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Evaluating the need for energy storage to enhance autonomy of neighborhoods

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Abstract

Energy storage is generally considered as a means to bridge a period between when/where energy is available and when/where it is in demand. Storage plays an important role by providing flexibility to energy systems, increasing the potential to accommodate variable renewables generation and improving management of electricity networks. However, currently it remains unclear when and under which conditions energy storage can be profitably operated at a district level. The present study aims to quantify the level of integration of solar energy and storage in the Junction district of Geneva. A simulation tool is developed to investigate the techno-economical and environmental assessment under different scenarios. For a given investment over 20 years, the model calculates the levelized cost of electricity (LCOE), the autonomy level as well as the CO2 emissions. Given the assumptions of the model, four scenarios are analysed based on the combination of solar PV, storage, solar thermal and heat pump to find out an economically optimal configuration in terms of system size. A comparison with the Homer software is performed to test the robustness of the solar PV and battery model. The economic profitability of solar PV and battery system is in very good agreement with Homer and the autonomy level is validated by using a simulation tool created by SI-REN (Services Industriels des Energies Renouvelables de Lausanne). However, combining solar PV with battery system doesn't bring additional autonomy to the model for Geneva study case. Under the assumptions of the model, to foster investments in solar PV and battery installations, falling investments costs seem necessary for the future. A reduction gap between buying and selling price in grid for solar panel is recommended to increase solar installations. A validated simulation tool has been developed in this work and provide a reliable based that will be extended in the future to include the thermal demand and production. The availability of thermal storage at a large scale as well as the production over a district should further increase the autonomy of the district.

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Keywords: Battery Storage, Electricity Price, Solar Energy, Solar Photovoltaic Power, Techno-Economic Model, Thermal energy storage

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1. Introduction

Renewable energy technologies are expected to play a major role in societal challenges (such as climate change, resource depletion and abandon of nuclear energy by 2050) in Switzerland [1] and with the development of decentralized energy systems [2]. Among the many options available, solar photovoltaic (PV) power has been found to have a particularly large physical potential for electricity generation [3]. PV systems are attractive because of the simplicity of the installations and the fact that PV systems are scalable and can be integrated directly into the unit [4].

While solar energy system captures sunlight, and turns it into power for use during sunlight hours; it is unable to provide power without direct and constant sunlight [5]. Consequently, there are often gaps between consumption and the supply of the plants. An effective means for reducing the mismatches between demand and supply as well as heating demand and supply by energy sources are storage technologies [5]. Energy storage have different aims as bridging seasonal differences and imbalances, levelling daily load cycle, peak shaving and improving grid stability, power quality and reliability of supply [6]. Unfortunately, adding storage technologies to solar PV increase the overall investment cost. It also currently remains unclear when PV and storage investments will become economically interesting in a large-scale application as studies focused mostly at individual building scale. It is however necessary to analyse the economic and ecological assessment of the combination of different energy storage strategies at large scale.

A simulation tool is thus developed and validated with several input parameters to analyse the economic and environmental aspect of the integration of several energy conversion units. The objective of this work is to furthermore to evaluate the integration of solar energy and storage on a specific cluster of buildings in the Junction district of Geneva with the aim of finding an optimal configuration in terms of system size. We will give an overview of the techno-economical model implemented and then devise multiple scenarios that will be studied with a combination of different SPV integration and energy storage size. Finally we describe the validation and the results obtained and discuss the future extension of the model to include the thermal demand and production.

2. Models

The approach chosen for the current study aims to consider the energy and cash flows for 8760 time steps in one year and over 20 years. In the next subsections, the mathematical models and the inputs required for the model (energy demand, CO_2 emissions, cost for each technology) will be explained.

2.1. Techno-economical models

Three criterions are used to evaluate the energy systems. The **Autonomy level** is defined as the share of electricity generated by the PV system that is directly consumed by the consumers. It is assumed that whenever electricity demand during the day met the electricity generation of the PV system, the consumers consumes its own electricity [5]. The ratio between electricity that is directly self-consumed and the total electricity demand defines the autonomy level (self-consumption ratio). In the model, self-consumption is calculated for each time step (hourly here) over one year. The autonomy level is calculated using:

$$Autonomy\ Level = \frac{Self\ Consumption}{\sum_{Total\ Demand}} \tag{1}$$

The **Levelized Cost of Electricity** (LCOE) is the net present value of the unit cost of electricity of the lifetime of a generating asset. It is a first order economic assessment of the cost competitiveness of an electricity generating system that incorporates all costs over its lifetime [7]. The LCOE concept determines the total costs that occur during the lifetime of a technology divided by the total energy demand and accounts for the differences in lifetimes across technologies [8]. LCOE may vary strongly from one technology to another depending on the application. With Eq. 2, an application with very high energy demand is likely to have a lower LCOE than an application with a little energy demand. LCOE will provide us with a useful metric to compare different costs of various technologies over the years.

$$LCOE = \frac{-NPV}{20 \times \sum_{Total\ Demand}} \tag{2}$$