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Employing Battery Storage to Increase Photovoltaic Self-sufficiency in a Residential Building of Sweden

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Abstract

Photovoltaic (PV) or hybrid PV-battery systems are promising to supply power for residential buildings. In this study, the load profile of a multi apartment building in Gothenburg and the PV production profile under local weather conditions are compared and analyzed. Three different types of batteries, including lead acid, NaNiCl (Sodium-Nickel-Chloride) and Lithium ion, are studied in combination with the PV systems. It is found that Lithium ion battery system is superior in achieving higher Self-Sufficiency Ratio (SSR) with the same Life Cycle Cost (LCC). Achieving high SSR with the hybrid PV-battery system is unrealistic because of the seasonal mismatch between the load and electricity production profile. The capacity match between the PV and battery to maximize SSR was investigated, showing different trends under system LCC range of 0.1-40 Million SEK (1SEK≈0.12USD). The system LCC should be lower than 10.6 Million SEK (at the SSR of 36%) in order to keep the payback time positive.

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Keywords: photovoltaic; battery; storage; self-sufficiency; building

1. Introduction

The PV produced electricity in Sweden only accounts for 0.06% of the total electricity consumption [1]. The widely employed method to improve the PV performance is to incorporate batteries (mostly lead acid), because they can help to mitigate the intermittence and to increase the SSR (Self-Sufficiency Ratio) of PV. Recent price drop [2] (ca. 14% annually from 2007 to 2014) of more advanced batteries has made

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them viable in PV systems. It is of importance to compare costs and performance of different batteries with careful consideration of the users' load profile.

In this study, we firstly analyzed the load profile of a residential building in Gothenburg and power production profile of 1 kW_p PV under local weather condition. Three typical batteries were then compared. We also analyzed the matches between the PV and battery and studied the maximal achieved SSR when guaranteeing the balanced LCC.

2. Methodology

2.1. Load and weather profile

The 2014 yearly load profile of a residential building (Gothenburg; N 57.70°, W 11.98°) that comprises of 140 apartments is recorded from Wallenstam AB. The weather data in Gothenburg including the global horizontal radiation (W/m2), the diffuse horizontal radiation (W/m2), wind speed (m/s) and ambient temperature (°C) is taken from a global climatic database, Meteonorm [3].

2.2. Photovoltaic panels

The hourly output of PV is given by:

$$P_{PV} = \eta_{PV} A_{PV} G_{g,t} \tag{1}$$

Where, $G_{g,t}$ is the total solar radiation; A_{PV} is the installed PV area; η_{PV} is the PV module efficiency [4]. The studied PV module is SUNTECH STP255-20/Wem. The PV panels are installed facing south, and the tilted angles are set to change four times a year (Change to 57.7°, 34.3°, 57.5° and 81.2° on the 5th of February, May, October and November, respectively) according to the altitude angle of the sun.

2.3. System configuration and simulation

A schematic diagram of the studied system is shown in Fig. 1. For system configurations without the battery, surplus electricity from the PV is dumped and insufficient electricity is supplied by the grid. For configurations with battery, surplus electricity from the PV after meeting the load is used to charge the battery. When the battery is fully charged, the extra electricity is dumped. When the PV electricity is not sufficient to meet the load, the battery is discharged.

Batteries are all set to strictly operate above the minimal SOC (State Of Charge). To maintain the minimal SOC, grid power is used when the PV power is not enough.

The Self-Sufficiency Ratio (SSR) and Self-Consumption Ratio (SCR) are defined as:

$$SSR = \left(1 - \frac{\int_{t_1}^{t_2} G(t)}{\int_{t_1}^{t_2} L(t)} \right) \times 100\% \tag{2}$$

$$SCR = \left(1 - \frac{\int_{t_1}^{t_2} D(t)}{\int_{t_1}^{t_2} P(t)} \right) \times 100\% \tag{3}$$