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CNS and wind farm

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ABSTRACT
The wind is an increasingly important source of energy for the Slovak Republic. It is exploited by the use of turbines to generate electricity. Because of their physical size, in particular their height, wind farms can have an effect on the safety aviation domain. Additionally, rotating wind turbine blades may have an impact on certain aviation operations, particularly those involving radar

KEYWORDS: Wind farm, Radar Theory, Air Traffic Management

1. Introduction

Air safety includes all the rules and processes that enable commercial and cargo aeroplanes to fly safely across the European Union. It includes rules on aircraft construction and use, infrastructure safety, data management and analysis, flying operations, and cargo.

Air safety management aims to spot potential accidents and incidents before they occur. It is not the same as air security, which seeks to prevent voluntary illegal and harmful acts in the field of aviation. The wind is an increasingly important source of energy, but negative impact on air transport is in area of Air Traffic Services. Communication Navigation and Surveillance systems are endangered with big wind farms. Primary problem is in radar system and is detailed described in my text.

1.1. Radar introduction

There are two types of radar used for air traffic control and air defence control and surveillance: Primary Surveillance Radar (PSR) and Secondary Surveillance Radar (SSR).

Primary radar operates by radiating electromagnetic energy and detecting the presence and character of the echo returned from reflecting objects. Comparison of the returned signal with that transmitted yields information about the target, such as location, size and whether it is in motion relative to the radar.

Primary radar cannot differentiate between types of object; its energy will bounce off any reflective surface in its path. Moreover, air traffic control primary radar has no means of determining the height of an object, whereas modern air defence radars do possess this capability, using electronic beam control techniques.

For SSR, the ground station emits ‘interrogation’ pulses of radio frequency (RF) energy via the directional beam of a rotating antenna system. When the antenna beam is pointing in the direction of an aircraft, airborne equipment, known as a transponder, transmits a reply to the interrogation. The reply is detected by the ground station and processed by a plot extractor.

The plot extractor measures the range and bearing of the aircraft and decodes the aircraft replies to determine the aircraft’s flight level and identity (Mode C operation).

In the Slovak Republic, all aircraft flying in controlled airspace must carry a SSR transponder. Some light aircraft do not, and aircraft that do carry them may not have them switched on, in which case they will not be visible to SSR. Most ATC units are equipped with both primary and SSR, but, increasingly, radar services are provided using SSR only.

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From 2008 onwards, a new type of SSR called 'Mode S' will begin to be introduced in the SR airspace. Mode S is a development of classical SSR that overcomes many of the current limitations of the SSR system. It is proposed, subject to formal consultation, to introduce Mode S initially in 2008 with a second phase of regulatory changes in 2008. In addition, it is proposed that the requirements for the carriage and operation of transponders will be significantly extended in conjunction with the Mode S plans for 2009/2010.

2. BASIC RADAR FUNCTIONS

2.1. Air Traffic Control (ATC)

Radar performs two functions for air traffic control:

- Aerodrome surveillance radar allows air traffic controllers to provide air traffic services to aircraft in the vicinity of an airport. This service may include vectoring aircraft to land, providing a radar service to departing aircraft or providing a service to aircraft either transiting through the area or in the airfield circuit.
- En route (or area) radars are used to provide services to traffic in transit. This includes commercial airliners and military traffic. Area radars have a longer range than aerodrome radars, particularly at high altitudes.

2.2. Air defence

Air Defence radars are used in two ways. On the one hand, they perform a similar function to their ATC counterparts, in that they are used by air defence controllers to provide control services to military (usually air defence) traffic. However, they are also used to monitor all air traffic activity within the Slovak Republic and its approaches in order that a Recognised Air

Picture (RAP) can be produced, with the aim of preserving the integrity of the SR airspace through air policing. The RAP is produced by allocating Track Identities to each radar return (or "plot") of interest. Often, a radar plot can fade from a radar display for a period of time due to a number of factors, but the Track Identity will remain, indicating that the associated plot is still actually present. [3]

2.3. Meteorological radars

Met Office weather radars use electromagnetic (EM) energy to monitor weather conditions (predominantly cloud and precipitation) at low altitudes, in order to assist weather forecasting. Wind profiling radars are used to measure wind speed at different altitudes.

2.4. Airborn Wather Radar

Airborne Weather Radar provides the pilot with a local (ahead only) weather picture in the cockpit and allows him to identify and avoid specific, undesirable weather formations. A maximum range of 180 Nm is common although the commonly used range (as selected by pilots) would normally be in the 30 to 80 Nm range.

3. The nature of the impacts of wind turbines

Masking

This is the main anticipated effect on air defence surveillance radars. Such radars work at high radio frequencies and therefore depend on a clear "line of sight" to the target object for successful detection. It follows that any geographical feature or structure which lies between the radar and the target will cause a shadowing or masking effect; indeed this phenomenon is readily exploited by military aircraft wishing to avoid detection. It is possible that, depending on their size, wind turbines may cause shadowing effects. Such effects may be expected to vary, depending upon the turbine dimensions, the type of transmitting radar and the aspect of the turbine relative to it.

The Met Office is also concerned with the effect of masking on their sensors. Met Office radars look at a relatively narrow altitude band, as near to the earth's surface as possible. Due to the sensitivity of the radars, wind turbines, if they are poorly sited, have the potential to significantly reduce weather radar performance.[2]

4. Radar returns/radar clutter

Radar returns may be received from any radar-reflective surface. In certain geographical areas, or under particular meteorological conditions, radar performance may be adversely affected by unwanted returns, which may mask those of interest. Such unwanted returns are known as radar clutter. Clutter is displayed to a controller as "interference" and is primarily to PVO and aerodrome radar operators, because it occurs more often at lower altitudes.

For an aerodrome radar operator, a wind turbine or turbines in the vicinity of his airfield can present operational problems. If the turbine generates a return on his radar screen and the controller recognises it as such, he may choose to ignore it. However, such unwanted returns may obscure others that genuinely represent aircraft, thereby creating a potential hazard to flight safety. This may be of particular concern in poor weather.

A structure which permanently paints on the radar in the same position is preferable to one that only presents an intermittent return. This is because an intermittent return is more likely to represent a manoeuvring or unknown aircraft, obliging the controller to act accordingly. With this in mind, it is possible that aviators and radar operators could work safely with one or perhaps two turbines in the vicinity of an aerodrome. Of greater concern is the prospect of a proliferation of turbines, which could potentially saturate an airfield radar picture, making safe flying operations difficult to guarantee.

Several turbines in close proximity to each other, painting on radar, can present particular difficulties for long-range air surveillance radars. A rotating wind turbine is likely to appear on a radar display intermittently (studies suggest a working figure to be one paint, every six sweeps).

Multiple turbines, in proximity to each other, will present several returns during every radar sweep, causing a 'twinkling' effect. As these will appear at slightly different points in space, the radar system may interpret them as being one or more moving objects and a surveillance radar will then initiate a 'track' on the returns. This can confuse the system and may eventually overload it with too many tracks. Measures can be taken to mitigate this problem and they are amplified in Section D4, but these too have their drawbacks. [1]

5. Radars errors

Scattering occurs when the rotating wind turbine blades reflect, or refract radar waves in the atmosphere. These are then subsequently absorbed either by the source radar system or another system and can then give false information to that system. It may affect both primary and SSR radars. This effect is as yet not quantified but is certainly possible - it has, for example, been witnessed at Copenhagen airport as a result of the Middelgrunden offshore wind farm.

The possible effects are:

- Multiple, false radar returns being displayed to the radar operator: blade reflections may be displayed at the controller's console as spurious radar contacts.
- Radar returns from genuine aircraft being displayed, but in an incorrect location (range, azimuth or both).
- Garbling or loss of SSR information.

The SSR code allocated to an aircraft may not be received correctly at the radar installation because of attenuation, scattering or refraction effects. Moreover, it is possible that displayed aircraft altitude information derived from Mode 'C' may also be lost or degraded.

6. Potential mitigating measures

6.1. Technical measures

Moving Target Indicator Processing

Objects that are moving cause a shift in the frequency of the returned EM energy to the radar receiver; this is known as Doppler shift. Moving Target Indicator (MTI) processing removes from the display any returned pulses which indicate no movement or are within a specified range of Doppler shift. This removes unnecessary clutter, eliminates unwanted moving targets (such as road traffic) and makes moving targets above a certain velocity more visible.

Rotating wind turbine blades can impart Doppler shift to EM energy reflecting off the blades. Depending on the MTI thresholds set in the radar processor, this may be displayed as a moving target. Changes in wind direction at the turbine, the position of the blade in its rotation, the blade pitch, plus other factors, may cause the amount of energy returned to the radar on different sweeps to vary. At single turbine sites, a radar return will be repeatedly displayed in the same position and MTI processing can be deployed. However, multiple-turbine sites cause a different effect and MTI processing is much more difficult. On one return, blades from one (or more) turbine(s) may paint on the radar; on the next sweep, the blades of a different turbine may paint. This can create the appearance of radar returns moving around within the area of the wind farm.

On both aerodrome and air defence radar this can appear (depending on the type of radar and the processing thresholds in effect) as unknown aircraft manoeuvring unpredictably. On air defence radars such as those used in the PVO Slovak Republic, the overall system may well interpret the activity as an aircraft and automatically start tracking the activity.[4]

Filters

It is technically possible with many types of radar to filter out returns from a given area to ensure they are not presented on operational displays. However, this is at the expense of detecting actual aircraft in the area concerned. In the case of radars that have the ability to discriminate returns in height, it may be possible to filter out only the affected height band. On other radars, all returns in the given area will be lost and, in effect, no overall operational benefit is gained.

Non-Automatic Initiation

A measure that can be taken within the Command and Control system to mitigate the effects of spurious radar returns is to establish what is known as a Non-Automatic Initiation (NAI) area. Within this area the system does not perform its normal function of automatic track association and correlation. This would prevent the system attempting to correlate the returns from a large number of turbines in order to form what it perceives to be aircraft tracks. Instead, a human operator monitors the affected area to manually detect genuine aircraft tracks. Whilst this technique can help to avoid the problems both for surveillance and control of spurious tracks, it can be manpower intensive and requires operator expertise. Furthermore, it cannot help to overcome the effect on safety of clutter. Indeed, the use of clutter filters and NAIs may be operationally mutually exclusive.

6.2. Operational measures

The type of operations being conducted and the type of airspace within which a controller is operating are both relevant factors if radar clutter is being experienced.

Controlled Airspace

Within controlled airspace, flight is only possible if approved by an ATC authority. Therefore, controllers should know of all aircraft within that controlled airspace. In this case, if radar clutter is experienced, whether from a wind turbine or other obstacle, the controller may assume that the return is not from an unknown aircraft and will not need to take any action. (There are exceptions to this rule, which do not need to be explored here.)

Outside Controlled Airspace

Outside controlled airspace (in the Slovak Republic, categorised as 'Class G' airspace), clutter and unknown radar returns present more of a problem. In such airspace, the radar returns of aircraft are the primary means on which the separation of aircraft is based; therefore, clutter must be avoided, as it is the only way of ensuring separation from unknown aircraft.

What may occur is that radar clutter from a wind turbine may be interpreted as being a return from an aircraft; or the clutter may be obscuring a genuine radar return from an actual aircraft operating in the vicinity of that clutter.

There are two ways a controller can deal with this problem; the safest option is to simply avoid the area of clutter, usually by a range of 5 nautical miles. Naturally, this is not always possible. Alternatively, the controller may 'limit' his radar service, whereby he informs the aircraft receiving the service that, due to being in an area of clutter, the pilot may receive late or no warning of other aircraft.

Controllers use both methods but each presents its own problem. The cumulative effects of clutter make vectoring to avoid clutter harder and harder. Controllers may be able to cope with one or two areas of clutter, but there is a difficult judgement as to how much proliferation is acceptable. Alternatively, limiting the service is often a last resort, and to admit that clutter may well be obscuring returns from genuine aircraft is a clear indication that flight safety may be compromised.

The significance of unwanted radar returns from wind turbines will depend not only on what type of airspace they are in or underneath, but also on their proximity to traffic patterns and routes. Wind turbines on an extended centreline of a runway are more likely to present a significant problem to controllers at longer ranges due to aircraft lining up for approaches and on departure. Similarly, aerodromes have Standard Arrival Routes (STAR) and Standard Instrument Departure (SID) routes, which may also be considered problematic.

7. Conclusion

All radars are different (even if only due to the physical impacts of their operating locations) and creating a 'rule of thumb' for wind farm developments near all systems would require such a level of generalisation as to make it probably worthless.

Therefore, in considering the effect of wind turbines on radar, developers need to focus on individual radars in the vicinity of their planned development. It is important also that developers appreciate the nature and extent of any problem. For example, studies into air defence radars that take no account of the associated Command and Control systems may be of very limited value.

Because both civil and military aviation communities have legitimate interests that must be protected; this includes protection against the adverse effects of wind turbines. However, there is scope for flexibility throughout the process of considering wind farm applications. The effects of wind turbines on the physical element of the air domain (as obstructions) are well understood and the procedures for handling them are relatively straightforward. Certainly, a flexible approach to sitting of turbines can be expected to pay dividends. Developers must, however, bear in mind that there are some locations in which the presence of turbines is unlikely ever to be tolerated.

The effects of wind turbines on electronic systems and the measures that can be taken to overcome these effects are less clear-cut. The sitting of wind turbines will, potentially, affect the radar sensors belonging to both civil and military users in much the same ways, although the operational impact of these effects will probably not be the same. As further research is conducted and experience with existing (and currently approved) wind farms grows, all stakeholders will be able to determine more precisely what may be acceptable and what will not. No matter what, however, this is an area in which early dialogue with the relevant stakeholders is particularly recommended.

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Bibliography:

[1] Knill : 'Potential Effects of Wind Turbines on Navigational Systems', (CAA), July 2002, available from BWEA Web site.
[2] 'Wind Turbines and Radar: Operational Experience and Mitigation Measures', BWEA, December 2001, available from BWEA Web site.
[3] LEWIS, R.: 'Information Paper – Radar Mitigations', (CAA), March 2001, available from CAA SRG.
[4] WIND TURBINES AND AVIATION INTERESTS - EUROPEAN EXPERIENCE AND PRACTICE, ETSU W/14/00624/REP, DTI PUB URN No. 03/515