HOW TO BOOST PV DEVELOPMENT WHILE MITIGATING GRID IMPACT USING ADVANCED ELECTRICITY TARIFFS

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Self-consumption and system profitability

- System profitability is given by SC and strongly depends on electricity tariffs (import and export)
- Batteries can increase self-consumption

self-consumption: \[ SC = \frac{A}{A + B} \]

\[ SC_{\text{min}} = SC \bigg|_{\text{profit}>0} = \frac{\text{LCOE} - t_{\text{exp}}}{t_{\text{imp}} - t_{\text{exp}}} \]

LCOE: Levelized cost of PV electricity
\( t_{\text{imp}} \): import tariff (retail electricity price)
\( t_{\text{exp}} \): export tariff (feed-in tariff)
Questions

• How tariffs influence investments in decentralized PV and storage?

• How tariffs impact grid operation?

• Can advanced tariffs help mitigate impact of large PV penetration on the grid?

• How to allow long term and profitable PV penetration?
Case study

- Data: 1 year @ 15 minutes, LCOE calculated on 25 years
- Operation: PV and battery operation (1 year)

RE Rolle demo site: low-voltage grid TR3716
Optimal building design and operation

Objectives

\[ \text{TOTEX} = \text{OPEX} + R \times \text{CAPEX} \]

Inputs

- Electrical demand
- Irradiance
- PV, battery cost functions
- Tariffs
- Interest rate, lifetime

MILP

Outputs

- PV and battery capacity
- Charging and discharging power
- PV generation, curtailment
Effect of tariffs on the design and operation

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

Design tariff scenarios

Optimize design and operation
Mixed-integer linear problem
Decision variables:
- PV capacity
- Battery capacity
- Battery operation
- PV curtailment
Obj: total cost of ownership

Solve power flow equations
Extract:
Voltage [p.u.]
Line current [A]
Transformer P, Q

Evaluate with relevant metrics:
Pv host = \( \text{Pv}^{\text{CAP}} / \text{Pv}^{\text{CAP}} \) max
Batt auto = mean daily energy
\( \text{GU}_{\text{IMP}, \text{EXP}} = \max(\text{P}_{\text{IMP}, \text{EXP}}) / \max(\text{P}_{\text{IMP}, \text{EXP}}) \)

Reference tariff

- Import: 21.02 cts/kWh
- Export: 8.16 cts/kWh
Solar tariff

- Cheaper at midday
Spotmarket tariff

- Mirror of the EPEX
- Scaled to ensure same DSO revenues
Capacity tariff

- Mix of a flat volumetric tariff and a capacity component
  - Import: 15.91 cts/kWh
  - Export: 12.09 cts/kWh
  - Power: 5.02 CHF/kW/month
Block rate tariff

- Import tariff increasing with power consumption while export tariff decreasing with power injection
Effects of advanced tariffs

- **PV hosting** always maximum except with block rate
- Dynamic and capacity tariffs promote larger **battery size**
- Playing on the spot market can actually increases the **Grid Usage**, capacity and block rate globally decreases it
- Variance in **payback time** between systems is important

Median of 41 buildings

Tariffs changes prosumer profiles
Dynamic tariffs tend to **increase the stress** on the grid

Block rate and capacity tariffs are able to **reduce the stress** on the grid

Impact on grid: Voltage deviation

Dynamic tariffs tend to increase the stress on the grid.

Block rate and capacity tariffs are able to reduce the stress on the grid.

Long term evolution

- Long-term PV and battery installations
- Grid usage constrains to keep grid safe operation

1. Analyze possible system upgrades
2. Identify upgrades with IRR > 8%
3. Calculate effect on grid operation
4. Force reduced grid usage if needed
5. Adapt tariffs to keep constant revenues for grid operation

Every year from 2020 to 2050
2020-2050 evolution

Based on RE single tariff

- **Import tariff** increases up to 0.28 CHF/kWh (+32%)
- **Grid usage** constraint starts in 2026
- **PV hosting** reaches 80% (30% higher than 50 TWh objective)

Profitability for prosumers

- Import tariff ↑ ⇒ IRR ↑
- GU constrain ↓ ⇒ IRR ↓
- 2% maximum variance around an 8% profitability threshold

Conclusions

• Dynamic volumetric tariffs promote investment in larger storage but increase the stress on the grid
• Capacity based tariffs change battery usage, from trading energy to reducing consumption peaks
• Block rate tariffs promote smaller installation, hence helping reducing the stress on the grid
• Long term installation of distributed PV systems can be promoted by tariffs adaptation and (possibly) operational regulations
• Adaptation of tariffs in addition to investment cost reductions ensure profitability for most prosumers
Outlook

• Analysis of
  • Effect of self-consumption communities
  • Effect of other flexible loads such as heat-pumps and EVs
  • Effect of advanced tariffs on long-term evolution

• Market opportunities for DSO
  (use of distributed resources by both prosumers and DSOs)

• Strategies to minimize (long-term) overall investment costs
Thank you for your attention