Karlsruhe Institute of Technology

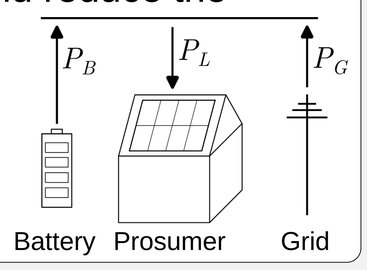
Institute for Automation and Applied Informatics (IAI)

Probabilistic Day-Ahead Battery Scheduling based on Mixed Random Variables[1]

Janik Pinter, Frederik Zahn, Maximilian Beichter, Ralf Mikut, Veit Hagenmeyer

Motivation

- Renewables increase uncertainty in power generation
- Interplay of uncertain consumption **and** production demands new uncertainty management strategies
- How to use a battery to quantify and reduce the uncertainties on a building-level?
  - ➢ **How to share quantified uncertainties between a battery system and the power grid?**

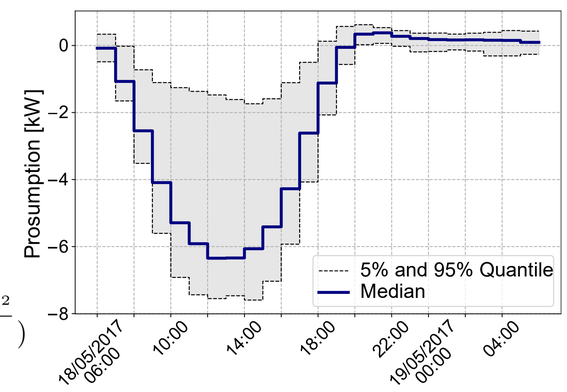


Probabilistic Forecasts

- Forecast Prosumption P_L
- ML-based autoregressive forecast creation
- Here, assume that P_L follows the sum of two normal distributions:

$$f_{P_L}(z) = \frac{1}{\sqrt{2\pi}}\left(\frac{\omega_1}{\sigma_1} e^{\frac{-(z-\mu_1)^2}{2\sigma_1^2}} + \frac{\omega_2}{\sigma_2} e^{-\frac{(z-\mu_2)^2}{2\sigma_2^2}}\right)$$

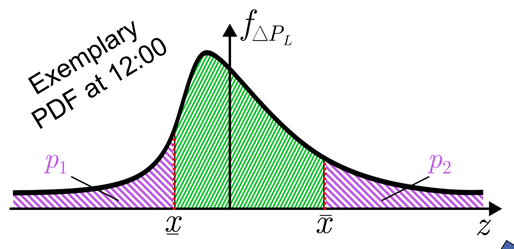
$$f_{\Delta P_L}(z) = f_{P_L}(z + \mathbb{E}[P_L])$$



Stochastic Optimization Framework

Fundamental Idea

- Divide the forecasted Prosumption PDF into a
  - Green part that is fed into the battery
  - Purple parts that are injected into the grid



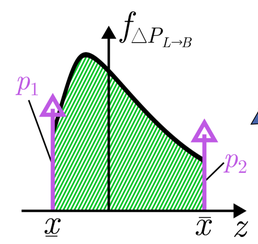
$$\Delta P_L \overset{!}{=} \Delta P_{L\to B} + \Delta P_{L\to G}$$

BATTERY

- Use Mixed Random Variables to model battery power uncertainty

$$\Delta P_{L\to B} = \begin{cases} \underline{x} & \Delta P_L \le \underline{x} \\ \Delta P_L & \underline{x} < \Delta P_L < \bar{x} \\ \bar{x} & \bar{x} \le \Delta P_L \end{cases}$$

- With that, schedule battery power intervals instead of single setpoints (restricted via $\underline{x}$ and $\bar{x}$)



Optimization

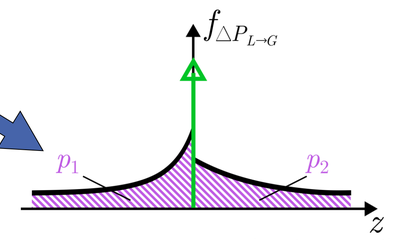
- Find optimized schedule and minimize deviations from the schedule
- Obj. Func.: $C = f(p_G, \mathbb{E}[\Delta P_{L\to G}^{<0}], \mathbb{E}[\Delta P_{L\to G}^{>0}])$
- Decision Variables: $p_B,\ \underline{x},\ \bar{x}$

GRID

- Use Mixed Random Variables* to model grid power uncertainty

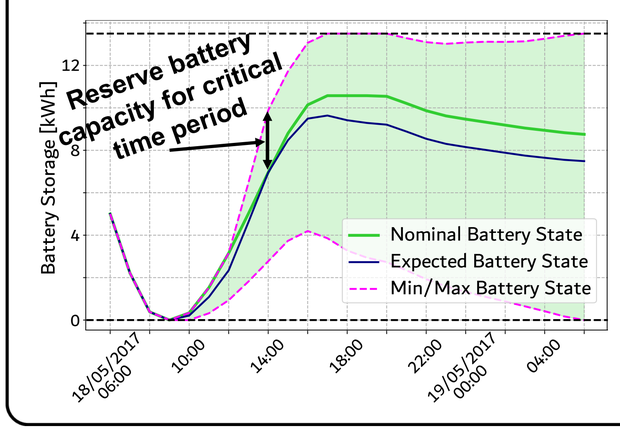
$$\Delta P_{L\to G} = \begin{cases} \Delta P_L - \underline{x} & \Delta P_L \le \underline{x} \\ 0 & \underline{x} < \Delta P_L < \bar{x} \\ \Delta P_L - \bar{x} & \bar{x} \le \Delta P_L \end{cases}$$

- Grid power uncertainty contains discrete event at zero



*contains continuous and discrete parts in the PDF

Probabilistic Battery Schedule



Results

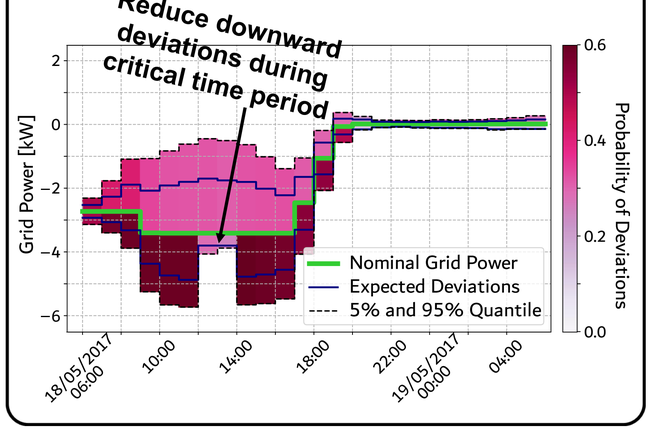
- Obtain both highly quantified probabilistic battery and grid power schedules
- Battery system can be used to influence the expected power exchange with the grid, as well as for **asymmetrical** compensation of the associated uncertainty

Outlook

Intra-Day Scheduling — Grid Impact Analysis

Flexibility Markets — PV Curtailment

Probabilistic Grid Schedule



Contact
Janik Pinter
janik.pinter@kit.edu
KIT-IAI

References
[1] Pinter et al. (2024) — Probabilistic Day-Ahead Battery Scheduling based on Mixed Random Variables for Enhanced Grid Operation

HELMHOLTZ
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN