Scuola universitaria professionale della Svizzera italiana
Dipartimento ambiente costruzioni e design
Istituto sostenibilità applicata all'ambiente costruito

brenet SUPSI

SUPSI

Fast sizing methods with realistic performance assumptions for residential electrification

Lorenzo Nespoli, Researcher - ISAAC, team leader Sistemi Energetici Intelligenti

SUPSI

The project

GARDEN PROJECT Grid Aware Decarbonization of Electricity-driven Neighbourhoods

- Scope: Driving Urban Transition promotes the study and creation of PEDs (positive energy districts)
    - Targets 100 PEDs by 2025 [1], 112 climate neutral cities by 2030 [2]
    - We cannot create them ex-novo, we must RETROFIT

- Scientific questions:
    - What's the best possible technical retrofitting solution (which set of buildings / which intervention), under fixed budget?
    - **Can we develop fast sizing methods for PV/battery systems with good generalization capabilities?**

[1] EU ped implementation plan
[2] Net Zero Mission Cities

SUPSI

Problem statement

Monolithic problem

$$\underset{p_b, E_{batt} P_{bat}, P_{PV}}{\arg\min} \quad LCOE(p, p_b, E_{batt}, P_{bat}, P_{PV})$$

$$s.t. \quad e_{t+1} = e_t + \eta_{ch} p_b^{ch} - \frac{1}{\eta_{ds}} p_b^{ds}$$

$$p_b^{ch} p_b^{ds} = 0$$

$$\mathrm{CAPEX}_{\mathrm{ann}} = \mathrm{crf}\left(c_{\mathrm{PV}}^{\mathrm{kW}} x_{\mathrm{pv}} P_{\mathrm{PV}}^{\mathrm{peak}} + c_{\mathrm{bat}}^{E} E_{\mathrm{bat}} + c_{\mathrm{bat}}^{P} P_{\mathrm{bat}}^{\mathrm{max}}\right)$$

$$\mathrm{OPEX}_{\mathrm{energy}} = R \sum_t \left(\lambda_t^{\mathrm{imp}} \frac{P_t^{\mathrm{imp}}}{1000} \Delta t - \lambda_t^{\mathrm{exp}} \frac{P_t^{\mathrm{exp}}}{1000} \Delta t\right)$$

$$\mathrm{OPEX}_{\mathrm{peak}} = R \sum_{p \in \mathcal{P}} \tau_p P_p^{\mathrm{peak}}$$

$$LCOE = CAPEX_{\mathrm{ann}} + OPEX_{\mathrm{energy}} + OPEX_{\mathrm{peak}}$$

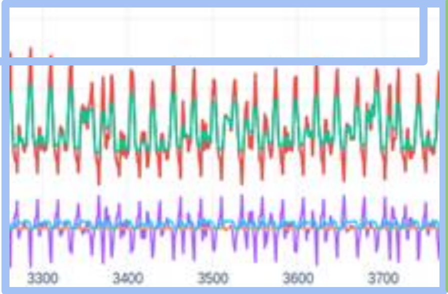
Decomposed problem

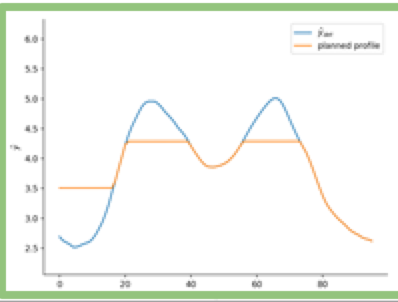
SIZING

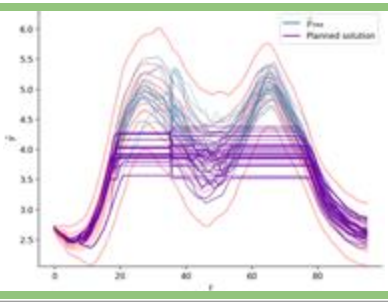
$$E_{bat}^*, P_{bat}^*, P_{PV}^* = \underset{E_{bat}, P_{bat}, P_{PV}}{\arg\min} \; LCOE(\pi^*(p), E_{bat}, P_{bat}, P_{PV})$$

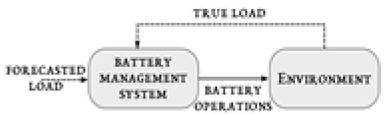
OPERATION

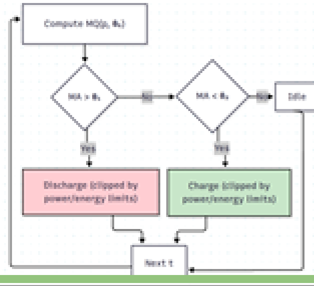
$$\pi^*(p) = \begin{cases} \arg\min_{p_b} OPEX(\hat{p}, p_b) & \text{MPC} \\ \arg\min_{p_{b,tree}} OPEX(\hat{p}_{tree}, p_b) & \text{SMPC} \\ \arg\min_{\theta} \mathbb{E}_{sim} OPEX(p, p_b = f(\theta)) & \text{RL} \end{cases}$$











	Deterministic, perfect forecast	Deterministic MPC (lookahead)	Stochastic (lookahead)	RL	Tunable RBC
Optimistic	+++, **lower bound**	++	+	+	+
CPU time	- 1-2 s full year opt	+ 0.06s per horizon	++ 1.2s per horizon	+++	low 6e-3s full year, 0.8s full year opt
Complexity	low (one shot sizing + operation)	medium (forecast + optimize)	high (tree based forecast / policy)	high (NN based)	low, interpretable policy

Problem statement

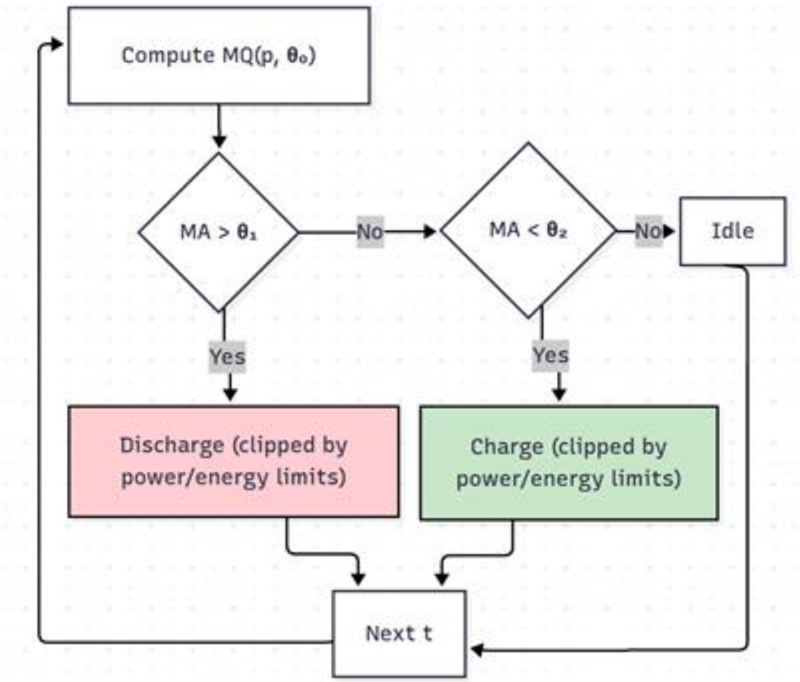
The idea

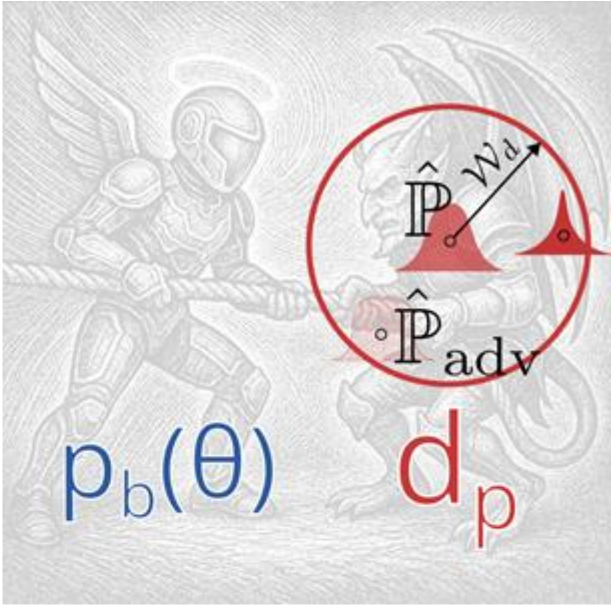
- Use a parametric (tunable) rule based controller [1], eg

```
for t in 1..T:
  if MQ(p, θo)>θ1:
     discharge within operative lims
  if MQ(p, θo)<θ2:
     charge within operative lims
```

- Tune the parameters **θ** on a Training Set and test it on hold out dataset

- Since simulating it is so fast, we can
  - Retrieve the loss landscape for inspection
  - Perturb the problem with adversarial noise to make it even more robust. This process is loosely connected with distributionally robust optimization [2].



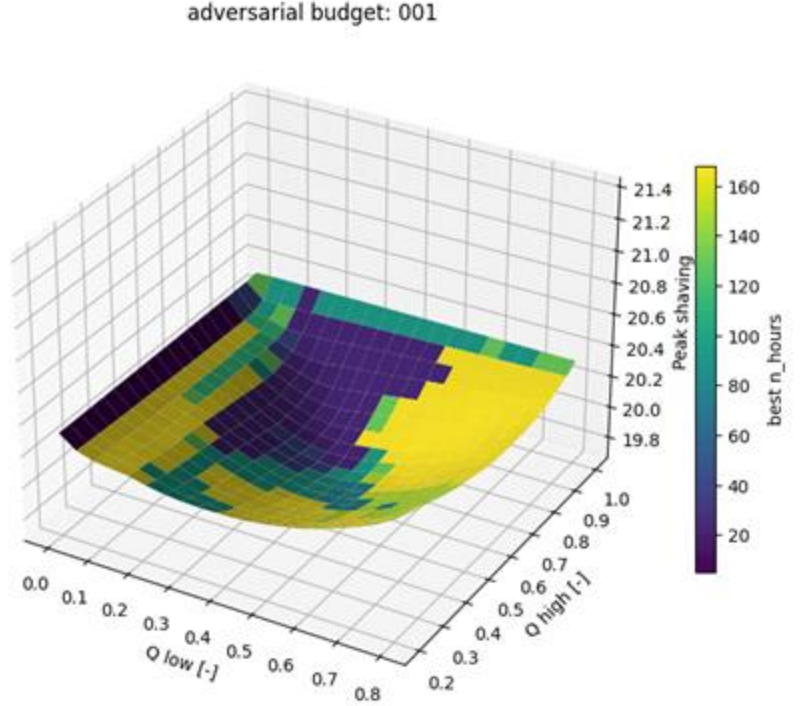


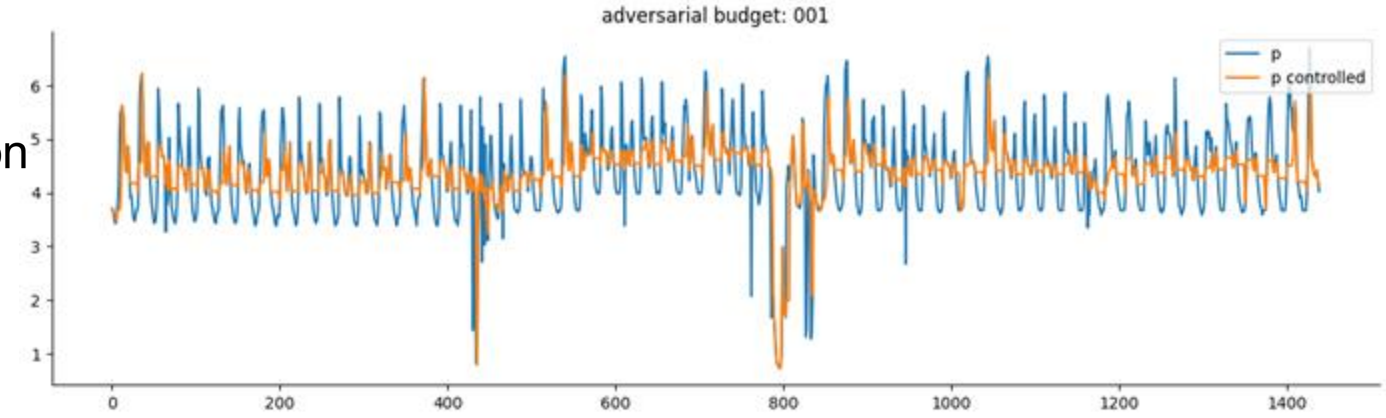
[1] W. Powell, The Parametric Cost Function Approximation: A new approach for multistage stochastic programming, 2022 [2] D. Kuhn et al. Distributionally Robust Optimization

SUPSI

Takeaways:

- Rule based controllers can be made robust via parametrization and stochastic tuning
- We can apply this technique to FAST simulators
    - e.g. thermodynamics of buildings via RC equivalent→ HP sizing
- The controller is interpretable (very few parameters) and easily embeddable





[HORIZON-CL5-2026-02-D3-18](#) Next generation distribution substation for increasing the system resilience

[HORIZON-CL5-2026-02-D3-19](#) Innovation solutions for a generative AI-powered digital spine of the EU energy system