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Energy autarky of households by sufficiency measures

Christian Brosig[1*a], Eberhard Waffenschmidt[a]

[a]CIRE (Cologne Institute for Renewable Energy), TH Köln, Betzdorfer Str. 2, 50679 Cologne, Germany

Abstract

A consciousness about being independent from energy suppliers is spreading due to several reasons. Many authors already analyzed PV battery systems with a focus on the grade of autarky and self-consumption. But what if someone wants to be autarkic? With what does the person have to cope with and how can it be influenced? To quantify these questions the sufficiency indicator is introduced. It describes the qualitative rate of self-sufficiency and involves personal ratings of devices. With its help the effect of the sufficiency measures “shifting” and “prioritized shutdown” on the contentment of households is quantified.

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Keywords: energy autarky; photovoltaic; off-grid; PV-battery-system; simulation; sufficiency; household.

1. Introduction

A consciousness about being independent from energy suppliers is spreading due to several reasons. Many authors already analyzed photovoltaic (PV) battery systems with a focus on the degree of self-sufficiency and self-consumption [1], [2], [3]. But some users would be willing to renounce the use of electric devices at times, when it is necessary, in order to limit the expenses for the components of the PV battery system. With what does the person have to cope with and how can it be influenced? Up to date no comparable work was found trying to quantify the personal dimensions. This work, based on the master-thesis of the same name by Christian Brosig [4], focuses on being autarkic with a PV battery system and includes measures of sufficiency. It is an approach, which overcomes the assumption, that a change of the user’s behavior is impossible and which states, that he is free to also renounce the usage of certain devices.

* Corresponding author. Tel.: +49-221-8275-4223.
E-mail address: christian.brosig@th-koeln.de

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The aim is to identify, what a user has to renounce and to find a way of measuring how happy he can be in his autarky. A new parameter is developed and introduced to quantify the user's contentment. It is complemented by a survey, to characterize the needs and priorities of specific households. Using its results, the power demand of the individual electric devices is derived from a load-profile-generator (LPG). Measures of sufficiency are identified and applied to households with a PV battery system via a simulation tool in Matlab. A typical household is analyzed and the potentials of the sufficiency measures are shown.

2. Methodology

2.1. Definition of a sufficiency indicator

The term of (self-) sufficiency is used in reference to different significations. In this paper, sufficiency refers to a personal balance of not consuming more than what is needed, but also not consuming less. It does not set the maximum as an aim, but the optimum [5]. Thus, measuring it is linked to personal needs and preferences.

In lack of existing models, a new parameter is developed and introduced: the sufficiency indicator (SI). It describes the qualitative degree of self-sufficiency, involves personal ratings of devices and is expected to express the user's contentment. On the background of sociological interrelations regarding sufficiency and a personal sense of renunciation, the assumption is proclaimed, that the device rating (D_{ra}) of a user, which is identified by a survey, includes his physical as well as psychological needs.

The SI, which is described by equation 2.1, primarily depends on the percentage of renunciation of a device (D_{re}), where 0 signifies no renunciation and 1 represents the full renunciation of the device. The individual D_{re} values are then weighted by the personal D_{ra} to build the overall sum of personally experienced renunciation. The D_{ra} rating ranges from 1 – unimportant, to 5 – very important. To be able to directly compare the SI to self-sufficiency, the sum is subtracted from full renunciation and multiplied by 100 %. Thus, an SI of 0 % means that the user has to waive everything and 100 % signifies that he can use any device without limitation.

$$SI = \left(D_{re_{full}} - \frac{\sum_{i=1}^{n_{device}} D_{re_i}(D_{ra_i})}{\sum_{i=1}^{n_{device}} D_{ra_i}} \right) \cdot 100\ \% \qquad (1)$$

First of all, different types of households are identified, based on the work of Noah Pflugrath et al. at TU Chemnitz and his load profile generator (LPG) [6]. It simulates households on a behavior-based approach, where needs of the inhabitants determine their use of devices, which leads to load profiles for every device in a household. A survey is conducted to quantify the D_{ra} concerning household devices of different people. These people are assigned to typical households on the basis of data addressing their personal situation.

2.2. Development of a simulation tool

A simple simulation tool is developed in Matlab, which is able to simulate the household as an off-grid PV-battery-system. As inputs, typical LPG profiles for every single device in a household on the one hand and two types of PV feed-in profiles on the other. One PV profile is measured with 15 minute resolution, the other one is a PV-simulation based on Sandia's PV-lib [7] and a weather-profile from the DWD, as used by Johannes Weniger 2011 [1]. The schematic of this simple model is shown in Figure 1. It is capable of scaling the installed PV-power, installed battery capacity, change the storage type from Li-Ion to Lead-acid and Redox-flow. It also connects the personal priority values as well as a limit to time-shift devices to the device-profiles. This way, it is possible to track any deviation in the balance of input and output directly to devices affected by a lack of energy.