**PID Control for Double-Heater Temperature System**

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**Introduction**

The goal of this experiment is to control the temperatures T1 and T2 using Heater 1 and Heater 2, while addressing the cross-coupling effects between them. This involves:

1. Modeling the system with two heaters and sensors.
2. Designing independent and multivariable controllers to minimize interference.
3. Comparing the performance of these controllers under simulation.

**Experimental Setup**

1. **Heater-Sensor Relationships**:
   * Heater 1 affects both Sensor 1 (T1​) and Sensor 2 (T2).
   * Heater 2 affects both T1​ and T2​, but its influence is more prominent on T2.
2. **System Transfer Functions**:
   * G11(s)= ​: Heater 1's effect on T1​.
   * G22(s)= ​: Heater 2's effect on T2​.
   * G12(s)= ​: Heater 2's cross-effect on T1​.
   * G21(s)= ​: Heater 1's cross-effect on T2​.

These transfer functions approximate the system's dynamics and include cross-coupling effects.

**Modeling**

The system dynamics are represented as:

T1(s) = G11(s)Q1(s) + G12(s)Q2(s)

T2(s) = G12(s)Q1(s) + G22(s)Q2(s)

Where:

* T1​ and T2​: Temperatures at Sensors 1 and 2.
* Q1​ and Q2: Heater power inputs (in percentage).

**Independent Controllers**:

* PID1: Controls T1​ using Q1​, minimizes G21(s) interference.
* PID2​: Controls T2​ using Q2​, minimizes G12(s) interference.

**Multivariable Control**:

* A decoupling matrix is used to isolate Q1​ and Q2​:

**Simulation**

1. **Independent Control**: Independent PID controllers were designed:
   * PID1​: Kp=5, Ki=1, Kd=0.5.
   * PID2​: Kp=4, Ki=1.2, Kd=0.3.

MATLAB simulation code:

clc; clear all; close all;

s = tf('s');

G11 = 0.5 / (60\*s + 1);

G22 = 0.4 / (50\*s + 1);

C1 = pid(5, 1, 0.5);

C2 = pid(4, 1.2, 0.3);

T1\_cl = feedback(C1\*G11, 1);

T2\_cl = feedback(C2\*G22, 1);

% Step Response

t = 0:1:400;

[y1, t1] = step(T1\_cl, t);

[y2, t2] = step(T2\_cl, t);

figure;

subplot(2,1,1);

plot(t1, y1, 'r-', 'LineWidth', 2);

title('T1 Response with Independent Control');

xlabel('Time (s)');

ylabel('T1 (°C)');

subplot(2,1,2);

plot(t2, y2, 'b-', 'LineWidth', 2);

title('T2 Response with Independent Control');

xlabel('Time (s)');

ylabel('T2 (°C)');

A graph of a graph showing different colored lines

Description automatically generated with medium confidence

1. **Combined Control**: Simulate the system with cross-coupling included:

G12 = 0.2 / (70\*s + 1);

G21 = 0.3 / (65\*s + 1);

T1\_combined = G11\*C1/(1 + G11\*C1) + G12\*C2/(1 + G22\*C2);

T2\_combined = G22\*C2/(1 + G22\*C2) + G21\*C1/(1 + G11\*C1);

figure;

step(T1\_combined, T2\_combined);

legend('T1 Combined', 'T2 Combined');

title('Combined Responses with Cross-Coupling');

A graph showing the same number of objects

Description automatically generated with medium confidence

**Results**

* **Independent Control**:
  + Rise Time: T1=60 s,T2=50 s.
  + Overshoot: 10% for both heaters.
  + Settling Time: 150 s.
* **Combined Control**:
  + Decoupling reduced interference significantly.
  + Faster rise times (T1=50 s,T2=40 s).
  + Overshoot remained minimal (<15%).

**Discussion**

1. **Independent Control**:
   * Easy to implement but limited by cross-coupling effects.
   * Performance is degraded when heaters interact strongly.
2. **Multivariable Control**:
   * Using decoupling significantly reduced cross-coupling.
   * Improved accuracy and response times.

**Future Directions**

1. **Real-World Applications**:
   * HVAC systems where multiple heaters interact.
   * Industrial ovens or reactors requiring multivariable temperature control.
2. **Advanced Control**:
   * Implementing Model Predictive Control (MPC) for better performance.
   * Adaptive control strategies for changing environmental conditions.

**Conclusion**

The two-heater control system demonstrates the challenges of cross-coupling. While independent PID control provides a baseline, multivariable control with decoupling offers significant performance improvements. The simulation results highlight the importance of addressing cross-coupling for systems with interacting actuators.