The Announcement Effect: The Dependency of Demand Response on Timely Information and the Impact on Efficient System Operation

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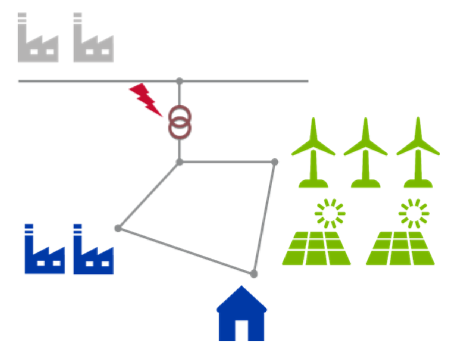
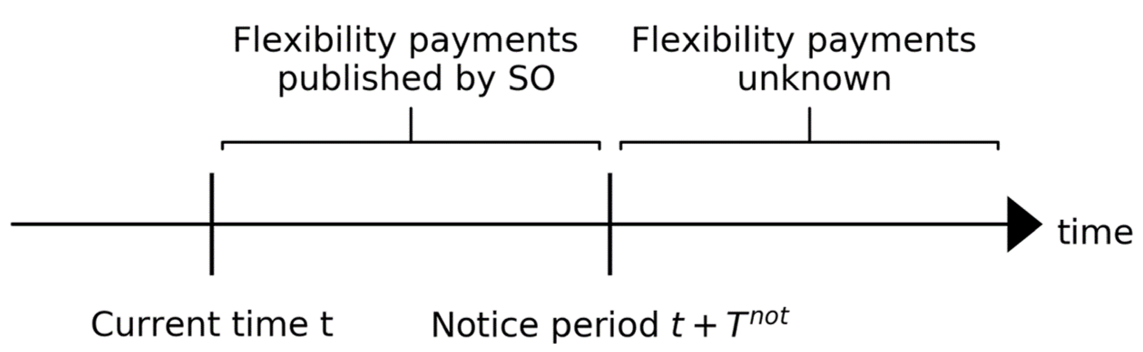
Introduction



- Power systems with significant renewable energies often experience system imbalances or congestion.
- System operators (SO) can leverage **Critical Peak Pricing (CPP)**:
- SOs reduce (or increase) retail rates on CP days to incentivize load increase (or reduction) and inform customers in advance.



- In this project, we analyse the application of temporary net price changes for general system operation objectives.
- **It is unknown** how much response can be achieved and how net price changes should be efficiently determined.

Objectives

- We **analyze time- and state-dependent flexibility potentials** of relevant flexible load types.
- We present **guidance for the design of CPP programs**, in particular with regard to net price changes and the notification period for future price changes.

Methodology

Approach

1. Formulate the SO's optimization problem
2. Identify relevant flexible load types
3. Formulate the stochastic cost optimization problem of flexible load operators
4. Solve and identify optimal policy functions for dispatch
5. Analyse dispatch behaviour of relevant load types under different scenarios and parametrization of loads
6. Use reinforcement learning to optimize net price changes

Perspective of the System Operator

Description

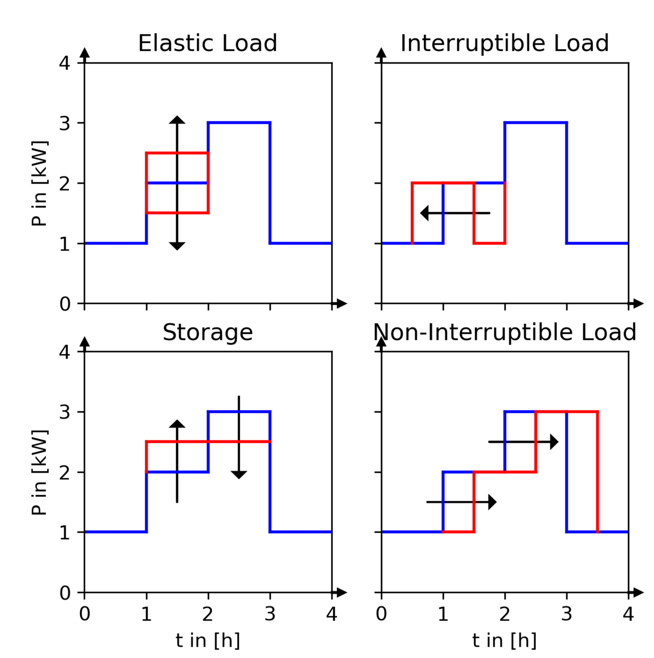
- The SO **minimizes aggregated system operation cost** of incentive payments and curtailment compensations by choosing net price changes Δp.

$$\min_{\Delta\mathbf{p}} C^{SO}(\Delta\mathbf{p}) = \lim_{T\to\infty}\frac{1}{T}\sum_{t=0}^{T}\{L_t^{tot}\Delta p_t + \Delta L_t^{+} Curt^L + \Delta G_t^{+} Curt^G\}$$
$$s.t.\, DR_t^{tot}(\Delta p_t, \mathbf{x_t})$$

- $DR_t^{tot}(\Delta p_t, \mathbf{x_t})$ describes the total demand response of the aggregated system load which is **unknown to the SO**.
- The choice of net price changes is therefore an **optimal control problem under uncertainty**. We model it as a Partially Observable Markov Decision Process (POMDP).
- **Data used for case study.** We use congestion data from SH Netz AG for the year 2017 and label congestion events for hours with more than 50 wind generators curtailed.

Relevant Flexible Load Types

- We select four relevant flexible load types (Barth et al. 2018).
- Consumers minimize electricity costs under price uncertainty.
- **We develop a unified optimal control framework** and find optimal policy functions.
- $\mathbf{x_t}$ describes the state of loads (e.g. SOC of a battery) and $\mathbf{u}_\tau$ their control (e.g. charging):

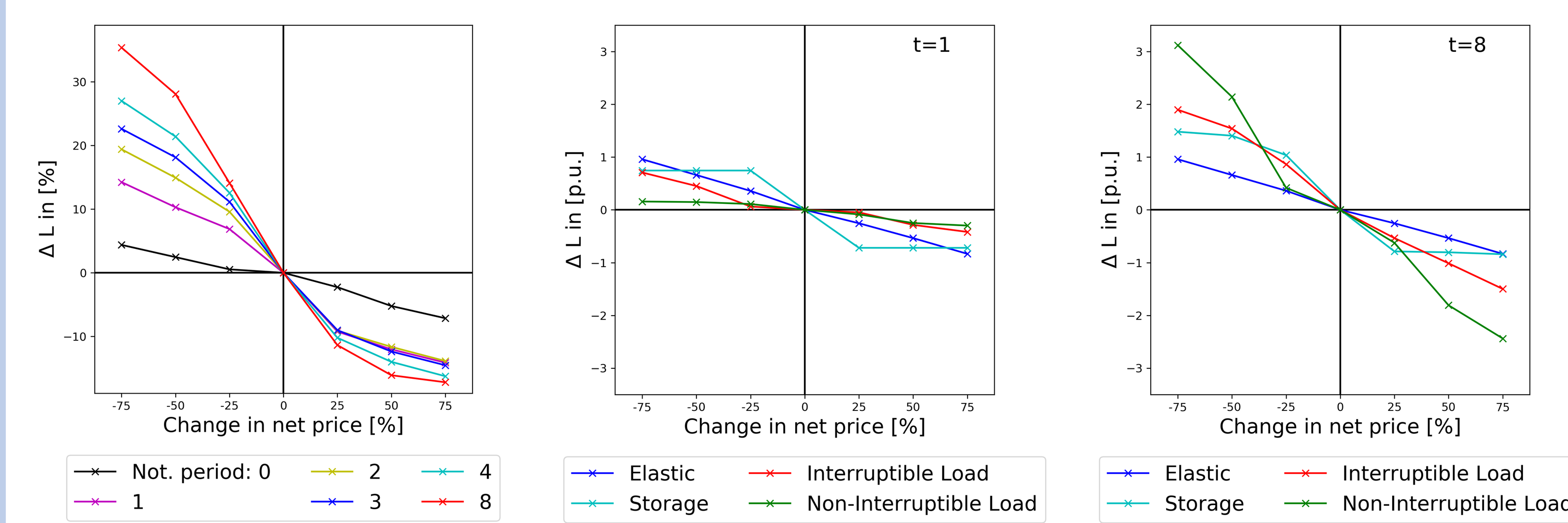


$$\min_{\mathbf{u}_\tau}\mathbb{E}\{C_t(\mathbf{u}_\tau,\mathbf{x_t},K_t)\} = \min_{\mathbf{u}_\tau}\lim_{T\to\infty}\frac{1}{T}\mathbb{E}\{\sum_{\tau=t}^{T-1} c_\tau(\mathbf{x}_\tau,\mathbf{u}_\tau)\}$$
$$=\min_{\mathbf{u}_\tau}\lim_{T\to\infty}\frac{1}{T}\{\sum_{\tau=t}^{T-1}(p_\tau+\mathbb{E}\Delta p_\tau)[L_\tau(p_\tau)+\Delta\mathbf{L}_\tau(\mathbf{x}_\tau)\cdot\mathbf{u}_\tau]+\mathbf{b}_\tau\cdot(\Delta\mathbf{L}_\tau(\mathbf{x}_\tau)\circ\mathbf{u}_\tau))\}$$

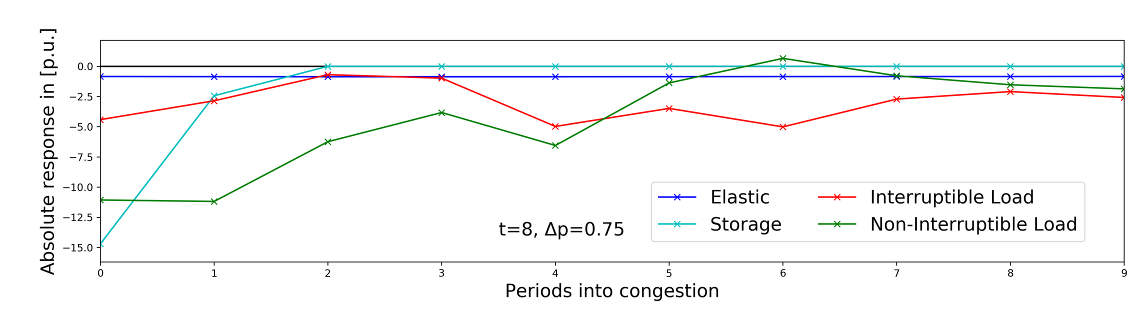
- $\Delta\mathbf{L}_\tau$ is the load profile and $\mathbf{b}_\tau$ the cost of exercising the flexibility. Type-specific technical constraints apply.
- **Data used for case study.** We randomly generate a synthetic flexible load portfolio.

Results

- **In general, longer notification periods and higher flexibility payments can increase load elasticity.**
- The aggregated DR supply function **depends on the portfolio of flexibility types** in the system and their parametrization.
- The following DR functions are based on a synthetic flexible load portfolio of six storages, nine interruptible and four non-interruptible loads, and thirteen elastic loads based on German residential and commercial standard load profiles (BDEW 2017).



- The available flexibility potential is **not constant over time**. The following diagram shows responses in the first ten periods into a congestion period.



- Storage is not able to provide flexibility in long congestion periods. Interruptible and shiftable loads can only provide flexibility when their constraints allow for it.

Outlook

- We will use actual load data to calibrate a load portfolio and run a realistic scenario.
- We will implement different reinforcement learning algorithms with changing parametrization to find the most efficient CPP scheme for the system operator.
- We will evaluate results using social welfare analysis.