Lab 02: Cascade control

CHEN4011: Advanced modeling and Control

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1 Objectives

1. To learn how to tune a cascade control system for stable secondary and primary processes
2. To learn how to tune a cascade control system for stable secondary process and integrating primary process.
3. To develop Matlab Simulink model of cascade control for the process simulation

2 Process information

2.1 Case 1

$$\begin{aligned}\text{Primary Process: } G_p(s) &= \frac{2.5\exp(-4s)}{(5s+1)} \\ \text{Secondary Process: } G_s(s) &= \frac{-1.6\exp(-1.2s)}{1.5s+1}\end{aligned} \tag{1}$$

2.2 Case 2

$$\begin{aligned}\text{Primary Process: } G_p(s) &= \frac{0.2\exp(-5s)}{s} \\ \text{Secondary Process: } G_s(s) &= \frac{2\exp(-0.8s)}{2s+1}\end{aligned} \tag{2}$$

3 Methodology

For each case in Section 2

1. Tune a PI controller using a classical PID tuning formula.
2. Develop the Simulink models for the feedback control using primary loop only and cascade control strategy (with a tightly tuned inner loop).

Evaluate the control performance for:

i. Setpoint tracking (Step input in setpoint)
ii. Disturbance rejections for input disturbance.
iii. Disturbance rejections for output disturbance.

Here are some common error metrics used to evaluate the performance of controllers:

1. **Integral of Time-weighted Absolute Error (ITAE):**

$$ITAE = \int_0^T t \cdot |e(t)| \, dt$$

   ITAE penalizes large errors that persist for a long time.

2. **Integral of Absolute Error (IAE):**

$$IAE = \int_0^T |e(t)| \, dt$$

   IAE gives a measure of the total absolute error over time and is sensitive to both the magnitude and duration of the error.

3. **Integral of Squared Error (ISE):**

$$ISE = \int_0^T e(t)^2 \, dt$$

   ISE penalizes larger errors more heavily than smaller errors, making it useful when minimizing large errors is particularly important.

4. **Integral of Time-weighted Squared Error (ITSE):**

$$ITSE = \int_0^T t \cdot e(t)^2 \, dt$$

   ITSE is similar to ISE but includes a time-weighting factor, penalizing errors that persist for longer periods.

5. **Peak Absolute Error (PAE):**

   PAE is the maximum absolute error that occurs over the time period of interest. It's a measure of the largest deviation from the desired output.

6. **Settling Time:**

   The settling time is the time required for the error to fall within a specified percentage (e.g., 2% or 5%) of the final steady-state value and stay within that range.

7. **Rise Time:**

   The rise time is the time required for the system response to rise from a specified lower percentage to a specified higher percentage of its final steady-state value.

8. **Overshoot:**

   Overshoot is the percentage by which the system's response exceeds its final steady-state value. It gives an indication of the stability and damping of the system.

4 Report Format

1. Provide and describe the MATLAB Simulink model of your cascade control system. (5 marks)
2. Answer the following questions (5 Marks)
3. Can the cascade control provide improvement over the single-loop control for the input or output disturbance? Show the plots of the closed-loop responses of the primary and secondary variables to support your argument. Use
4. Can the cascade control provide improvement over the single-loop control for the setpoint change? Show the closed-loop responses of the setpoint tracking for the primary variable.
5. What happens if the system is subjected to modelling errors, e.g., 10% errors in model parameters? Show the closed-loop responses to support your discussion.