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Advanced tariffs for grid friendly distributed PV and storage: A case study in Rolle

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Motivation

- Integration in distribution grids of **large amount of PV** could be an issue due to the **excess of power generation**.
- Appropriate **tariff structures** could prevent the need for grid reinforcements while ensuring an acceptable **pay back time** for the prosumers.

This work aims at estimating the **potential of advanced electricity tariff** structures to **mitigate the impact of photovoltaics** in distribution grids.

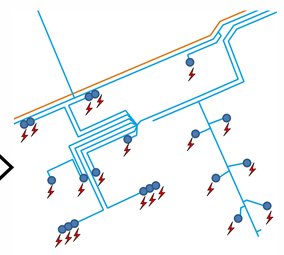
Methodology

building properties
annual consumption

power profile at the transformer

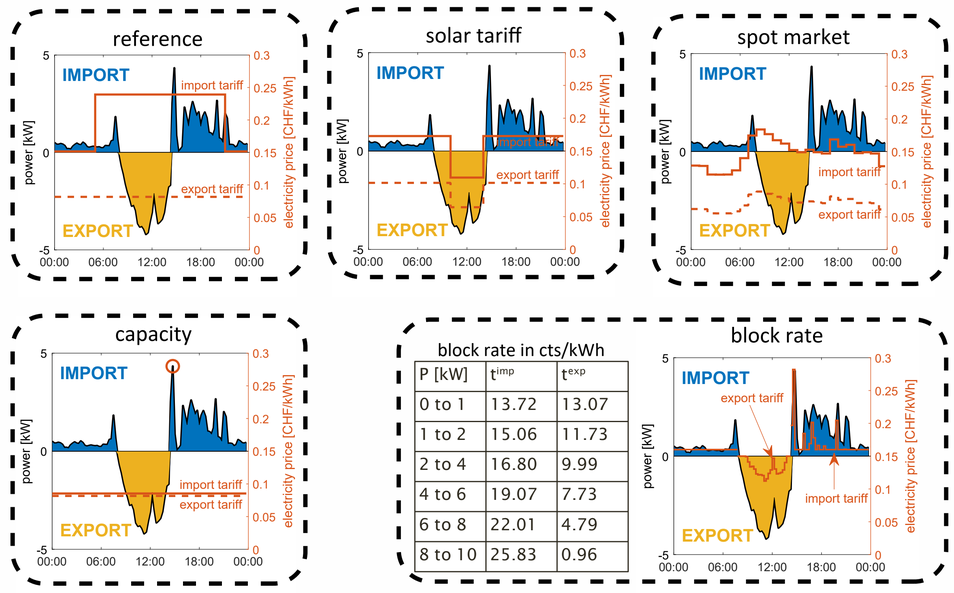
database of load profiles

Allocate the load profiles
- match annual cons.
- match power at trafo

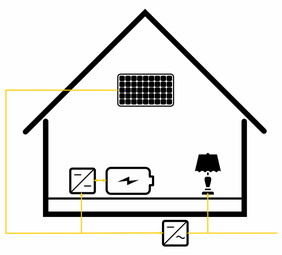


one electricity consumption profile for each meter

Design tariff scenarios

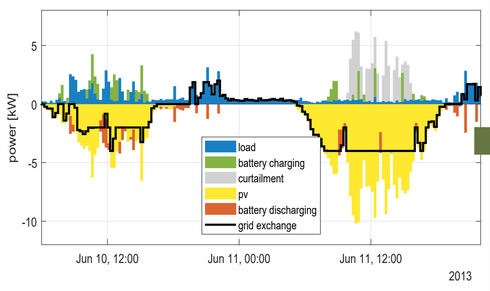


Optimize design and operation
Mixed-integer linear problem



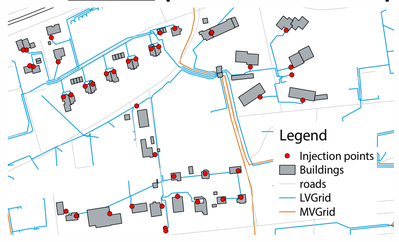
Decision variables:
- PV capacity
- Battery capacity
- Battery operation
- PV curtailement

Obj: total cost of ownership



Solved for one year at 15min resolution

Solve power flow equations



Extract:
Voltage[p.u]
Line current [A]
Transformer P,Q

Case study:
41 buildings in Rolle (sub network of TR3716)
1500 kW pv potential capacity

Evaluate with relevant metrics:

$$\text{PV host} = PV^{CAP} / PV^{CAP}_{max}$$

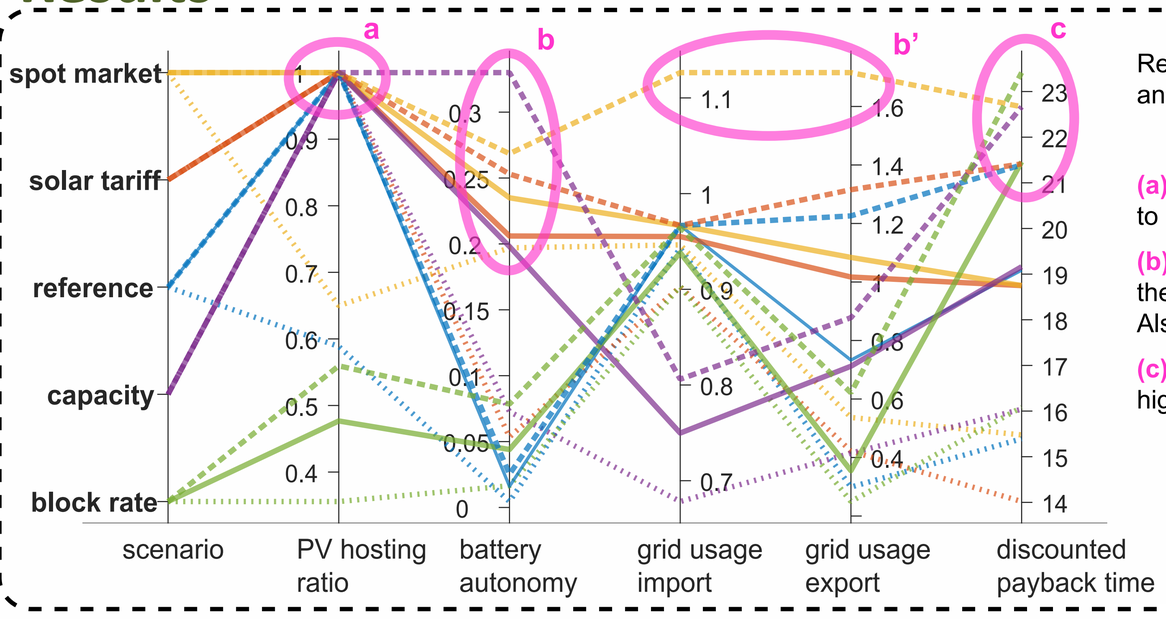
$$\text{BAT auto} = \frac{E^{BAT}_{CAP}}{\text{mean daily energy}}$$

$$GU_{IMP,EXP} = \max(P_t^{IMP,EXP}) / \max(P_t^{LOAD})$$

$$DPP = T \mid \frac{\sum_{t=1}^{T} CF_t - OPEX_t^0}{(1+r)^t} = 0$$

CF_t : the net cash flow (investment + operational cost at time t, taking into account replacement of the battery and inverter at end of life

Results

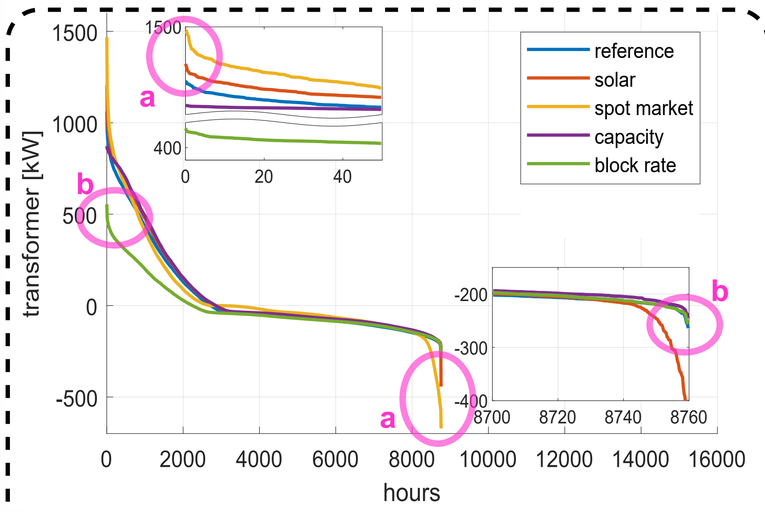


Results are evaluated from the grid impact and economic perspective.

(a) The PV hosting ratio is always close to 1 except for the block rate scenario.

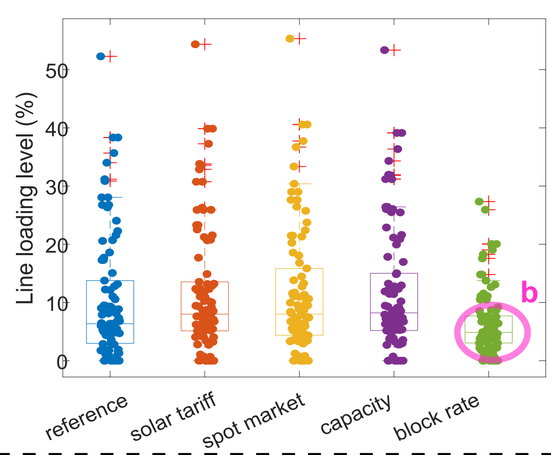
(b) The battery autonomy is higher for the spot market and solar tariff scenarios. Also leading to higher grid usage ratios **(b')**.

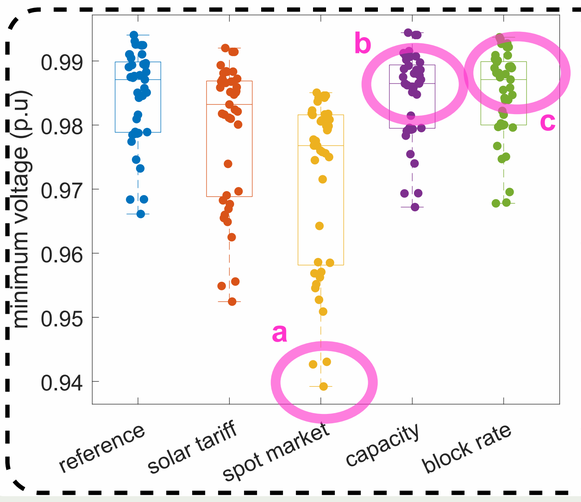
(c) The block rate tariff shows slightly higher payback time.



(a) Spot market and solar tariff both induce higher power at the transformer.

(b) The block rate tariff decrease both the max feed-in or withdrawn power and the line loading.





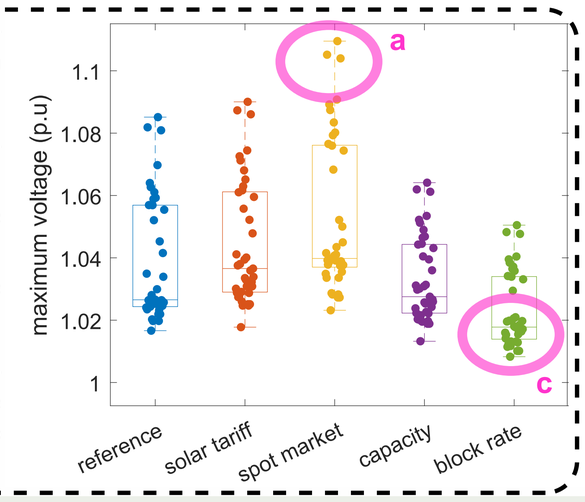
The voltage deviations are considered seperataly when below 1 p.u (on the left) and when above 1 p.u (on the right).

(a) Solar and spot market scenarios increase the voltage deviation.

(b) The capacity tariff scenario reduces the voltage deviation when it's below 1 p.u.

(c) The bloc rate tariff reduces the voltage deviation in all cases.

Dynamic tariffs promote investment in batteries to increase flexibility but actually increase the pessure on the grid. Block rate helps to redcue over-voltage.



Conclusion

We performed the **integrated optimization** of both **design** (PV and battery capacity) and **operation** (battery charge, discharge and PV curtailement) for **41 buildings under 5 different tariff scenarios**.
Considering the cost of 2025, all scenarios but the block rate tariff scenario promote a **PV penetration close to the maximum** potential. The **highest investment in batteries** is achieved under t**he spot market scenario** but it also leads to **higher stress on the grid.** The **capacity tariff scenario** slightly **reduces the voltage deviation** and the line loading while the **block rate** scenario significantly **reduces the over-voltage**, line loading level and transformer reverse power flow.

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