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Minimizing the costs of decentralized use of PV-electricity based on examples of the Austrian building stock

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Overview

In recent years PV-electricity has become an increasingly competitive energy source for decentralized use. In the last few years the cumulative installed capacity in Austria increased from 50 MW_p, in 2009, to over 180 MW_p, in 2011, while the system costs for PV decreased significantly in the same period. In addition, there are also a lot of initiatives which focus on energy autarky and promote the idea of decentralized storages. The core objective of this paper is to identify the cost optimal use of photovoltaic with different PV-integration and with different types of refunds. In scenarios, battery storages and storage strategies to increase the self-consumption of PV-electricity are considered. The impacts on the overall costs and the PV-revenues will also be analyzed.

Methods

With the software MATLAB, based on measured data of global horizontal irradiation and temperature, the PV-generation is, depending on direction and work angle, calculated. The power-output is calculated after a model suggested by Huld et al (2010) which only depends on the in-plane irradiance G_{mod} and the module temperature:

$$P(G, T_{Mod}) = P_{stc} * \frac{G_{mod}}{Gstc} * \eta_{rel}(G', T')$$

P_{STC} is the power at standard test conditions of G_{STC}=1000W/m^2 and T_{STC}= 25°C. The relative efficiency is calculated as:

$$\eta_{rel}(G', T') = 1 + k_1 * \ln(G') + k_2 * (\ln(G'))^2 + T' * (k_3 + k_4 * \ln(G') + k_5 * (\ln(G'))^2) + k_6 * T'^2$$

G' and T' are normalized Parameters to STC Values: $G' = \frac{Gmod}{Gstc}$, $T' = T_{mod} - T_{stc}$. The parameters k_1 to k_6 are technological parameters from different module types and the module temperature can be estimated from the ambient temperature: $T_{Mod} = T_a + c * G_{mod}$ where c is the temperature coefficient and depends on the way the modules are mounted.

Standardized load profiles for households and office buildings are also implemented in the model, as well as the battery. It is modeled as a LiIon-battery with a typical loading gauge and with an efficiency of 0.9. The specific costs for the PV-System and the battery are taken from literature. PV-revenues result by selling the surplus of electricity on the spot market or from a fixed feed in tariff. In the first step, the battery is eliminated and the self-consumption and the surplus on PV-electricity will be identified. The net present value of the cash-flow is calculated and will be compared to the cash-flow considering the battery. The aim is to identify the cost optimal size and direction of the PV-system, considering storage systems, spot market prices and feed in tariffs.

Results

The following figures show the results based on the following parameters: PV-Size: 5 kW_p; Direction: South; Angle: 30°; Load Profile: Household; Demand: 4000 kWh/a; Location: Bregenz

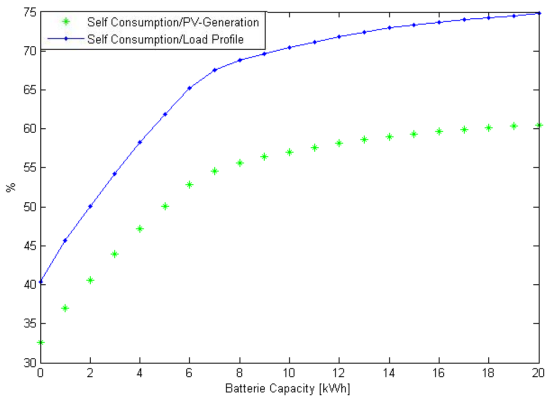

Figure 1: Self consumption depending on battery capacity

First of all it is important to identify the rate of self-consumption to know how much electricity remains to feed in or to sell on the market. Figure 1 points out the rate of self-consumption in relation to the PV-generation as well as the relation to the load profile with different storage capacities.

Without a storage system, the self-consumption in relation to the generation is about 32%, which means that 68% of the generation is left to feed in or to sell. 40% of the demand can be covered by PV-generation. With a battery, the rate of self-consumption is increasing with an ideal capacity of about 6 to 7 kWh. A further increase would not achieve much more benefit. The system costs for PV-systems are about 2400 €/kW_p in 2012 - without investment incentives - and the annual operation- and maintenance costs account for 1% of the system costs. The investment costs for the battery are about 700 €/kWh (Sauer et al., 2011). Figure 2 points out the development of the net present value with a fixed feed in tariff of 10 c/kWh over the lifetime of the PV-system without a battery. Figure 3 points out the development with a 6 kWh battery system.

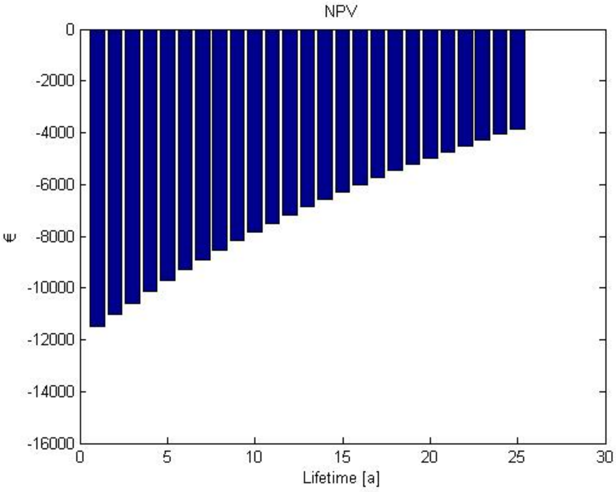

Figure 3: NPV without battery

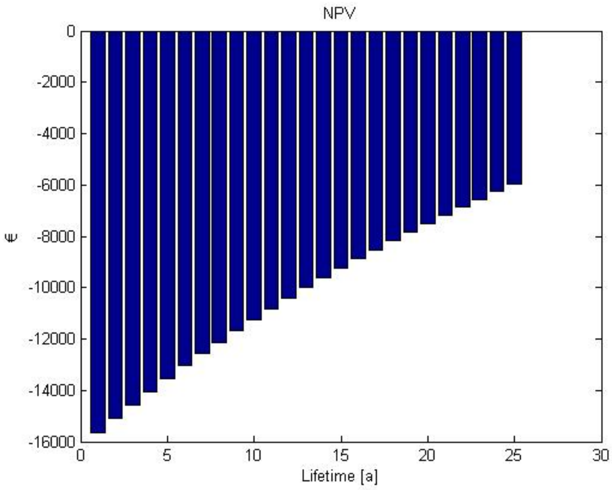

Figure 2: NPV with battery

There is no special charging strategy implemented yet. The battery is charged, when PV-generation is above demand, and discharged, when PV-generation is below the demand. It is obvious, that there is no optimal solution for these input parameters. There is no break-even point, either with or without a storage system.

Conclusions

Currently, from a pure economic point-of-view, PV-systems with battery are not cost-effective. Yet, there are several approaches which could change the described picture: The first is to look into revenues from selling PV-electricity on the spot market and to implement different charging strategies. Different business models for batteries – including co-financing from utilities - might also be a cost-effective solution for energy utilities and for owners of a PV system.
Results of these additional opportunities will be considered in the final version of the paper.

References

Huld et al. (2010) “Mapping the performance of PV modules, effects of module type and data averaging”, Solar Energy, 84(2010), 324-338.

Sauer et al. (2011) “Dezentrale Energiespeicherung zur Steigerung des Eigenverbrauchs bei netzgekoppelten Anlagen - Studie im Auftrag des Bundesverbands Solarwirtschaft“