Towards smart management of PV in Swiss low-voltage grids

Insights into export tariff structures and curtailment policies

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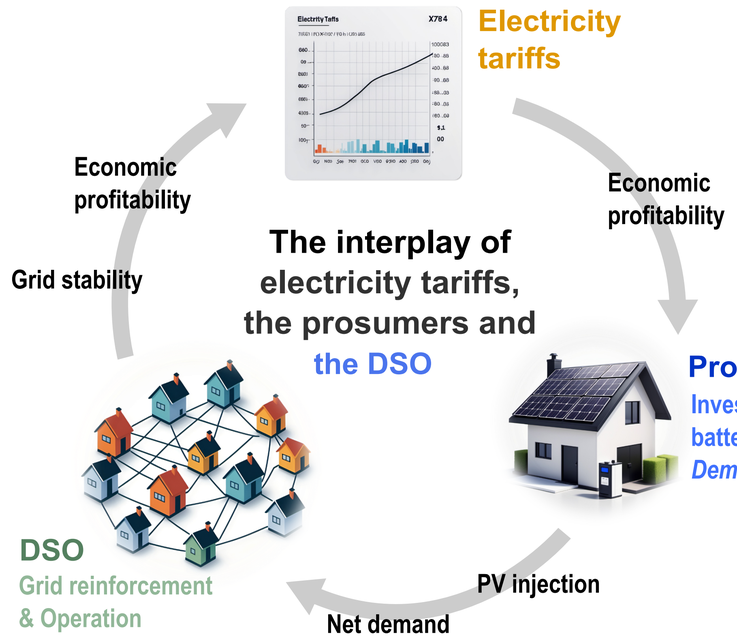
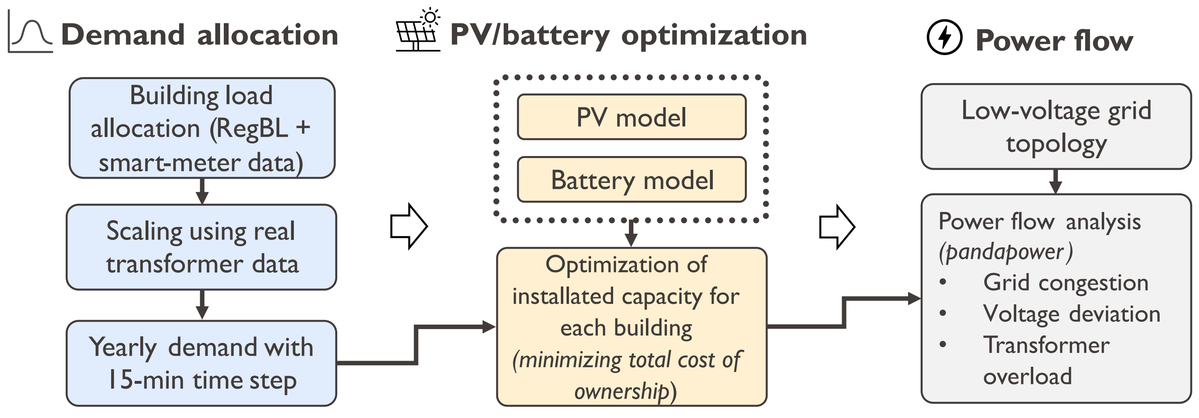
Introduction

- High PV penetration in low-voltage grids, crucial for Switzerland's energy transition, presents significant challenges for DSOs and may lead to costly grid upgrades [1]
- Alternative import tariffs are known to drive prosumer-level investment in storage and recover grid costs with minimal impact on the economics of PV systems [2]
- However, import tariffs only marginally mitigate the impact on the grid, as the major problem in low-voltage networks comes from PV injection [2,3]

In this work, we investigate the effects of **export tariffs** and **PV curtailment policies** on managing PV exports to **mitigate grid impacts without reducing the economic attractiveness of rooftop PV**.



Methodology

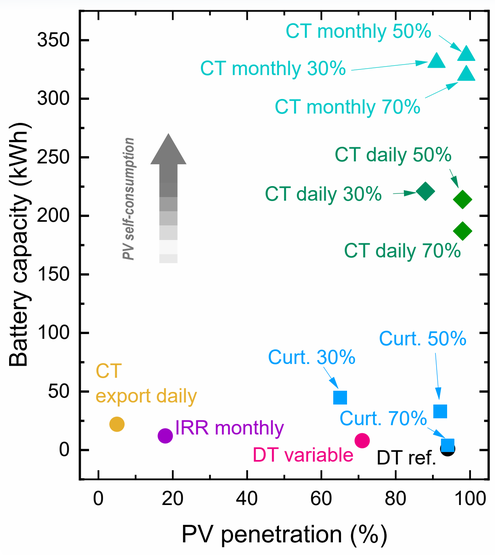


About import and export tariff structures

Tariff structure	DT reference	DT variable	CT export daily	IRR monthly	Curtailment only	CT monthly	CT daily
Import price	**Variable** (on/off peak hours)	**Variable** (on/off peak hours)	**Variable** (on/off peak hours)	**Variable** (on/off peak hours)	**Variable** (on/off peak hours)	**Variable** (on/off peak hours) + **variable capacity component** (depending on the max. *monthly* net power demand)	**Variable** (on/off peak hours) + **variable capacity component** (depending on the max. *daily* net power demand)
Export price	**Flat**	**Variable** (on/off peak hours)	**Flat** + **variable capacity component** (max. *daily* PV injection)	**Variable irradiance component** (max. *monthly* irradiance)	Flat	Flat	Flat
Curtailment	No	No	No	No	Yes	Yes	Yes

Results on a Swiss rural low-voltage grid

Private PV and storage investment

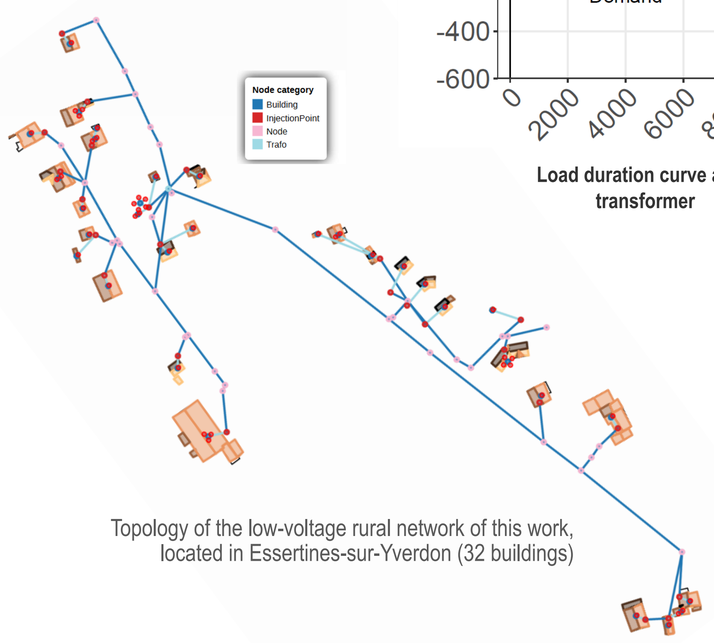


- ✗ Tariffs with a **capacity component** at the export (*CT export daily*) or based on the **irradiance** (*IRR monthly*) strongly **penalize PV penetration**
- ✗ *DT variable* tariff also lowers PV penetration
- ✓ **Curtailment** (at 50% and 70%) does **not hinder PV deployment**, due to the limited impact of PV production peaks.
- ✓ **Combining curtailment with a capacity-based component** (at the import) also encourages the use of storage (therefore limiting energy imports)

Economic profitability

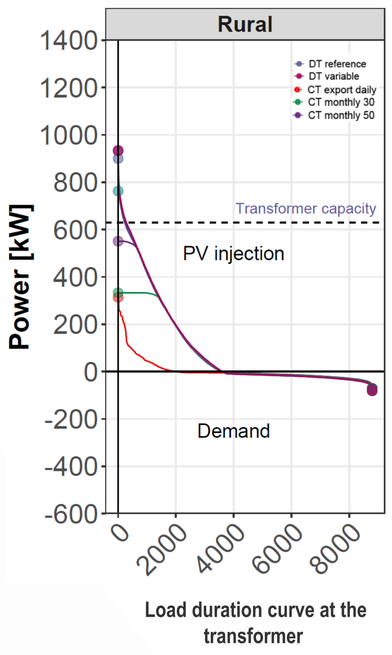
Tariff structure	DT ref.	DT var.	CT export daily	Curt. 50%	IRR monthly	CT monthly 50%	CT daily 50%
Profit (CHF p.a)	16104	6606	-37827	13184	-5880	15426	16090
Cost (CHF p.a)	543	526	748	480	529	472	463

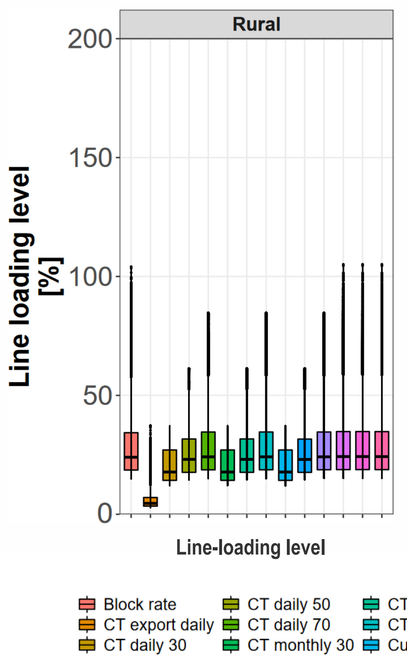
✓ *CT monthly* and *CT daily* allow for the highest profit (PV capacity installed is the same in all scenarios)

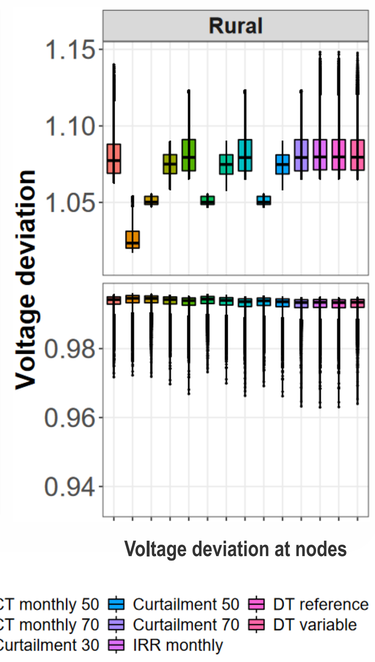


Topology of the low-voltage rural network of this work, located in Essertines-sur-Yverdon (32 buildings)

Grid impacts







Block rate · CT daily 50 · CT monthly 50 · Curtailment 50 · DT reference
CT export daily · CT daily 70 · CT monthly 70 · Curtailment 70 · DT variable
CT daily 30 · CT monthly 30 · Curtailment 30 · IRR monthly

- ✗ With 100% PV penetration, voltage deviations and feed-in powers exceeding the transformer capacity are observed
- ✓ **Curtailment** (≤ 50%, w/ or w/o a CT component) or a tariff with a **capacity component only** (*CT export daily*) limits grid impacts
- ✗ *IRR monthly* tariff does not encourage the use of batteries and therefore has almost no effect on grid impacts

Conclusion & Outlook

Curtailment reduces grid impacts without limiting PV penetration, unlike capacity-based or irradiance-based export tariffs, which strongly discourage PV installation.

Combining curtailment with a capacity-based component in the import tariff also encourages the use of energy storage, which maximizes PV self-consumption and reduces energy imports. This approach is also the **most profitable for prosumers**, given the same PV capacity. Similar results are observed in both urban and semi-urban areas.

Future work will focus on tariff fine-tuning, and exploring the impact of resource sharing and local energy communities.

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References

[1] Eidgenossenschaft S. Bundesgesetz ¨uber eine sichere Stromverso mit erneuerbaren En-ergien ¨Anderung des Energiegesetzes und des Stromversorgungsgesetzes. *Schweizerische Eidgenossenschaft*. 2023

[2] Pena-Bello A, Junod R, Ballif C, Wyrsch N. Balancing DSO interests and PV system economics with alternative tariffs. *Energy Policy.* 2023

[3] J. Holweger, L. Bloch, C. Ballif, and N. Wyrsch, “Mitigating the impact of distributed PV in a low-voltage grid using electricity tariffs,” *Electr. Power Syst. Res.*, 2020

Acknowledgments

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