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Performance of a photovoltaic plus battery home system with load profile scenarios changing over the system life

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Abstract

The ratio of self-consumed electricity to total electricity produced by a photovoltaic (PV) system depends on whether consumption and production match in time. A temporal mismatch can be partially overcome by buffering the energy produced by PV, e. g. in a battery. A key impact factor which affects the techno-economic performance of PV-battery systems is the household load profile, which may significantly change over the lifetime of the PV-battery system, but the effects of a changing load profile on e. g. the self-consumption ratio were not yet investigated. This paper shows on three different examples the possible changes over the 21 year lifetime of a typical PV-battery system. It is demonstrated that changes in the behavior patterns and the number of residents can cause the self-consumption to vary by more than a factor of 2 over the lifetime of the system. When dimensioning such a system e. g. for optimal return on investment over the lifetime or for a certain degree of autarky, not only changing energy prices, but also changing household structure and changing behavior of the household members should be taken into account.

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Keywords: photovoltaic; PV; battery; energy storage; household load profile

1. Introduction

The desire for increased self-consumption of electric power from rooftop photovoltaic (PV) systems and for higher autarky is one of the key drivers for the addition of batteries to PV systems [1]. The ratio of self-consumed to

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total electric energy production from a PV system increases, the better consumption and production match in time. A temporal mismatch can be partially overcome by buffering the energy, e. g. in a battery. Therefore the load profile of the household (HH) must be taken into account for the sizing of PV and battery systems. While the PV-battery system remains constant over the years of operation, the household's load profile can change significantly, but, to our knowledge, the effects of a changing load profile were not yet investigated. In this paper the effects of a changing HH load profile on the techno-economic parameters share of self-consumption and degree of autarky are shown for three examples.

Nomenclature

DWD Deutscher Wetterdienst, Germany's National Meteorological Service
HH household
LPG LoadProfileGenerator
PV photovoltaic
SCY scenario year
Share of self-consumption: The share of electric energy produced by the PV system which is consumed by the household, either directly or after intermediate storage in the battery
Degree of autarky: The share of the electric energy consumed by the household which is supplied by the PV-battery system

In previous work, the performance of a PV-battery system for powering a household was examined [2, 3]. It was found that the performance highly depends on the assumed load profile and realistic results can be achieved only with an individual time series of the HH load, not with an averaged load profile. Also the step width must be short enough to appropriately model the short power peaks of typical HH appliances [4, 5].

Some publications use individual load profiles, too. E. g. [6] uses a HH load time series in 1 sec resolution from [7]. They note that the results depend "on the system configuration and the coincidence between the PV output and load demand". The time series from [7] are very good representations of the real world, but the HH type which a time series belongs to is not known, so it remains open which of the time series in this source would be appropriate to model the effect of changing HH members and their behavior.

There are many other publications on PV-battery system optimization, e. g. [4, 6, 8-10], but none of them investigated the influence of a household load profile changing over the years of system lifetime.

The question arises, how large is the effect of changes in the HH members and their behavior on the performance of the PV-battery system.

To answer this question, different load profiles are generated by a model which takes into account the household members and their behavior. The LoadProfileGenerator (LPG) developed in the thesis [11] and shortly described in section 2.1 was extended in this context for more easy modelling a series of years of a household with changing members and behavior.

2. Methodology and basis data

2.1. Short description of the LPG

Most load profile generators are based on a probability approach, which in the most simple form consist of rules such as "Between 7:00 and 8:00 there is an 80 % chance of running the coffee machine for breakfast". Since this simple approach yields unsatisfying results due to human behavior being much more complex than such simple rules, a lot of different models with various additions to the simple rules have been created. In [12] a good overview of the existing model approaches is provided. One of the approaches for improving the results is using activity probabilities instead of device probabilities, since e. g. by setting the rule that the TV and the set-top boxes are usually turned on together. Another one is modulating the activation probabilities by an occupancy profile to ensure