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Locating Multi Energy Systems for A Neighborhood In Geneva Using K-Means Clustering

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Abstract

To determine the optimum location for non dispatchable renewable energy systems, this study comes up with an integrated tool to place energy systems considering distributed energy demand and renewable energy potential.
The Citysim urban energy planning software is used to compute the hourly heating demand of 371 buildings in Jonction, a neighborhood in Geneva. Hourly solar irradiation on the roof tops of each building is computed using the Citysim model. The electricity demand profile for each building is generated using the hourly profile for Geneva using the databases of Swissgrid and Swiss building database. Subsequently, k-means algorithm is used to cluster the buildings based on spatial distribution. An energy economic model is used to evaluate the losses in the thermal and electrical distribution networks and initial investment. Sensitivity of cluster size is evaluated using the energy economic model to obtain an optimum number of clusters and the locations for the energy systems.

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Keywords: distributed energy systems; energy-economic analysis; K-means clustering; thermal networks; urban energy systems

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1. Introduction

Integrating renewable energy technologies into energy infrastructure is important to face the global challenges due to climate change, depletion of fossil fuel resources etc. Distributed energy systems such as hybrid energy systems, energy hubs, multi-vector energy systems etc. can play an important role in this context [1]. These systems can support integration of more non dispatchable renewable energy technologies such as Solar PV (SPV) and wind energy, which are challenging to integrate directly to the main grid beyond a certain limit. However, designing such distributed energy systems is a challenging task due to the fluctuation in demand and non-dispatchable energy sources. A number of recent studies have focused on this aspect [2]–[5]. When moving into urban scale, it is required to consider more than one distributed energy system. One of the main challenges in this context is locating these energy systems. Hourly time series of the demand for multi energy services and losses in the distribution networks among others should be carefully considered in this context. Several recent studies have focused on this topic from the perspective of combined energy system optimization [6], [7].

This study focuses on applying clustering algorithms to locate distributed energy systems in Jonction, a neighbourhood in Geneva. This provides a detailed case study combining the building simulation model Citysim, an energy flow model developed in Matlab and data gathered from Swissgrid and SITG. Results obtained from the case study are subsequently discussed in detail. The research paper is organized as follows; Section 2 of the paper presents a concise overview about the demand model used, cost model developed and the energy flow model used for the study. Section 3 presents the clustering algorithm developed for this study. Finally, Section 4 presents the results obtained using the clustering algorithm.

2. Computational model

The computational model developed in this study combines the demand for heating, electricity and solar energy potential for each building that are obtained using different sources with the clustering algorithm. A concise overview of the demand, cash and energy flow models used in this context are given in this section.

2.1. Computational model for heating and electricity demand

The energy demand for electricity and heating and the solar PV production of each building in the Jonction neighbourhood are presented in this section. The coordinates of each building are gathered through the ArcGIS software using the map of Jonction obtained from the SITG web database (Fig. 1). Then the software computes the corners of each building and creates a centre for each one. This data is exported to a spreadsheet. In this case, each building is linked to a BuildingID number, which corresponds in total to 836 buildings. The hourly electricity demand has been modelled using different sources. First, the annual consumption data for each building has been obtained from SITG. Each data is linked to an EGID number which corresponds to a building number. Since we are interested in the hourly consumption over the whole year, we need to downscale each building's annual consumption to an 8760-hour time series. We use aggregated hourly profiles for each Swiss canton provided by Swissgrid [9] (Fig. 2).