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Innovative Reactive Energy Management for a Photovoltaic Battery System

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Abstract

This paper presents an optimizing model-based energy management system for an AC-coupled grid connected photovoltaic battery system. The energy management consists of a prediction module, an optimization module, and a reactive management module. The main focus of this article is to present an innovative reactive management that can handle forecast uncertainties. The so called "SOC-bound method" will be described in detail. Main idea is to combine the outputs of the dynamic programming algorithm with a simple rule-based strategy. Furthermore, the results of a start-time and start-/end-SOC sensitivity analysis concerning the six performance criteria self-sufficiency, self-consumption, grid relief factor, economic parameter, battery full cycles, and specific battery stress value will be discussed.

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Keywords: energy management, dynamic programming, energy storage, power flow optimization, smart home

1. Introduction

Many international studies present energy management (EM) concepts for grid connected photovoltaic (PV) battery systems in residential buildings [1 – 14]. These can be classified in rule-based and optimization-based concepts. Simple rule-based approaches [1, 2], mostly found in commercial PV battery systems, only maximize the self-consumption of solar energy (one optimization criterion) as follows: If there is more PV power available than the consumer demand and the battery is not fully charged, the energy is stored. If the consumption is higher than the

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PV power, the load is supplied by the battery. A major disadvantage is a fully charged battery before reaching the midday peak. The consequences are a high feed-in power or curtailment losses.

To overcome this problem improved rule-based concepts additionally relieves the grid by reducing the maximum feed-in power (two optimization criteria) and obtains a fully charged battery in the evening [3 – 6]. Considering further criteria such as battery lifetime, variable price and feed-in tariffs and component losses over time, optimization-based concepts are utilized. Recently, dynamic programming has been applied to solve such multi-criteria optimization problems to find an optimal power flow distribution [7 – 13]. Common implementations of an EM with dynamic programming define the optimization start-time at midnight with a start-SOC of 50 % and a prediction horizon of 24 h [7 – 9]. Furthermore, many publications assume ideal PV and load profiles and neglect the influence prediction errors [9 – 13]. One weakness of EM based on dynamic programming is that the quality of the optimization results strongly depends on the prediction accuracy of PV and load profiles. In order to overcome the mentioned prediction uncertainty problem a new “SOC-bound method” will be introduced in this article. Our previous publications [14, 15] presented a model-based EM in detail with subject to the optimization-module and the implementation of the dynamic programming algorithm in the simulation environment Matlab.

The structure of this paper is organized as follows: Section 2 describes the system configuration. Section 3 presents the optimizing model-based EM focussing on the SOC-bound method. Section 4 shows and discusses the results of two investigations. First, the influence of the optimization start-time and the start-/end-SOC will be examined. Second, the influence of the SOC-bound will be analyzed. Both investigations are assessed relating to six performance criteria. Section 5 gives a summary and a brief outlook for future research.

2. System configuration

The AC-coupled PV battery system studied in this paper is shown in Fig. 1. The main components of the system are the PV-generator, the lithium-ion battery, the inverters, the consumer load, the interface to the grid, and the EM.

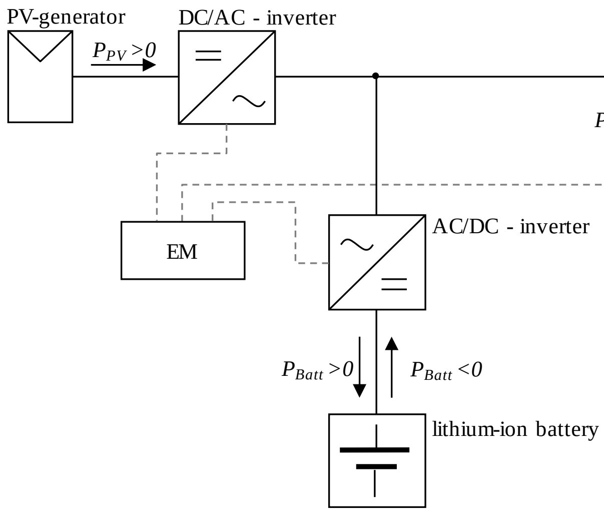

Fig. 1. Configuration of the AC-coupled PV battery system including the powerflow direction and sign convention.

The PV power P_{PV} is expected to be always positive. The battery power P_{Batt} is assumed to be negative during discharging and positive during charging. The load power P_{Load} is always positive. The grid power P_{Grid} is negative, if the grid supplies the loads, and positve if power is fed into the grid. The power balance criteria in the AC-coupled system must be valid every time.

$$P_{PV} - P_{Load} - P_{Batt} - P_{Grid} = 0 \tag{1}$$