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Model Predictive Control of Industrial Loads and Energy Storage for Demand Response

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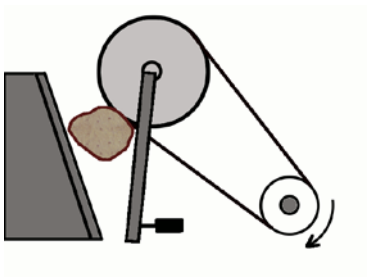
Background

- Demand Response
  - a cost-effective solution for new challenges
- DR by Industrial Loads
  - advantages
    - infrastructure
    - response
    - economic incentive
  - challenges
    - reliability (quality)
    - complexity
    - granularity
- Research Objective
  - fully utilize DR potentials from industrial loads
  - this paper: overcome the granularity restriction

Overcome Granularity Restriction



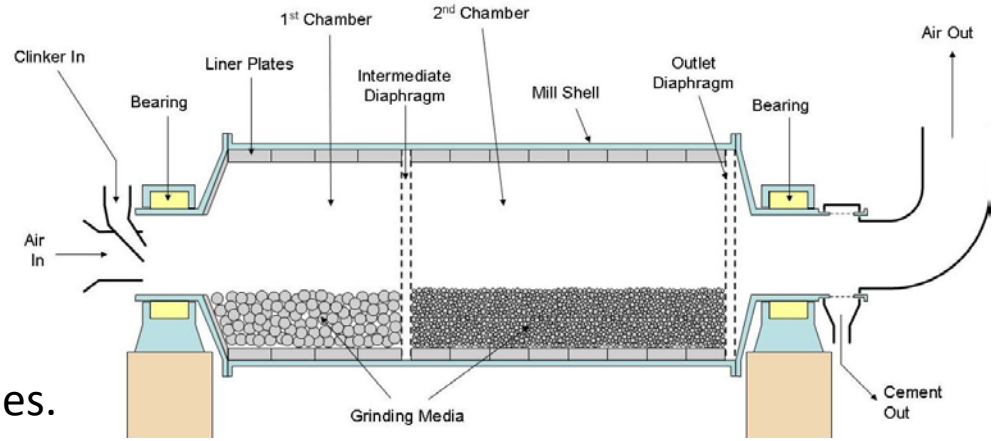


Fig. Examples of industrial machines.

- Coordination by Model Predictive Control
  - industrial loads
    - **large/discrete** power change => **main regulation**
  - on-site energy storage
    - **fine/continuous** power change => **handle mismatch**
  - MPC: **predict** signal trend, **optimize** loads switching

Signal Prediction

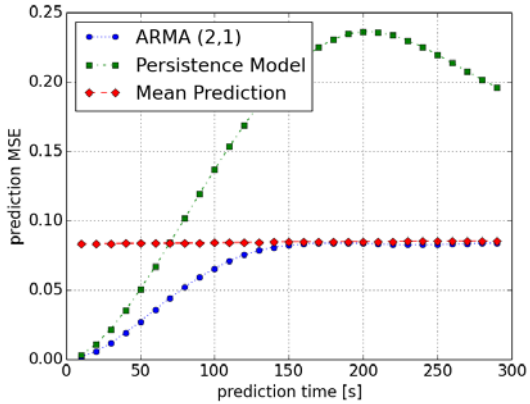


Fig. Prediction mean squared errors.

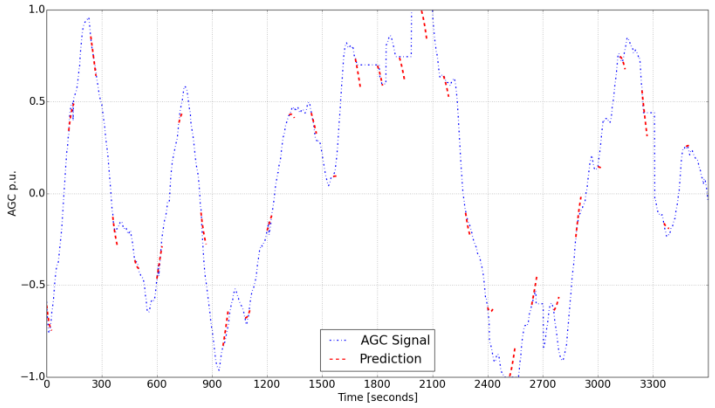


Fig. Regulation signal over one hour and its prediction.

Optimal Control

- Objective

$$\text{minimize} \quad \sum_{i \in H} (\alpha v_i + \beta s_i) + \gamma d$$

- Regulation Violation

$$v_{t+i} \geq |B + R\hat{\omega}_{t+i} - P_m x_{t+i} - y_{t+i}| \quad \forall i \in H$$

- Machine Switching

$$s_i \geq |x_{t+i} - x_{t+i-1}| \quad \forall i \in H$$

- Storage Level Deviation

$$d \geq |e_{t+H} - \bar{e}|$$

- Storage Energy Balance

$$e_{t+i} - e_{t+i-1} = y_{t+i}\delta \quad \forall h \in H$$

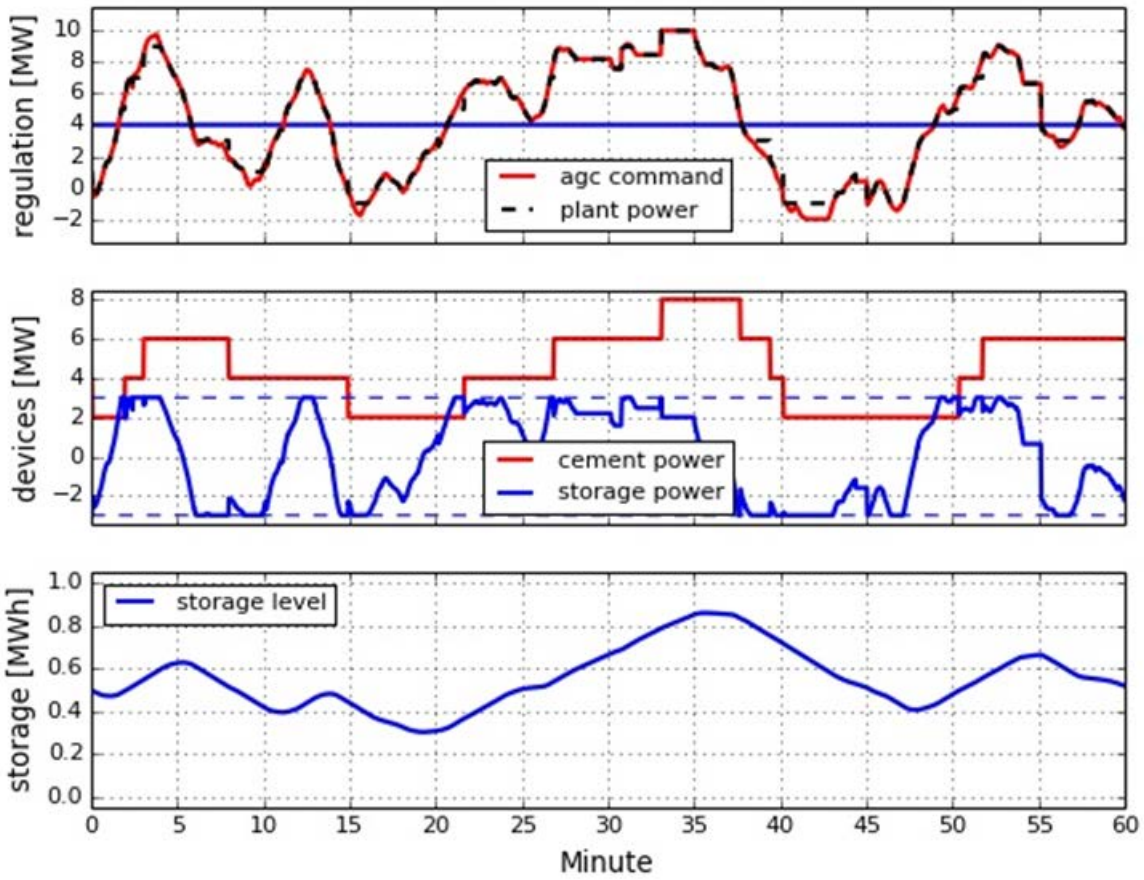
- Switching Limitation

$$\sum_{j=t+i-L}^{t-1} \tilde{s}_j + \sum_{j=t}^{t+i} s_j \leq \bar{s} \quad \forall i \in H$$

- Variable Ranges

$$x_{t+i} \in \{0, 1, \ldots, n\} \text{ and } -P_s \leq y_{t+i} \leq P_s \quad \forall i \in H$$

Results



Simulation Setup
- machines 4*2 MW
- storage 3 MW 1MWh
- regulation 6 MW

Over the Hour
- 0.1 MWh violation
- 12 times switching
  (3 times per machine)

Conclusions

- MPC Coordination Framework
  - "the whole is greater than the sum of its parts"
  - many potential applications
    - e.g. coordination among fast/slow generators, between buildings and energy storage, ...
- Fully utilize industrial loads' DR potentials
  - add more balancing resources to power system
  - encourage loads to be more active in DR