Intro to Process Dynamics and Control

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Process Dynamics and Control

Defining process dynamics and control

- **Process** - conversion of feed materials to products using chemical and physical operations
  - Continuous, batch, semi-batch
- **Process dynamics** - unsteady-state/transient process behavior
  - Start-ups, shutdowns, process disturbances, planned transitions
- **Process control** - maintain a process at desired operating conditions
  - Utilize information flow
  - Impacts safety, environment, quality, economics
  - **Manual control** - control strategy implemented by a person
  - **Automatic control** - control strategy automated by computers

Types of variables

- **Set point** - desired nominal value of controlled variable
- **Controlled variable** - variable being regulated and maintained (to be controlled) at set point
- **Manipulated variable** - variable that can be adjusted
- **Disturbance variable** - variable that perturbs the system, changes controlled variable, but cannot be directly tuned

Classification of control strategies

- **Feedback control** - controlled variable is measured to adjust manipulated variable (disturbance variable not measured)

- **Feedforward control** - disturbance variable measured to adjust manipulated variable (controlled variable not measured)

Feedback control measures controlled variable

- **Feedback control** - controlled variable is measured to adjust manipulated variable (disturbance variable not measured)
  - **Negative feedback** - controller forces controlled variable toward set point
  - **Positive feedback** - controller forces controlled variable farther away from set point
  - ➕ Correction occurs regardless of source of disturbance
  - ➕ Reduces sensitivity of controlled variable to unmeasured disturbance and process changes
  - ➖ Correction only happens after controlled variable deviates set point (disturbance has occurred)

Feedforward control measures disturbance variable

- **Feedforward control** - disturbance variable is measured to adjust manipulated variable (controlled variable not measured)
  - + Correction happens before controlled variable deviates set point
  - − Disturbance variable must be measured or accurately estimated
  - − Do not account for unmeasured disturbances
  - − Process model is required

Challenges in process control

- Systems are often nonlinear
- Time delays are common at scale
- Real systems are complex and interconnected

Types of control processes

- **Single-input/single-output (SISO)** - one manipulated variables (input) and one controlled variables (output)
  - + Easy to model and implement
  - − Less control
- **Multiple-input/multiple-output (MIMO)** - multiple manipulated variables (input) and multiple controlled variables (output)
  - + Better control
  - − Hard to model and implement
- Balance robustness to disturbance and complexity of model

Hierarchy of control activities

1. Measurement and actuation (< 1 s)
2. Safety and environmental/equipment protection (< 1 s)
3. Regulatory control (sec - min)
4. Multivariable and constraint control (sec - min)
5. Real-time optimization (hr - day)
6. Planning and scheduling (day - month)

Theoretical models of chemical processes

- **Theoretical models** - developed using principles of physics, chemistry, and biology

- **Empirical models** - obtained by fitting experimental data

- **Semi-empirical models** - numerical values of 1(+) parameters in a theoretical model are calculated from experimental data

Theoretical models of chemical processes

- **Theoretical models** - developed using principles of physics, chemistry, and biology
  - + Physical insight into process behavior
  - + Applicable over wide ranges of conditions
  - − Expensive and time-consuming to develop
  - − Model parameter not readily available
- **Empirical models** - obtained by fitting experimental data
  - + Easy to develop and use
  - − Do not extrapolate to conditions beyond range
- **Semi-empirical models** - numerical values of 1(+) parameters in a theoretical model are calculated from experimental data
  - + Incorporate theoretical knowledge
  - + Extrapolate over wider range of operating conditions
  - + Requires less developmental effort