Back to the Basics - Process Control Diagnostics Improves Refinery Performance

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  – 19 Years at Eastman Chemical Company

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A Solid Control Foundation is Essential to the Success of Any APC project

- The core of a solid foundation is good measurements and final elements.
- Deficiencies in the measurement and final element can increase the time required for process testing and identification by a factor of 5 or more and can significantly reduce the improvement in process capacity and efficiency provided by APC.
- Significant economic benefit can be obtained from a good control foundation!
A Winning Combination

When Performed Together, Loop Optimization and APC Yield The Best Financial Return (Add ~25% APC Budget)

McKinsey Study June 97

Average APC Spend: $300K - $750K (30 to 40 Loops)
Average Loop Spend: $250K (30 Loops)

Value Realized:
- 40 - 50% for APC
- 50 - 60% for Loop Variability

Business Systems
Production Management
Real-Time Optimization
Monitoring and Analysis
Advanced Process Control
Control Loop Performance (Includes Instrumentation)
Key Take-Away Message

➔ Control key process parameters with less variability

➔ Operate closer to constraints with less variability
Largest and Most Frequent Opportunities in Basic Control

- Eliminate variability at the source
- Tune the controllers to meet control objectives
  - Coordinate Tuning Speed Based on Operating objectives
  - Attenuate Variability with Control/Equipment
- Utilize cascade and feed forward control
- Use a process analysis system to diagnose problems and tune loops
“The undesirable behavior of control valves is the biggest contributor to poor loop performance and the destabilization of product uniformity”.

W. L. Bialkowski, President
EnTech Control Engineering
Eliminate Sources of Variability: Valve Problems

Process Heaters

Methane Header
Eliminate Sources of Variability: Valve Problems - Flow Control Loop

Controller in automatic

Controller Output
2% change

PV
20% change

Time (sec)
Data (%)

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Eliminate Sources of Variability: Valve Problems - Flow Control Loop

Controller in manual - flow still moves

1% Steps

Controller Output

Flow PV

Data (%)

Time (sec)
Eliminate Sources of Variability: Valve Problems - Flow Control Loop

Controller in manual - stem position is moving

Flow PV
Eliminate Sources of Variability: Valve Problems – Regenerator Pressure Valve

→ New facility, new valve
→ Periods of good and back control performance
→ The valve was a rotary “tight shutoff” made for on-off service but was “adapted” to continuous control
Eliminate Sources of Variability:

Valve Problems – Regenerator Pressure Valve

4 hour trend

Periods of poor control

Setpoint

Pressure

Output

Valve Position
1) Valve doesn’t move then jumps 3%
2) When valve moves, pressure rises
3) Stem is rotating but ball is not rotating for 8% ???
4) Valve position spikes 2-3%

200 seconds
Eliminate Sources of Variability: Valve Problems – After Improvements

Setpoint
Pressure
Output
Valve Position
Eliminate Source of Variability: Poor Tuning

Before

After

PV

PV

Output

Output

© 2008, Emerson Process Management
Eliminate Source of Variability: Poor Tuning

Reactor Temperature and Set Point

Jacket Temperature and Set Point

Jacket Temp Controller Output

After re-tuning
10.5 / 18,490 sec / 0
Utilize tuning methodology as a TOOL to coordinate tuning of all loops as a system

- Methodical selection of the closed loop time constant of each loop, considering all interactions
- Attenuate variability with control/equipment
- Tuning to minimize resonance or “disturbance amplification” of lower level loops
**Tuning Methods**

- First tuning method due to Ziegler & Nichols (1942)
  - Called Quarter-Amplitude-Damping (QAD)
- "little black books"
- Default tuning (gain=1.0, Reset=1 min)
- Many people still do not use any method preferring to "tune-by-feel"
  - Classical control skills now rare
- Most older tuning methods try for "as fast as possible"
- Net result is each loop tuned independently
  - process dynamics not coordinated
**Tuning Issues**

- More aggressive – less robust – more resonance - less change in the process dynamics to cause instability

- Some loops require aggressive tuning for disturbance rejection – must be sure process dynamics are “constant” and carefully coordinate tuning in other loops in the system.

- Most loops benefit from the none-oscillatory tuning - allows coordinated tuning of all loops in the unit and minimizes resonance.
“In addition, optimized tuning procedures for unaided feedback controllers have limited practical value for continuous processes; they yield results that are far inferior to those obtainable with well damped feedback controls with simple feedforward and override control.”*

Coordinated Loop Tuning

Manipulate the closed loop time constant, Lambda, (\(\lambda\)) to:

- reject disturbances while ensuring stability
- separate the break frequency of cascaded or interacting loops
- treat all the loops in a Unit Operation as a SYSTEM
- control variability pathways

Allows optimization aimed at manufacture of uniform product more efficiently
Coordinated Tuning – Select Speed of Response

Dead Time = 1.5 seconds
Time Constant = 4 seconds

Setpoint
Process Variable

g = 4 sec.

Manual Step of Controller Output

Process Variable
Coordinated Tuning of all Loops as a System

→ Reactor feed  Process Goal: constant feedstock ratios
Ziegler-Nichols Tuning

Setpoint Change

Feedstock A  FC-1

Feedstock B  FC-2

Flows %

Seconds

0 10 20 30 40 50 60 70 80 90 100
Impact of Z-N Tuning - Feedstock Ratios Upset

- Ratio A/Total - Varies by 10%
- Ratio B/Total - Varies by 10%
Ziegler-Nichols Tuning

- **Feedstock A** (FC-1)
- **Feedstock B** (FC-2)
- **Setpoint Change**

*Graph showing flows as a percentage over time.*
Lambda Tune Both Loops for Identical Response

Feedstock A

Lambda Tuning
Time to Steady State = 4 x Lambda = 80 sec

Feedstock B
Impact of Lambda Tuning - Feedstock Ratios Constant

Ratio A/Total - Absolutely Constant

Ratio B/Total - Absolutely Constant
Coordinated Loop Tuning

Goal: Reduce Steam Usage

Issues: When the reflux was reduced, the steam was reduced and the product was on spec. However, the column control variables started to oscillate and the column tripped on low base Temp.
Coordinated Loop Tuning

Interaction!
Coordinated Loop Tuning

Coordinate speed of loops
Lambda shown in seconds
Tuning sequence critical
(Sequence – Lambda)
Results of Coordinated Loop Tuning

- Less variability of key process variables which reduced low base temperature shutdowns

- Reduced reflux from 275 lbs/hr to 200 lbs/hr

- Reduced steam usage by 25%
“Capacity” in the process can be used to attenuate or absorb variability

Primary source of process capacity is level control

To utilize level control as a capacity tune the controller as slow as possible but still “fast” enough to hold the PV within the allowable level deviation (ALD) for a maximum load change
Lambda Tuning for Integrating Processes - Load Disturbance Response

Step change in load (inflow) Outflow = inflow

Controller Output changing outflow smoothly!

PV Back to SP in 6 x Lambda

Change in PV stopped Setpoint

Lambda

Inflow Outflow

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Utilize Level Control as Variability Sinks

Choose the arrest time (Lambda) “slow” enough to provide a variability sink yet maintain level within the allowable variation

Lambda = f (ALV / (Kp * MLD)

- ALV = Allowable Level Variation
- Kp = Integrating process gain
- MLD = Maximum Load Disturbance
**Level Tuning – Results Coker Tower**

Before

![Before Graph](image1)

8 hours

After

![After Graph](image2)

8 hours
Reactor Levels and Outflows
Utilize Cascade and Feedforward

“In addition, optimized tuning procedures for unaided feedback controllers have limited practical value for continuous processes; they yield results that are far inferior to those obtainable with well damped feedback controls with simple feedforward and override control.”*

Utilize Cascade and Feedforward

Before

After
**Process Analysis Toolkit**

→ You MUST have a process dynamics analysis and diagnostic toolkit of some type!

→ If you don’t have process analysis toolkit, you are leaving a TON of money on the basement floor!
Process Analysis Toolkit
Process Analysis Toolkit

First Order Response
Process Analysis Toolkit

Bump Summary

Model: 1st Order

<table>
<thead>
<tr>
<th>Bump</th>
<th>DU</th>
<th>DY</th>
<th>Kp</th>
<th>Td</th>
<th>Tau1</th>
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</thead>
<tbody>
<tr>
<td>01</td>
<td>-0.498</td>
<td>4.02</td>
<td>-8.06</td>
<td>7.73</td>
<td>11.1</td>
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<td>02</td>
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<td>21.8</td>
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<td>0.495</td>
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<td>-32.1</td>
<td>6.26</td>
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<tr>
<td>05</td>
<td>0.500</td>
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<tr>
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<td>07</td>
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<td>1.63</td>
<td>-3.65</td>
<td>23.3</td>
<td>10.1</td>
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<tr>
<td>08</td>
<td>-0.498</td>
<td>5.49</td>
<td>-11.0</td>
<td>16.3</td>
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<tr>
<td>09</td>
<td>-0.501</td>
<td>20.0</td>
<td>-39.9</td>
<td>3.54</td>
<td>23.1</td>
</tr>
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</table>

Bump Table Summary

<table>
<thead>
<tr>
<th></th>
<th>Low Spread(%)</th>
<th>Average</th>
<th>High Spread(%)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>12.8</td>
<td>93.5</td>
<td>8.58</td>
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<tr>
<td>Average</td>
<td>-35.4</td>
<td>3.95</td>
<td>23.5</td>
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<tr>
<td>High Spread(%)</td>
<td>21.6</td>
<td>58.4</td>
<td>8.59</td>
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</table>

Suggested Values

<table>
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<tr>
<th></th>
<th>Auto Discard</th>
<th>Man. Discard</th>
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</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>-35.4</td>
<td>3.95</td>
</tr>
<tr>
<td>Spread</td>
<td>21.6</td>
<td>58.4</td>
</tr>
</tbody>
</table>

Units: DU in %Open, DY in ATS, Kp in ATS/%Open, Time Parameters in Sec
Process Analysis Toolkit

Tuning Parameters

Loop Overview
Tag: PC-202B.PV - R-2B Pressure
Pv: 0 to 2000 ATS, Op: 0 to 100 %Open
Process: 1st Order
Parameters: Kp=-1.77 %Span/%Out, Td=3.95 Sec, Tau1=23.5 Sec
Actuator: Class 1 (Poor)
Controller: Emerson Delta V [Series, D on PV]
Classical PID (D on Pw), [Units=%Out/%Span], [Ctrl Int.=0.1 Sec]

Tuning Rule: Suggested: PI (P-Z Cancellation)
Accept
Click Accept button to allow calculation of Controller Settings

Lambda: 30
Approx. Load Corner Period: 213.33 Sec
Wizard

Controller Settings

<table>
<thead>
<tr>
<th>Tuning Rule</th>
<th>PI (P-Z Cancellation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Filter</td>
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<tr>
<td>Proportional</td>
<td>0.3915 Gain</td>
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<tr>
<td>Integral</td>
<td>23.53 Sec/Rep</td>
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<tr>
<td>Derivative</td>
<td>None Sec</td>
</tr>
<tr>
<td>Ctrl Filter</td>
<td>None Sec</td>
</tr>
</tbody>
</table>

Lambda Range
Minimum Lambda Limit is 3.9525 Sec.
Due to the process dynamics, the Aggressive Lambda Value is 23.532 Sec.
Suggested Lambda Value is 70.595 Sec.

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Process Analysis Toolkit

Identifying Bumps

<table>
<thead>
<tr>
<th>Response</th>
<th>Bump</th>
<th>Register</th>
<th>Help</th>
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<tr>
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<td>A Pure Gain</td>
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</tr>
<tr>
<td></td>
<td>B 1st Order</td>
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<tr>
<td>![Checkmark]</td>
<td>C 2nd Order, OverDamped</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>D 2nd Order, UnderDamped</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E 2nd Order, Lead</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F 2nd Order, Lead with Overshoot</td>
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<td></td>
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<tr>
<td></td>
<td>G 2nd Order, Non-Minimum Phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>H Integrator</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>I Integrator, 1st Order Lag</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>J Integrator, 1st Order Lead</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>K Integrator, Non-Minimum Phase</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Emerson’s EnTech Toolkit

2nd Order Overdamped
Emerson’s EnTech Toolkit

Integrator + Lag
Summary

→ Eliminate variability at the source
→ Tune the controllers to meet control objectives
  - Coordinate Tuning Speed Based on Operating Objectives
  - Attenuate Variability with Control/Equipment
→ Utilize cascade and feed forward control
→ Use a process analysis system to diagnose problems and tune loops
Process Control Foundation Courses

- Course 9030, PCE I – Process Dynamics, Control and Tuning Fundamentals - 4.5 days

- Course 9031, PCE II – Process Analysis and Minimizing Variability – 4.5 days

- Course 9032, MLT – Modern Loop Tuning – 4 days, can be taught onsite or at LBP office
Thank You!

Questions?