IIT Bombay
Systems and Control Engineering
Intelligent Feedback and Control

SC 645 — ***Assignment 2*** — Maximum Marks: 10

Deadline
Date: 18.02.24, 11.59pm

Instructions:

- Submit the answers to this assignment on or before the deadline at 11:59 p.m. on 18.02.2024. This is a strict deadline, and no request for any extension will be entertained.
- All the results and the associated observations/analysis must be compiled in a single pdf file. This pdf and the associated code must also be submitted in a single zip folder on moodle on the relevant submission link.
  Label this folder in the form: FirstName_RollNumber_AS02.
- Please preserve the code and the report till the end of this semester.
- Assumptions made, if any, must be clearly stated and must be justified.
- After the end of each question, the numbers to the right, in square brackets, indicate marks allotted to it.

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1. A physical example (temperature control of a jacketed CSTR) is shown in Figure 1. The output of the primary controller (reactor temperature) is the setpoint to the inner-loop controller. The manipulated variable for the secondary loop is the jacket flow rate. If the flow rate becomes constrained, or if the jacket temperature controller is not tuned tightly the jacket temperature will not closely match its setpoint, causing problems with the integral action in the primary loop. For simplicity, let the primary and secondary processes be represented by the following second-order transfer functions,

$$g_{p_1}(s) = \frac{1}{10s^2 + 2s + 1} \tag{1}$$

$$g_{p_2}(s) = \frac{1}{2s^2 + 4s + 1} \tag{2}$$

   and assume PI tuning, where the secondary process dynamics were neglected in the design of the primary controller. The primary and secondary loops used closed-loop time constants of 5 and 2 minutes, respectively. The manipulated input is assumed to saturate at ± 1.

   - Draw the closed-loop block diagram considering cascade control and calculate the primary and secondary system characteristics (i.e., damping ratio, undamped natural frequency) for unit step input.

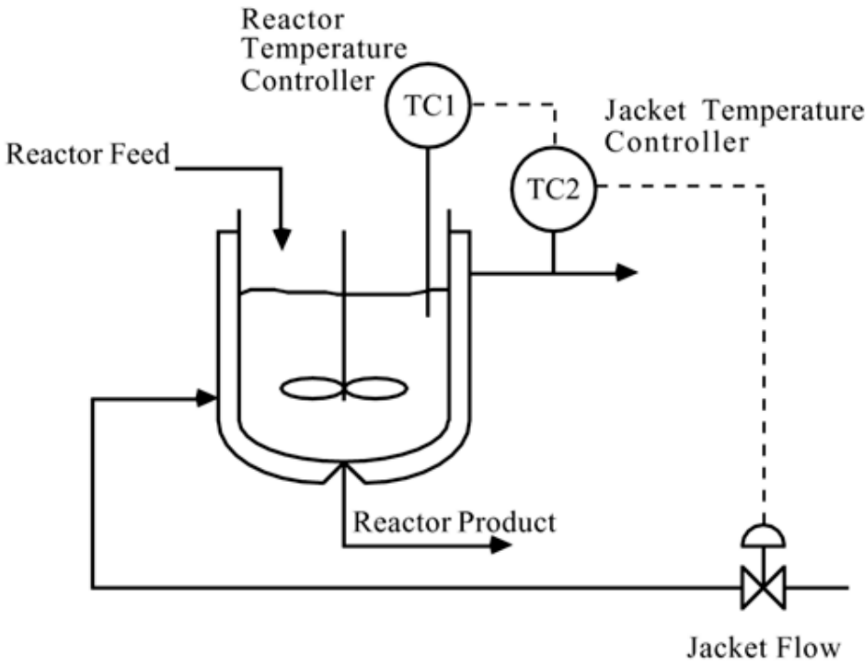

Figure 1: Cascade-control applied to a CSTR

- Use simulation (such as MATLAB, Simulink, or Python) to simulate a control system with and without Integral Windup to a unit setpoint change. Present visualizations, graphs, or plots that demonstrate the impact of Integral Windup on system behavior.
- Discuss the simulation results, draw conclusions about the importance of addressing Integral Windup in the system above, and suggest a possible solution validated with results to overcome the windup.

Ensure you provide clear explanations, use relevant equations, and support your answers with appropriate references and examples. [06]

2. Given the following transfer function:

$$G(s) = \frac{e^{-1.2s}}{s^2 + 2} \tag{3}$$

- Analyze the stability margins using the Nyquist Stability Criterion using theory as well as simulation. Discuss the implications of positive or negative stability margins on the system's performance.
- Explore how system parameters or controller gain changes affect the stability margins. Provide insights into how engineers can tune the system to achieve desired stability characteristics.

[04]