OPTIMIZING LOW VOLTAGE DISTRIBUTION NETWORKS WITH HIGH FEED-IN OF RENEWABLE ENERGIES

Benjamin Schott¹, Christoph Williams¹, Jann Binder¹, Michael A. Danzer¹, Gerd Heilscher², Holger Ruf², Martin Felder¹
¹Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)
Industriestraße 6, 70565 Stuttgart, Germany, benjamin.schott@zsw-bw.de
²Hochschule Ulm, Eberhard Finckh-Str. 11, 89075 Ulm

Scope of the project
The rising share of decentralized photovoltaic systems leads to increasing requirements for network operating resources and the management of low voltage networks. Several flexibility options are available to supply system services like voltage control and reducing the overload of resources. All flexibility options are characterized by a range of various technical and economical parameters. These parameters determine an option’s role in the technical model and allow different options to be combined in a cost function to achieve low-cost-solutions. The aim of this project is therefore to evaluate and compare different combinations of flexibility options for application in low voltage networks. In particular, battery storage technologies are compared to evaluate the „best-available“-technology for different purposes. The project is funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear safety (FKZ 0325385).

Approach and Results

Test networks and solar roof potentials

Two different test networks build a sound basis for the grid simulation. Roof potential measurements deliver input parameter for setting the boundaries for PV expansion in the reference networks. The network plan on the left side shows the test network Hitlitsetten with 1162 kWp PV installed on 59 roofs which have an estimated roof potential of 1008 kWp.

Battery technologies and applications

Different battery technologies are compared for application within households to evaluate the „best-available“-technology for increasing self-consumption. The evaluation includes techno-economical data as investment costs, efficiency, P/E ratio for Lithium-Ion, Lead-acid, High-Temperature (NaS/NaNiCl₃) and Redox-Flow batteries. The data has been selected through intensive literature research.

Grid simulation and Optimization

Methodical Approach:
Typical standardized low voltage grids for rural, village and suburban settings [3] are simulated using DlgSILENT PowerFactory. Load profiles for the households are assigned randomly from the pre-generated load profiles, such that prescribed PV penetration rates and battery installations are fulfilled.

An Evolution Strategy is then employed to optimize grid costs, taking into consideration all grid stability requirements. The results are then validated with real data sets from two different test networks within the low voltage network of SWU Netze GmbH. The optimization routine is indicated in the flowchart (Figure 2.1).

First results:
Local (household) level: Starting from the PV generation, the local consumption is subtracted and the storage operated with delayed charging. Delayed charging is optimized to reduce injection above a defined „grid injection limit“. The resulting grid injection duration curves are displayed in Fig. 2.2.

Grid level: a network structure typical for a village in Germany with 57 household boundaries for PV expansion is [3] is analysed. Applied randomly to these households is one of 15 different household load profiles [4]. The effects of PV injection, the use of storage and „peak shaving“ onto the network voltage levels are shown in Fig. 2.3. The following simulation steps are used:

- The annual local „net-grid injection“ profiles are calculated in MATLAB at a 6-min resolution with the 15 profiles and varying capacities of PV and storage. Optimized delayed charging being applied to storage.
- Extracted from the resulting full-year profiles is a single selection of 10 days for all profiles, which after scale-up show a similar duration curve as the 365 days. This is achieved through a suitable mix of days, seasons and weather conditions (cloudy, full sun-shine and cloudy morning).
- The „net-grid injection“ profiles of those 10 days are fed into the grid analysis tool PowerFactory
- The occurrence of voltages of all nodes are sorted by magnitude and plotted as voltage duration curves of Fig. 2.3 and 2.4.

结论

The aim of the study is to determine technically and economically optimized combinations of flexibility options for different shares of PV in low voltage networks. The poster presents the approach and a snapshot of first results. Application of delayed charging increases the usefulness of local storage in terms of grid relief. Capping remains necessary to avoid excessive voltage levels. An algorithm to optimize the network based on evolution strategies and guided by the fitness of populations is implemented and applied.