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First Year of Smart Metering with a High Time Resolution—Realistic Self-Sufficiency Rates for Households with Solar Batteries

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Abstract

Measured data from distribution grids with a high time resolution is scarce although it is where most volatile power profiles occur. Electrical storage systems (ESS) can mitigate the imbalance of generation and demand. In this study smart meter data with a temporal resolution of 15 s is analyzed and an algorithm described, that allows identifying differently oriented generator in mixed PV plants. Various self-consumption scenarios are simulated with different setups and temporal resolution. The calculated self-sufficiency rates lead to recommendations for the dimensioning and give precise values for the correction of key parameters from simulations if data is not available in high temporal resolution.

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Keywords: residential smart meter; PV simulation; PV battery systems; self-consumption; dimensioning; temporal resolution

1. Introduction

PV solar power supplies a considerable share of the electrical energy demand in Germany, namely 5.9 % in 2015. In the federal state of Bavaria the share is even twice as high, 11.8 % in 2014. PV penetration is not evenly distributed and concentrated in rural areas. Comparing the annual PV generation and demand, some neighborhoods already exist that could provide for themselves electrically. One example is the district Epplas belonging to Hof/Bavaria. It generates more than twice the energy it consumes in a year because of a high presence of rooftop PV

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plants. The obvious restraint is that PV generation is highly volatile, underlies seasonal effects and is not controllable and therefore independent of the demand. Additionally most plants are connected on the lowest voltage level so if feeding into the grid is allowed and a surplus occurs it is technically challenging to transfer it to other areas. The political will to increase the share of renewables has to consider both the interest of the plant owner as an investor and the interests of the grid operator as the technical enabler. The financial benefit of a prosumer's PV plant depends on decreasing electrical supply from the grid, which means an increase of the electrical self-sufficiency rate. From the grid operator's perspective peak load and feed-in are the decisive parameters based on which the grid has to be designed or expanded. The aim of this paper is to give insight on the influence of varying PV generator orientation or installing an electrical storage system (ESS) on the electrical self-sufficiency rate—based on measured data.

Nomenclature

A	Albedo factor, estimated to be 0.2
C_{stor}	usable storage capacity in kWh
CF_{sim}	correction factor that scales the simulated PV powers according to the measured values
$E_{diff,g}$	diffuse irradiance perpendicular to the generator in kW/m²
$E_{diff,h}$	diffuse irradiance on the horizontal plain in kW/m²
$E_{dir,g}$	direct irradiance perpendicular to the generator in kW/m²
$E_{eff,i}$	effective fraction of the irradiance E_i in kW/m²
$E_{glob,h}$	global irradiance on the horizontal plain in kW/m²
$E_{refl,g}$	reflected irradiance perpendicular to the generator in kW/m²
P_{STC}	rated module power in kW/(1000 W/m²) at standard test conditions
W_{cons}	annual electrical consumption of the household in MWh/a
η	overall efficiency of the PV plant, including modules and inverter
γ_g	elevation of the generator in °, horizontal = 0 °
γ_s	elevation of the sun in °
θ	angle between the normal of the generator and the direction of the sun in °

2. Methodology

In November 2014 15 households were provided with smart meters that measure voltages, currents and power factors on three phases with a time resolution of 15 seconds as part of the ***Smart Grid Solar*** project. The smart meters whose data is used in this study consist of 15 units measuring load demand and 12 measuring PV generation.

In the following, the term *PV plant* will be used for a setup that is measured by *one* smart meter but can consist of various, differently oriented *generators*. The orientation of one generator is defined by its azimuth α_g and elevation γ_g. In Epplas 6 PV plants are single-oriented. The other 6 include up to 4 generators, which are not measured independently but aggregated. For that reason an algorithm was applied to identify each single-oriented generator in the mixed setups as a first step to gain a broader variation of orientations.

2.1. Splitting mixed setups

The generated solar power P_{PV} can be ascribed to three effects: direct, diffuse and reflected irradiation [1].

$$P_{PV} = P_{STC} \cdot \eta \cdot \left(E_{dir,g} + E_{diff,g} + E_{refl,g} \right) \tag{1}$$

Several models for the diffuse fraction have been described in the literature. For our approach the Klucher [2] model was chosen. There are a lot of factors, that influence the efficiency of the PV generation, for example the