How to Tune Cascade Loops

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Background

• Established 1989 - British Standards Institute (BSI) ISO9001:2000 Tick IT registered
• “Certified Suppliers” of FDA / GAMP Validated Control Systems for AstraZeneca -international Pharmaceutical Manufacturer
• Approved Solutions Partner (Sales, Support & Training) of ExperTune Inc.
• Experience of working in Oil, Pharmaceuticals, Chemicals, Glass, Food and Water.
How to Tune Cascade Loops

- An overview of Cascade Control.
- Tuning Cascade Control Loops.
- Case Study.

Cascade Control

In the right circumstances, Cascade Control can greatly improve the performance of a control system.
Temperature Control Loop

Steam Header

To other User

Heat Exchanger

TIC

TT

Process Schematic

FLOW TEMP

Temperature Control Loop
Temperature – Flow Cascade

Steam Header

To other User

FT

FIC

TIC

TIC (Master)

FIC (Slave)

TT

FLOW

TEMP

Process Schematic

The Cascade Loop
What's The Inner Loop For?

- Reduces phase lag of inner process
- Disturbances to the inner loop are compensated for before they upset the outer loop
- Prevents non-linearities in the inner loop from reaching the outer loop

Temperature – Flow Cascade

Steam Header

FT

FIC (Slave)

TIC (Master)

TT

Response to a Load Change
When slave is NOT in Remote/Auto mode Master OP is to track Slave Setpoint.
Integral action in Master is to be Inhibited when OP limit reached in Slave

Other Examples of Cascade

- Batch Reactor Temperature Control (Batch Temperature onto Jacket Temperature)
- Level – Flow Control
Level Control

Level loops are Integrating Processes

IN > OUT: Level Rises
IN < OUT: Level Falls
IN = OUT: Level Holds

Level Control

Level loops are Mass Balance Systems
A failure of the control valve to reposition itself correctly following a reversal in the control signal – level will cycle!!
Fixing the problems
Level – Flow Cascade

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What happens when cascade loops are poorly tuned?

- Loops “fight” each other
- Create oscillations
- Neither variable is properly controlled
- Operator puts loop in manual.

**Tuning Cascade Loops**

1. Always check for measurement and valve-related issues.
2. Inner Loop Tuning - put slave into Local Auto or Manual and tune the slave controller as a normal PID loop.
3. Outer Loop Tuning - put slave into Cascade and tune master controller as a normal PID loop.
4. Adjust outer loop tuning values to ensure that the RRT (Relative Response Time) of outer loop is 3-5 times slower than the inner loop.
Test Data - Inner Loop

Test Data - Outer Loop
Relative Response Time – What is it?

1. An indication of the closed loop response of a control loop.
2. Loops with short RRT’s are fast loops
3. Loops with long RRT’s are slow loops.
4. The RRT approximately defines the period of any load disturbance initiated oscillations when the controller is in automatic.

Relative Response Time and Cascade Loops

1. The closed loop response (i.e its RRT) of the outer loop MUST be 3 – 5 times slower than the inner loop.
2. After tuning, adjust outer loop PID values to achieve this.
3. Our example:
   Inner: 38 seconds
   Outer: 400 seconds
Determining the Relative Response Time

ExperTune derives the Relative Response Time by:
1) Calculating the closed loop frequency response to a load upset.
2) Finding the frequency where the amplitude ratio peaks.
3) Converting this to a time period.

Relative Response Time (RRT)
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Cascade Control – A Case Study

Waste Water Industry - Dissolved Oxygen Control
Dissolved Oxygen Control – As Found

- Oxygen Concentration controlled by QIC adjusting the flow of air.
- PID Control implemented in a Siemens S7 PLC.
- PIC used to control blower speed.
- Flow measurement for information only.
- If the blower speed exceeded 95% the second blower started (at the same speed) to assist the duty blower.
- Poor control.

Dissolved Oxygen Control – As Left

- Control Specialists Ltd modified the software at the request of the end user.
- Flow loop quickly rejects disturbances due to duty-standby boosters coming on and off line.
- Blower operating costs reduced.
- Control dramatically improved.
Bridging the gap between Industrial Processes and the Programmable Systems that control them.

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