Selected Aspects of the Windmill Construction Impact on Air Traffic Safety

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Abstract. This article focuses on the problems of windmill construction impact on air traffic safety. We present the methodology for assessment of the windmill construction impact on the aviation electronic system operation and safety of IFR and VFR flights.

Introduction

The foreign companies which enter the Slovak market want to invest in the electricity production using wind power. This very positive trend brings even more complex issues that need to be solved. One of these problems is a thorough assessment of the windmill construction (WM) impact on air traffic safety. The difficult task is to assess the impact of WMs on the operation of aviation electronic systems which are located around them.

Object Assessment within Protective Areas and Aerodrome Obstacle Zones

The Buildings Being a Subject to the Approval of the Transport Authority (TA) of the Slovak Republic

In accordance with the adopted legislation [1, 2] the proposed buildings, which are outside the obstacle limitation surfaces and exceed the height limit determined by TA, must be discussed with the Transport authority with the aim to approve the air-operational assessment impact of such a building on air traffic.

In areas outside the obstacle surface limitations, the obstacles are objects with the height of 100 meters and more above the ground. In areas out of determined range of obstacle zone, the obstacles are objects with the height of 100 meters and more above the ground. Both if the air-operational assessment proves that it is not dangerous for an aircraft.

The objects, the height of which do not exceed the approach zone but would unfavourably affect the optimum location or performance of visual or non-visual facilities, must be removed. Everything that could, according to the Transport authority appraisal, endanger the aircraft on the movement area or in the airspace under inner horizontal surface and conical surface, should be considered as an obstacle and removed if possible.

Under certain circumstances, the objects that do not exceed any surface or airport area may represent danger to aircraft e.g. one or more isolated objects in the airport vicinity.

Airport Protective Areas

The height limit of buildings, equipment, construction mechanisms, coppice etc., defined in [1, 2, 4]. When analyzing the intervention of CM into airport protective zones the primary consideration must be given to the protective zone of:

- airport take-off and approach areas
- airport transition areas
Further restrictions are set by:
- protective aerodrome zone,
- protective zone of manoeuvring aerodrome areas,
- protective zone of against the lights which may cause confusion,
- protective zone with construction limitation of high-voltage overhead electricity lines (high-voltage underground cables must be available),
- inner ornithological protective zone,
- outer ornithological protective zone,

When analyzing the impact of WM on aviation guidance technology it is necessary to lay emphasis on the protective zone of:
- precision approach radar (PRL),
- navigation aids DVOR/DME.

The protective zones of other guidance technologies are not generally violated because they are located close to the runway (RWY) and the construction of WM is not planned in these areas.

The exact parameters of the protective zones and their specific limitations are described in the appraisal declaring protective zones of individual airports which are available at the Transport Authority at the department of protective aerodrome zones and ground facilities.

When analyzing the interference of WM with the protective aerodrome zones, it is appropriate to use an electronic map of the surrounding aerodrome areas in the WGS 84. The maps show the individual protective zones and obstacle clearance surfaces and also the coordinates of the planned WM construction.

The task of the analysis of WM interference with the protective aerodrome zones is to investigate whether particular WMs exceed the determined protective zones and obstacle clearance surfaces at the airport. Those WMs which go beyond the protective zones and obstacle clearance surfaces must be excluded from the construction plan.

The WM Construction Impact on Aviation Guidance Technology

Primary Surveillance Radar (PSR)

When analysing the impact of WM construction on the operation of aviation guidance technology it is required to use technical parameters. Further, it is required to use the results of the analysis of interference with the planned WM construction in the aerodrome protective zones and surfaces and to use the technical data of aviation guidance technologies. The analysis of the impact of the WM construction on aviation guidance technology should be performed in accordance with the methodology of EUROCONTROL’s Institute Of Air Navigation Services.

The construction of WM has the following effects on the PSR operation: radar signal loss due to shading, radar signals reflection from the wind turbine, the indication of WM as the moving target due to the Doppler effect, which is caused by WM’s propeller, the signal loss due to the increased threshold of the signal, the saturation of receiver and the height measurement errors.

Radar Signal Loss Due to Shading. This is a significant problem for long-range and air-defence primary radars of air traffic control. It may result in reduced ability to detect targets in the direction of the wind turbines. If the WM is placed near the PSR, shading will occur. Consequently, there is a radar shadow behind the WM. See Fig. 1. The consequences of shading can be very successfully predicted using the methods of modelling and simulation. In modelling and simulation of signal loss due to shading the special software can used that allows you to simulate a line of sight between the PSR antenna and scheduled WM.
Radar Signal Reflections from the Wind Turbine. At airports and terminal management areas (TMA) where the PSR is used there the radar signal reflections from WM are the most important (Fig. 2). The reason is that the reflections may distract controller’s attention and complicate the monitoring of other data displayed on the same place of the screen (other targets and information from the secondary radar (SSR)).

This reflection may also lead to generating false flight track of an object what may cause a serious problem for the air traffic control. The reflection may mask the targets and radar information on the screen right above or near the WM and in some cases can causes the loss of echo from aircraft.

The Doppler Effect. That being said, Doppler Effect occurs when a transmitter and receiver are in motion relative to each other. The rotor blades rotate, so we can assume that the position of the blade tips is changed relative to the PSR antenna. Therefore the frequency shift $f_D$ [3] occurs between the received and transmitted radar signal PRL. The negative impact of this effect on the PSR so that the rotating blades can be assessed as a slow moving target even though the distance between the WM and PRS does not change. This effect may occur at the navigation aid of VOR by deterioration in the measurement accuracy of the navigation parameter.

The Signal Loss Due to the Increased Threshold of a Signal. This may impact the radar ability to detect the objects in the vicinity of wind turbines. If the increased number of false targets occurs, the signal processor may react by including a greater number of filters automatically. The addition of more filters into signal processing brings the loss in the evaluation of targets.

The Saturation of a Receiver. The saturation of a receiver means its inability to handle echoes from targets due to interference with operating points of active elements on the radar receiver input.
It is because of the large received echoes. Saturation of the receiver will affect the ability of PSR to detect the distance, altitude and azimuth of targets, due to reflections from wind turbines that are close to the PSR.

The **Height Measurement Errors.** The height measurement error is specific for the radar that uses the FM carrier signal. The reflections from the rotating propeller blades of WM could cause a change in the spectrum of reflected signals from the rotating propeller blades and therefore the height measurement errors.

**Secondary Surveillance Radar (SSR)**

The SSRs are usually a part of primary radars. When examining the impact of WM on the secondary radar, four factors that have an adverse effect on its operation were found. These factors include azimuth errors, generation of false targets, signal loss due to shading and the degradation of signal because of multipath propagation. The evaluation of all four factors shows that a key parameter is WM distance from the ground-based radar system. With the increasing distance, the impact of WM construction in the operation of the secondary radar is reduced considerably. Another important factor is the line of sight between SSR and WM.

**Radio-Navigation System VOR/DME**

Examining the impact of WM on the radio-navigation system VOR/DME has revealed three factors that have an adverse effect on its operation. These factors include azimuth errors, signal loss due to shading and the degradation of a signal because of multipath propagation.

**VHF Radio-Communication Systems**

Examining the impact of WM on VHF radio-communication systems has revealed two factors that have an adverse effect on their operation. These factors include signal loss due to shading and the degradation of a signal because of multipath propagation.

All mentioned factors that affect the operation of aviation guidance systems must be analyzed in detail in accordance with the elaborated methodology. Considering the effects of WM on operation of aviation guidance technology is necessary to remove the WMs which have a negative effect on their operating parameters.

**Objects and IFR Procedures Assessed**

The assessment of the WM impact on the air traffic safety involves the assessment of the WM impact on IFR and VFR procedures. The procedures of mentioned flights are displayed on ICAO aerodrome maps. It is necessary to assess the WM impact on air traffic from the following aspects:

- Holding, approach, standard instrument arrival route (STAR), instrument approaches, circling approach, radar procedures and standard instrument departure route (SID). The next step is to assess the impact of WM on air traffic safety for VFR flights, which generally include:
  - Arrivals and over flights, departures, local flight activities and holding. In assessing the WM impact on air traffic safety it is necessary to analyze the impact on individual procedures and exclude all WMs from the construction plan, which lower the safety of air traffic at the proper airport or on published routes.

**Summary**

The companies that want to invest into electricity production using windmills are entering the Slovak market. It brings complex problems that need to be solved. These problems include, inter alia, the thorough assessment of the impact of WM construction on the environment and air traffic safety. We have come to a conclusion that the negative tendencies prevail in the construction of windmills in
Slovakia even without detailed analysis of their impact on the environment. Therefore, in the SR, it is appropriate to elaborate the assessment principles of the WM impact on individual areas to avoid, for example, deterioration of air traffic safety due to incorrect assessments or use of other economic tools.

References


