École Polytechnique Fédérale de Lausanne
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Student project proposal

Project title

Self-aware load control for ex-post grid tariffs: Design and field-test on the EPFL smart-grid platform

Project type ☒ MSc thesis ☐ BSc thesis ☐ MSc semester project

Project responsible and e-mail

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Project description

Electrification and cheap automation are turning household loads (EVs, heat pumps, batteries) into *price-responsive* loads. With ex-ante fixed, step-shaped price signals—time-of-use or critical peak pricing—automated controllers all shift into the *first* cheap slot, and the resulting synchronised "rebound peak" can exceed the original peak: simulations for a Swiss grid node find rebound peaks growing from 5–15 % (2020) to over 40 % (2050) [1], and the same peak-shifting effect is reported for European distribution grids [2] and grid-connected storage [3]. *Ex-post* grid charges, billed on the *metered* grid load after delivery, create a negative feedback loop that removes the incentive to over-coordinate by construction [1] and align network charges with actual congestion [2]—but the price is then unknown at the moment of dispatch *and* partly caused by the dispatch itself. A load controller therefore has to be *self-aware*: it must recognise its own share of grid load (price taker vs. price maker), forecast the tariff level that its own dispatch helps create, and cope with the fixed point dispatch $\rightarrow$ ex-post load $\rightarrow$ tariff $\rightarrow$ dispatch, whose convergence, oscillation and damping are open questions.

The goal of this project is to design such a self-aware load-control algorithm and to test it, first in simulation and then in the field, on the EPFL smart-grid demonstrator (smartgrid.epfl.ch). The thesis is embedded in ongoing research on distribution grid tariff design; results will feed into an SFOE-financed research project and form part of its decision making. We offer joint supervision from the control and the tariff-design side, real measurement data, access to a unique demonstrator, and a realistic path to a co-authored publication and to policy impact.

Tasks of the student

- Master the relevant literature and the existing simulation code:
  Get familiar with the rebound-peak problem and ex-post tariff formulations [1]–[3]; simulation code can be provided from the project.
- Design the self-aware load-control algorithm:
  (i) *Forecast* the inflexible load, and from it the ex-ante total load $L^{xA}(t)$ and the ex-ante price $P^{xA}(t)$;
  (ii) *regress* the ex-post load response on the forecast quantities and on past own dispatch decisions, in order to separate the effect of *own* dispatch L_i^D from that of other customers L_{-i}^D, e.g.

  $$\hat{r}^{xP}(t) = b_0 + b_1 L^{xA}(t) + b_2 \frac{P^{xA}(t)}{\max_d P^{xA}} + b_3 L_i^D(t) + \dots$$

  (identifying b_3 may require deliberately perturbing the own schedule);
  (iii) *optimise* own dispatch given (i) and (ii);
  (iv) *iterate* until convergence.
- Define the tariff scenarios:
  Ex-post grid tariffs designed as step functions with different threshold values, following the formulation of [3],

against a flat-tariff benchmark without dispatch optimisation. The threshold matters: a tariff that signals scarcity even when the grid is uncongested destroys the incentive to minimise energy cost [1].

- Test in simulation and in the field:
  Run each test twice—first in simulation, re-calibrating the response function until convergence; then on the EPFL smart-grid platform, starting from an un-calibrated response function, to determine the time to convergence.
- Evaluate the results:
  Absolute and per-daily-kWh values for peak load, sum of grid and energy cost, participant bill and its volatility; iterations (resp. days) to convergence; robustness as the controlled share of total load is scaled from $\sim$1 % to 100 %.

Requirements

- Background in Electrical and Electronic Engineering or Energy Science and Technology.
- Proficiency in Python; experience with optimisation (MILP/MIQP, e.g. Pyomo with Gurobi or open solvers).
- Basic time-series econometrics is a plus, but can be learned during the thesis.

Literature

[1] C. Winzer, P. Hensler-Ludwig, "Design and Impact of Grid Tariffs," *Energies* 17(6):1364, 2024. doi:10.3390/en17061364

[2] N. Morell-Dameto et al., "Network tariff design with flexible customers: Ex-post pricing and a local network capacity market," *Energy Policy* 184:113907, 2024. doi:10.1016/j.enpol.2023.113907

[3] L. Deguenon et al., "Impact of dynamic grid tariffs on grid-connected storage dispatch and revenues," *Journal of Energy Storage* 120:116472, 2025. doi:10.1016/j.est.2025.116472

[4] P. Ludwig, C. Winzer, "Tariff menus to avoid rebound peaks," *Energies* 15(17):6354, 2022. doi:10.3390/en15176354