Boiler Drum Water Level Control

Comparison of PID and Lead/Lag Controllers

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1 Introduction

In thermal power plants, precise control of the boiler drum water level is essential. Poor control may cause low steam quality or overheating of equipment. This project models the boiler drum dynamics as a simplified linear time-invariant (LTI) system with two inputs (feedwater flow and steam outflow) and one output (drum water level).

Two classical control strategies are designed and compared:

- A PID controller (2-DOF form, tuned via SIMC rules).
- A Lead/Lag compensator (phase-lead design at desired crossover).

2 System Model

The plant is modeled as:

$$h(s) = G_1(s)u_1(s) + G_2(s)u_2(s)$$

with

$$G_1(s) = \frac{K_1}{T_1 s + 1}, \quad G_2(s) = \frac{K_2}{T_2 s + 1}$$

where u_1 is feedwater input, u_2 is steam disturbance, and h is the drum level. Default parameters: $K_1 = 1$, $T_1 = 50$ s, $K_2 = -0.8$, $T_2 = 60$ s.

3 Controllers

3.1 PID Controller

A PI form was chosen with parameters from SIMC tuning:

$$C_{\text{PID}}(s) = K_p + \frac{K_i}{s}$$

with 2-DOF weights ($\beta = 0.8$ for proportional, $\gamma = 0$ for derivative). This ensures zero steady-state error for step references and disturbance rejection.

3.2 Lead/Lag Compensator

The compensator is designed as

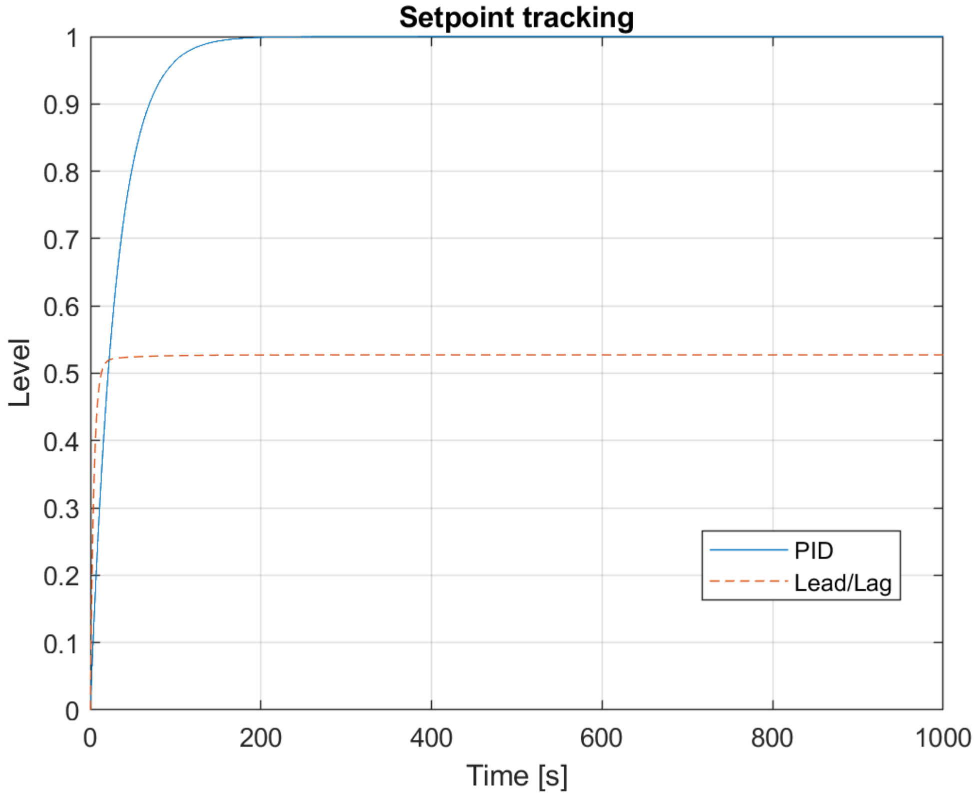
$$C_{\text{LL}}(s) = K\frac{Ts + 1}{\beta Ts + 1}$$

tuned for crossover at 0.05 rad/s with $\phi \approx 45^\circ$ phase boost. Unlike the PID, this controller does not contain an integrator, so steady-state errors remain.

4 Results

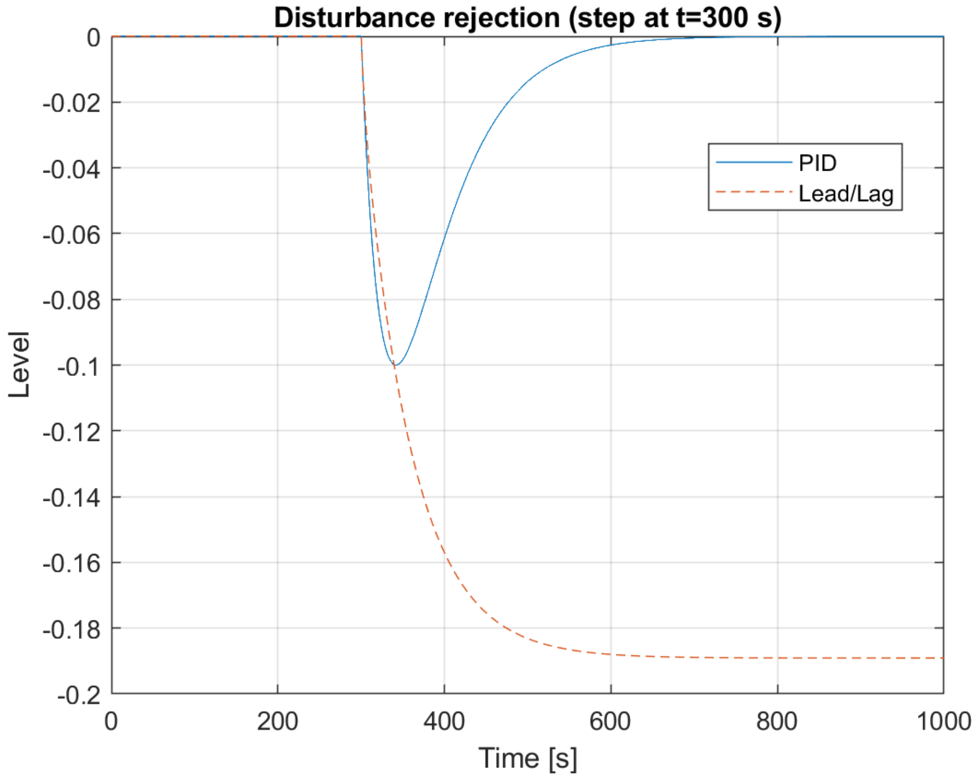
Simulations were performed in MATLAB/Simulink for two scenarios.

4.1 Setpoint Tracking



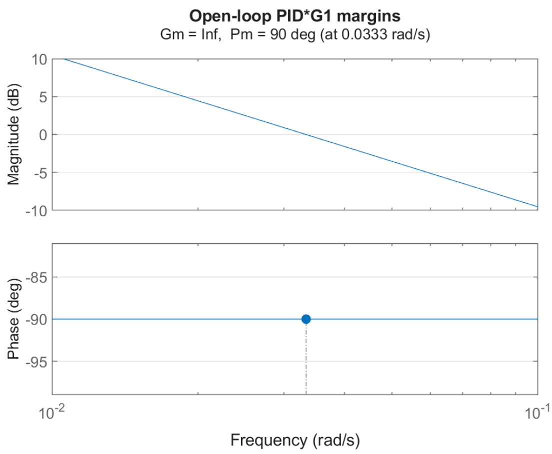
Observation: The PID tracks the setpoint perfectly ($h \to 1$), while the Lead/Lag settles with a steady-state offset ($h \approx 0.5$).

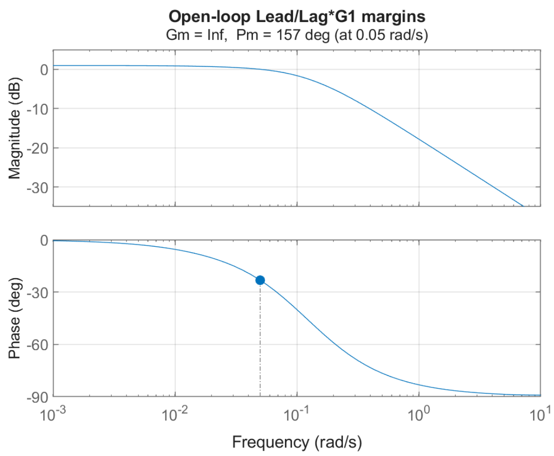
4.2 Disturbance Rejection



Observation: Under a steam flow disturbance, the PID restores the level to its reference, while the Lead/Lag leaves a permanent offset.

4.3 Frequency Response





Observation: PID design is conservative (low bandwidth, high robustness). Lead/Lag design provides higher phase margin (157°) and faster response, but lacks integral action.

5 Discussion

- The PID controller achieves perfect steady-state tracking and disturbance rejection, at the cost of slower dynamics.
- The Lead/Lag controller improves transient performance and stability margins but cannot eliminate steady-state error.

- In industrial practice, Lead/Lag is often combined with PI action to gain both advantages.

6 Conclusion

The project demonstrates the fundamental difference between integrator-based (PID) and non-integrating (Lead/Lag) classical controllers. PID ensures accuracy, while Lead/Lag emphasizes speed and robustness. The comparative results align with theoretical expectations.