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LES analysis over the edge of a building roof-top for wind turbine placement

Farshad Rezaei[1], Mojtaba Kheiri[2], Marius Paraschivoiu[3]
[1,2,3] Department of Mechanical, Industrial, and Aerospace Engineering, Concordia University, Montreal, Quebec, Canada
[1]farshad.rezaei@concordia.ca
[2]mojtaba.kheiri@concordia.ca
[3]marius.paraschivoiu@concordia.ca

ABSTRACT

The integration of renewable energy generators in urban areas is beneficial for sustainable development, with wind energy playing a key role in this transition. To maximize wind energy potential in cities, a comprehensive analysis of wind flow around and over buildings is essential. Recent studies have shown that placing Vertical Axis Wind Turbines (VAWTs) on roof-tops can significantly enhance their power generation performance by leveraging the building-induced flow acceleration. However, optimizing turbine placement requires a detailed understanding of the aerodynamic effects caused by building geometry and wind conditions.

The interaction between the incoming wind and the building shape, including the angle of incidence, roof shape, and building height, has a profound impact on flow patterns, velocity distribution, and turbulence characteristics. These parameters determine the optimal placement of turbines to achieve maximum efficiency. While previous studies have investigated wind flow over buildings, only a limited number have employed high-fidelity Large Eddy Simulation (LES) to precisely analyze turbulence characteristics and identify optimal turbine placement. This research uniquely integrates LES modeling with different types of atmospheric boundary layers to provide a more accurate assessment of high-energy zones on roof-tops, offering insights that are often overlooked in conventional Reynolds-Averaged Navier-Stokes (RANS)-based studies. LES known for its high accuracy in capturing flow dynamics, is employed in this study using the Star CCM+ computational fluid dynamics (CFD) toolbox to simulate airflow over a roof-top.

This study examines how flow velocity magnitude and turbulence intensity vary across different roof-top locations. Results indicate that velocity decreases near some corners of the roof but increases smoothly at short distances away from them, while turbulence characteristics exhibit significant variation. Furthermore, the analysis highlights how the heights above the roof affect kinetic energy availability, emphasizing the importance of selecting appropriate turbine installation heights.

By systematically analyzing these flow characteristics, this research identifies optimal roof-top locations for VAWT placement, considering key parameters such as building orientation, roof geometry, and incoming wind velocity atmospheric boundary layer profiles. The results from this study contribute to the efficient deployment of urban wind energy systems, enhancing renewable energy integration in high-density environments.