NUMERICAL EVALUATION OF AERODYNAMIC PERFORMANCES OF VERTICAL-AXIS WIND TURBINE ROTOR WITH FLOW CONCENTRATOR

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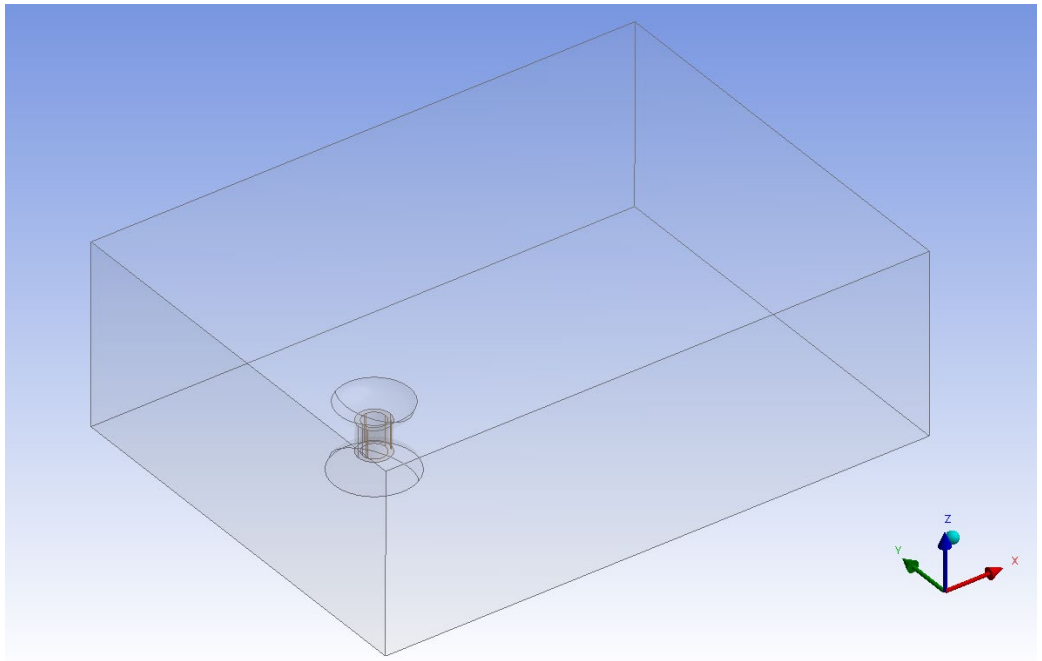
Introduction

- Finality of fossil fuels → renewable energy sources
- Wind energy → small-scale vertical-axis wind turbines (VAWTs)
- Advantages: low production and maintenance costs, omnidirectional operability in "dirty", slower winds and decreased noise
- Disadvantage: lower efficiency
- Can be improved by additional elements
- Here, flow concentrator comprises 2 half-ellipsoids
- Flow is complex: unsteady, spatial, viscous (turbulent)

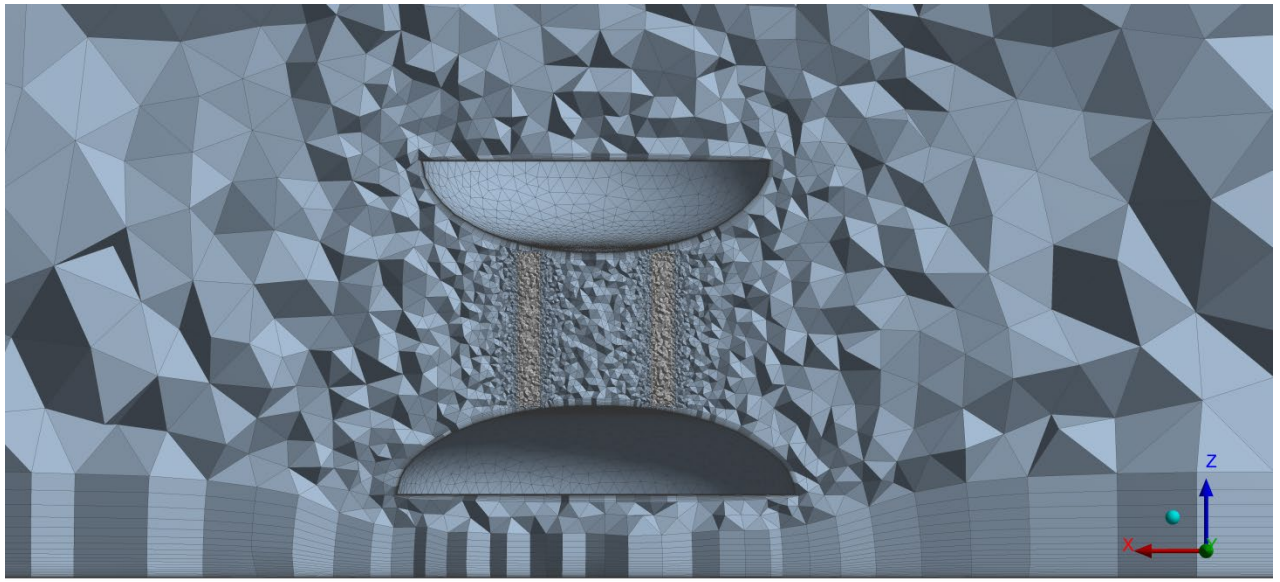
Geometric model

- Aerodynamic performances estimated in ANSYS Fluent
- VAWT's characteristics: R = 0.75 m, L = 1.5 m, N_b = 3, c = 0.10 m, σ = 0.2, airfoil NACA 0018
- Flow concentrator:
  a_1 = 1.92 m, b_1 = 1.00 m,
  a_2 = 2.20 m, b_2 = 0.97 m
- Velocity profile:
  $V(h) = V_o(h/h_o)^{\alpha}$



Computational grid

- Hybrid unstructured meshes containing approx. 3-3.2 million cells
- Surface sizing along the interface boundary
- Edge sizing along the blades
- Boundary layer around the blades: 25 layers, $y^+ < 5$
- Relaxed boundary layers around flow concentrator and ground



Zonal and boundary conditions

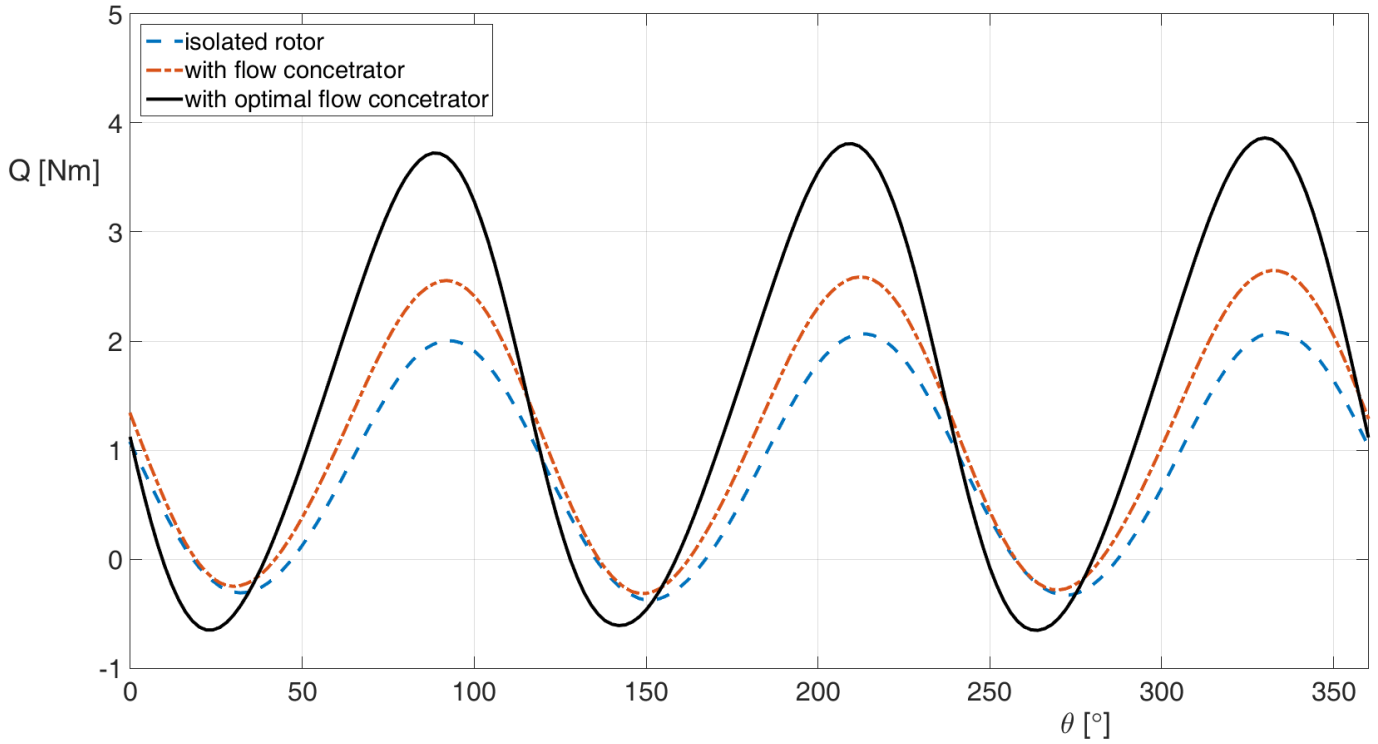
- Flow is modeled as unsteady, incompressible and viscous (turbulent)
- Velocity inlet
- Pressure outlet
- Blades as no-slip rotational walls
- Concentrator walls and ground as no-slip and stationary
- Inner zone rotates with angular velocity Ω

Numerical set-up and schemes

- Unsteady Reynolds-averaged Navier-Stokes equations are closed by a two-equation k-ω SST turbulence model
- Pressure-based solver
- SIMPLEC pressure-velocity coupling scheme
- Spatial derivatives by 2nd order schemes
- Temporal discretization is 1st order
- Time step ~ 2° angular increment
- Simulations performed until reaching quasi-convergence

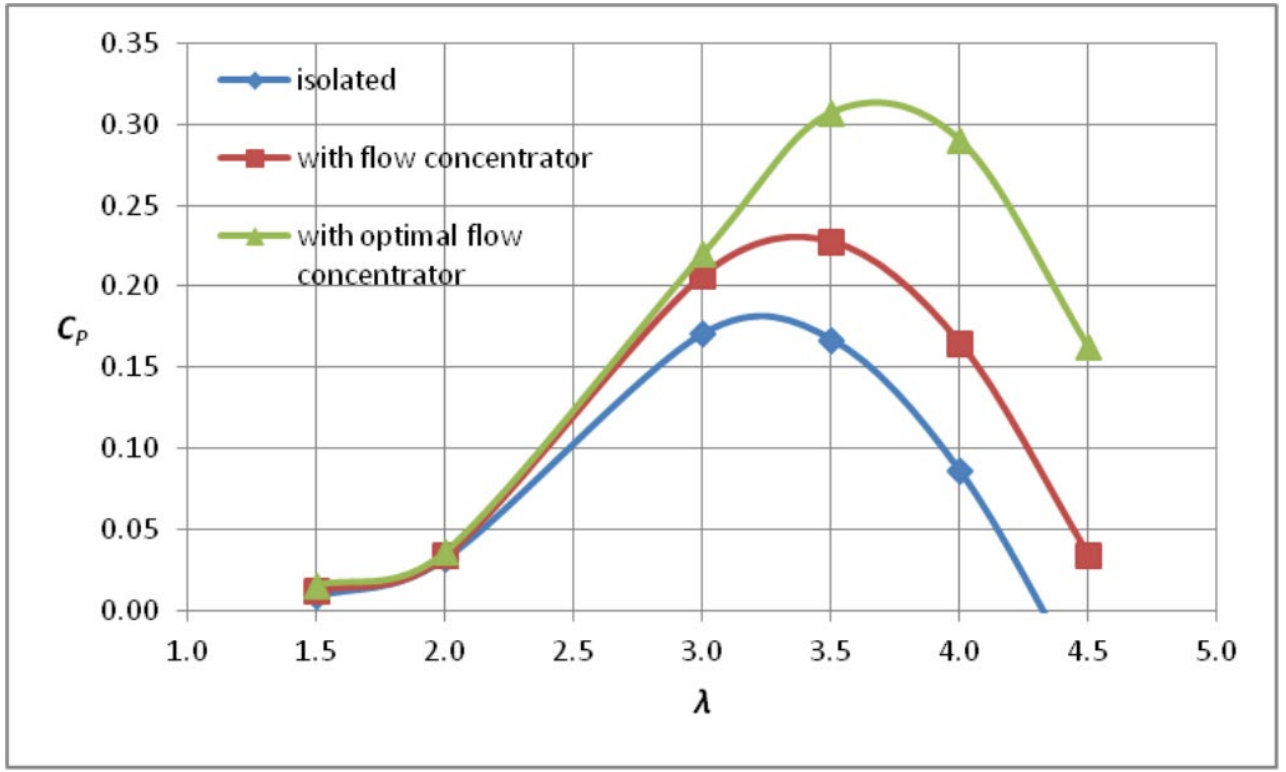
Quantitative analysis

- Mean values from instantaneous during a single rotation



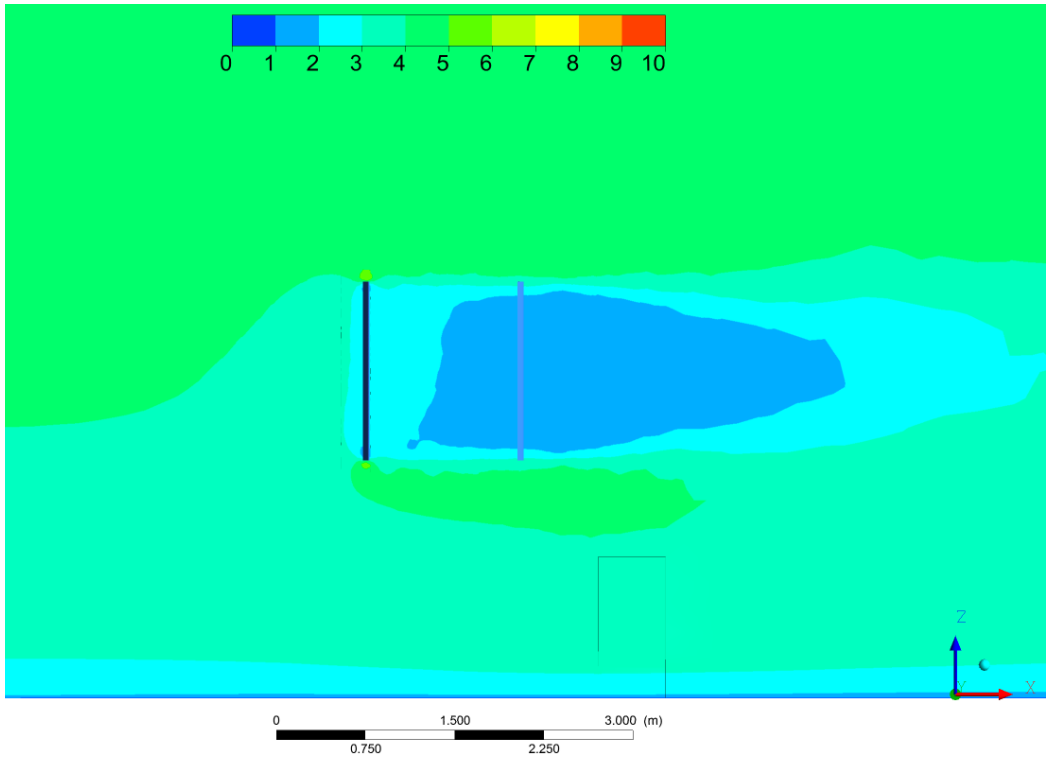
Quantitative analysis

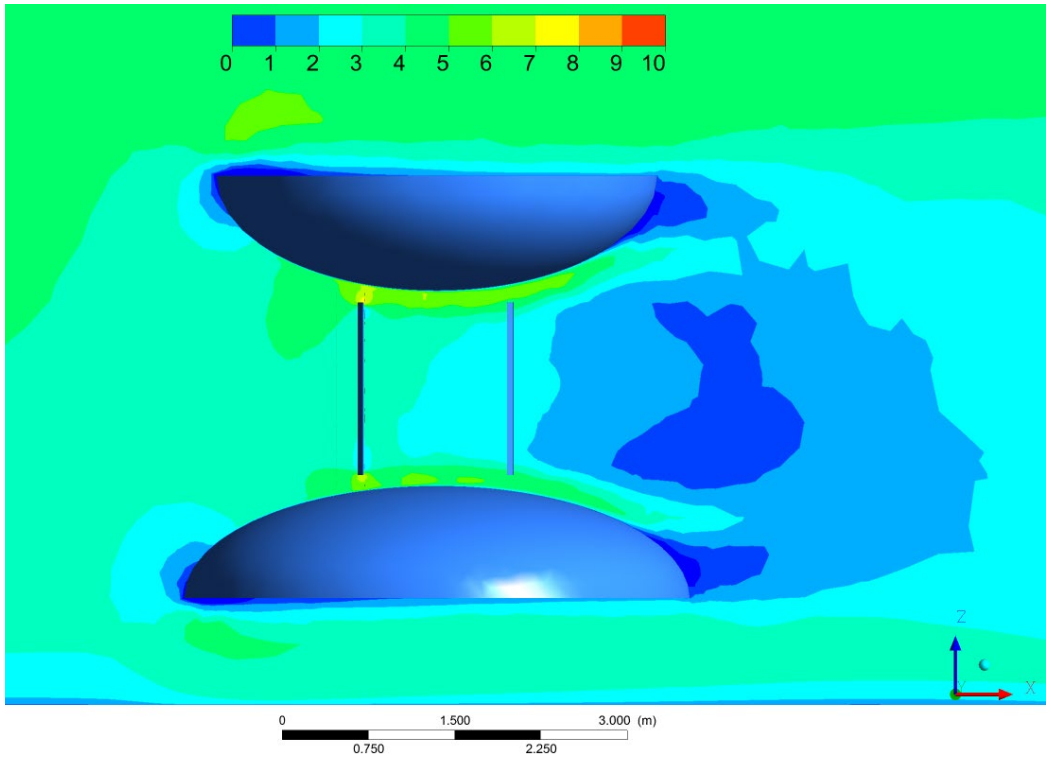
- Computed power coefficient curves



Qualitative analysis

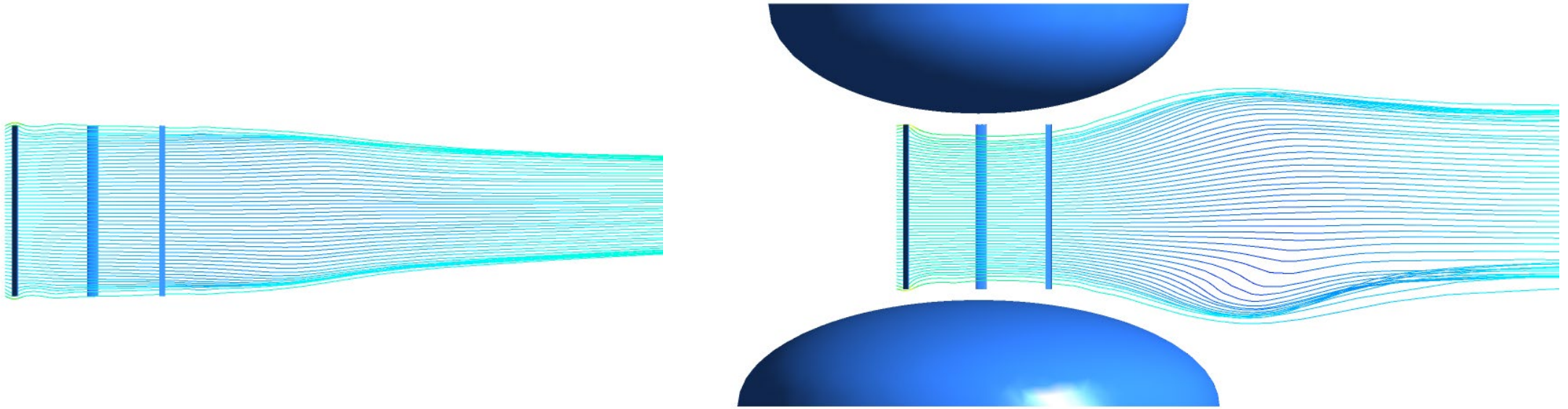
- Computed velocity contours





Qualitative analysis

- Computed streamlines



Conclusions

- Detailed description of all the necessary steps for performing numerical simulation of the 3D, unsteady fluid flow around a vertical-axis wind turbine rotor are provided
- Means to improve VAWT efficiency in urban environments by adding additional elements are investigated
- With optimal flow concentrator, power coefficient can be increased by more than 80%

THANK YOU VERY MUCH!

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