Integrating battery storage and photovoltaic power generation in private households

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The expansion of household-scale photovoltaic (PV) capacity in Germany is forcing distribution system operators to focus more attention on preventing the overload of grid components and keeping the voltage within established limits. To ensure safe grid operation on sunny days, PV plants must either reduce their power generation to comply with feed-in limitations or store excess electricity in batteries. Since peak shaving is often impossible with the conventional operating strategy of the storage system, PV plants must frequently be throttled back.

This work presents a grid-optimized operating strategy for PV storage systems based on a fuzzy logic controller. This strategy reduces peak feed-in and thus also PV curtailment losses. The fuzzy logic controller uses data on PV power surplus and battery charge level as input variables, and, to improve results, is enhanced by evolutionary programming.

The energetic assessment shows that even small batteries (<<5 kWh) reduce curtailment losses considerably under the grid-optimized strategy. The economic assessment shows that, in 2016, investments in PV storage systems with large PV plants and small batteries have low internal rates of return. The use of an electric car by the plant operator, a higher cycle stability of the storage system and higher electricity purchase prices all increase PV storage system profitability. Moreover, there is an economic benefit when operators of existing plants switch from the conventional to the grid-optimized strategy. Interestingly, solar forecast inaccuracies and variations in load and generation profiles have a negligible impact on the performance of the control algorithm.