Optimal Control in a Smart Grid Aggregator

Jonathan Ridenour, Joachim Lindborg

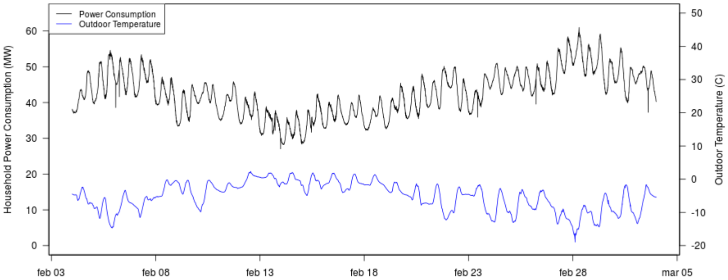
October 15, 2018

NGENIC

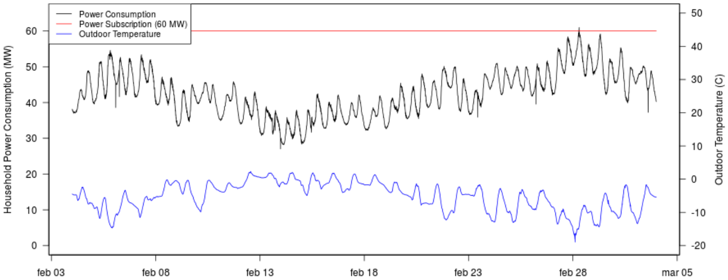
Overview

1. Critical peak power, what do we mean?
2. Critical peak power: a problem for DSOs.
3. Coordinating Power Control: VäxEl.
4. Model Predictive Control.
5. Björklinge, Uppland.
6. Simulation results.

Critical peak power, what do we mean?

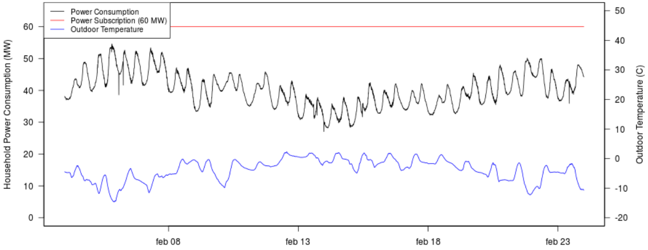


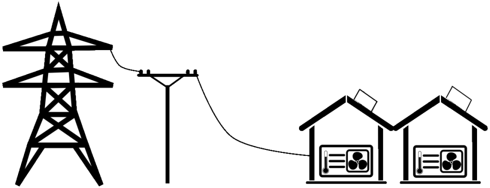
Critical peak power may only occur once or twice a year.



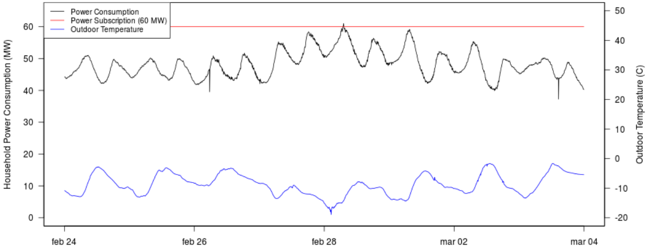
NGENIC

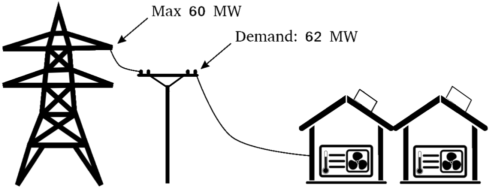
Critical peak power: a problem for DSOs.



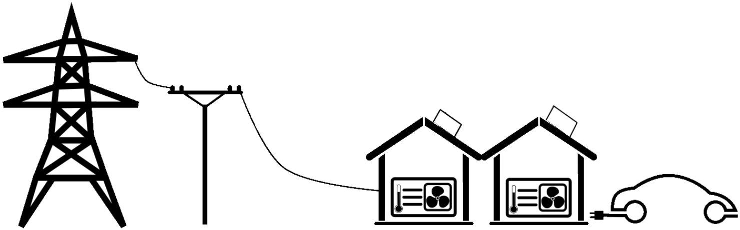


When demand exceeds subscribed power.





Critical peak power: exacerbated by EVs.

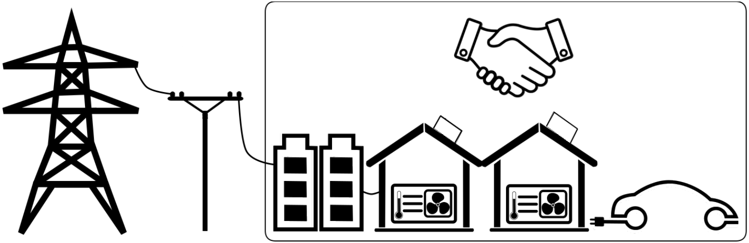


NGENIC

A plethora of “smart” devices.

NGENIC

VäxEl: creating a smart energy community.



Model Predictive Control: peak into the future.

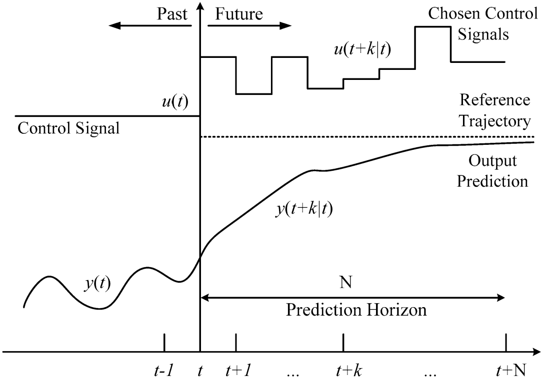


Figure 1: The idea behind model predictive control [1].

[1] Godina, Radu et. al. (2018), *Model Predictive Control Home Energy Management and Optimization Strategy with Demand Response*, Applied Sciences, 8, 3.

Model Predictive Control: optimize over a time horizon.

$$
\begin{aligned}
\underset{u}{\text{minimize}} \quad & f(x, x^r, u), \quad t \in \Omega && \text{(1a)} \\
\text{subject to} \quad & x_{t+1} = Ax_t + Bu_t + Dw_t, \quad t \in \Omega, && \text{(1b)} \\
& C^x x_t \leq c_t^x, \quad t \in \Omega, && \text{(1c)} \\
& C^u u_t \leq c_t^u, \quad t \in \Omega, && \text{(1d)} \\
& C^f x_N \leq c_f^x, && \text{(1e)}
\end{aligned}
$$

where

- x_t, x_t^r, u_t, and w_t are multivariate time series;
- A, B, and D describe the behavior of the system;
- C^x and c_t^x, C^u and c_t^u, and C^f and c_f^x denote optimization constraints.

Model Predictive Control.

Data: A, B, D, C^x, c_t^x, C^u, c_t^u, C^f, and c_f^x
Result: u_{t+1}
repeat

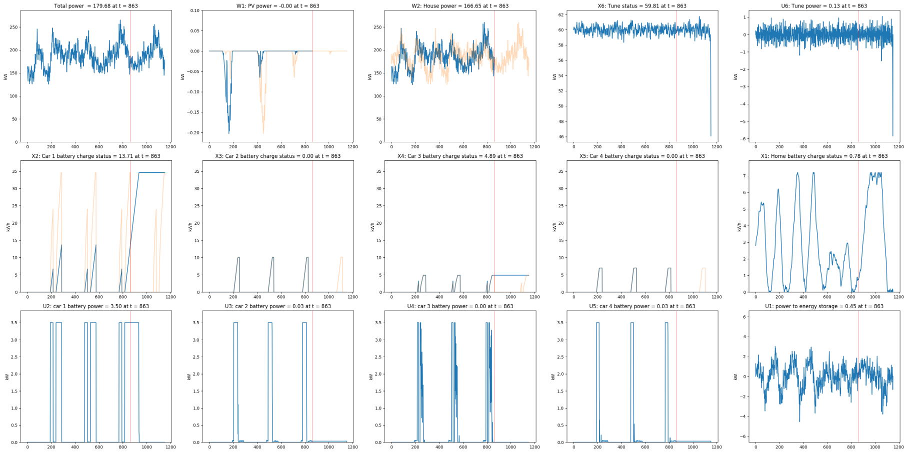
measure x_t;
solve finite-horizon MPC problem to get $u_{t+1,\ t+2,\ ...,\ t+N}$;
apply u_{t+1}

$t \leftarrow t+1$;

Algorithm 1: The basic idea.

NGENIC

Model Predictive Control: a simulation.

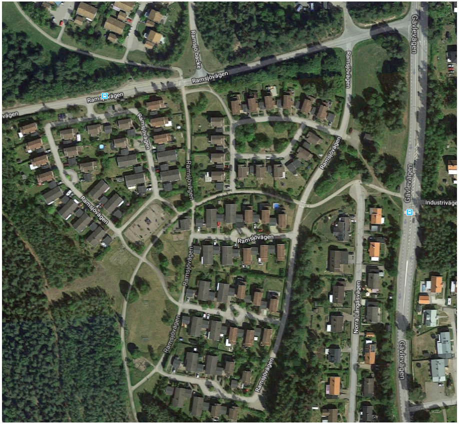


NGENIC

Uppland, Sweden.

NGENIC

Ramsjöåsen, Björklinge, Uppland.

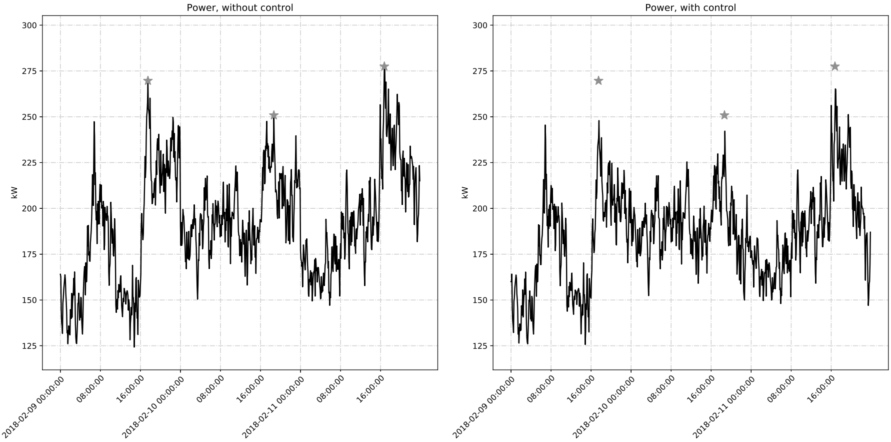


Scenario.

- a residential area comprised of 60 households;
- 30 households are connected to *Ngenic Tune*;
- the area is serviced by a solar array with a 37 kW production capacity;
- the area is equipped with a FerroAmp *Energy Storage Module* of type $Li(FePO_4)$ with a charge/discharge capacity of 6 kW and a storage capacity of 7.2 kWh;
- 4 households are outfitted with chargestorm *Wallbox EVA Connected* with a charging capacity of 3.7 kW;
- 4 householders drive EVs with different charge profiles.

NGENIC

Results: critical peak power reduced!



NGENIC

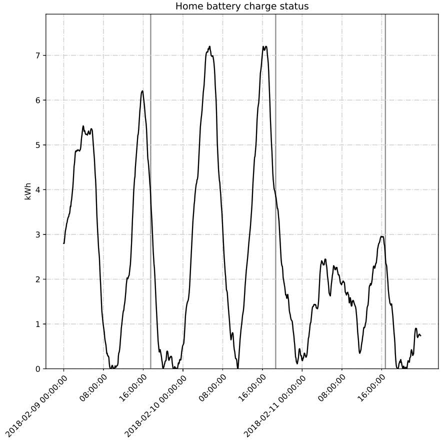
Results: tabulated over three days.

Table 1: Critical peak power values for 60 households.

time stamp	CPP (kW)	optimized (kW)	reduction (kW)
2018-02-09 17:30:00	269.68	238.26	31.42
2018-02-10 18:40:00	250.82	225.05	25.78
2018-02-11 16:45:00	277.46	252.37	25.09
average	**265.99**	**238.55**	**27.43**

NGENIC

Results: Home battery performance.



NGENIC

Scaling up.

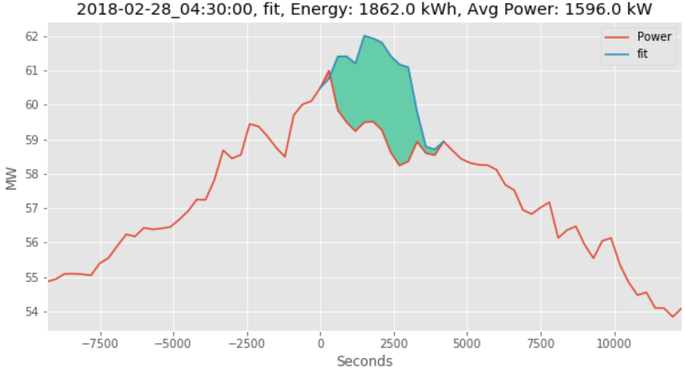
If we scale up our numbers by a factor of $40,000$, we get the following scenario:

- 2.4 million households,
- 1.2 million connected heating-systems,
- $160,000$ electric vehicles,
- $40,000$ connected home batteries (288 MWh capacity),
- 1.5 GW solar array.

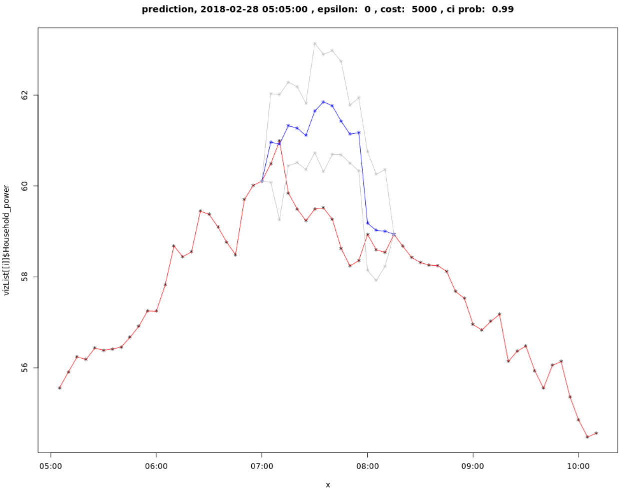
If we assume the CPP reduction scales linearly, the result is a reduction in CPP of 1.2 GW.

NGENIC

Results: coordinating heat-pumps during Feb 2018.



Results, with bootstrapped confidence intervals.



NGENIC

Thanks for your attention!