Grid-aware Control of an Energy Community in the Project GrECCo

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Introduction

- Low-voltage grid strained by
  - local generation (PV)
  - electric vehicle charging (EV), heat pumps (HP)
- Grid operator can obtain “flexibility” from energy community
- Community coordinates individual agents’ responses

Algorithm

$$\min_{z_{a=0,\dots,A-1}} \sum_{a=0}^{A-1} J_a(z_a|w_a) \quad \text{Local Problems} \quad (1a)$$

$$\text{s.t.} \quad h_a(z_a|w_a) \le 0 \quad \forall a, \quad (1b)$$

$$\left|\sum_{a}^{A-1} G_a z_a\right| \le p^{\lim} \quad \text{Grid} \quad (1c)$$

- Distribute scheduling every 15 minutes for a 24 h horizon
- Iterate between coordinator and agents
  - Query planned consumption profiles
  - Determine grid signal
- Converge to signal solving grid issue

Iterate

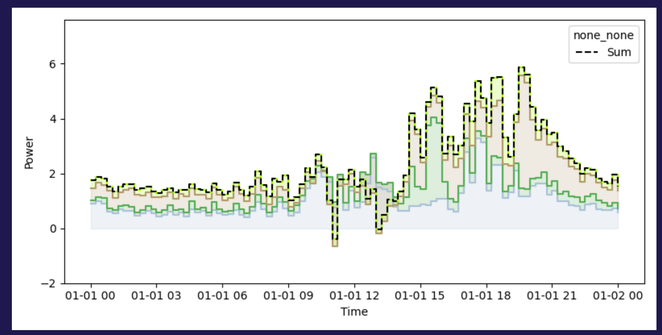
1. Gather z_a for all agents and calculate $R = \sum_a G_{a,k} z_{a,k}$.
   Terminate if $\|R\| < \epsilon$ with some tolerance parameter ϵ or if $\|R^+ - R\| < \varepsilon$.
2. Update signals / dual variables λ_a, z'_a depending on method
3. Solve for each subsystem $a = 0, \dots, A$

$$\min_{z_a} \quad J_a(z_a|w_a) + \phi(\lambda_a, z'_a, z_a) \quad (7a)$$

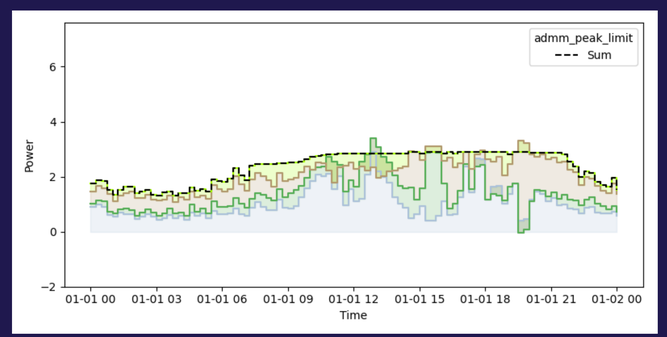
$$\text{s.t.} \quad h^a(z_a|w_a) \le 0 \quad \forall a \quad \text{Local bounds} \quad (7b)$$

How to Motivate Households with Flexibilities to Contribute to Distribution Grid Stability

No Control
Consumption Peaks in early evening



Distributed Control
Flexibilities are activated to mitigate grid stress



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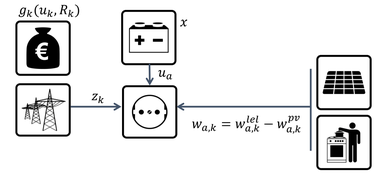
Local Test System: PV Battery



- Simulation for households with PV Battery System
- Very simple system

More Details

Initialization

Initialize

- For $a = 0, \dots, A-1$ solve

$$\min_{z_a} \quad J_a(z_a|w_a) \quad (5a)$$

$$\text{s.t.} \quad h^a(z_a|w_a) \le 0 \quad \forall a \quad (5b)$$

- Set

$$z_A = \min\left(p^{\lim}, \max\left(-p^{\lim}, -\sum_{a=0}^{A-1} z_a\right)\right) \quad (6)$$

- Set $\lambda = 0, z'_a = z_a$

Update Rules

Alternating Direction Method of Multipliers

- Update multiplier $\lambda_a^+ = \lambda_a + \rho G_a(z_a - z'_a)$
- Solve central problem

$$\min_{z'_a} \quad \sum_{a=0}^{A} \rho/2 \|G_a(z_a - z'_a)\|^2 - (\lambda_a^+)^T G_a z'_a \quad (8a)$$

$$\text{s.t.} \quad \sum_{a=0}^{A} G_a z'_a = 0 \quad \forall k \quad (8b)$$

- Update $z'_a \leftarrow z'^+_a$ and $\lambda_a \leftarrow \lambda_a^+$

ALADIN

- Choose Hessian approximation

$$H_a = \nabla^2 \left[f_a(z_a) + s_a^T h_a(z_a)\right] \quad (9)$$

with s_a the multiplier of the constraint in the local OCP

- Choose Constraint Jacobians

$$C_{a,j} = \begin{cases} \frac{\partial}{\partial x}(h_a(x|w_a))_j\big|_{x=z_a} & \text{if constraint active} \\ 0 & \text{otherwise} \end{cases} \quad (10)$$

- And gradient $g_a = \nabla J_a(z_a)$
- Solve central coupled QP

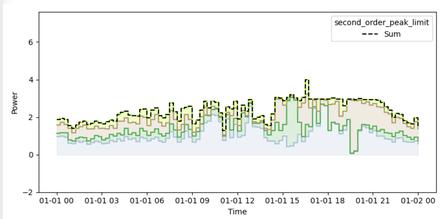
$$\min_{\Delta z, s} \quad \sum_{a=0}^{A} \left[\frac{1}{2} \Delta z_a^T H_a \Delta z_a + g_a^T \Delta z_a\right] + \lambda^T s + \frac{H}{2}|s|^2 \quad (11a)$$

$$\text{s.t.} \quad \sum_{a=0}^{A} G_a(z_a + \Delta z_a) = s \quad |\lambda^{QP}, \quad (11b)$$

$$C_a \Delta z_a = 0 \quad \forall a \quad (11c)$$

- Update $z'_a = z_a + \Delta z_a$ and $\lambda = \lambda^{QP}$

Result of Second Order Method



Valuation of Delivered Flexibility

- Reward agents for contributions made by change of behaviour
- Algorithm defines additional grid fee
- Next research questions
  - How to determine reward from additional fee
  - How to prevent cheating