Grid Integration Impacts of Vertical Bifacial Agri-Photovoltaics

Fraunhofer IEE

How vertical bifacial photovoltaic systems can contribute to a sustainable grid utilization.

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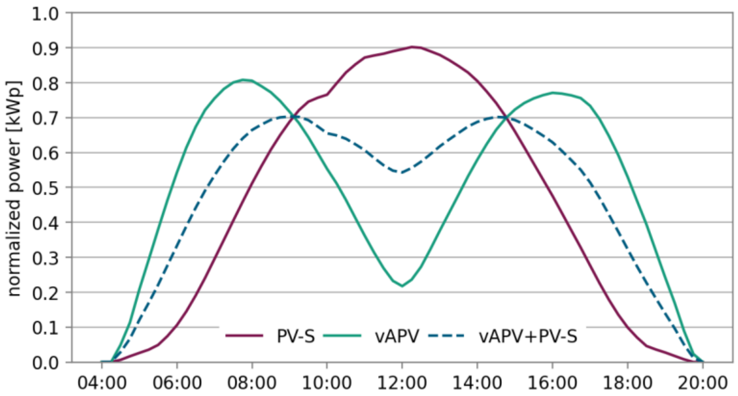
Motivation

Preventing the climate catastrophe requires a scaling of the current German ground-mounted photovoltaic (GM-PV) system capacity by a factor of eleven to at least 150 GWp [1][2]. To make this massive expansion sustainable, an immense increase in demand for land-neutral and grid-supporting PV technologies is expected to mitigate emerging land-use conflicts and reduce overall societal grid expansion and grid flexibility costs. **Vertical bifacial agri-photovoltaics (vAPV)** has the potential to meet both needs due to its **complementary** and **flexible feed-in behavior** compared to conventional GM-PV.



PV production on a sunny summer day with different orientations. Inclined south (PV-S), vertical east-west (vAPV). A combined system of 48% PV-S & 52% vAPV shows a more balanced generation behavior.

Impacts of vAPV on the future energy system

Methodology

- Residual load optimization of the climate neutral German energy system was performed depending on the share of vAPV in the PV-GM portfolio and compared to a reference scenario.

Key results

The analysis showed that the expansion of **vAPV contributes** to significant **reduction** of **residual load peaks** and **gradients** of **10 and 5 %, respectively** for an **optimal share of vAPV** in the total PV portfolio and in the PV-GM portfolio of **20 and 50 %,** respectively. *Further results are:*

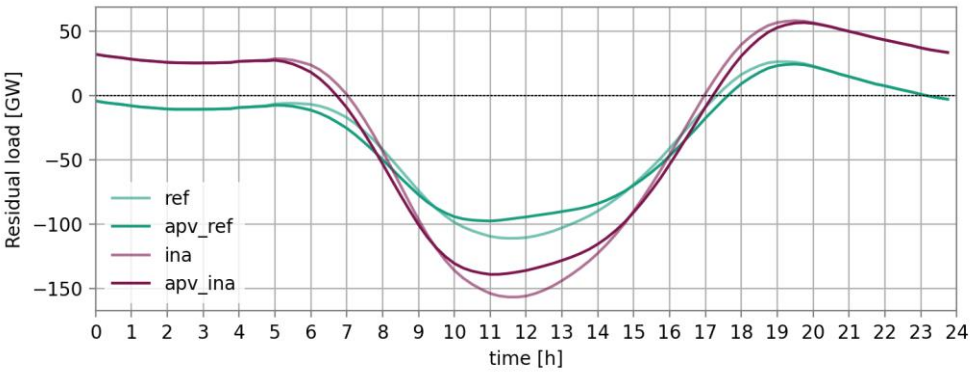
- The optimized **energy system requires** a **vAPV** capacity of **60 - 90 GWp** and a **PV-S share** of only **30 %** of the total PV portfolio.
- vAPV leads to a **reduction** of the **positive residual energy** by 5 %.
- vAPV leads to an **increasement** of **storage full load hours**.

Implications

→ **Reduction** of required **capacity** of flexible **generators** and **loads** (gas-fired power plants, batteries, heat pumps, power-to-X).

→ **Reduction** of **requirements for flexibility** of flexible generators and loads .

→ **Reduction** of **temporal dependence** on storages and **fossil fuels**.



Comparison of the modeled mean daily variation of the residual load between PV-S and vAPV scenarios for two different energy system extension scenarios (Reference & Inacceptance) 2045.

Impacts of vAPV on a mid-voltage grid

Methodology

- Calculation of grid infrastructure loads in a rural medium voltage grid using dynamic load flow calculations for a reference scenario 'PV-S' and a feed-in optimized scenario 'vAPV + PV-S'. The grid states are then compared.

Key results

The simulation resulted in **significantly lower** maximum **loads** on the **grid resources with** the integration of **vAPV**. Maximum loads of **lines** and **transformers** could be **relieved** by an average of **19 and 16 %,** respectively. The **maximum power** fed back into the **high-voltage grid** was **reduced** by **16 %.** *vAPV further enables:*

- **Increase** in the **power** that can be **integrated** in the **grid** by almost **27 %** without placing a greater load on the grid infrastructure.
- Reduction of maximum feed back line loads by an average of 19 %.
- **Reduction** of **transformer losses** by 2 %.
- Reduction of peak voltages by an average of 0.17 %p and up to 1.0 %p.

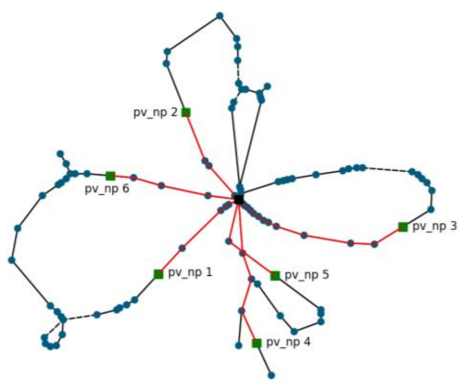
Implications

→ **Less demanding design** of **grid infrastructure** on medium- and high-voltage level.

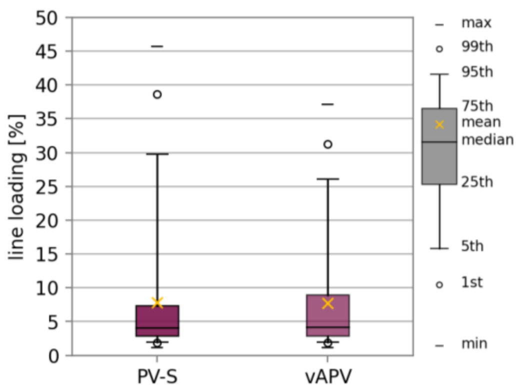
→ Later or **less extensive network expansion**.

→ Lower voltage maintenance requirements in the distribution grid (e.g. provision of inductive reactive power to reduce voltages).

→ **Advantages** in grid **expansion costs** and grid **stability**.



Topology of the rural medium voltage grid model [3]. Feed back lines to the substation are indicated in red. Network users in blue.



Comparison of the statistical distribution of the determined mean loads of the feed back lines for both scenarios.

Conclusion and Outlook

The **advantages** of **vAPV** compared to conventional PV-S systems could be clearly worked out **in terms of grid efficiency**. To make the expansion of the GM-PV segment sustainable, the dual use of agricultural land in the form of **vAPV** shows a **great potential** to ensure **preservation of agricultural land** as well as a **cost-optimized and stable power grid**.

Future work:

- Determination of the reduced costs of the energy transition resulting from the vAPV grid serviceability.
- Validation of the results with other grid integration approaches.
- Consideration of el. demand in grid simulation to investigate further potential due to demand-orientated power generation of vAPV.
- Consideration of seasonal balancing effect of south-facing vAPV.

1 Prognos, Öko-Institut, & Wuppertal-Institut. (2021). Klimaneutrales Deutschland 2045 - Wie Deutschland seine Klimaziele schon vor 2050 erreichen kann - Zusammenfassung im Auftrag von Stiftung Klimaneutralität, Agora Energiewende und Agora Verkehrswende. www.stiftung-klima.de

2 Sterchele, P., Brandes, J., Heilig, J., Wrede, D., Kost, C., Schlegl, T., Bett, A., & Henning, H.-M. (2020). Wege zu einem klimaneutralen Energiesystem - Die deutsche Energiewende im Kontext gesellschaftlicher Verhaltensweisen.

3 Meinecke, S., Sarajlić, D., Drauz, S. R., Klettke, A., Lauven, L. P., Rehtanz, C., Moser, A., & Braun, M. (2020). SimBench-A benchmark dataset of electric power systems to com-pare innovative solutions based on power flow analysis. Energies, 13(12). https://doi.org/10.3390/EN13123290

More information on the methodology can be found here.

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