

# Reliable Control via Contextual MPC and Approximate Dynamic Programming: Integrating Bayesian Foresight

Monday, 30 March 2026 13:30 (20 minutes)

Industrial energy management presents a challenging control problem characterized by strict safety hierarchies, stochastic load fluctuations, and setting actions often has a significantly delayed effects. This work investigates a Reliable Hierarchical Control Architecture composed of probabilistic forecasting paired with a decision-maker.

The processed problem is characterized by an uncontrollable base load and a controllable variable load, which are added together to create the total load-consumption of the system. Estimation via Bayesian Structural Time Series (BSTS) is utilized for inferring the base load. On top of this probabilistic context, a “Safety Shield” derived from SCADA logic enforces deterministic constraints, ensuring that high-priority assets (e.g., generators) are switched strictly according to operational hierarchies. Within the control task, we rigorously evaluate three distinct decision-making methodologies on their speed, accuracy and adaptability, specifically analyzing their ability to handle unknown plant parameters and actuation latency:

1. A Greedy Heuristic Baseline that employs an adaptive continuous load estimator to dynamically learn power consumption parameters during operation, to enable a perpetual correction of strategy. While fast-reacting to unexpected parameter drift, this approach remains myopic, risking high latency and therefore fewer corrections for constant, time-consuming adaptations.
2. Mixed-Integer Quadratic Programming (MIQP), which provides globally optimal scheduling over a finite horizon. However, its effectiveness is limited by the requirement for linearized plant models and explicit, pre-defined delay compensation, making it brittle to unmodeled temporal dynamics.
3. Dynamic Programming (DP), which serves as a theoretical benchmark by naturally incorporating delayed effects into the state space, though its practical application is severely limited by exponential computational scaling in the number of flexible loads.

Our results highlight a critical trade-off: optimization-based methods (MIQP, DP) offer theoretical guarantees but struggle with the “Reality Gap” of unmodeled delays and non-linearities. The adaptive heuristic offers practical resilience but lacks refined foresight. Consequently, we propose that future work must bridge this gap through learning-based approaches, such as Shielded Reinforcement Learning, which can implicitly learn high-dimensional delay dynamics and non-linear interactions that are computationally intractable for formal optimization models.

## Student

Yes

**Primary authors:** TRAUSNER, Sarah (University of Salzburg); HIRLAENDER, Simon (PLUS University Salzburg)

**Presenter:** TRAUSNER, Sarah (University of Salzburg)

**Session Classification:** Contributed talks