Interesting and Useful Features of the DeltaV PID Controller

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Where ideas become solutions.

EMERSON GLOBAL USERS EXCHANGE '08

Introduction

- Provide additional information on useful features of the DeltaV PID and related function blocks.
- Discuss some common PID function block parameters where the default values can cause poor control.
- Provide examples of the use of these features.
- Note – “BOL” is DeltaV Books on Line (the embedded, electronic DeltaV documentation)

Topics

- PID Form
- PID Structure
- Integral Dead Band
- SP Filter/Rate of Change
- SP Limits
- Cascade Features
- Gain Scheduler
- Non-linear Gain
- Output Characterization (to Valve)
- Anti-Reset Windup Limits
- Questions

PID “Form”

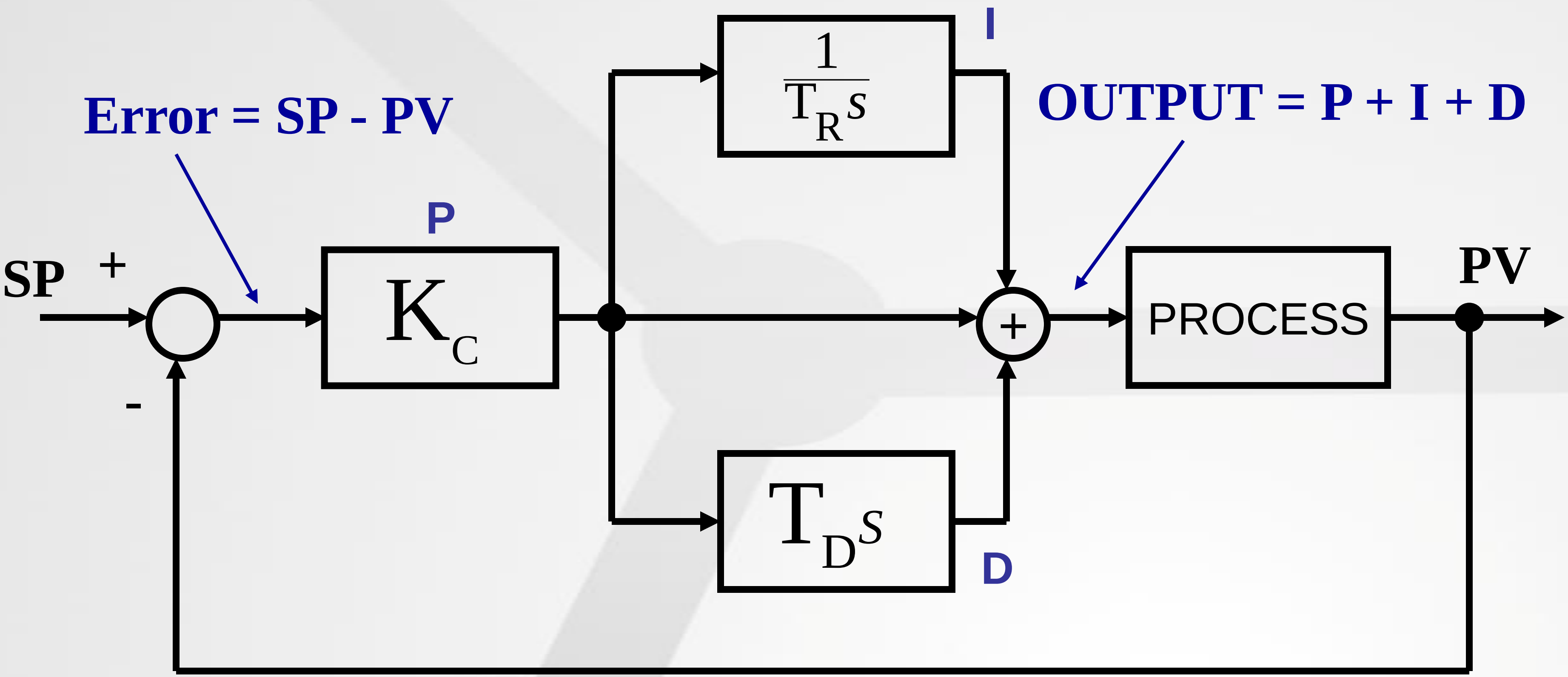
- Three Common PID Forms
  - Parallel Form
  - Standard, aka ISA Form,
  - Series, aka Classical Form.
- DeltaV has Choices
  - Standard (default)
  - Series

PID "Form" - PID Function Block

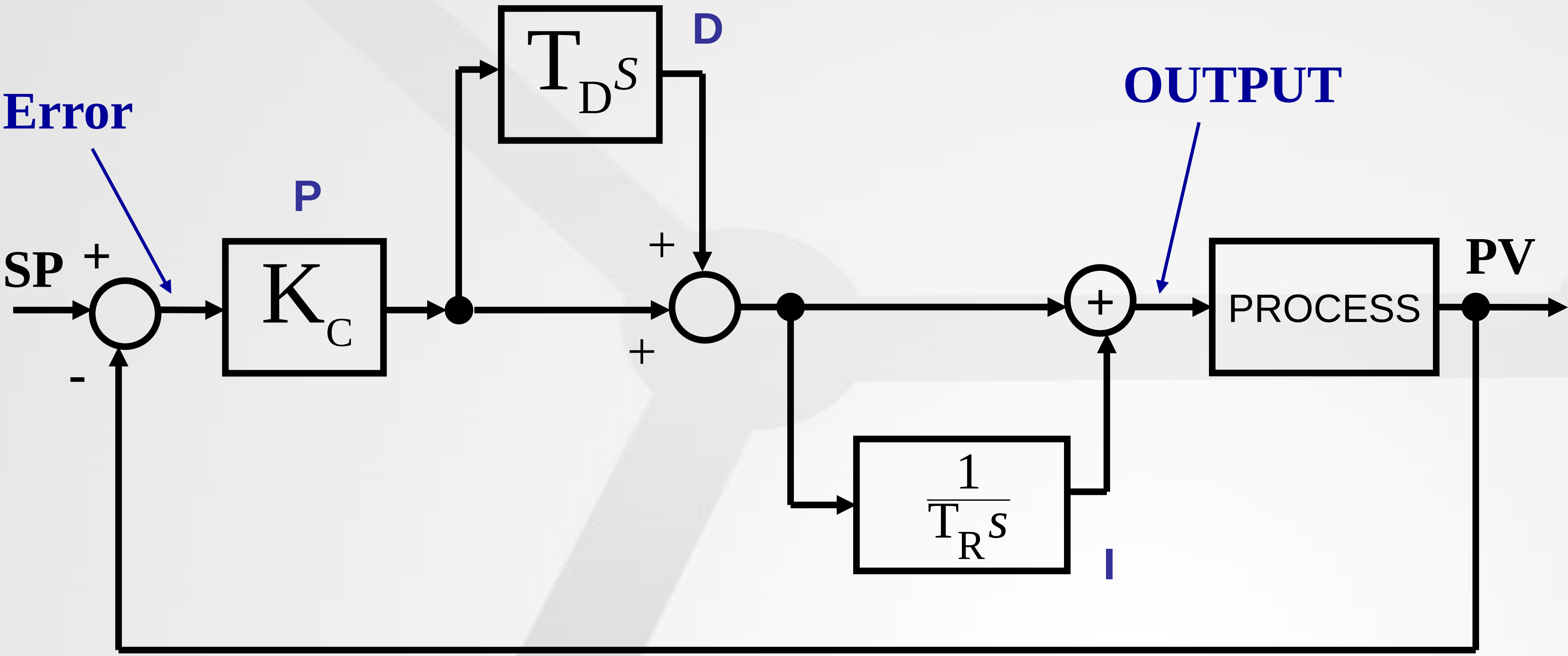
- DeltaV default is "Standard"
- Note that if you choose "Nonlinear Gain" in FRSPID_OPTS then the FORM becomes "Standard" – More on this later

FORM	None	Selects equation form (series or standard). If Use Nonlinear Gain Modification is selected in FRSIPID_OPTS, the form automatically becomes standard, regardless of the configured selection of FORM.

Standard Form of the PID Equation



Classical Form of the PID Equation



PID "Form" Choice

- Prior system experience
- Personal Preference for Standard or Series
- Series is identical to Standard form if Derivative action is NOT used
- Can impact conversion of tuning constants from previous control system

Convert Series (Classical) to Standard

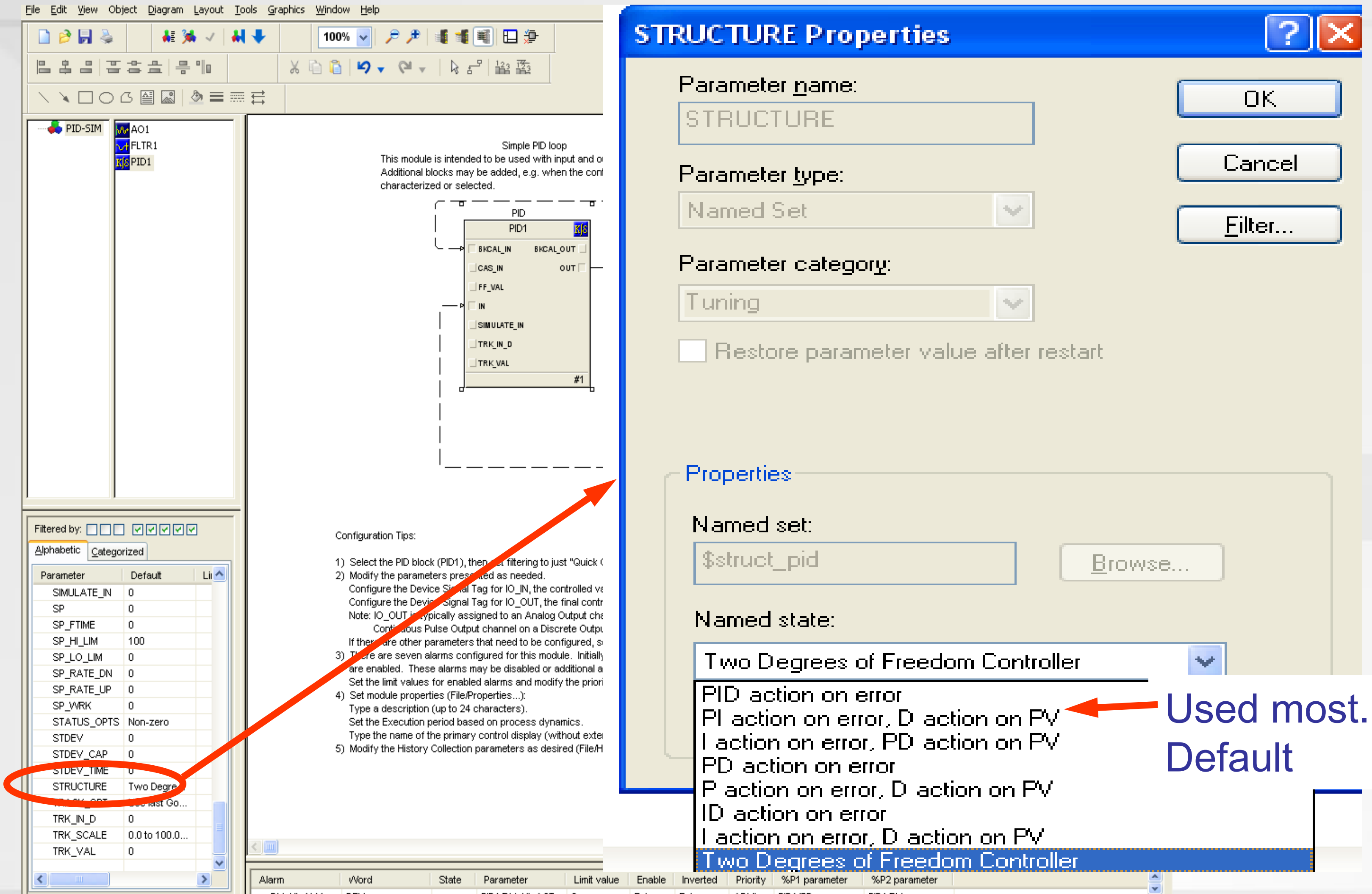
- Series is identical to Standard form if Derivative action is NOT used
- T_R should be time/rep & same time units as T_D
- Be sure to convert units after form conversion

$$K_{C\ Standard} = K_{C\ Series} * \frac{T_{R\ Series} + T_{D\ Series}}{T_{R\ Series}}$$

$$T_{R\ Standard} = T_{R\ Series} + T_{D\ Series}$$

$$T_{D\ Standard} = \frac{T_{R\ Series} * T_{D\ Series}}{(T_{R\ Series} + T_{D\ Series})}$$

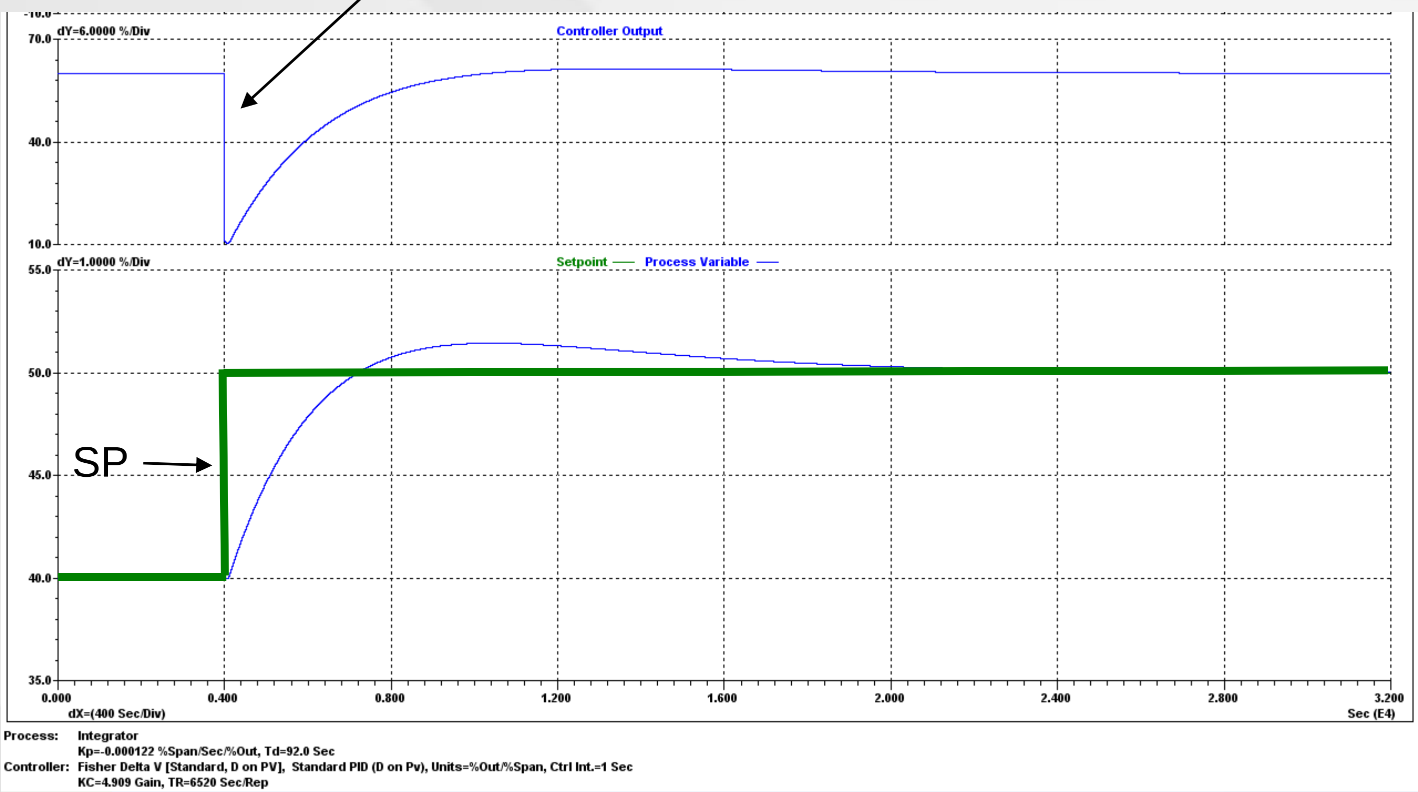
PID Function Block “Structure” Parameter



PID Function Block "Structure" Parameter

- SP Change on Reactor feed tank level: PI on error, D on PV

Controller Output – Flow to reactor



PID Function Block "Structure" Parameter

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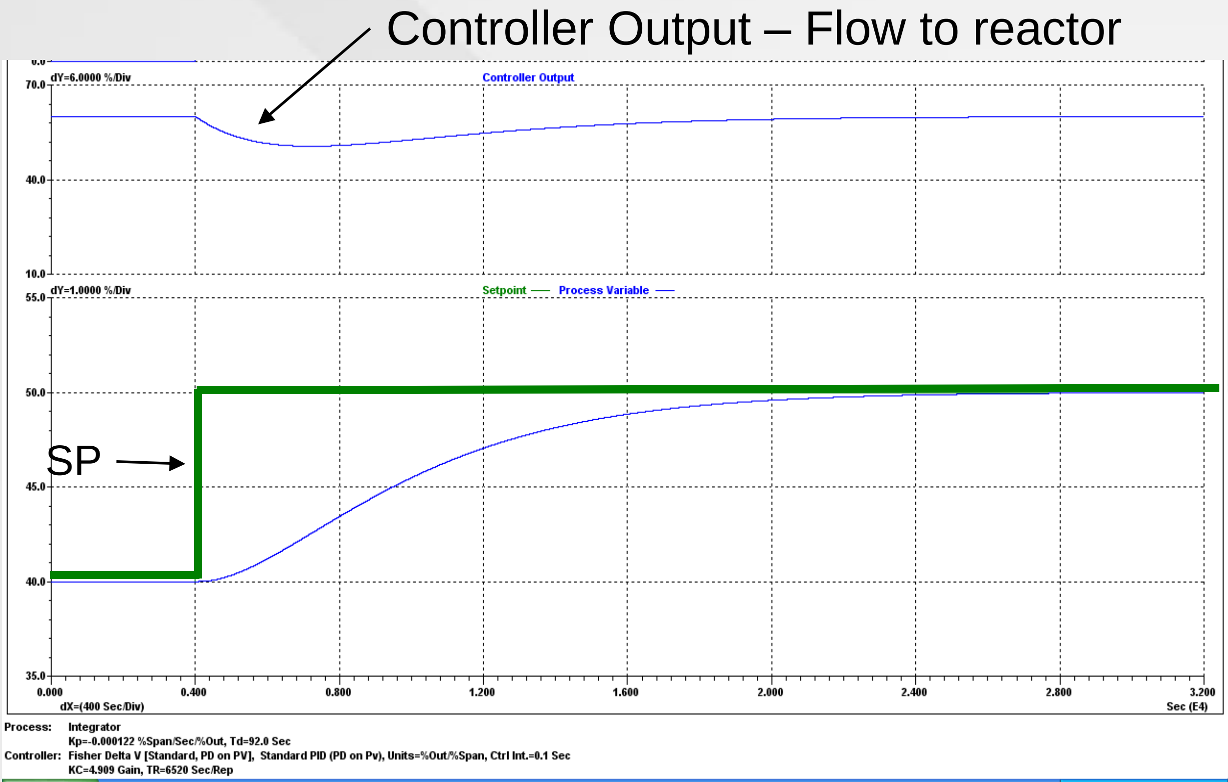
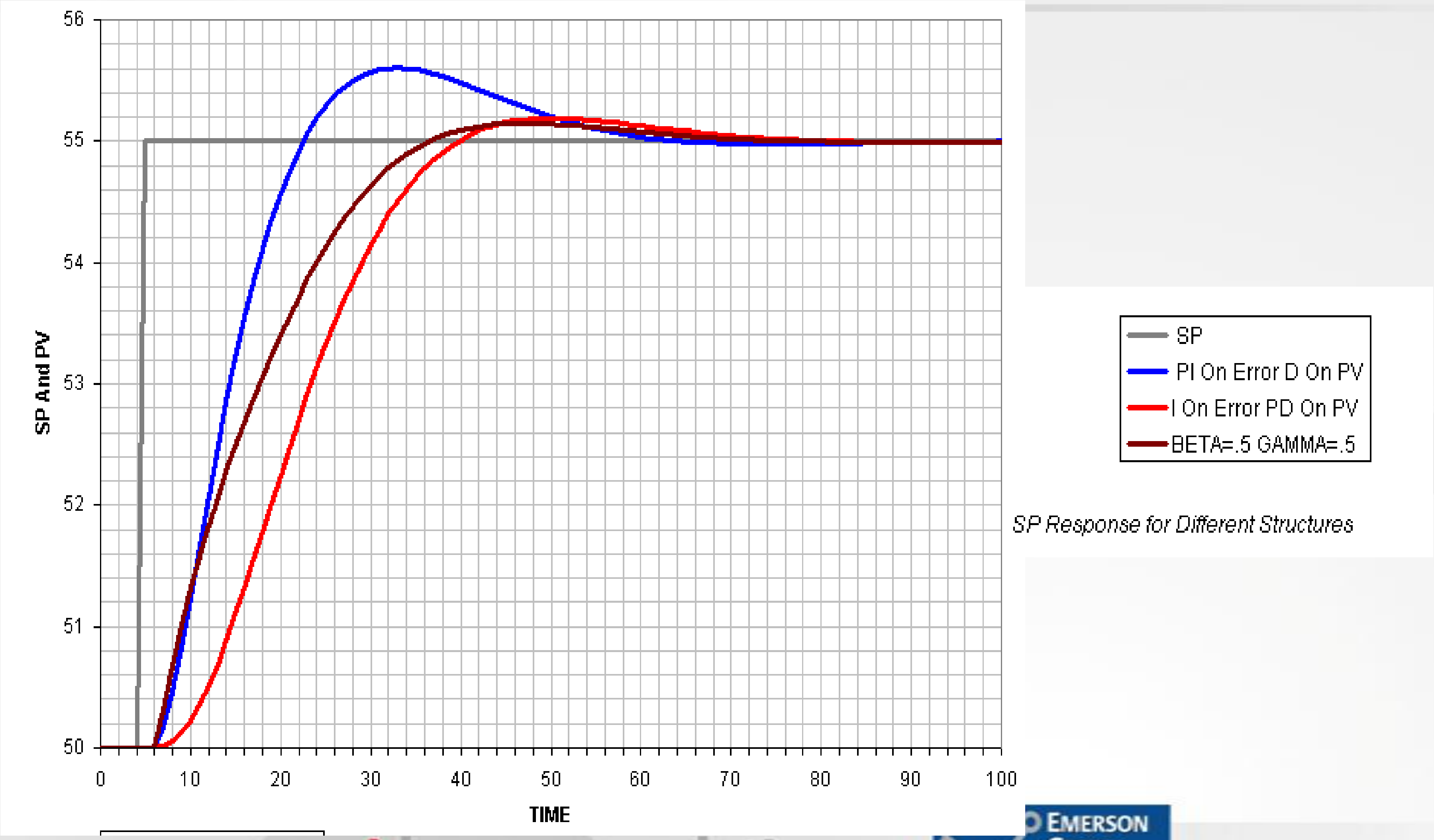


PID Structure – 2 Degrees of Freedom

- BETA - determines the degree of proportional action that will be applied to SP changes.
  - Range = 0-1
  - BETA=0 means no proportional action is applied to SP change.
  - BETA=1 means full proportional action is applied to SP change.
- GAMMA - determines the degree of derivative action that will be applied to SP changes.
  - Range = 0-1
  - GAMMA=0 means no derivative action applied to SP change.
  - GAMMA=1 means full derivative action is applied to SP change.

PID Structure – 2 Degrees of Freedom



SP Response for Different Structures

Integral Dead Band

- IDEADBAND - When the error gets within IDEADBAND, the integral action stops. The proportional and derivative action continue. Same Engineering Units as PV Scale
- May be used to reduce the movement of the controller output when the error is less than the “IDEADBAND”. For example on a level controller that feeds the downstream unit.

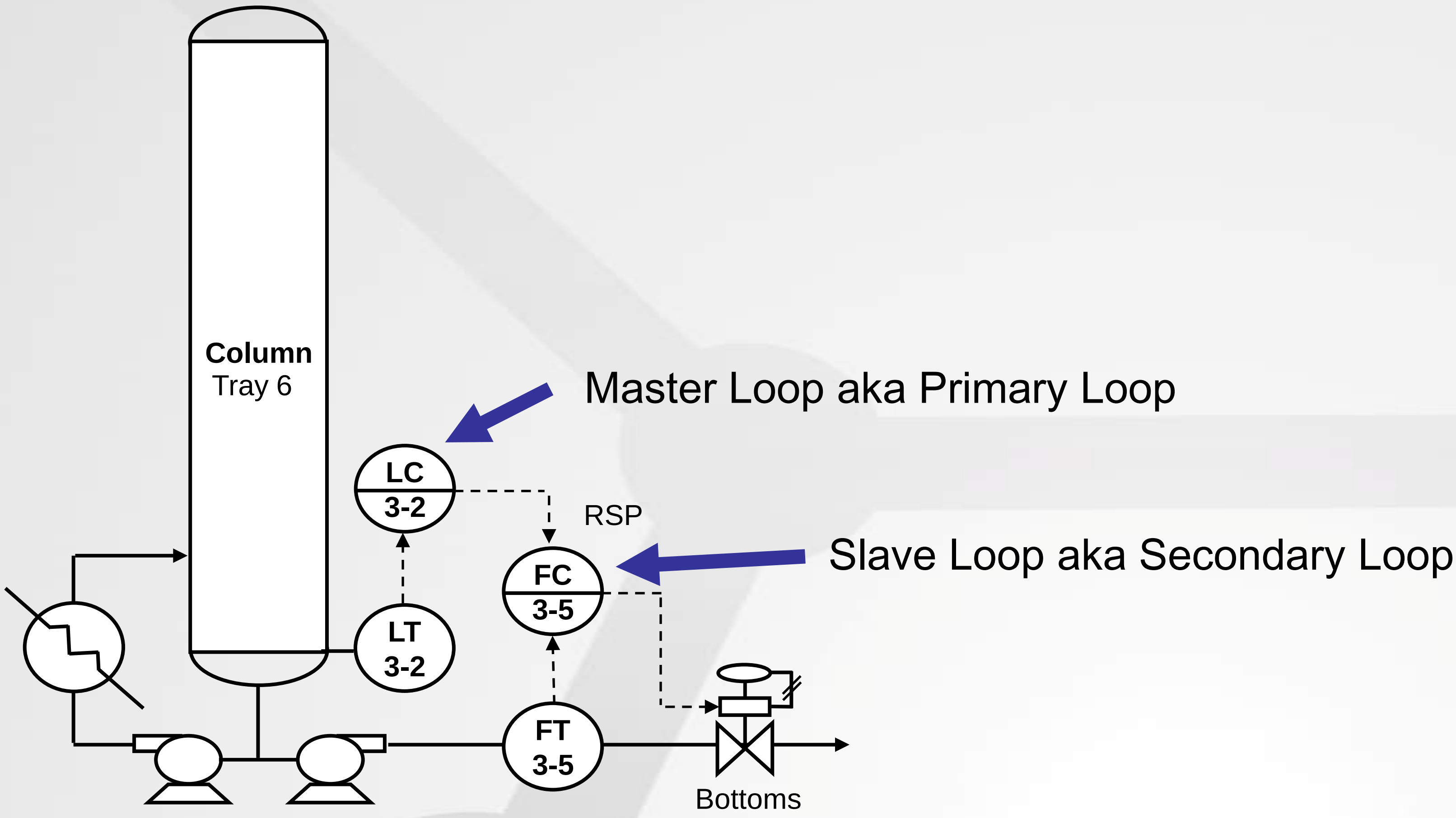
Set Points Filter/Rate of Change

- SP_FTIME - Time constant (seconds) of the first order SP filter. The Set Point Filter applies in AUTO, CAS and RCAS (not specified in BOL).
- SP_RATE_DN - Ramp rate at which downward setpoint changes are acted on in Auto mode, in PV units per second. If the ramp rate is set to 0.0, then the setpoint is used immediately. For control blocks, rate limiting applies only in Auto (not CAS or RCAS).
- SP_RATE_UP - Ramp rate at which upward setpoint changes are acted on in Auto mode, in PV units per second. If the ramp rate is set to 0.0, then the setpoint is used immediately. For control blocks, rate limiting applies only in Auto (not CAS or RCAS).

Set Point Limits

- SP_HI_LIM- The highest SP value (EU's) allowed.
- SP_LO_LIM - The lowest SP value (EU's) allowed.
- Control Options – allow you to specify if SP Limits to be obeyed in "CAS and RCAS"
- Can use "Output Limits" of Master loop in cascade pair to limit SP to Slave loop ONLY in CAS and RCAS

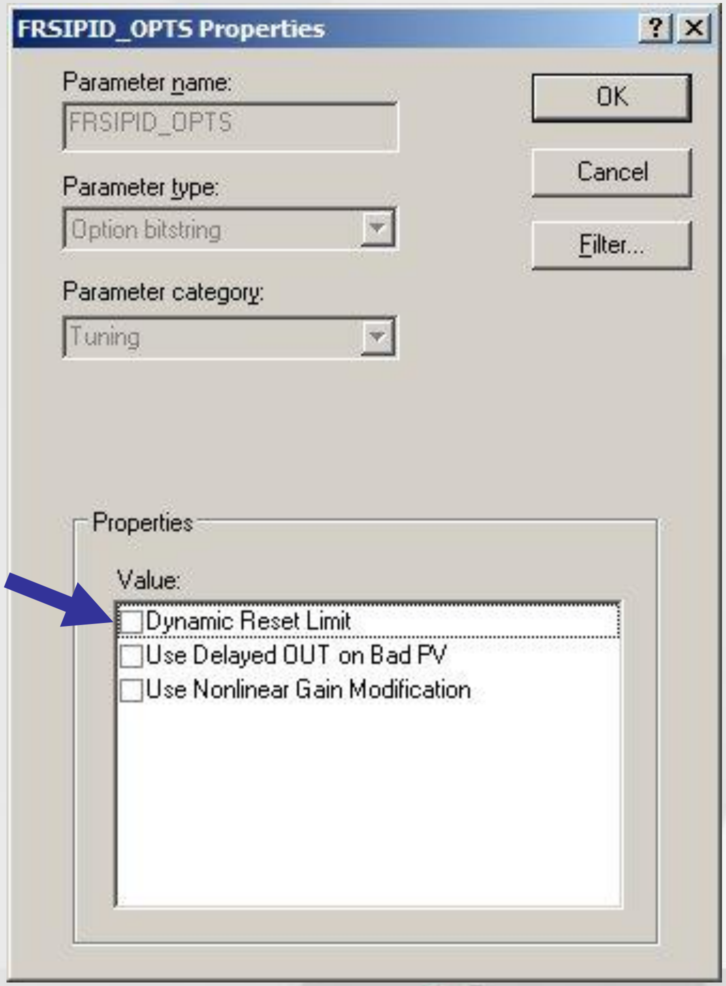
Cascade Features



Cascade Features

- Mode tracking and bumpless transfers are automatically provided through the BKCAL feature
- Limited conditions in the Slave loop are taken care of through the BKCAL feature
- Prevent reset windup with external reset by selecting “Dynamic Reset Limit” in FRSIPID_OPTS on the Master loop
- “Use PV for BKCAL_OUT” in CONTROL_OPTS should be selected on Slave loop for use with Dynamic Reset Limit in Master

Enabling PID External Reset



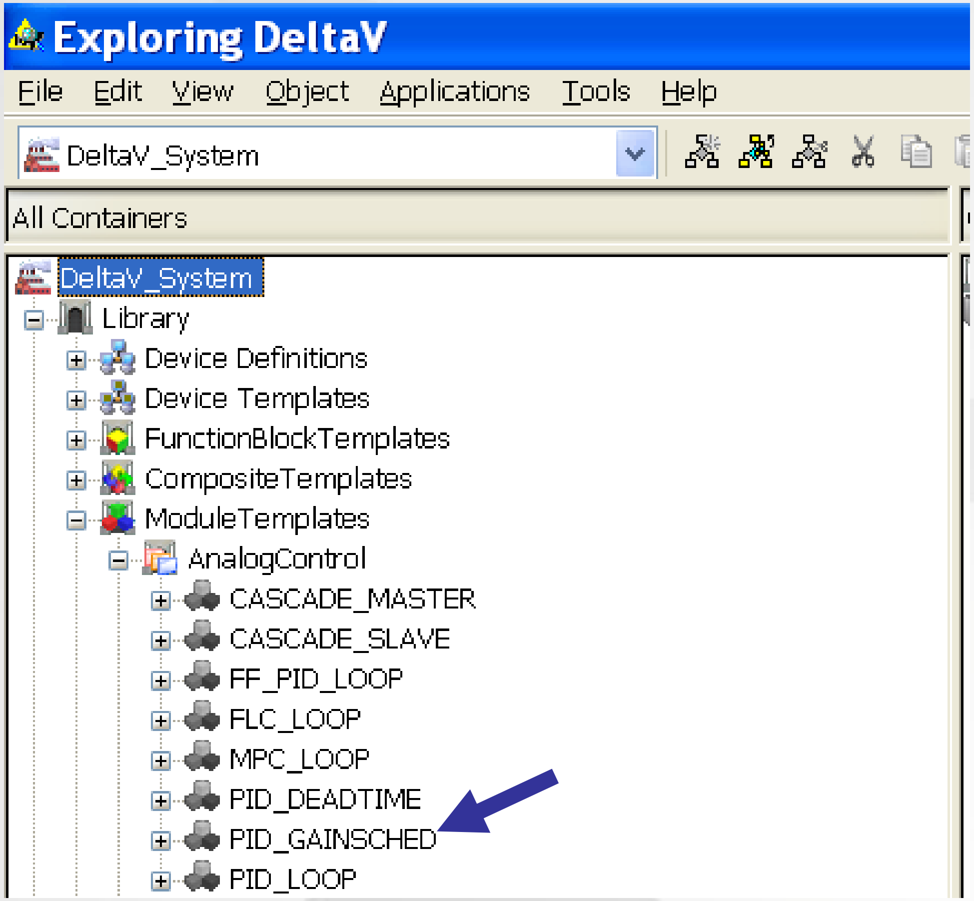
- Utilized most often in the primary loop of a cascade
- Automatically compensates for poor secondary loop response

Gain Scheduler

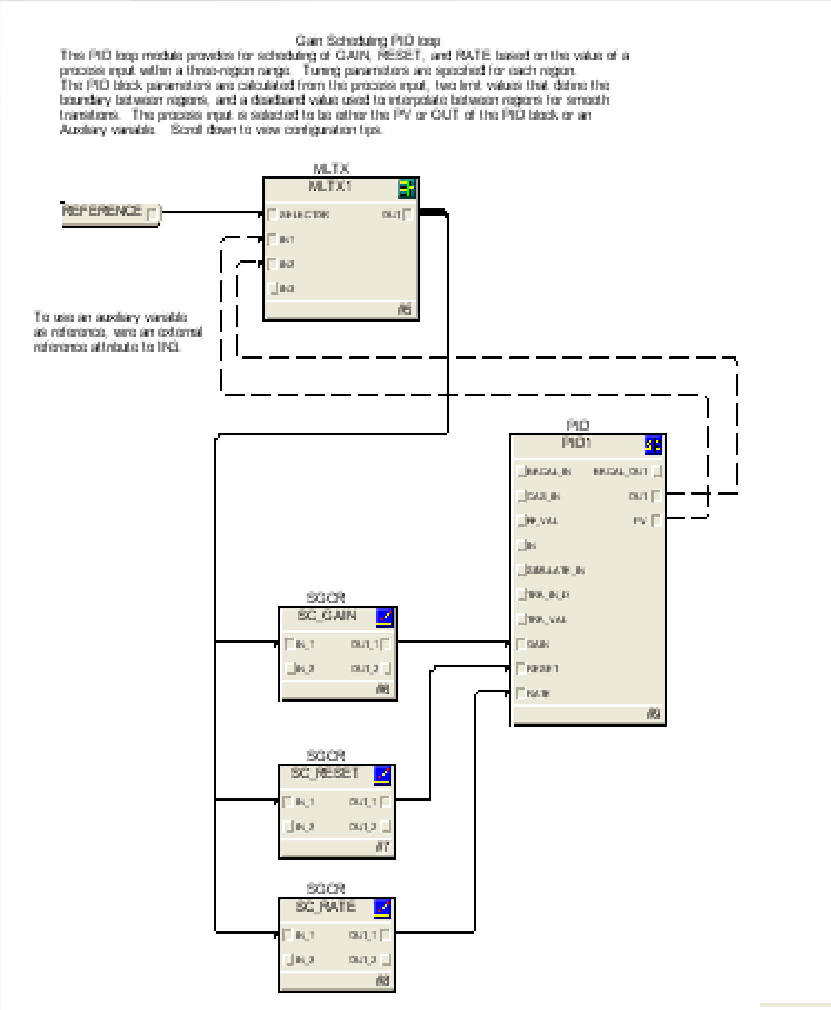
- Proves up to 3 regions of different PID tuning parameters based on a selected state variable (output, PV, error, production rate, etc.)
- Provides a smooth transition between regions
- Create PID module using Module Templates: Analog Control/PID_GAINSCHED
- OR, add function to existing PID module
  - Expose Gain, Reset and Rate parameters on PID function block
  - Copy all function blocks from template except the PID FB and link as needed.

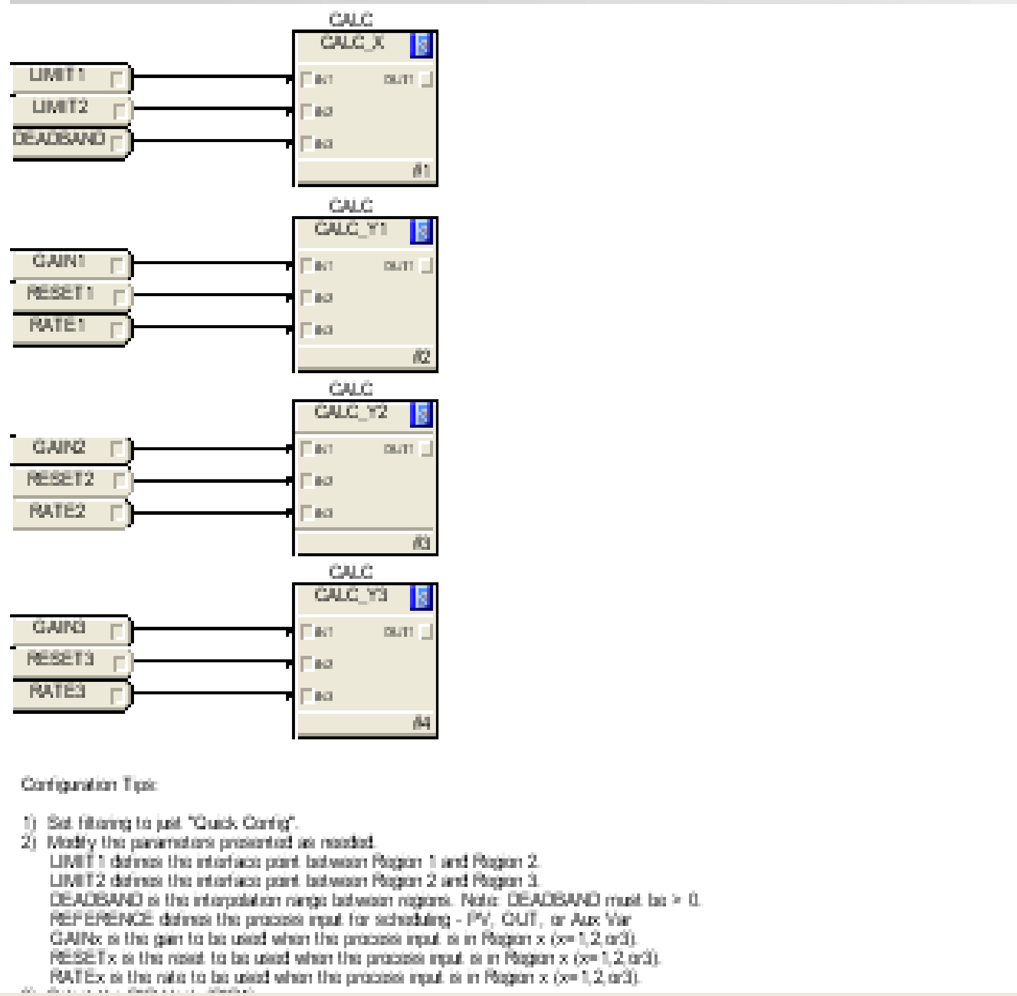
Gain Scheduler

Module Templates: Analog Control/PID_GAINSCHED



Gain Scheduler

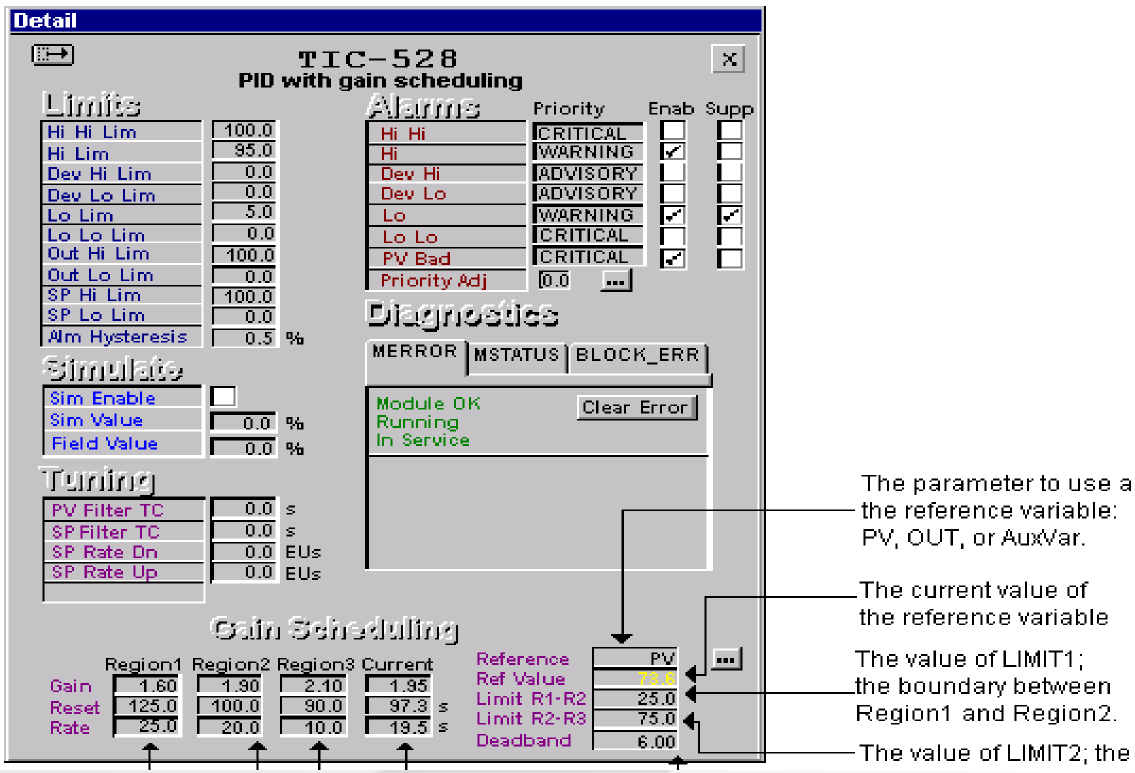




Gain Scheduler – Detail Display

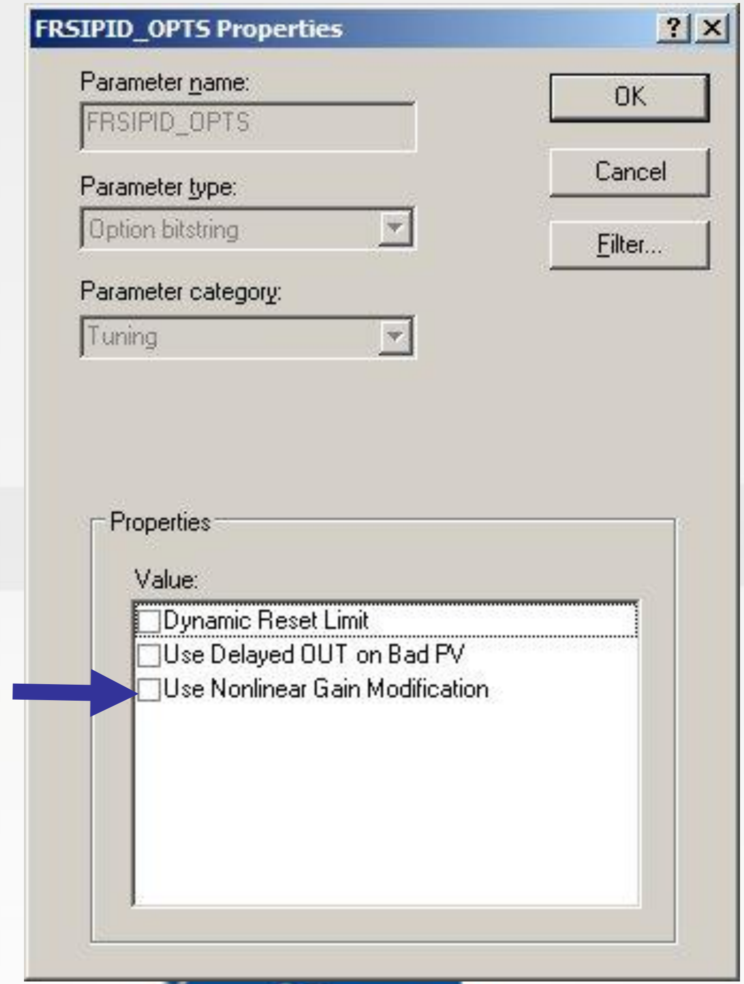
PID_GAINSCHED Module Detail Display (GS_DT)

The following figure shows the detail display in DeltaV Operate's run mode and describes the gain scheduling parameters. In order to minimize controller CPU loading, it takes about ten module scans to fully reflect the change of some of the configuration parameters. However, the actual GAIN, RESET, and RATE are calculated and written to the PID block every scan.



FRSIPID_OPTS: Non-linear Gain

- Modifies the proportional Gain as a function of the error (PV-SP)
- Can be used to make the tuning more aggressive as the PV is farther from the set point
- Can create the “error squared” PID function

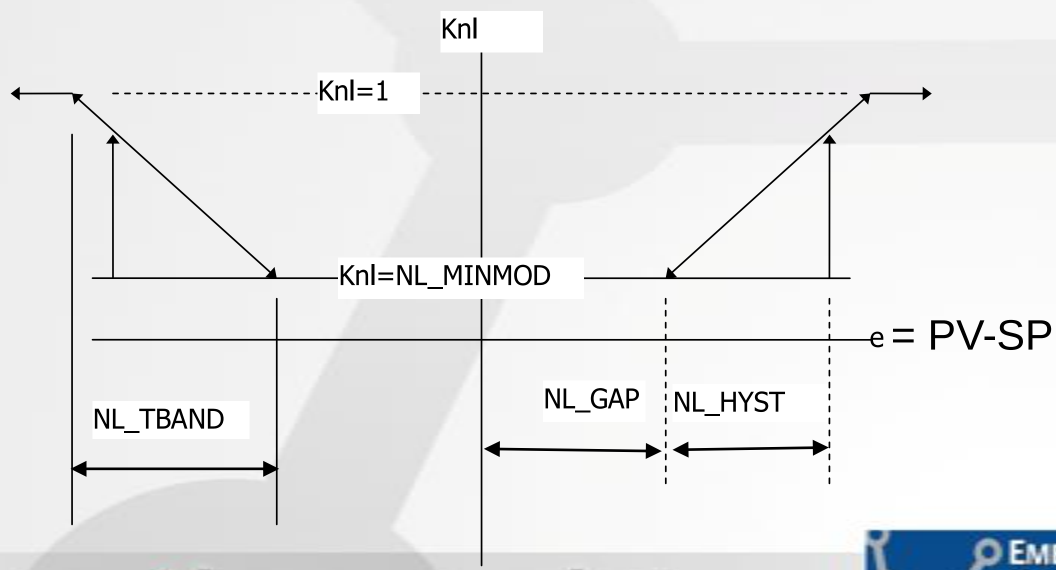


FRSIPID_OPTS: Non-linear Gain

The standard form is a discrete implementation of:

$$OUT(s) = \underbrace{\pm GAIN_a \bullet \Bigg(KNL}\bullet\left(\frac{P(s)\bullet T_r s}{(T_r s+1)} + \frac{E(s)}{(T_r s+1)}\right) + \frac{D(s)\bullet T_r s \bullet T_d s}{(T_r s+1)(\alpha T_d s+1)}\Bigg) + \frac{L(s)-F(s)}{(T_r s+1)} + F(s)$$

The PID "Gain" is multiplied by "KNL" which has a value between 0 and 1 as a function of the error (SP-PV).

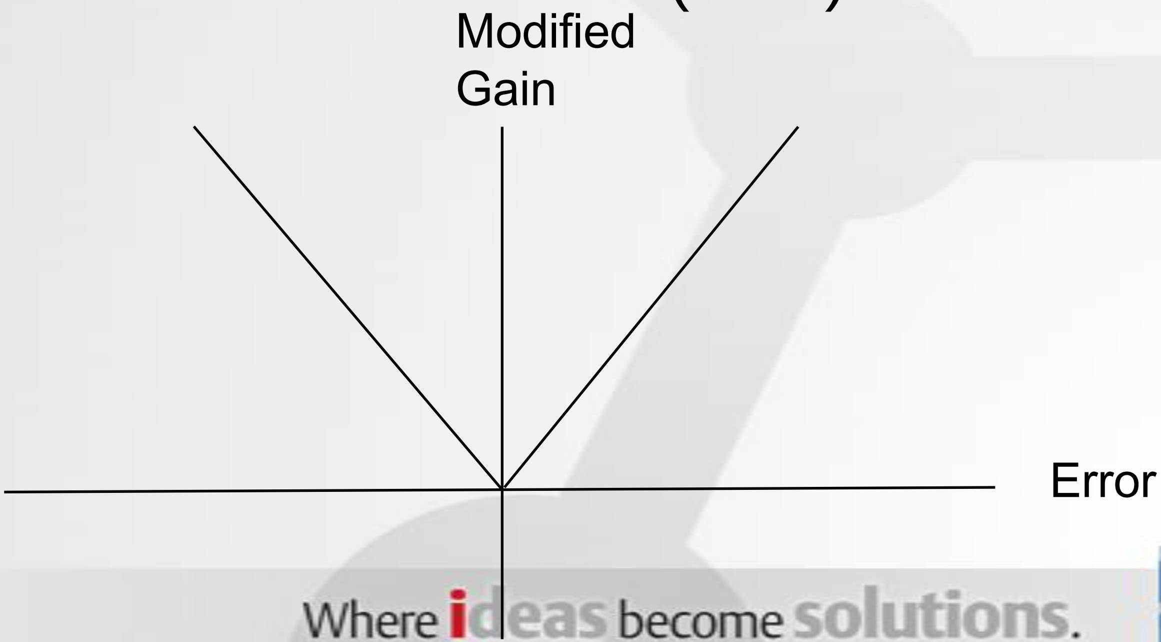


FRSIPID_OPTS: Non-linear Gain

- The PID "Gain" is multiplied by "KNL" which has a value between 0 and 1 as a function of the error
- I typically set NL_HYST = 0
- Be aware that using this feature on an integrating process, like levels, can cause oscillations at the reduced gain. For these applications, the reset time should be based on "Gain*MINMOD" which will result in a larger reset time to prevent oscillations.
- For this affect on integrating processes, consider using the Gain Scheduler

FRSIPID_OPTS: Non-linear Gain "Error^2"

- "Error squared" PID function – error*abs(error)
- Proportional = error*abs(error)*gain
  = error* (abs(error)*gain)
- Proportional = error*(Modified Gain)
- Modified Gain = abs(error)*Gain

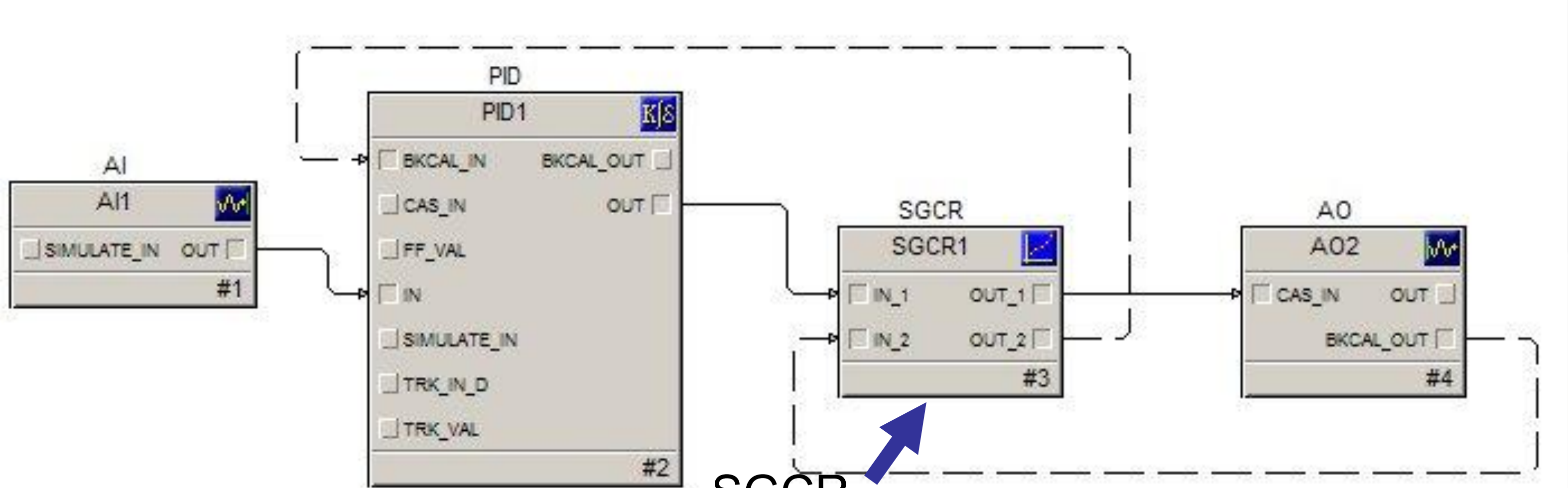


Non-linear Gain Settings for E^2

Activate NL Gain
NL_MINMOD = 0
NL_GAP = 0
NL_TBAND = 100
NL_HYST = 0

Output Characterization to Valve

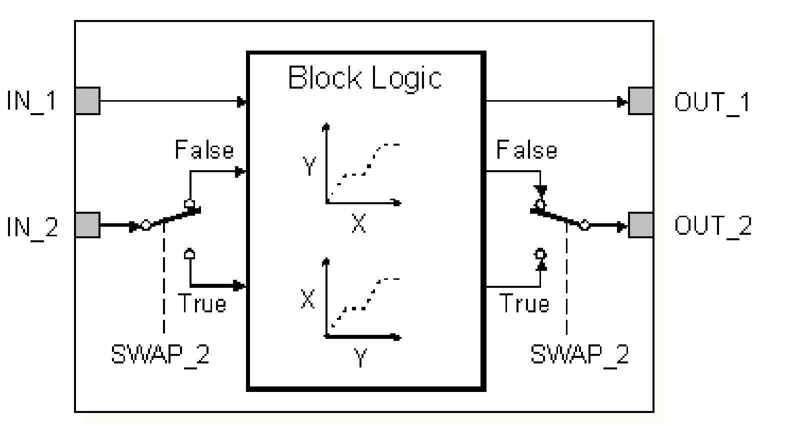
- Use a “Signal Characterizer” function block to change valve characteristics
  - Note the best solution is to change valve trim to proper characteristic



SGCR
•Characterizes IN_1 to OUT_1
•Reverse Char. IN_2 to OUT_2

Output Characterization to Valve

- See Books On Line for rules for the X and Y curves
- Set “SWAP_2” = TRUE to provide a “reverse” characterization for the BKCAL signal (The answer in V9.3 and later is “Change X by Y axis on IN-2”.)



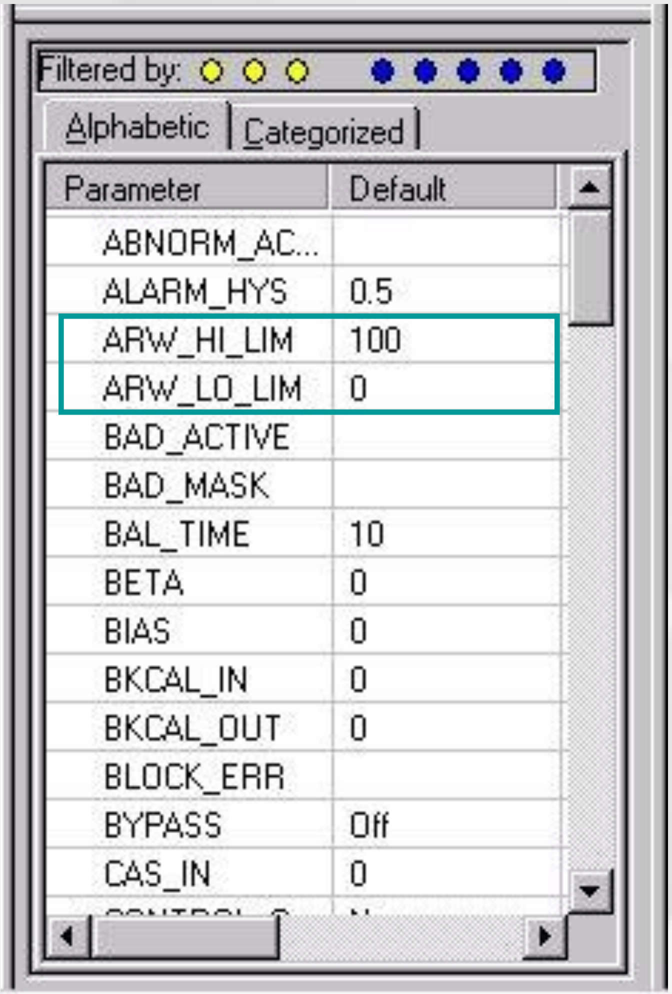
Signal Characterizer Function Block Schematic Diagram

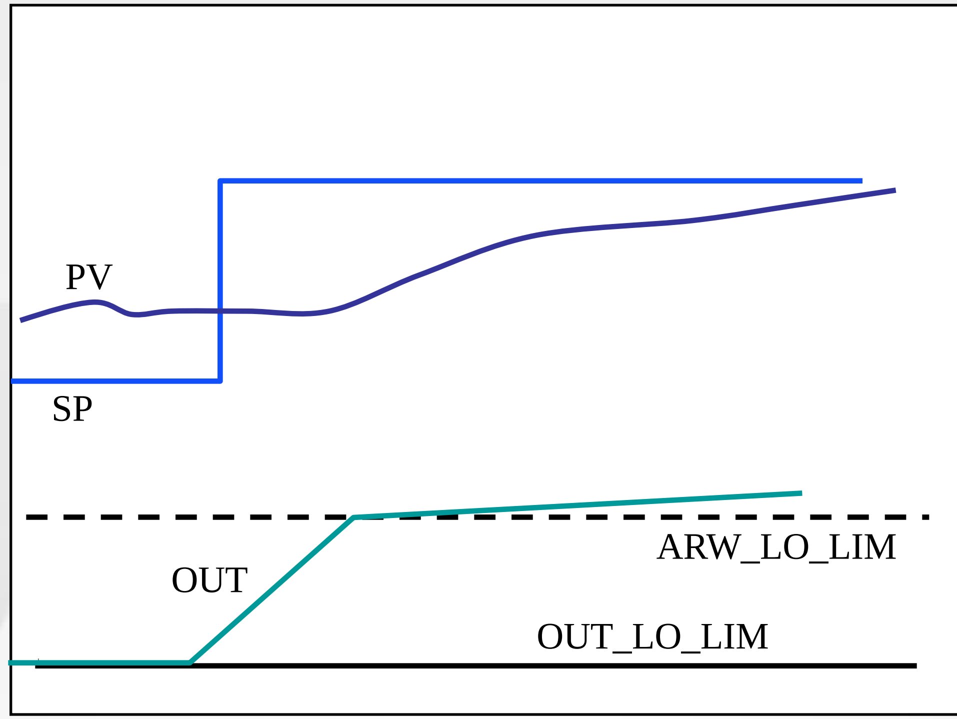
- BOL: The SWAP_2 parameter swaps the X and Y axes used for OUT_2. When the SWAP_2 parameter is True, IN_2 references the CURVE_Y values and OUT_2 references the CURVE_X values. In addition, the IN_2 units change to Y_UNITS and the OUT_2 units change to X_UNITS.

Anti-Reset Windup Limits

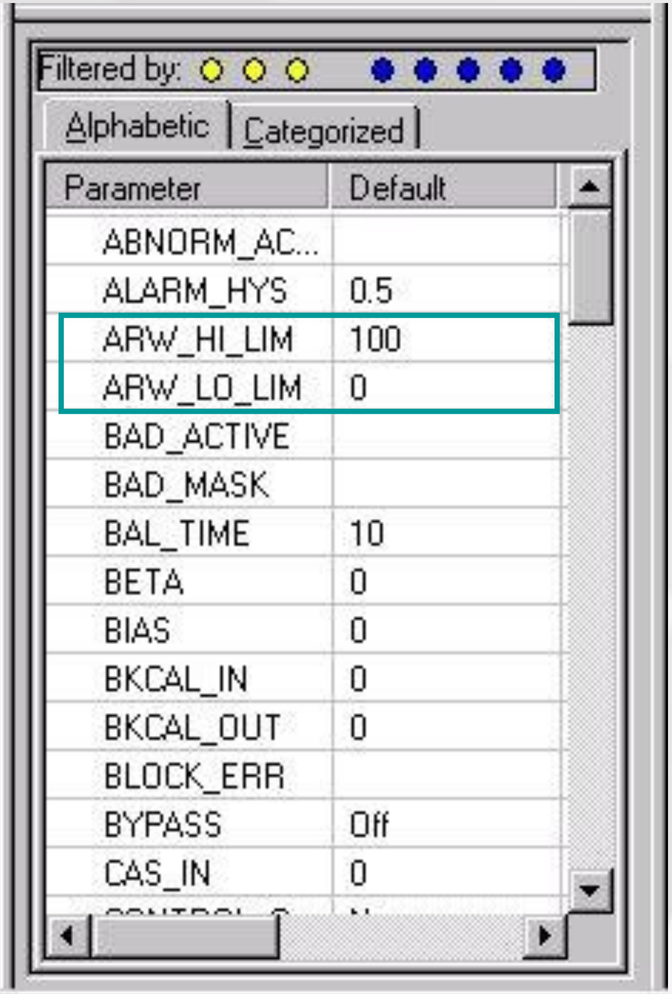
- Improves process recovery from saturated conditions
- On recovery from a saturated condition, when the ARW_HI_LIM and ARW_LO_LIM are set inside the OUT limits, the reset time will automatically be decreased (faster) by 16X until the OUT parameter comes back within the the ARW limits or the control parameter reaches setpoint.

Setting ARW limits





Setting ARW Limits – Important!!!!!



Filtered by:

Alphabetic | Categorized

Parameter	Default
ABNORM_AC...	
ALARM_HYS	0.5
ARW_HI_LIM	100
ARW_LO_LIM	0
BAD_ACTIVE	
BAD_MASK	
BAL_TIME	10
BETA	0
BIAS	0
BKCAL_IN	0
BKCAL_OUT	0
BLOCK_ERR	
BYPASS	Off
CAS_IN	0

- ARW limits are in Engineering Units of the OUT_SCALE. The default is 0-100. If the OUT_SCALE is other than 0-100, be sure to initially set ARW limits to the OUT_SCALE limits.

- For example, for the master loop of cascaded loops, the OUT_SCALE is 0-25,000 lbs/hr. Set ARW_HI_LIM = 25,000 and ARW_LO_LIM = 0.

Business Results Achieved

- These features can be used to significantly improved the performance of PID control
- The default ARW limits of 0-100 is a common problems for the master loop in a cascade arrangement. Correcting the ARW limits improves control.
- These features can be used to customize the response of the PID controller to meet process requirements
- "Difficult" process dynamics can be handled
- Bottom line – Better control performance = $$$$

Summary

- DeltaV has many useful control features
- Watch out for default parameters (ARW limits) that don't match your application
- Better control performance = $$$$
- Questions

Where To Get More Information

- Emerson Process Management Education Services
  - DeltaV™_ Advanced Control
    Course: # 7201 - CEUs: 3.2
  - DeltaV™ Operate Implementation I
    Course: # 7009 - CEUs: 3.2
  - EnTech - Process Dynamics, Control and Tuning
    Course: # 9030 CEUs: 2.8
- Emerson Process Management, Advanced Automation Services
  http://www.emersonprocess.com/solutions/consulting/advancedautomation/index.asp
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About the Presenter

- **James Beall** is a Principal Process Control Consultant with Emerson Process Management. He has over 26 years experience in process control, including 7 years with Emerson and 19 years with Eastman Chemical Company. He graduated from Texas A&M University with Bachelor of Science degree in Electrical Engineering. His areas of expertise include process instrumentation, control strategy analysis and design, control optimization, DCS configuration and maintenance, control valve performance testing and Advanced Process Control. James is a contributing author to Process/Industrial Instruments and Control Handbook (5th Edition, G.K. McMillan, McGraw-Hill, New York, 1999. He is a member of AIChE and is currently the chairman of ISA Subcommittee 75.25, Control Valve Performance Testing.