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Dynamic Pricing in an Intraday Market with Application to Peer-to-Peer Trading

The Intraday Market

Intraday market trading is a pricing method where electricity grid users have the possibility to adjust their consumption on the day of delivery after determining an estimated consumption in the day-ahead market, 24 hours prior to delivery.

Within each pricing period, consumers are encouraged to reduce their consumption and save electricity by offering an incentive price on energy purchases from the power grid.

Problem Setting and System Design

Market players:

- prosumers: grid users who consume and generate energy
- consumers: grid users who only consume energy
- utility power grid: provides balancing energy to grid users

Transactions between the market players:

- transactions between prosumers and consumers; prosumers sell excess solar energy to consumers at price λ
- transactions between users and the utility power grid; users purchase balancing energy to satisfy their demand at price μ

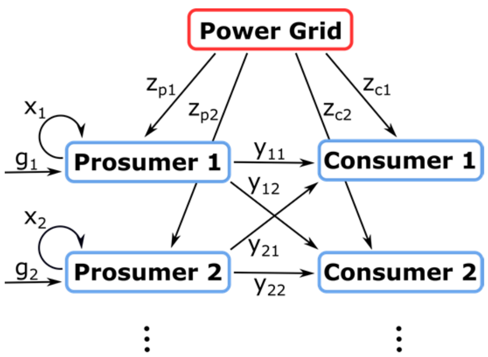

Fig. 1: System model.

Optimization Problem Formulation

Market players act in a way that maximizes their economic welfare. Thus, the optimization problem that describes the market dynamic is formulated as follows:

$$x_i(t) = \begin{cases} \arg\max_{x_i} \{v_{p_i}(x_i(t)) + \lambda_{p_i}(t)\,(g_i(t) - x_i(t))\}\,, \text{ if } g_i \geq x_i \\ \arg\max_{x_i} \{v_{p_i}(x_i(t)) - \mu_{p_i}(t)\,(x_i(t) - g_i(t))\}\,, \text{ if } g_i < x_i \end{cases}$$

for prosumer i with utility function v_{p_i}, consumption x_i, solar energy generation g_i, and prices λ and μ;

$$\chi_j(t) = \arg\max_{\chi_j} \{v_{c_j}(\chi_j(t)) - \lambda_{c_j}(t) \sum_{i \in P} y_{ij}(t) - \mu_{c_j}(t)\, z_{c_j}(t)\}$$

for consumer j with utility function v_{c_j}, consumption χ_i, power from prosumers i y_{ij}, balancing energy z_{c_j}, and prices λ and μ;

$$s_\ell(t) = \arg\max_{s_\ell} \{\mu_\ell(t)\, s_\ell(t) - c_\ell(s_\ell(t))\}$$

for the supply s_ℓ the grid supplies to user ℓ with cost function c_ℓ, and price μ.

Simulation Results

We considered a grid of six users, four consumers and two prosumers. Qualitatively, all users exhibit the same behaviour, so the results are presented exemplary for one of the users.

Day-ahead estimates

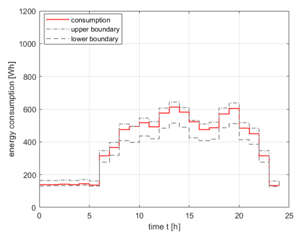

Fig. 2: Day-ahead consumption.

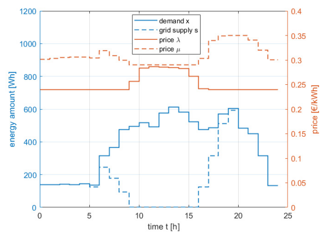

Fig. 3: Balancing energy demand and price development.

Intraday power reduction

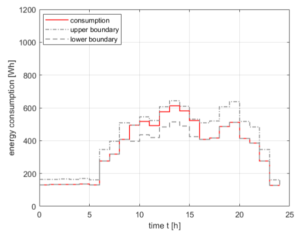

Fig. 4: Intraday consumption.

Grid users are offered an incentive price for reducing their load on the grid in the intraday market. Therefore, we do not observe power reductions at times when the generated solar energy satisfies the consumption.

References

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