Optimal Storage Control Facing Dynamic Prices

The Problem: Dynamic prices can effectively reflect the real time market conditions. However, it also poses significant risks for the end users with limited flexibility and limited intelligent control devices. With the decreasing cost of storage systems and the wide deployment of smart meters, we seek to design the optimal storage control framework for end users facing dynamic prices.

Challenges: If we knew the dynamic prices beforehand, the storage control problem could be formulated as a simple LP problem. However, the dynamic prices are highly volatile. Hence, an online control framework, though challenging, is desirable. The challenges come from the volatility in dynamic prices as well as the storage temporal constraints (coupling all the decisions).

Our Idea: Inspired by Chau *et al.* [1], we use the one-shot load decomposition technique to decompose the original optimization problem into a sequence of one-shot load serving problems (as shown in Fig. 1). Given the knowledge of dynamic price distributions, we propose that a simple threshold policy is already optimal in terms of minimizing the expected cost for the one-shot load serving problem [2]. Figure 2 demonstrates the empirical performance of the threshold policy, by examining the regret ratio. We further compare the performance of the threshold policy with the offline optimal through the characterization of the regret bound [3]. We also prove that the one-shot load decomposition maintains the solution space. Hence, the optimal control policies for the decomposed sequence of one-shot problems can effectively construct the optimal control policy for the original problem.

The assumption of knowledge on the price distributions can be relaxed by designing a data-driven distribution estimator. We employ the Gaussian Mixture Model (GMM) for this task, and use the EM algorithm for GMM parameter estimation.

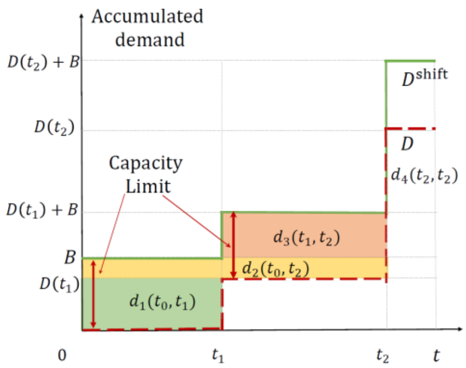

Fig. 1 Example for one-shot load decomposition

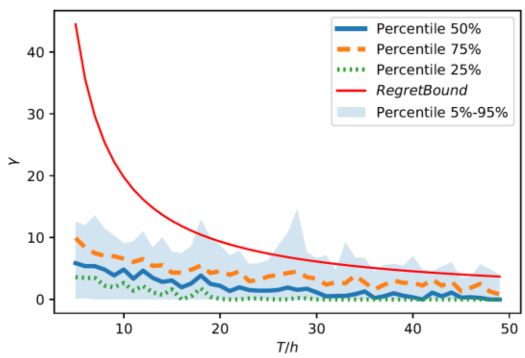

Fig. 2 Performance for one-shot load serving

Future Work: We intend to use Reinforcement Learning (RL) to design a better control scheme with fewer assumptions. In addition, we plan to include the renewable energies in the stylized model. The decision making in such a model is even more challenging due to the coupled uncertainties: one from the dynamic prices, the other from the renewable energy generation.

References

[1] Chi-Kin Chau, Guanglin Zhang, Minghua Chen, “Cost minimizing online algorithms for energy storage management with worst-case guarantee,” IEEE Trans. on Smart Grid, vol. 7, no. 6, pp. 2691–2702, 2016.

[2] Jiaman Wu, Zhiqi Wang, Yang Yu, **Chenye Wu***, “Optimal Storage Control for Dynamic Pricing”, in submission to IEEE PES General Meeting 2020. https://arxiv.org/abs/1911.06963

[3] Jiaman Wu, Zhiqi Wang, **Chenye Wu***, Kui Wang, Yang Yu,“A Data-driven Storage Control Framework for Dynamic Pricing”, in submission to IEEE Transactions on Smart Grid, Initial Submission: Nov. 2019.