Computational Fluid Dynamics (CFD) analysis of downbursts affecting overhead electricity transmission lines

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(Dated: 26 August 2011)

I. INTRODUCTION

On March 1st 2008 the powerful late winter cyclone “Emma” caused widespread damage over Central Europe. In Austria a thunderstorm with a downburst was embedded in “Emma”. This downburst led besides damages to buildings and forests (Pistotnik et al. 2011) to collapses of overhead electricity transmission lines. A total of 12 towers of two transmission lines failed in an area of approximately 1 km in diameter, whilst another line 600m away remained nearly unaffected. In 1990 the cyclone “Vivian” caused similar but less damage in a neighboring area but was not brought into connection with a downburst at that time.

The question arose if the terrain triggers wind speed-up responsible for such high winds that could leed to the collapse of overhead transmission lines, or if downbursts were causing these failures.

II. PRESENTATION OF RESEARCH

To investigate the influences of terrain and/or downbursts on overhead transmission lines, a high resolution Computational Fluid Dynamics (CFD) model was adapted to this task. Steady state RANS simulations (no physics included) were carried out for four different scenarios: storm winds within Emma and Vivian were simulated in a 2.4x2.4x0.7km domain with and without downburst (as boundary conditions typical downward wind speed values (assumption) used,ambient winds taken from meteorological observations). The highest grid resolution of the simulation is 0.8m. Fig. 1 shows the domain as built in the CFD model FLUENT. Forests were parametrized and included as porous media (green areas). The elevation of the terrain is included as well as simplified villages (both gray). The towers of the transmission line are small green pyramids.

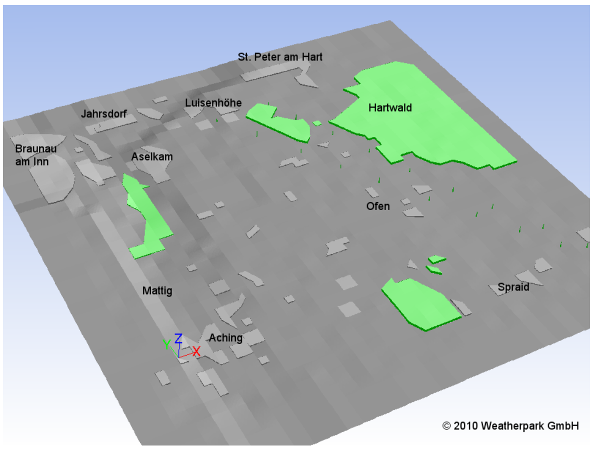

FIG. 1: View of the domain for the 2008 storm “Emma” in the CFD model. Buildings, villages and the terrain are gray, forrests are green. The transmission towers (dark green) are simplified. Coordinate system: X→E; Y→N. Z vertical coordinate.

Analyses of the 3D wind fields show, that the relatively flat terrain is only responsible for small wind speed-up not capable of damaging transmission lines. Downdraft simulations of Emma (Vivian) result in wind speed-up – with respect to the downdraft wind speed of 29m/s (33m/s) – of up to 2 (2.3). Fig 2 illustrates the flow situation in the domain during the downburst. The location of the downburst is assumed to be west of the power lines (in the background of fig. 2). The mean flow is 7 m/s from Westnorthwest, i.e. it comes from the background in fig. 2. The backward trajectories starting at the towers show where the air comes from that reaches the towers. On the right hand side the air comes down directly from the downburst and is deflected towards the east. Influenced by the mean flow and increased in speed by the ground the air reaches the towers. On the left hand side of fig. 2 the horizontal mean flow aloft is whirled by the downdraft and deflected downwards.

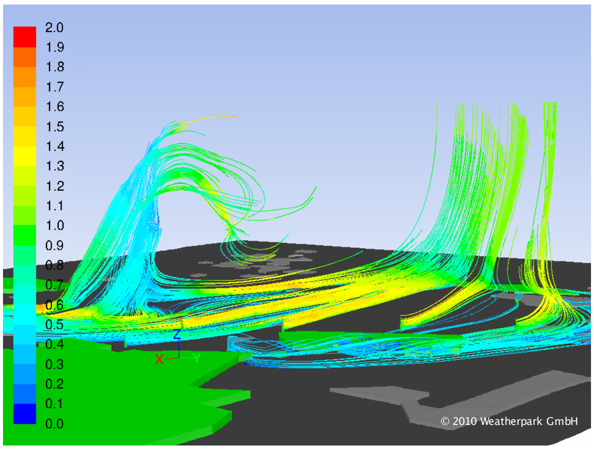

FIG. 2: Computer domain for the 2008 storm “Emma” looking southwest. Colored lines are backward trajectories of the flow field colored by amplification factors.

III. RESULTS AND CONCLUSIONS

The results of the study led to the conclusion that the local topography contributes very little to an enhanced probability of the collapse of overhead transmission lines near St. Peter. The damages to the electricity transmission lines result from storms in combination with severe convection. The exact local position of the tower collapses are arbitrary at the scale in focus. On a larger scale the probability for such events depend on thunderstorm tracks. If that particular part of Upper Austria has high thunderstorm frequency has to be examined in further studies.

IV. REFERENCES

Pistotnik G., Holzer A.M., Kaltenböck R., Tschannett S., 2011: An F3 downburst in Austria—A case study with special focus on the importance of real-time site surveys. *Atmos. Res.*, 100 565-579.