Large Eddy Simulation of HAWT and VAWT performances in the vicinity of a building

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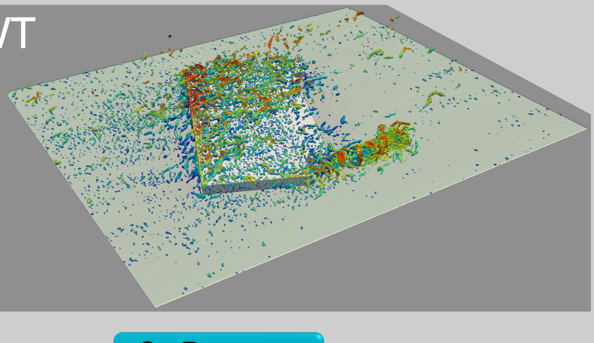


1- Context

The current energetic and environmental challenges induce a significant growth of the use of renewable energies. Wind energy production is undergoing intense research and development work. Progress in the development of wind energy in urban areas [1] has led to competition between Vertical Axis Wind Turbines (VAWTs) and Horizontal Axis Wind Turbines (HAWTs).

Problematics

The wind flow in urban environment has an unpredictable behaviour [2]:

- complex turbulent phenomena at the bottom of the boundary layer
- constantly changing wind direction

Which turbine (VAWT vs HAWT) performs best in this context?

→ **high fidelity numerical simulation** to better understand how wind turbines work in complex environments.

Objectives

Comparison of the aerodynamic performance of a VAWT and a HAWT located close to a full-scale low-rise industrial building, for various wind directions

2- Methodology & Setup

Numerical model

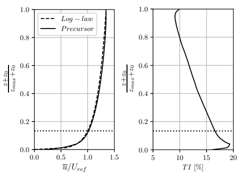
Wall Modeled Large Eddy Simulations (WMLES) YALES2 [3,4]

- **Low Mach number N-S equations solver**
- **4th order** central finite volume method, **4th order** time integration
- Turbulence model: **σ-model** [5]

Turbulent inflow generation

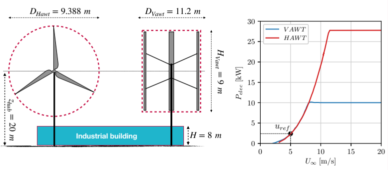
Channel flow Precursor Database Method [6,7]

- $u(z) = \frac{u_\tau}{\kappa}\log\left(\frac{z+z_0}{z_0}\right)$
- $u_{hub} = 5\ m/s\ ;\ \kappa = 0.37$
- $z_{hub} = 20\ m\ ;\ z_0 = 0.06\ m$
- TI [%] ~ 15 - 20



Wind Turbine

- HAWT : NREL5MW scaled; $\lambda_{opt} = \omega\, r/u_{ref} = 7.55$
- VAWT : 3-bladed H-rotor; generic NACA ($c = 0.45m$) $\lambda_{opt} = 3.65$
- **ALM** : 32 points per blade; $\epsilon/\Delta x = 2$

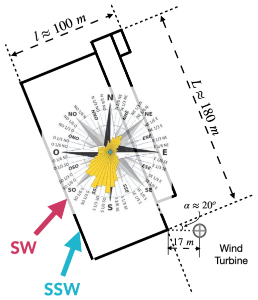


- Design criteria : $(P_{elec})_{HAWT} = (P_{elec})_{VAWT}$ for $u_\infty = u_{ref}$

Building & simulation cases

- Low-rise building (H = 8 m)
- Typical industrial area (TI ~ 17 %)
- Wind rose obtained from IRM meteorological model ALADIN [8]
- Two relevant wind directions: SW and SSW

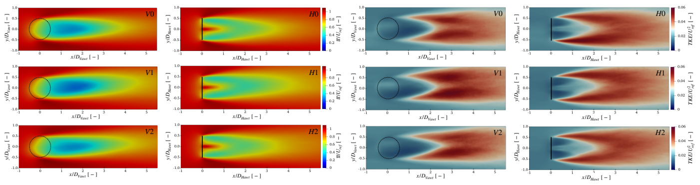
Cases (color)	Wind Turbine	Building	Wind direction	Incident angle [°]
V0 (-----)	VAWT	No	-	-
V1 (-----)		Yes	SW	45
V2 (-----)		Yes	SSW	67.5
H1 (—)	HAWT	No	-	-
H1 (—)		Yes	SW	45
H2 (—)		Yes	SSW	67.5



3- Results

Flow topology

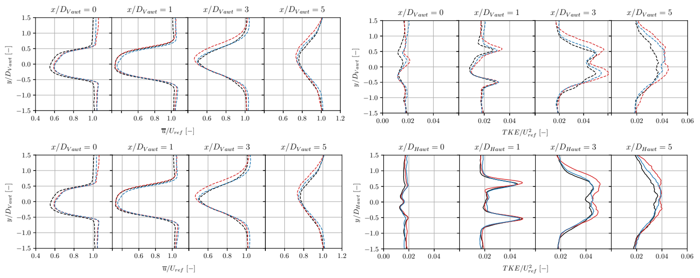
- Vertical slices colored by time-averaged streamwise velocity and TKE
- Slight flow deviation in SW and SSW cases (greater in SW cases)



Flow statistics

Time-averaged streamwise velocity and Turbulent Kinetic Energy (TKE)

- Horizontal profiles ($z = 20m$) at several downstream locations of the rotor
- Local overspeed up to $x/D = 3$ (~4% for SW and ~2.4% for SSW cases): low-rise building
- Higher TKE Levels for SW and SSW cases
- In the near wake $TKE_{Vawt} \leq TKE_{Hawt}$



Power and Thrust

	V0	H0	V1	H1	V2	H2
C_P	0.4	0.42	0.42	0.46	0.42	0.45
C_T	0.72	0.71	0.75	0.75	0.75	0.74

- Higher production for HAWT overall.
- C_P ($V1$ and $V2$) = C_P (H0)
- Higher production for SW and SSW cases **→ positive effect of the building**

4- Conclusion & Perspectives

Methodology :

- WMLES to access aerodynamic performances
- Modelling the flow in a realistic way
- Highlight the effect of the building

The building locally disturbs the flow. It induces overspeed, which improves the power production of the wind turbines, but also leads to high turbulence levels, so the blades are subjected to more loads. HAWTs however have better performances

Perspectives :
→ Investigates of other wind directions
→ Influences of the upstream buildings
→ Noise pollution and fatigue effects

5-References & Acknowledgements

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This study has received funding from the POPE research project Pôle Mecatech, infrastructure funded by the Walloon Region under the grant agreement No.7961. This research benefited from computational resources were made available on the Tier-1 supercomputer of the Fédération Wallonie-Bruxelles, infrastructure funded by the Walloon Region under the grant agreement No.1117545. Computational resources were also provided by the Consortium des Equipements de Calcul Intensif, funded by the Fonds de la Recherche Scientifique de Belgique under Grant No.2.5020.11 and by the Walloon Region.

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