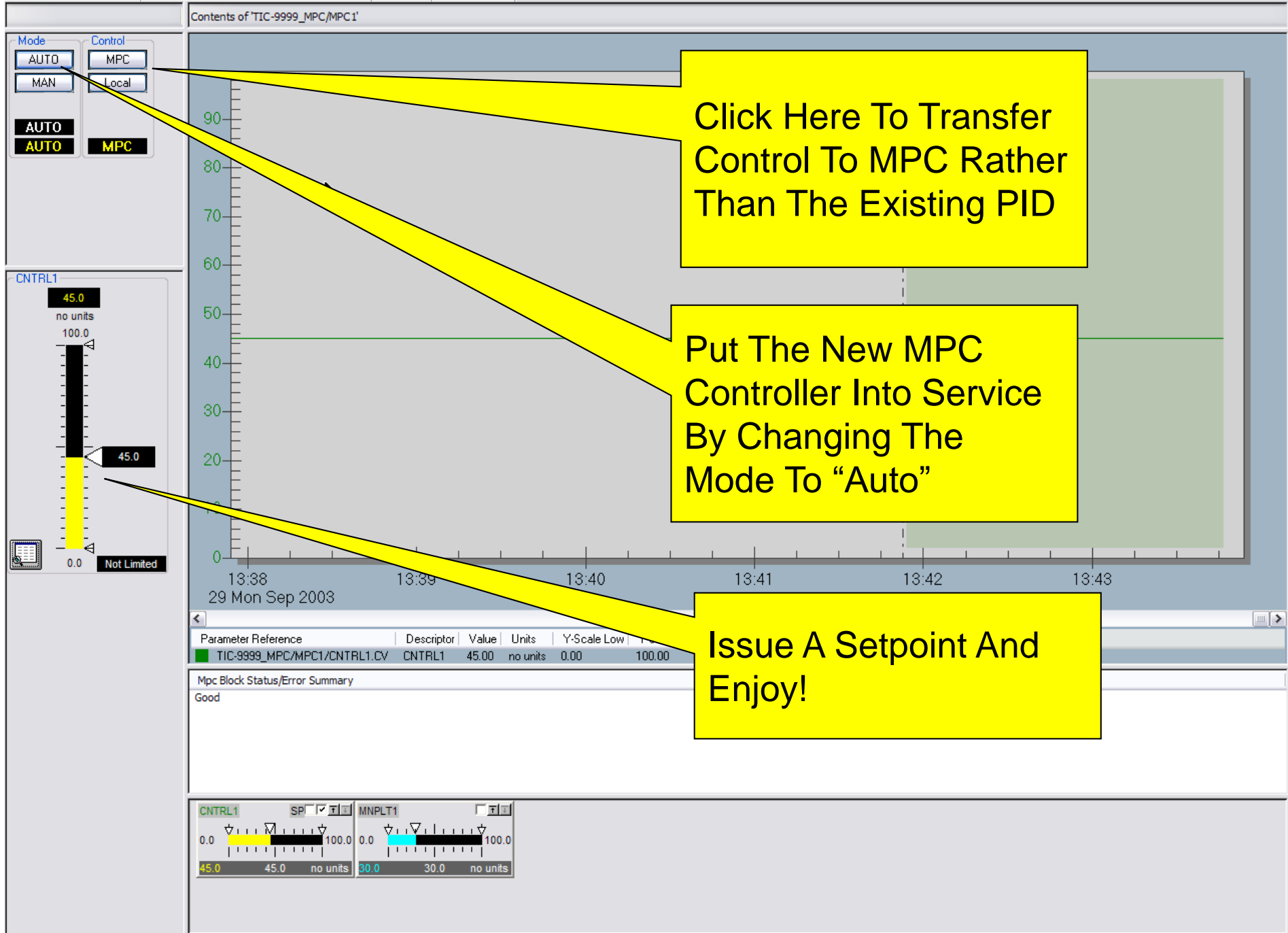


Click Here To Launch
"MPC Operate" In
Order To Interact With
Your New Controller

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

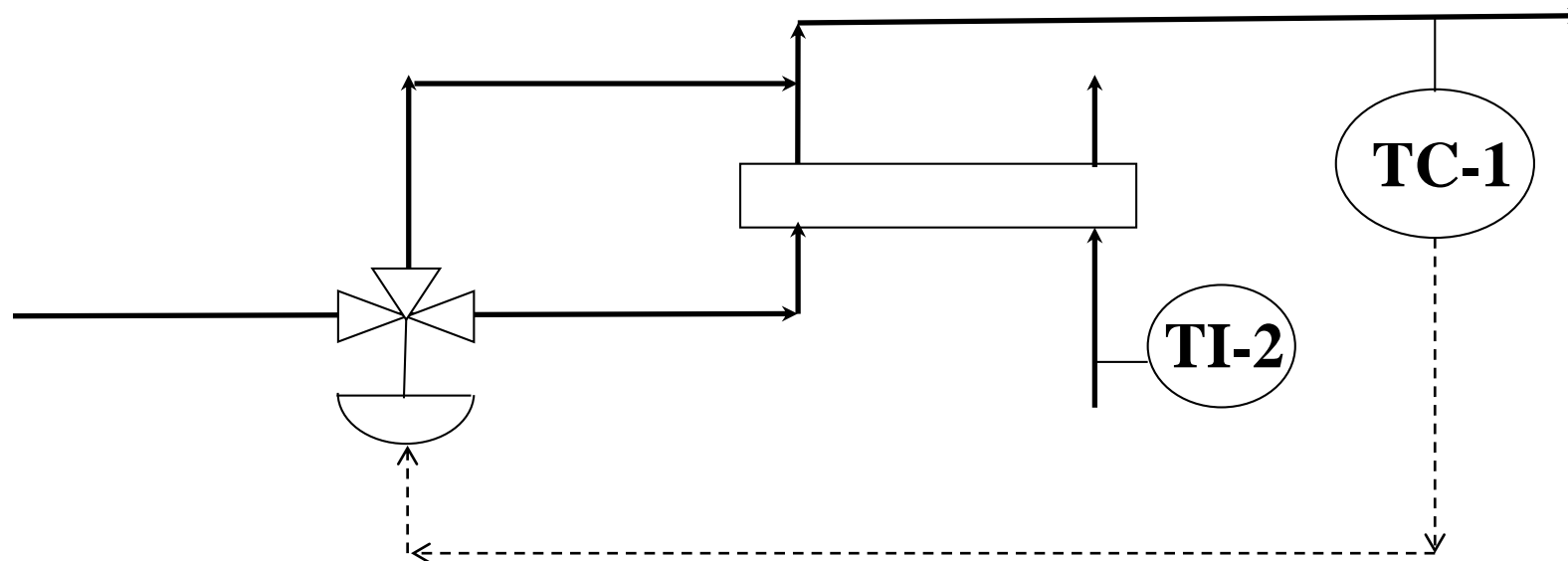


Click Here To Transfer Control To MPC Rather Than The Existing PID

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

Issue A Setpoint And Enjoy!

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

Extensible Parameters - MPC1

Template name:
MPC

Extensible parameters:

Name	Number of Parameters
NOF_CNSTR	0
NOF_CNTRL	1
NOF_DSTRB	1

OK
Cancel
Modify...

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:

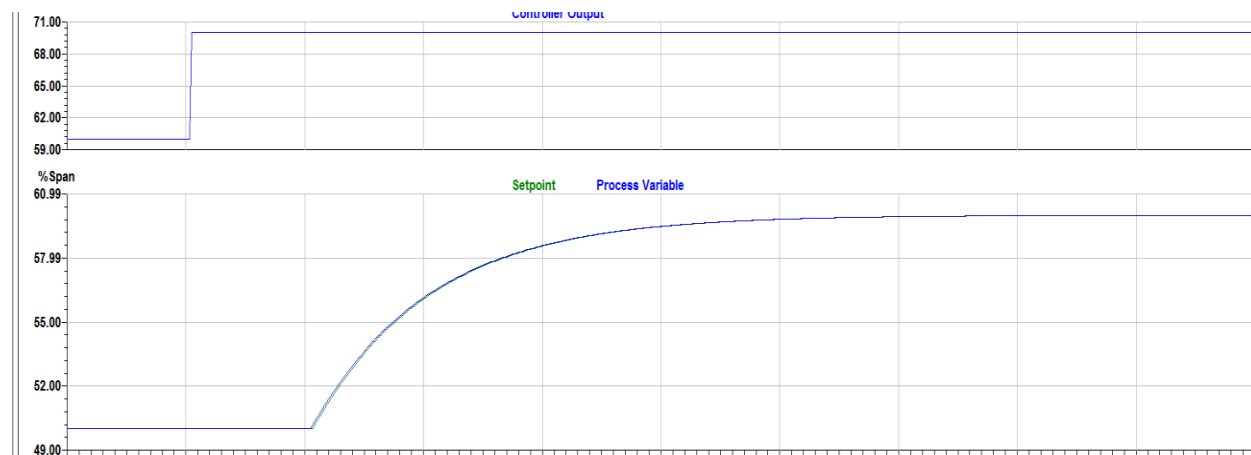
Tag: PV

Desc: Process Variable

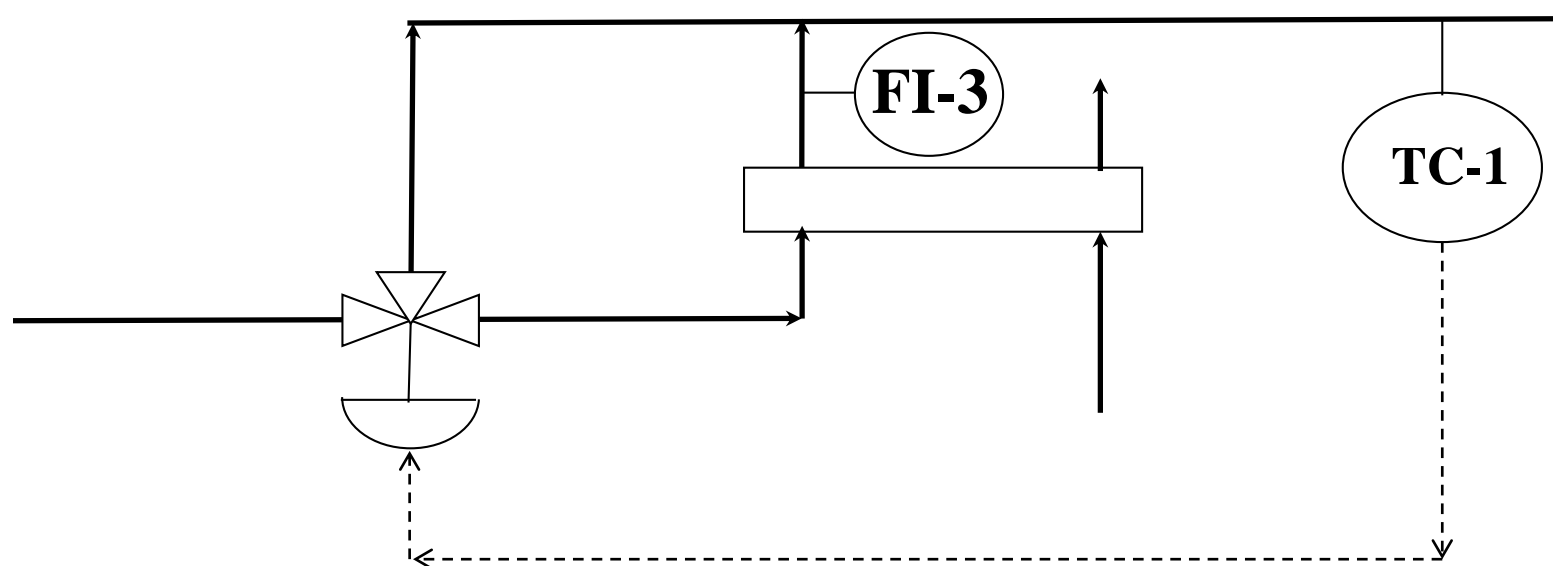
Process: *Unknown*

Response: 1st Order

Parameters: $K_p=0.5300$ %Span/%Out, $T_d=536.0$ Sec, $\tau_1=248.0$ Sec

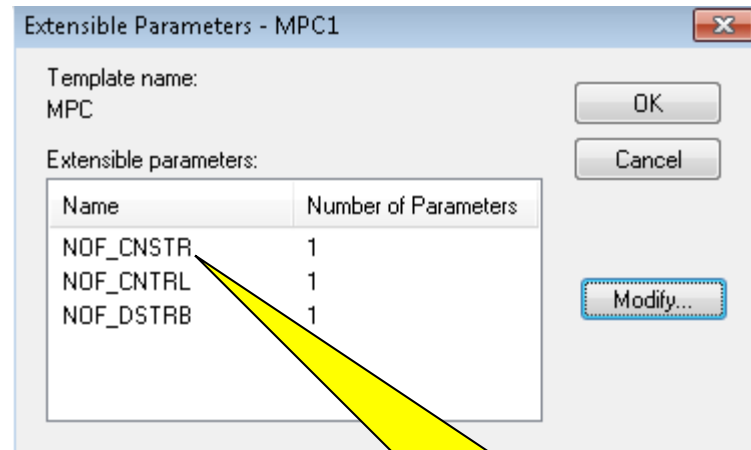


Constraint Override with MPC



- 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

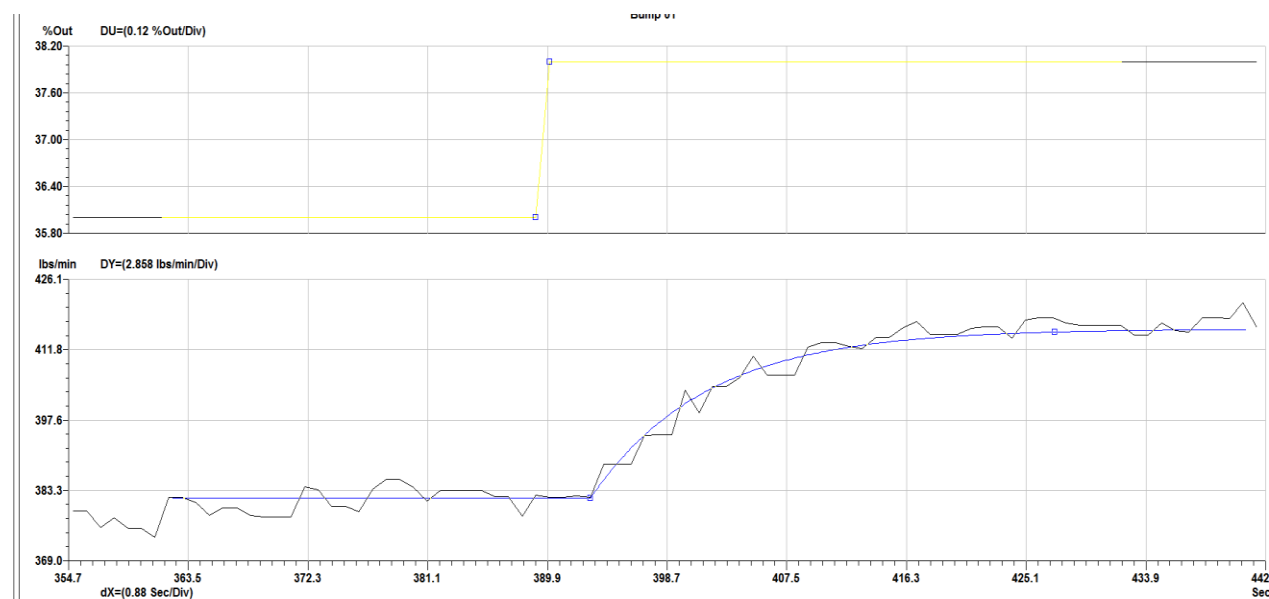


Change Your Number
Of Constraint Variables
to One

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: $K_p=0.8596$ %Span/%Out, $T_d=4.000$ Sec, $\tau_1=8.538$ 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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