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FLOW SIMULATIONS FOR THE ASSESSMENT OF SMALL WIND TURBINES IN URBAN AREAS

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Abstract: In the frame of a national research project, as a part of the "City of future" program of the Austrian Research Promotion Agency, the potential and applicability of Small Wind Turbines (SWTs) in urban areas is investigated. The wind profile within the urban boundary layer is observed continuously for two years with a METEK SODAR in an industrial area in the northern part of Vienna. Close to the SODAR site, two types of SWTs are operated, one after another, on top of a building. Additionally, ultrasonic measurements are undertaken at two masts on the roof-top.

Focus of the presentation is stationary and non-stationary simulations of the wind field at roof-level of a building in an urban area with the models MISKAM, FLUENT and OpenFOAM. Differences and agreements between the model first results are discussed. The results are evaluated in comparison to ultrasonic and SODAR measurements. Main purpose of the project is the investigation of the capability of SWTs in an urban area and giving recommendations for site assessment of SWTs in a building environment.

Key words: *Small Wind Turbines, wind field simulations, SODAR measurements, CFD, MISKAM, FLUENT, OpenFOAM*

INTRODUCTION

Small Wind Turbines (SWTs) are getting more popular when dealing with renewable energy. The practical application of the SWT is a big challenge, since the site assessment for them is quite complex and a rather unclear situation concerning certifications and laws exist up to now. In the following work the potential and the capability for SMTs in urban area are investigated. For this purpose measurements with METEK SODAR are conducted in an industrial area, near to the building of interest on the top of which the two SWTs will be operated (see **Figure 1** and **Figure 2**).

Figure 1. Picture of the SWT (left) and one of the masts with ultrasonics in 3m and 6m above roof level and a sonic at 9m above roof level for site calibration at the SWT mast (right) on the top of the roof of the Energy Base building in the northern part of Vienna.

Figure 2. Location of the METEK SODAR east of the Energy Base building (left) and SODAR antenna array (right)

Additionally, ultrasonic measurements are undertaken at one 6m, one 10m mast and at the SWT mast (for site calibration) on the same roof.

RESULTS

Figure 3 shows 1min wind speed measurements from December 2015 at the masts in 6 m and 10 m above roof level compared to the site calibration data recorded in 9 m above roof level at the SWT mast. The wind speed measurements at the 6m are in good agreement with the site calibration measurement (**Figure 3** right).

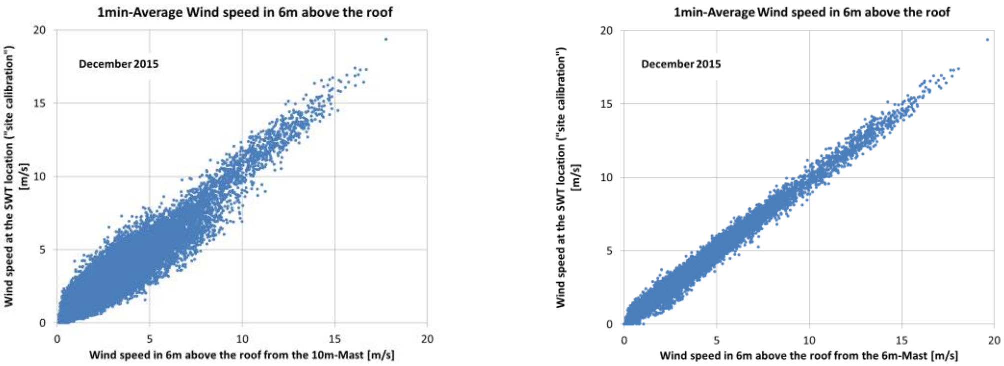

Figure 3. Example of the wind speed measurement on the roof of the building

Wind speed measurements for some selected days in December 2015 are depicted in **Figure 4**. Due to the deflection of the flow, as expected, wind speeds above the building tend to be higher than at the same height in the relatively undisturbed area where the SODAR is located. A good agreement between these wind measurements is found in days with prevailing westerly flow (e.g. 1.12.2015 and 13.12.2015). During southerly (e.g. 7.12.2015) or south-easterly flow (31.12.2015), the wind speeds measured with the SODAR are up to 6 ms^{-1} lower than at the same height above the Energy Base building as the flow at the SODAR site is obviously influenced by the one-storied building situated south of the SOADR, which is visible in Figure 2.

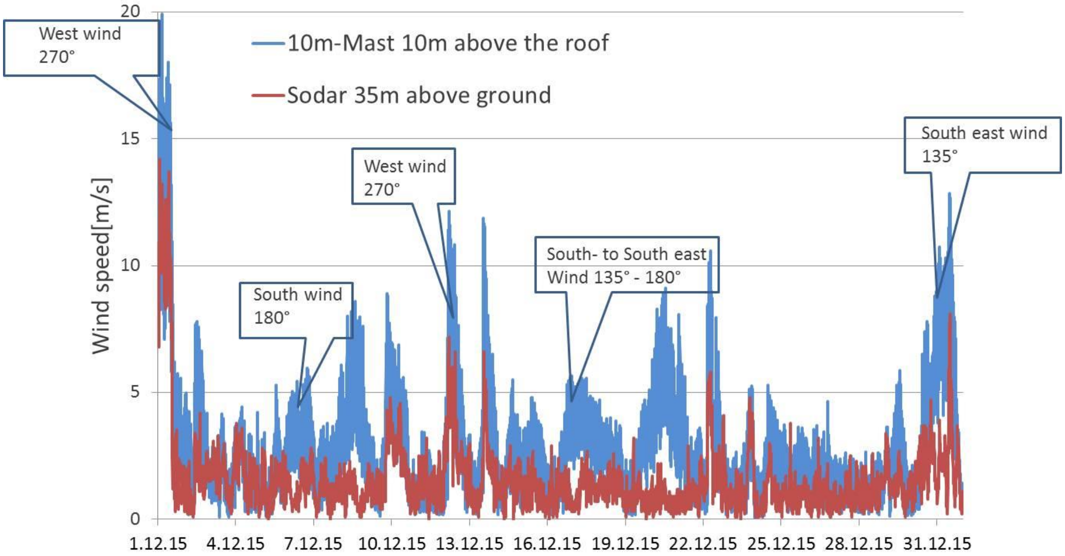

Figure 4. Time-series of SODAR wind speeds at 35m above ground and wind speeds measured with sonic at the 10m mast above roof for December 2015. The building is 25 m high. Main wind directions are depicted for selected episodes with good/poor agreement between the wind flow above roof and at the SODAR site.

A main focus of the project is the proceeding of stationary and non-stationary simulations of the wind field at the roof of the building with the models FLUENT, MISKAM and OpenFOAM. The input data for all the models are kept as identical as possible, nevertheless general differences in the models mesh, boundary conditions, solver etc. are to be kept in mind by the interpretation of the results. The turbulence models in FLUENT is the RSM (Reynolds Stress model) and MISKAM and OpenFOAM are conducted with RANs, where for OpenFOAM the standard k-e turbulence model (Hargreaves and Wright, 2007) and the SIMPLE solver method for velocity-pressure coupling were applied. An example of the mesh generated with SnappyHexMesh in OpenFOAM is shown in **Figure 5**.

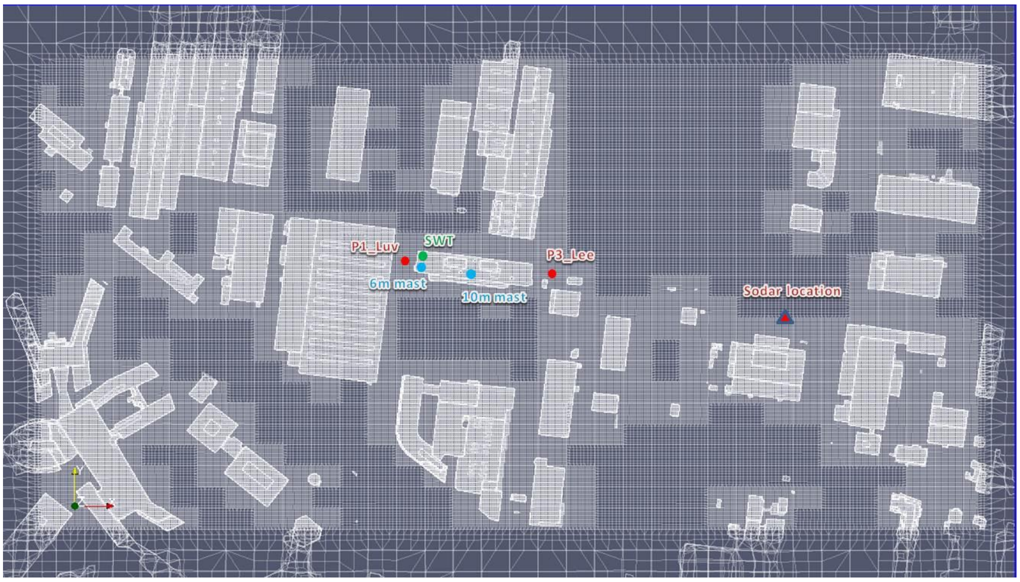

Figure 5. Mesh in OpenFOAM with ENERGY Base building in the centre of the model domain. Red points depict model grid points luv and lee of the building for model comparison (for 270° case), the red triangle indicates the SODAR site, green point the SWT site and blue points depict the 6m and 10m wind masts.

Figure 6 and **Figure 7** depict the RANS model simulations for a 270 ° flow. There is a good agreement among the models on the top of the building (SWT location), but some differences are found for the model simulation for the selected luv and lee points near the building.

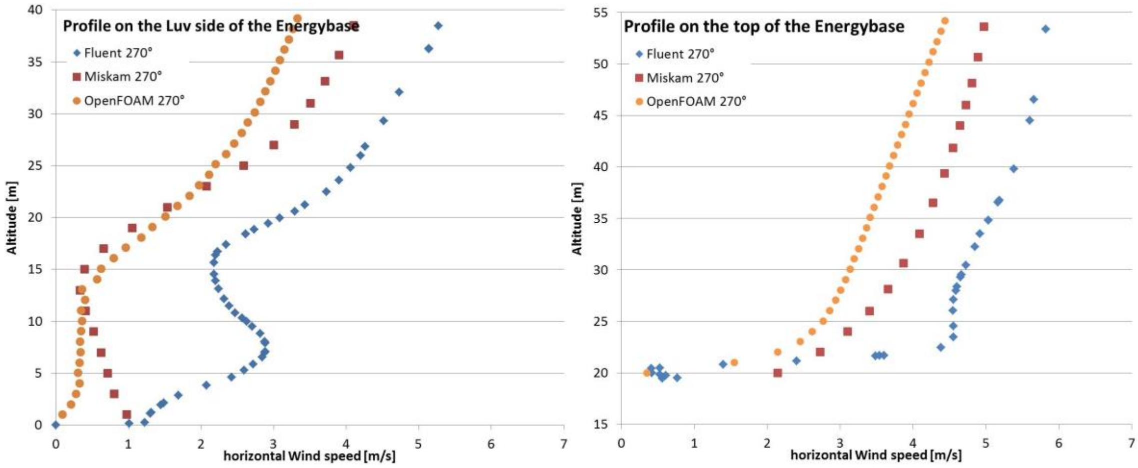

Figure 6. Profiles of the horizontal wind speed on the luv side (left) and at the SWT site on top of the Energy Base building (right) simulated with FLUENT, MISKAM and OpenFOAM for the 270 ° flow case.

Model simulations for a 270° case and SODAR measurements averaged over a period with nearly homogeneous upper level westerly winds (06.07.2015 from 7:00 am to 8:00 pm) are compared in the following. The models and the SODAR show similar profiles.

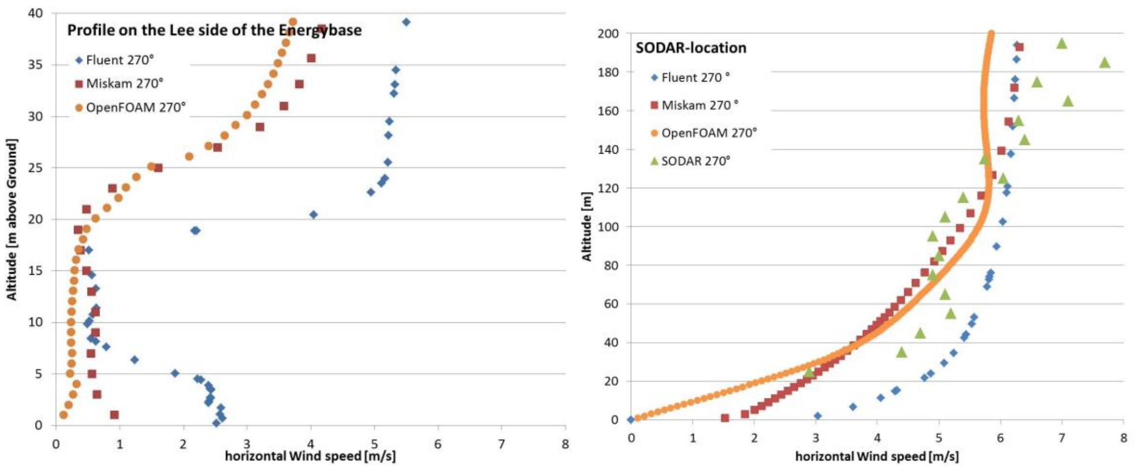

Figure 7. Profiles of the horizontal wind speed on the lee side of the building (left) and at the SODAR site (right) simulated with FLUENT, MISKAM and OpenFOAM for the 270 ° flow case compared to SODAR wind measurements averaged for a period with nearly homogeneous westerly flow (06.07.2015 from 7:00 am to 8:00 pm).

CONCLUSIONS

First analyses of wind measurements at three masts on top of a building and from SODAR nearby as well as from RANS model simulations with MISKAM, FLUENT and OpenFOAM conducted in the frame of a national research project on site assessment for roof-mounted small wind turbines in urban areas are presented. The wind measurements at the different sites reveal clearly that the winds in the first ten meters above the building are accelerated due to the deflection of the flow. Small building structures on top of the roof have a visible impact on the winds at the 10m mast site. The wind profiles measured by the

SODAR are clearly influenced by a nearby one-storied building during southerly flow. The RANS model simulations for a 270 ° flow render similar profiles on top of the building and at the SODAR site while relatively large differences are found in the luv and lee of the building. Some of these differences may be explained by differences in the models inputs (boundary conditions, mesh etc.). Main output of the project will be a report on the capability of different types of SWTs at an urban site and recommendations for measurements and model simulations for site assessment of SWTs in a building environment.

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