Supra Self-Learning Modules in Chemical Engineering

Module 6: Industrial Process Control

Part I: Primary Process Control (Study Time 25 Hrs.)

Part I consists of Sections 1-9.

1) Overview of Modern Industrial Process Control

- a) Overview
- b) Need For Process Control
- c) Distributed Control System
  - i) Field Wiring ii) Analog Input Signals iii) Analog Output Signals iv) Digital Input Signals
  - v) Digital Output Signals vi) Input/Output Devices vii) Control Processors
  - viii) Control Network ix) History Module (HM) x) Operator Screen Monitors
  - xi) Computing Module (CM) xii) Host Computer
  - xiii) Programmable Logic Controller (PLC)
    - (1) Ladder Logic Programming
    - (2) Dual Or Triple Redundancy
    - (3) Plant Safety and Shutdown Logic
    - (4) Direct Valve Or Equipment Control
    - (5) Independent & Segregated Control Architecture
    - (6) PLC - PC Interface
- d) Choice of DCS or PLC
- e) Laboratory Information Management System (LIMS)
- f) Safety Interlocks and Shutdowns
- g) Permissives

2) Process Control Variable Definitions

- a) Controlled Variables (CV)
  - i) Temperature Control ii) Product Purity Control iii) Level Control iv) Pressure Control
- b) Manipulated Variables (MV)
- c) Process Variable (PV)
- d) Setpoint (SP)
- e) Process Dynamics
- f) Transfer Function
- g) Transfer Function Parameters
- h) Linear and Nonlinear Processes
- i) Identifying Process Dynamics
- j) Dynamics Identification Procedure
- k) Dynamics Identification With Multiple Inputs
- l) Rules For Conducting Pulse Tests

3) Primary Control and The PID Algorithm

- a) Manual Control
- b) Automatic Control
- c) The PID Algorithm
- d) Sign of the three terms
- e) Offset
- f) Primary Control

4) PID Algorithm - Additional Options and Parameters

- a) Process Noise
- b) Filter Time Constant
- c) Direction of Control Action
- d) Direct and Reverse Action
- e) Other Forms of The PID Algorithm
  - i) Gap Action PID ii) Gap High and Low Limits iii) Gap Gain
- f) Nonlinear PID
- g) Output Sponge PID
- h) Split Range PID
- i) PID Faceplate
- j) PID Detailed Screens

5) Cascade PID Algorithm

- a) Level-To-Flow Double Cascade
  - i) Valve Characteristics ii) Variable Tank Head
- b) Temperature-To-Temperature Double Cascade
- c) TC-FC Double Cascade
- d) AC-TC-FC Triple Cascade
- e) AC-TC-QC-FC Quadruple Cascade

6) Override Control Strategies

- a) Dual Level Control
- b) Dual Temperature Control
- c) Low Level Override Constraint Control
- d) Distillation Reflux Flow Override
- e) Compressor Override Controls
- f) High and Low Override Constraint Control
- g) Maximization of Production Rates
- h) Need For Constraint Override Control Strategies

7) PID Modes and PID Activation Procedure

- a) PID Controller Modes
  - i) Manual State ii) Automatic State iii) Cascade State or Remote State
  - iv) Not-Cascade State or Local State
- b) Summary of Different PID Modes and States
- c) How To Change PID State
- d) Ranges of A PID Controller
  - i) PV Range ii) SP Range iii) OP Range
- e) Setpoint Tracking and Output Initialization
- f) The "Track" Flag
- g) Bumpless Transfer
- h) Cascade Chain Activation Sequence
- i) Chain Activation Sequence For A Constraint Override Loop
- j) PV Tracking
- k) How To Enable PV Tracking
- l) Benefits of PV Tracking
- m) When To Use PV Tracking
- n) PV Tracking In Case of Master PIDs

8) PID Tuning Procedures and Control Quality

- a) Open-Loop and Closed-Loop Mode
- b) Engineering Units of PID Tuning Parameters
- c) PID Tuning Procedures
  - i) Method 1 - Startup Tuning
    - (1) Flow controller (FC)
    - (2) Pressure Controller (PC)
    - (3) Temperature Controller (TC)
    - (4) Analyzer Controller (AC)
    - (5) Valve Position Controller (ZC or VC)
    - (6) Level Controller (LC)
    - (7) Surge Controller (UC)
    - (8) Motor Power Controller (JC)
  - ii) Method 2 - Open-Loop PID Tuning
    - Equations For Determining PID Tuning Parameters
  - iii) Method 3 - Closed-Loop PID Tuning
    - Tuning Tips
  - iv) Method 4 - DCS Auto-Tuning
- d) Effect of Range Change on PID Tuning Parameters
- e) Advanced Control PID Control
- f) PID Tuning and Control Quality
  - i) Integral Absolute Error ii) Integral Squared Error iii) Integral Time Absolute Error
- g) Comparison of The Criteria

9) Process Control Schematics

Part II: Advanced Process Control (Study Time 30 Hrs.)

Part II consists of Sections 10-15.

10) Disturbances, Feedforwards and Decouplers

- a) Disturbance
  - i) Unmeasured Disturbances ii) Measured Disturbances
- b) Feedforward Control
- c) Feedforward and Feedback Control Examples
- d) Feedforward Strategy Implementation In DCS or PLC
- e) LEAD and LAG Action
- f) Final Steady State Value From Feedforward
- g) Cases where Feedforward Control may not be effective
- h) Distillation Column Feedforward
- i) Decouplers

11) Process Signal Filtering and Control Valve Checkout

a) Signal Noise
b) Effect of excessive noise on control quality
c) Filter Constant
d) When To Use Filtering
e) Selecting Filter Constant
f) Optimal Filtering
g) Adding Filtering During PID Tuning
h) Impact of Noise Band on Open-Loop Test Procedure
i) Identifying Valve Problems
j) Effect of Noise on PID Control Action

12) Dead Time Compensation and Model-Based Control

a) Dead Time in Control Loops
    i) Transportation Delay   ii) Thermal Inertia and Capacitance   iii) Mass or Volume Holdup
b) Effect of Dead Time On Control Quality
c) When Dead Time Is Really Harmful In A Control Loop
d) Methods to combat dead time
e) Dead Time Compensation Implementation in DCS or PLC
f) Model-Based Control
g) Pure Transfer Function-Based Models
h) Rigorous Predictive Models
i) Steps In Implementing A Rigorous Model-Based Control Scheme

13) Control Schemes Using Discrete Signals

a) Continuous Signals
b) Discrete Signals
c) PV Sample Delay
d) Discrete Signals
e) Distillation Control With PV Sample Delay
f) Distillation Cascade Control With PV Sample Delay
g) Analyzer Multiplexing
h) Inferential Model-Based Control
i) Analyzer Data Validation
    i) Spike Rejection   ii) Frozen Value Check
j) PID Scan Time

14) Model Predictive Control and Rule-Based Control

a) Types of Process Control Strategies
b) Characterizing Process Dynamics In MPC
c) Control Matrix
d) MPC Algorithm
e) Feedback Correction
f) Rate of Change
g) Multivariable MPC System
h) Priority of Controlled Variables
i) Local Optimization
j) When To Use MPC and When To Use TAC
k) When To Use MPC and When To Use TAC
l) Analyzing the criteria to select TAC or MPC
m) Benefits Due To Advanced Control
n) Pros and Cons of MPC Versus TAC
o) Operating Zones
p) Rule-Based Control and Fuzzy Control
    i) Slow Control Near A Constraint   ii) Startup Versus Steady-State Operation   iii) Fuzzy Control
q) Types of Advanced Control Tools
    i) TAC   ii) MPC   iii) Rule-based or Fuzzy Control

15) Handling Nonlinearities

a) Linearity
b) Valve-To-Flow Nonlinearity
c) Gain Scheduling
d) Valve Characterization
e) Constraint Control
f) Reflux-To-Product Impurity Nonlinearity
g) Average Temperature Control

Part III: Lab Session (Study Time   20 Hrs.)

Part III consists of Section 16.

16) Lab Sessions (Practical Exercises)

The various simulation exercises will be conducted with **PITOPS** industrial process control software. This software accompanies this training module and can be used in a variety of ways. PITOPS software consists of two modules - **PITOPS-PID** and **PITOPS-TFI**.

PID stands for PID Control Tuning and Design.
TFI stands for Transfer Function Identification.
PID module simulates PID controllers, cascade PIDs, feedforward loops and Dead Time Compensator.
Various other features are provided for primary and advanced control tuning and design.
TFI module identifies transfer functions using time-series plant data.

The following nine lab sessions will be conducted using the PITOPS-PID module and tenth session using PITOPS-TFI module.

1. Configure a transfer function and study open-loop response.
2. Configure a PID loop, simulate a setpoint change, tune the PID.
3. Add random noise to the previous simulation.
4. Configure external disturbances.
5. Tune a Temperature Control PID (TC).
6. Tune a Level Control PID (LC).
7. Tune a cascade PID.
8. Configure Disturbance and Feedforward transfer function.
9. Configure a Model-based Dead-time compensator.
10. Identify a transfer function using simulated plant data.

Guidelines and Recommendations

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