Building Integrated Photovoltaic (PV) Systems – Energy production modelling in urban environment

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Nature du financement demandé : Stage de M2
Montant de la demande de financement : 3600 euros (6 mois)

Summary :

The purpose of the Master thesis relies on impacts of massive integration of photovoltaic (PV) panels and PV power plants within urban environment. The first objective of the proposed study is to investigate the contribution of PV systems and their layout (facades and roofs) on the local urban warming. The effects of radiative coatings to enhance cooling of PVs and as consequence the PV power generation management will be also investigated. This work will be based on CFD simulations, energy balance of PV panels and data processing such as deep learning, neural networks.

Context and objectives

The purpose of the Master Thesis relies on the solar potential and the estimation of energy generation from building integrated photovoltaic (BIPV) systems and the mutual solar interactions among buildings that face complex urban phenomena in the built environment. The existing energy generation models usually consider the buildings in isolation and take into consideration the close built environment as masks.

However, several specific physical phenomena occur in urban areas. Some are due to natural weather conditions, such as the days/seasons cycle (time variability of the solar resource) or the cloud movement (intermittency of the solar radiation). Others are due to the built environment, such as the spatial heterogeneity due to the surrounding buildings, the interbuilding reflections or the wind channeling effect due to the narrow space between buildings in urban areas.

Considering an integrated methodology taking into consideration urban multi-physics (including solar radiation and airflow modeling) and multi-scales (evaluation of the spatial heterogeneity) features appears then as a crucial issue for the evaluation of the solar energy potential of buildings and urban surfaces (roofs, facades and ground).

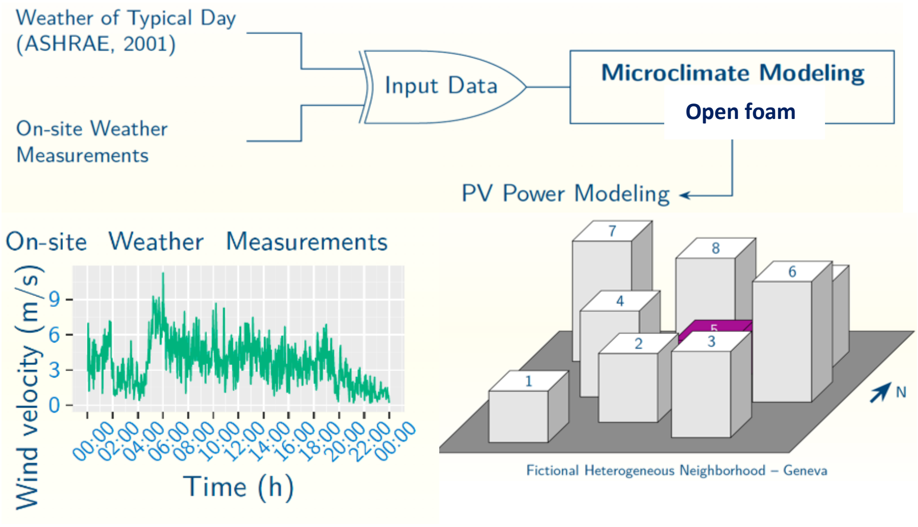

Figure 1 : Integrated methodology

Using the methodology presented in Figure 1, the work will focus firstly on wind behavior in proximity to the buildings' facades and BIPV panels. In particular, parts of convective / radiative fluxes will be assessed according to material properties (thermal, radiative, roughness) of the walls and typology of districts and urban canyons (high/medium/low-rise). Those aspects coupled with weather data climate (database and/or on-site weather measurements) will be taken as boundary conditions to test the PV power generation model and construct energy management rules.

The main tools that will be used are OPEN FOAM for urban microclimate simulation and Matlab for the PV power generation model. A coupled airflow model and radiative model able to account for the solar inter-building reflections will be considered for this purpose. The case studies will be based on fictional districts and on database of cities located, according to The Koppen Climate Classification at Marine West Coast Climate (Lyon) and Continental Subarctic Climate (Trondheim). This climate differentiation will allow to test the model at different latitudes characterized by peculiar solar geometry, sun path and seasonal conditions.

A secondary objective of this Master Thesis will be around the estimation of the PV power generation and its management under different climate and through different timescales. This consists in the elaboration of weather data forecasting to predict PV power generation in short (1-72 hours), mid (50 years) and long (100 years) term under climate change scenarios. The weather data projections could be generated, for example, through the tool Climate Change World Weather File Generator for World-Wide Weather Data (CCWorldWeatherGen).

Govehovitch, B., Thebault, M., Bouty, K., Giroux-Julien, S., Peyrol, É., Guillot, V., ... & Desthieux, G. Numerical Validation of the Radiative Model for the Solar Cadaster Developed for Greater Geneva. *Applied Sciences*, *11*(17), 8086, 2021. DOI : 10.3390/app11178086