Effects of wind turbines on the use of meteorological radar based products

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1. Introduction

The use of radar products and radar based algorithms is very important for weather prediction tasks, especially in nowcasting, and for early warnings in the context of flight and emergency management. Strong efforts have been undertaken in the last years to develop, optimise, and expand the use of radar data. At the same time, a change in the concepts of energy production has taken place. The planned and successive exit from nuclear and fossil-fuel energy production is a political objective in Europe. Regenerative energy has become a major player in the field of energy production, especially in Germany, and wind energy is playing a key role. These two developments are happening in parallel with mutual influence.

When rotating wind turbines extend into weather radar beams, they act as non-meteorological reflectors. In these cases, they contribute to the signal which is detected by the radar receiver. The wind turbine also acts as blocking obstacle inhibiting a full radar return echo from possible meteorological targets which are localised behind the turbine (seen from the radar site). This effect is also known as shadowing effect. In consequence, the meteorological final products are disturbed. This is very risky as for aviation purposes and emergency management reliable nowcasting data are crucial and can save life.

In the last years, radar engineering at DWD, radar and nowcasting product development have taken a big step forward. With the new radar systems, more detailed and accurate data can be obtained and processed (e.g., Helmert et al. (2014) in radar networking session 4.4). This has also led to an increase in the expectations in meteorological radar data, e.g. in accuracy, availability and reliability. Disturbances by interfering wind turbines affect the quality of the radar data (e.g., poster presentation Frech and Seltmann (2014), DAC.P01) and the final meteorological products significantly.

In this regard, automatically generated warning products are very important. In emergency situations, e.g. when a large number of convective cells at a cold front or convergence line cross the country, immediate action has to be taken under real-time conditions. In these situations, the effects of wind turbines are most critical. This presentation will show examples of wind turbine disturbances.

2. Meteorological radar products and wind turbine clutter

For the assessment of external disturbances like wind turbines, it is important to take a look at the final meteorological products, as decisions are taken on this level. Several effects can interfere.

The meteorological products can be classified into two groups:

- products where additional expert knowledge is necessary and
- products which can also be used by laypersons.

Most of the traditional radar products belong to the first group, e.g. radar reflectivity, precipitation and radial wind velocity data. The advantage of these products is a fast product generation with a lot of detailed information. Most of the nowcasting products belong to the second group and are used e.g. by pilots and emergency services. At DWD, all of these products are based on radar data. Some nowcasting products contain additional data input from other remote sensing data (e.g., satellite and lightning data) or numerical model output. In these products algorithms are used which combine these data sets and classify the results using predefined thresholds. The results are visualised in a way, that the users can fast and easily exploit the information.

Real radar data sets contain also faulty pixels due to clutter, e.g. buildings, topography etc. Therefore, these data sets have to be corrected before further data processing can be operated. Clutter can usually be removed by Doppler filters which suppress near-zero Doppler wind components. Unfortunately, wind turbine signals notably resemble weather signals (due to moving rotor blades) with respect to non-zero Doppler wind contributions, so that the classical clutter mitigation fails. As of now, there are no filtering techniques for operational use available, that can successfully separate weather and wind turbine signals and that can suppress the latter ones. One may argue, that since the positions of wind turbine installations can be determined, the affected pixels in the radar data can be blacklisted and weather signals in this area can be interpolated. However, atmospheric conditions are not fully known and are changing permanently both in time and in space. Interpolation implies a homogeneous distribution of the signals, e.g. in precipitation fields. Experience shows that the assumptions are often quite rough and not appropriate for highly dynamic situations, e.g. in strong convective situations with thunderstorms, heavy precipitation like hail or tornadoes.

3. Development of wind energy sector in Germany

Wind energy is becoming a major player in the field of energy production. In January 2014, nearly one fourth of energy in Germany was made out of wind, biomass, water, photovoltaic etc. (see Fig. 1).

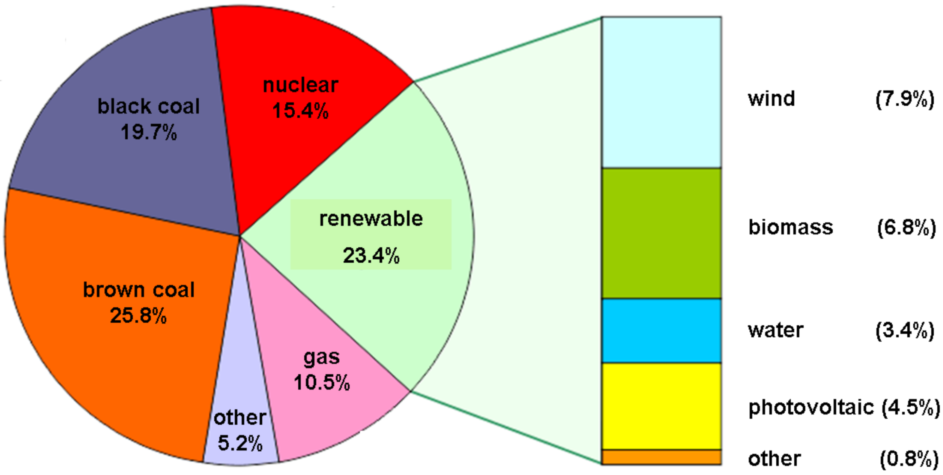

Figure 1: Percentage of wind energy on total production of electricity in Germany in January 2014, CRP-Infotec (2014).

In the recent years, there was a rapid development of renewable energy, especially with wind energy, and the developement was regionally quite different. While in the northern regions near the coast a lot of wind turbines have been installed, this tendency was substantially less pronounced in the central and southern regions. Figure 2 shows the current distribution of wind energy turbines in Germany. There are much more installed wind turbines in the North than in the South. In addition, this figure shows the DWD weather radar and wind profiler sites.

Figure 2: Site of installed wind turbines (blue points) in Germany and DWD weather radar (red points) and wind profiler (yellow points) sites surrounded by grey circles which represent the 5 km exclusion and the 15 km protection zones (with use of data of © Bundesamt für Kartographie und Geodäsie (2013), Frankfurt am Main).

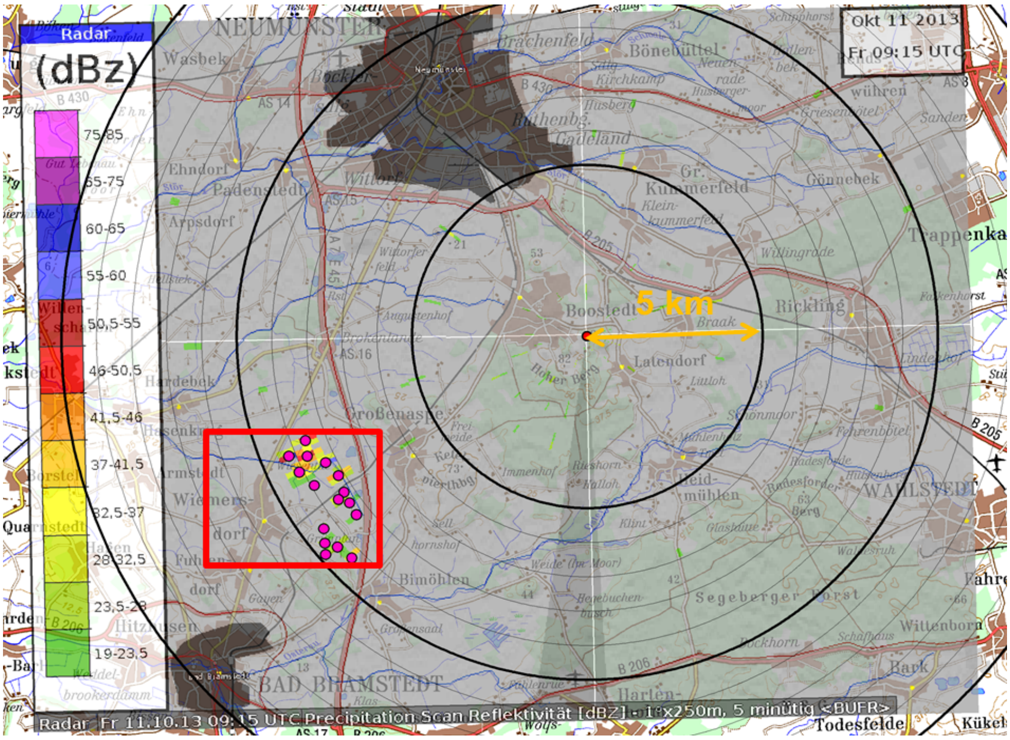

Figure 3: Example of high-resolution radar reflectivity image (250 m) of the precipitation scan with signals of disturbances of wind turbines in the neighbourhood of the DWD weather radar Boostedt (with use of data of © Bundesamt für Kartographie und Geodäsie (2013), Frankfurt am Main).

The present situation will change significantly due to the development goal for the year 2023. More wind turbines should be installed in the Centre and South of Germany. For the coast, more off-shore sites are planned.

4. Wind turbine clutter in meteorological products

Even now there are radar sites that are disturbed by a lot of wind turbines in the 15 km protection zone as Figure 2 shows. This zone is regarded as a protection zone: The guidelines of WMO even point out that in a impact zone until 20 km distance to the radars no wind turbines should be installed. In a zone between 5 km and 20 km terrain effects could be a factor, that means, that a wind turbine would not affect the radar measurement, when the total wind turbine height would not reach the radar beam height (e.g., when the wind turbine is installed in a valley, blocked by a mountain or when the radar is on a high mountain).

Figure 3 shows a typical example of wind turbine clutter in the high-resolution reflectivity product of the terrain-following precipitation scan (250 m spatial and 5 min temporal resolution). Each wind turbine is represented by a reflectivity pixel, some of them exceed the threshold for a severe weather warning of 46 dBZ. The clutter is temporally highly variable but can unambigously be traced back to the local wind turbines, e.g. the newer and higher wind turbines in the northern part of the wind farm cause higher intensities than the older and lower wind turbines in the southern part. The reason for this is the larger radar cross section of the newer wind turbines. More examples will be shown in the oral presentation.

Even in the nowcasting products, there are examples where wind turbines cause automatic warning proposals. An example is presented in Figure 4 for mesocyclones which were detected by the automatic detection algorithms (see also poster presentation Hengstebeck et al. (2014), NOW.P11) near the radar Ummendorf in February 2014. There, a precipitation field was moving over the radar and over the ambient wind turbines. In the shadowing area behind the wind turbines (seen from the radar site), areas of near-zero radial wind velocity occured although due to missing precipitation and scatterers no radial wind velocity data was expected. In combination with the meteorological signals of the passing precipitation field several mesocyclones were identified.

In order to cope with the political expectations concerning the energy transition from nuclear to renewable energy and the size of existing generations of wind turbine installations, DWD demands a protection zone of 15 km around the radar sites. This shall represent a reasonable compromise between the different interests. The newest development shows, that higher wind turbines are produced. This leads to negative effects on meteorological data as even outside the 15 km protection zone more and more wind turbine clutter is detected in the radar data.

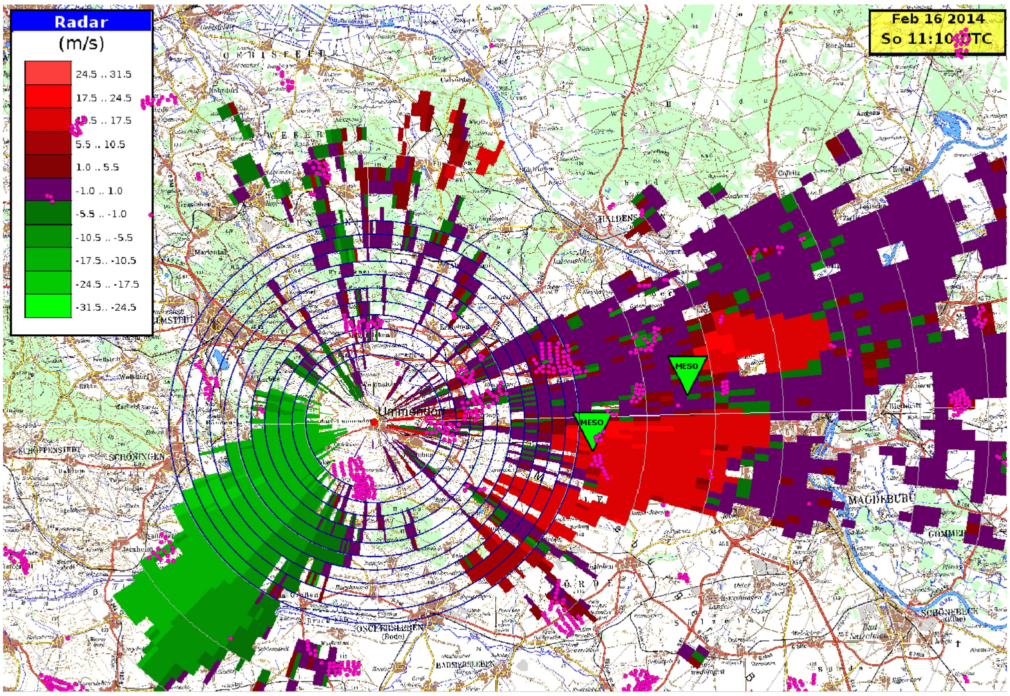

Figure 4: Example of mesocyclones which were detected due to wind turbine clutter in the radial wind velocity data of the lowest volume scan elevation near the DWD weather radar Ummendorf (with use of data of © Bundesamt für Kartographie und Geodäsie (2013), Frankfurt am Main).

5. Conclusion

The presentation shows that situations with conflicts between wind turbine installations and weather radars i.e. economic interests and safety aspects arise increasingly. More and more frequently, the final meteorological products are disturbed by wind turbines signals. As due to cost reduction and technical progress the automatisation process takes also place in weather forecasting this conflict is enforced. Although strong efforts have already been undertaken, no satisfactory solution is yet foreseeable.

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