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Extending building integrated photovoltaics (BiPV) using distributed energy hubs. A case study in Cartigny, Switzerland

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Abstract

The integration of renewable energy technologies in the existing energy infrastructure plays a key role in improving the sustainability of cities. Due to the stochastic nature of some renewable energy sources, primarily wind and solar energy, direct integration into the grid is challenging. One solution is to use distributed multi-energy hubs which make it possible to intelligently integrate renewable energy sources into the grid and optimize resources. This paper presents an energy hub development and its integration in the Swiss village of Cartigny. Energy demand of buildings is estimated with CitySim Pro, hourly results are then exported to the microgrid simulation tool HOMER Pro to perform optimization, and system performance and lifecycle cost are evaluated under different BiPV capacities. The results for Cartigny show that relying entirely on renewable energies is not yet realistic due to their stochastic nature. They also show the importance of integrating daily and seasonal storage systems.

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Keywords: Energy Hub, Urban energy modelling, Building integrated photovoltaics

1. Introduction

Swiss energy strategy 2050 strictly emphasizes the importance of integrating renewable energy technologies in the existing energy infrastructure. Due to the increased share of decentralized renewable energy sources, as well as their stochastic nature, it is essential to promote multi-energy hubs. Multi-energy hubs help to match the local production with the consumption by integrating generation, conversion and storage technologies [1]. However, the role of an

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energy hub and its various configurations, designed in order to integrate solar BiPV (in multiple steps), has not been studied much, especially considering the Swiss context. Energy hub is a conceptual model which represents the interactions between the energy conversion systems and the storage technologies [2]. The first conceptualization of the energy hub was proposed by Geidl [3], defined as a mixed energy carrier power system, able to provide input/ output, conversion and storage of different energy carriers. The energy hub concept was later modified, by including the modelling and optimization of the energy systems, already at the concept stage [4][5]. Several case studies were already performed at the urban scale, showing the nice potential of integrating multi- energy hubs in existing villages, as an example the village of Zernez [6] [7]. The aim of this study is to present a comprehensive techno-economic analysis for a distributed energy hub which can be implemented in Cartigny, a small village in the Canton of Geneva in Switzerland. To achieve the above aim the present study focuses on the following steps: (i) modelling energy demand (thermal and electrical) of the village on an hourly basis using the urban energy modelling tool CitySim Pro [8], (ii) coupling the building simulation model with the energy hub model using Homer [9], a microgrid simulation tool. The proposed model, a multi-energy hub, will be directly interacting with the main grid and consists of BiPV panels, wind turbines, a bio-gas generator, and H2 fuel-cells. Finally, (iii) the system configuration of the energy hub is optimized while maintaining BiPV capacity as a constraint. System performance and its lifecycle cost are then evaluated under different BiPV capacities. In addition, (iv) different scenarios for the energy consumption are also considered in the modelling, that is, through (a) occupancy profiles (including electric lighting and appliances, as required by the Swiss normative), and (b) proposing the refurbishment of the village according to Minergie-ECO standards [10].

2. Case study and methodology

2.1. The village of Cartigny

Cartigny (46.18 North, 6.01 East, 430 m a.s.l.) is located in the canton of Geneva in Switzerland (Fig.1). The village, with a population of 865 inhabitants, is situated on the left bank of the Rhone River. The village is characterized, according to the Koeppen climatic classification [11], by a Cfb climate (C: warm temperate; f: fully humid; b: warm summer). Based on the data retrieved from Swisstopo, the village is composed of 370 buildings, most of which are residential houses. Cartigny acts strongly towards sustainability and it has obtained the energy label "Cité de l'énergie" in 2007 and 2010. The central wood-fired heating system provides the heat energy for 95% of the buildings; on the rooftop of the building, BiPV are installed, producing 19,300 kWh per year. The central wood-fired heating system produces 6 million of kWh hot water, at 75°C, which is sent by the central heating system to the buildings and, after the use, back at 63°C [12]. The solar potential of the site is huge. However, due to the rural and historical value of the village, it is classified, by the Geneva Canton, as "Zone 4B Protected", to preserve the esthetic value of the site. Due to this regulation, installation of PV on the buildings is a challenge, and their unobtrusive integration in the built stock is essential.

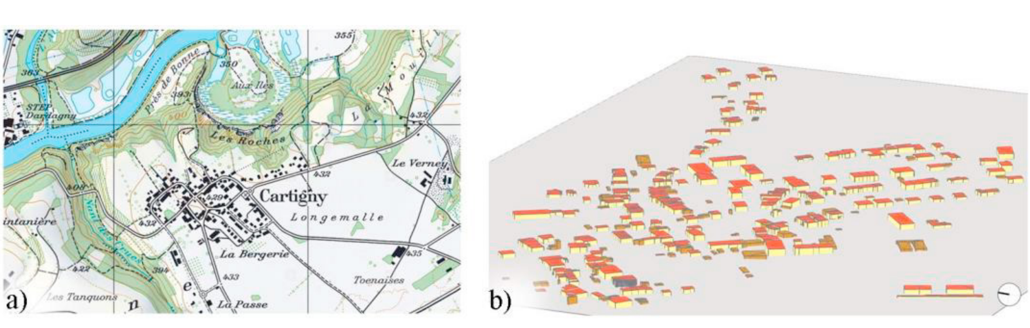

Fig. 1. (a) 2D Map of the village of Cartigny, Source: Swisstopo (b) 3D view of the site, Source: CitySim Pro

Three main energy sources are available on the site: solar irradiance, wind speed and biomass. The global horizontal solar irradiance corresponds to 1,248 kWh·m^{-2} [13] and the average wind speed is between 5 ms^{-1} to 6 ms^{-1} [14]. The