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Comparative Study of Battery Storage and Hydrogen Storage to Increase Photovoltaic Self-sufficiency in a Residential Building of Sweden

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Abstract

Photovoltaic (PV) is promising to supply power for residential buildings. Battery is the most widely employed storage method to mitigate the intermittence of PV and to overcome the mismatch between production and load. Hydrogen storage is another promising method that it is suitable for long-term storage. This study focuses on the comparison of self-sufficiency ratio and cost performance between battery storage and hydrogen storage for a residential building in Sweden. The results show that battery storage is superior to the hydrogen storage in the studied case. Sensitivity study of the component cost within the hydrogen storage system is also carried out. Electrolyzer cost is the most sensitive factor for improving system performance. A hybrid battery and hydrogen storage system, which can harness the advantages of both battery and hydrogen storages, is proposed in the last place.

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Keywords: photovoltaic; battery storage; hydrogen storage; genetic algorithm

1. Introduction

The Photovoltaic (PV) electricity accounts only for 0.06% of total electricity consumption in Sweden [1]. Some important reasons attribute to the local weather condition, low incentive, intermittence and the seasonal mismatch of PV production. The intermittence of PV generation is usually mitigated by energy

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storages, which in most cases are batteries. However, battery storage contributes little to the seasonal mismatch because of high expense and inability for long-term storage [2]. Hydrogen storage system comprises of electrolyzer, hydrogen tank and fuel cell. It has lower round-trip efficiency. However, it is suitable for addressing the seasonal mismatch problem, because it is capable of storing the excess electricity in the form of hydrogen for long period.

In this study, the comparisons between battery storage and hydrogen storage under different PV capacities are carried out. Genetic Algorithm is employed to solve the multi-objective problem concerning achieving high Self Sufficiency Ratio (SSR) and high Net Present Value (NPV). A sensitive study is also conducted to investigate the influence of component costs on the system SSR-NPV relationship. A hybrid battery and hydrogen system is also proposed.

2. Methodology

2.1. System configuration and simulation

Schematic diagram of the studied system is shown in Fig. 1. Either battery storage or hydrogen storage will be employed. NPV and SSR are calculated by equations 1 and 2, respectively.

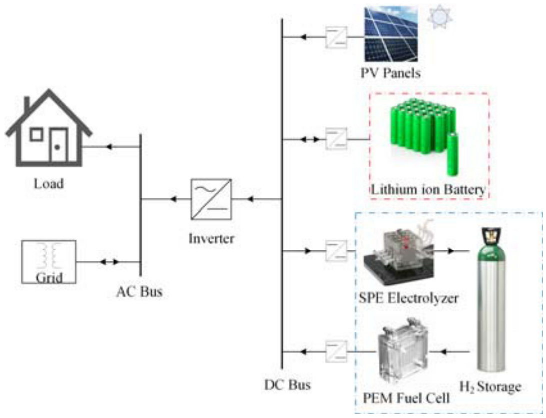

Fig. 1. Schematic diagram of PV-battery and PV-hydrogen System

$$NPV = \sum_{y=1}^{25} \frac{(R_y - C_{OM,y} - C_{R,y})}{(1+d_r)^{y-1}} - Inv \tag{1}$$

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

R_y, $C_{om,y}$, $C_{R,y}$ are revenue, O&M cost, replacement cost at year *y,* respectively. *Inv* is the investment cost. d_r is the discount rate (2%) [3]. The revenue is the sum of deferred retail purchases (Price: Elspot price plus 0.84 SEK/kWh [4]) from the grid and wholesale electricity (Price: Elspot price [1]) sold to the grid. Information related to the cost of different components can be found in Table 1.

The simulation of the system is carried out in Matlab R2015a environment.

2.2. Load and weather profile

The hourly load profile in 2014 (644 MWh) of a residential building (Gothenburg; N57.70°, W11.98°) is used as study case (data from Wallenstam AB). The weather data is taken from Meteonorm [5].