WINDFARMS-A CHALLENGE OF AIR SURVEILLANCE SYSTEM IN XXI CENTURY

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The extesively utilities of the eolian energy to realize with the great development of the wind farm with great areas. Dispose wind park in the areas of interest for air surveillance systems have an immediately effect on influencing that with immediately consequences about ability to defend of the country.

We can identify as a challenge to air surveillance system, in the 21st century, its ability to perform the basic air defense of sovereignty of Romania with increased electrical energy needs which are necessary to the economical development of the country.

Keywords: radar systems; wind park; air surveillance system.

In recent years there is a growing interest of public and private sector in generating electricity using wind power. Thus, over 60,000 MW are produced worldwide using the wind energy. These systems are generally composed of plants from 2-3 up to several hundred wind turbines with rotating blades that reach heights of over 160 m. The number, height and rotation of these wind turbines pose technical challenges to the effectiveness of radar systems that must be carefully evaluated on a case by case basis to ensure that they maintain an acceptable level of airspace surveillance capacity.

In 2001, the EU agreed that the share of electricity produced by renewable energy sources in EU consumption should reach 21% in 2010. But according to the current trends, the EU will miss this target by 1-2 percent. In order to meet its long-term objectives on climate change and to reduce its dependence on imported fossil fuels, the EU must reach or exceed these objectives. Renewable energy is already on the third position in the world among the energy sources used to generate electricity and it still has a growth potential, with all benefits for the economy and environment.

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Wind energy will be the key factor to achieving the goal set by the European Union for 2020, namely to consume 20% less energy. The European Wind Energy Association estimates that the wind-generated electricity will represent between 13% and 16% of the total amount of electricity consumed in the European Union by 2020. On average per year, the EU will consume about 100 terawatts per hour, respectively 3.3% of the total energy consumption in Europe. Germany and Spain are the largest providers of wind energy.

The strategic objective for 2010 was that the contribution of the renewable energy sources in EU countries to be 12% of the total consumption of primary resources. The global wind energy capacity will reach over 32.000 MW and the percentage increase is 32% per year. The target of 12% of global demand for electricity produced by wind by 2020 seems to be already reached.

It is believed that the global technical potential of wind energy can provide five times more energy than it is consumed nowadays. This level of exploitation would require 12.7% of the Earth surface (excluding oceans) to be covered by wind turbine parks, assuming a total of 6 large wind turbines per square kilometer. These figures do not take into account the future improvements of the turbine efficiency and technical solutions used.

The interest of the investors in this domain is high. Romania even entered in a *Top 30* of the countries which are attractive to investors in renewable energy. If the law would be favorable, investments in this field may exceed 10 billion euros. A study conducted by the European Wind Energy Association shows that Romania has increased its installed wind energy capacity with 448 MW in 2010, currently reaching 462 MW. According to the estimates, it will be commissioned another 600 MW by the end of 2011.

The energy production based on renewable resources will continue to be promoted, such as electricity consumption made from renewable energy to account for 35% of gross domestic electricity consumption in 2015 and 38% in 2020. In 2010, 11% of gross domestic energy consumption was provided by renewable sources.

The wind energy is extensively used today, and new wind turbines are built around the world, wind energy is the energy source with the fastest growth in recent years. Most turbines produce power over 25% of the time, this percentage increasing in winter, when winds are stronger.

The speed of the wind which makes it an energy resource should be measured at the height of the rotor of the power turbines (50, 70, 80, 90 m above ground). Romania's wind map was developed which includes annual average wind speeds measured at 50 m above the ground.

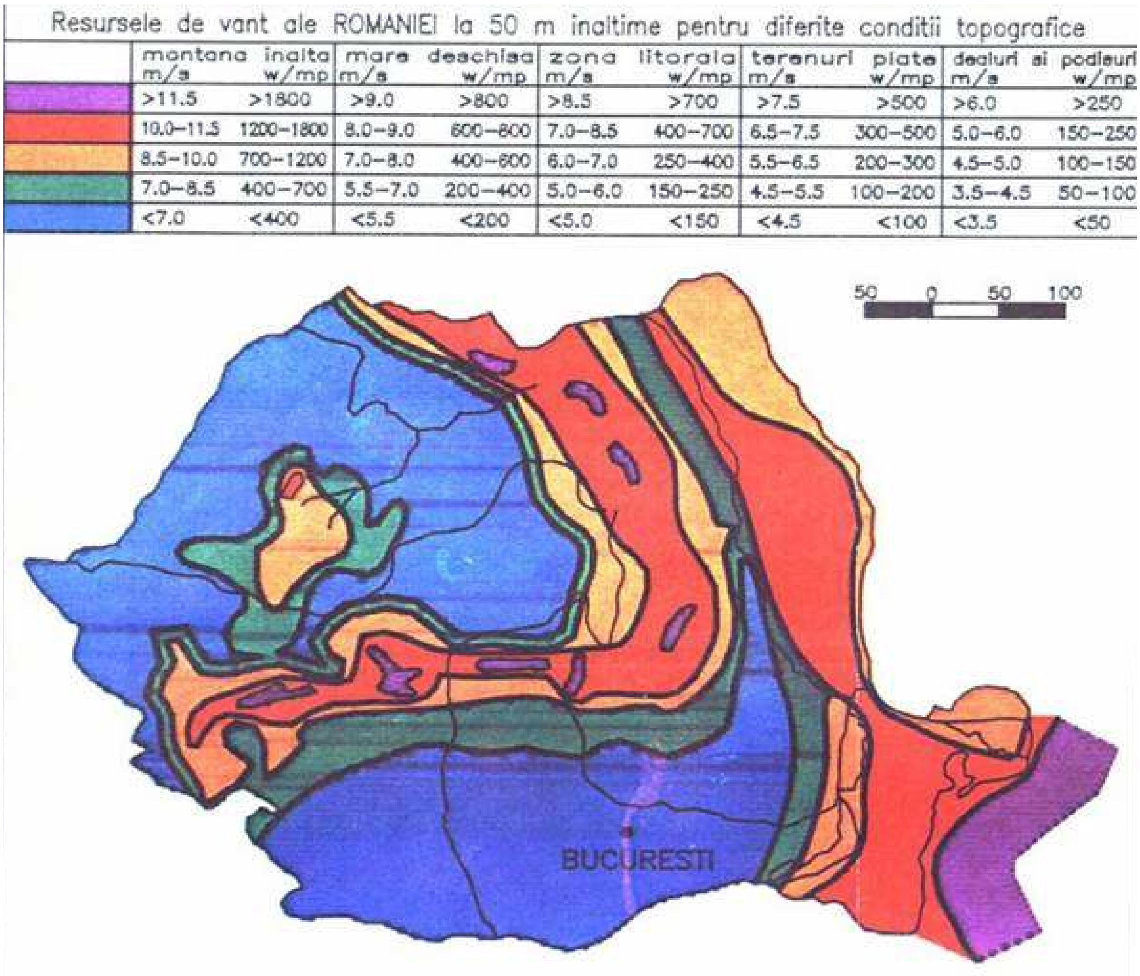

Fig. 1 *Romania's wind map*

The distribution of the average wind speed in Romania shows that the main area of wind energy potential is represented by the mountain peaks where the wind speed exceeds 8 m/s.

A second area with wind energy potential which can be used in a cost-effective manner is the Black Sea coast, the Danube Delta and the northern part of Dobrogea where annual average wind speed is around 6 m/s. Unlike other areas with wind energy potential, the exploitation in these areas is favored by less turbulent winds.

The third area with considerable potential is the Barlad Hills where the average wind speed is about 4-5 m/s. Favorable wind speeds are reported in other smaller areas in the west, Banat and western slopes of the Western Hills.

In the near future, these areas will become the targets for the investors in renewable energy who plan to build large wind farms having from 2-3 to several hundreds wind turbines spread over a few hectares or several hundreds.

The wind turbines can cause the interference of the signals by reflecting them with the turbine blades so that the nearby receptors receive both the direct and the reflected signals. The interference occurs because the reflected signal is delayed due to the wavelength corresponding to its own frequency and the Doppler Effect due to turbine blade rotation. The interference is stronger in the case of metallic materials (highly reflective) and weaker for wood or epoxy (absorbent). The modern blades, made of a metallic strength span wearing fiberglass reinforced polyester, are partially transparent to electromagnetic waves.

The communication frequencies are not significantly affected if the transmitter's wavelength is four times bigger than the total height of the turbine. For the usual commercial turbines the limit frequency is 1.5-2 Hz (150-200 m). Theoretically, there is no upper limit.

The types of civil and military communication signals that can be affected by electromagnetic interference include radio and television signals, microwaves, cellular radio communication and various air and sea traffic control systems. The primary and secondary radars are among the control systems of military and civilian air traffic which are influenced by the wind farms.

The radar systems are widely used for many applications, both military and commercial. In its simplest form, the radar is a sensor which uses the electromagnetic radiation with the frequency range from a few MHz to beyond the visible spectrum (laser radar), consisting of a transmitter, an antenna, a receiver and a processor. The most often used signal consists of a train of short pulses generated by the radar transmitter and radiated into space by the antenna. The electromagnetic wave that reaches an object, which is usually called a target, creates oscillations induced in the body of the target which make the target to behave as an electromagnetic energy generator. A small amount of energy is re-radiated in the direction of radar and its antenna creates an echo signal which is the bearer of information about the target. The basic operation of the radar is determined by the content of the information from the echo signal and the way this signal is processed.

The term "electronic jamming" refers to any unwanted reflected signal received by the radar which may interfere in determining the parameters of the target. The objects located on the direction of the propagation of the electromagnetic wave affect its characteristics by blocking the propagation of the wave or by causing interferences in the continuity of the wave due to the diffraction caused by different or multiple objects. The effect caused by them is often called "the shading" of the radar beam.

The presence of a single tall building on the direction of propagation of the electromagnetic wave provides a typical example of blocking the radar beam. Since a high building effectively blocks the propagation of electromagnetic waves, the area behind that building is not visible to the radar. If the building is close to the radar, there will be areas completely or partially "covered".

In the area where the wave is completely blocked the target detection is impossible. In the partial blockage area the detection is still possible, but with greater difficulty. In this area both the emitted and the reflected signals will be affected. This is a form of the coverage effect.

The second form of disturbance is due to a phenomenon called diffraction. The diffraction effects have been studied by the Danish physicist Christian Huygens and the French physicist Augustin Jean Fresnel. This phenomenon can be illustrated as the propagation of spherical waves from each of the objects. These waves will combine constructively and destructively on the opposite side of the objects. In the area where the waves are disturbed, the reflection signal is significantly different than in areas where they were not disturbed. These differences include variations of the intensity and the phase of the radar's signal related to the frequency of the emission and the distance between objects. These effects will disturb both the wave emitted by the antenna and the wave reflected by the target. Therefore, the ability to detect a target in this area will be altered. This form of coverage is of concern in the case of wind farms because they can create this phenomenon called diffraction.

Air defense radars usually operate in what is called a "primary surveillance" mode (active radar with passive response). When operating in this mode, the radar is referred to as "Primary Surveillance Radar" (PSR). Such radars will emit radio frequency waves concentrated by the antenna to form the directivity characteristic. The form of the directivity characteristic of the radar depends on the type and form of the antenna and its ability to rotate and balance.

The Secondary Surveillance Radar is interactive radar because it requires the cooperation of the target aircraft. The secondary surveillance radar operates by emitting a coded signal (query signal) which is received by a transponder on the aircraft. The transponder decodes the interrogation signal and responds by transmitting a coded signal. This signal contains information identifying the aircraft and other data, such as flight altitude. The query and the response signals' frequencies are different, and both frequencies are different from the primary radar's frequency, so that these signals do not interfere.

The modern wind turbines from the "utility class" consist of three major elements: the tower, the nacelle, and the turbine blades. The electricity generating unit itself is mounted in a cradle on top of a vertical column. Most columns are cylindrical or conical and made of steel. The height of the tower is adapted to the specific conditions of the terrain where the wind turbines are located. Increased tower height can allow positioning of wind turbine blades in favorable conditions but this increases the construction costs. The wind turbine towers have an average height of approximately 30 to 200 m. From the radar perspective, the tower appears as a stationary reflector without Doppler reflections. The nacelle houses the generator. The last generation turbines have nacelles that can be rotated 360 ° to allow the wind turbine blades to face the wind and provide maximum efficiency. Their rotating speed tends to be relatively low and thus, they will appear on the radar as stationary objects even when they rotate. The turbine blades are large, with an aerodynamic shape, and work the same way as an aircraft wing. The blade angle of the modern turbines is usually controlled by computer to charge a high energy flow in a reduced number of turns. The nacelle rotates so as to position the blades perpendicular to the direction of the wind, thus ensuring a constant air flow. The rotation speeds of the blades falls generally in a range from 10 to 20 revolutions per minute. Higher rotational speeds are generally avoided in order to limit the centripetal forces and to minimize the noise generated by the turbines.

The significant dimensions of the turbine blades create a target with large reflective surface whether being "viewed" from front or side radar. The maximum speed of these turbines is similar to a range of speeds available for aircrafts. Consequently, the turbine blades will appear on the radar's display as a moving target of significant size if they are in the area of radar surveillance.

In recent years, there has been a renewed effort to explore and document the impact that wind turbines have on air defence and radar systems. This was a direct result of the growing number of wind farms already built, the number of proposed wind farm to be built and the number of wind turbines in these parks, and the dramatic increase of their physical dimensions. It should be noted that when the wind turbines are not in the sight of the radar or when they are masked by natural or artificial obstacles, they do not affect the radar.

The specialists are relatively unanimous when they say that in order to make an assessment of the impact of the wind farms on the radars there should be defined at least three areas corresponding to different levels of technical expertise, combined with the influence of the turbines on the radars' capability to fulfill their missions, respectively an area of exclusive protection, an area in which detailed assessment are to be conducted and possibly an area where no more assessments are necessary.

In accordance with the details and studies conducted by the ICAO (International Civil Aviation Organization) and EUROCONTROL, these areas are shown in the tables below:

For the secondary radar, these areas are:

Zone 1 Protection	Zone 2 Detailed Assessment	Zone 3 No Assessment Required
0 - 5 km	5 km - 16 km and within the radio-horizon	Over 16 km and out of the radio-horizon

For the primary radar, these areas are:

Zone 1 Protection	Zone 2 Detailed Assessment	Zone 3 Simple Assessment	Zone 4 No Assessment Required
0 - 5 km	5 - 15 km and within the radio-horizon	Within the limits of the radio-horizon but within 15 km	Out of the radio-horizon

The primary radar protection area, where no turbine should be located, and the other areas were obtained by studying the practices commonly used by several NATO member states, ICAO and ECAC (European Civil Aviation Conference). It can be noted that for the secondary radar there is no simple assessment area. Beyond 16 km away from the site of the radar, the impact of wind turbines on the secondary radar is considered tolerable.

The simple technical evaluation for the primary radar implies the analysis of the following factors: the probability of targets discovery, the occurrence of false targets and the radar's processing capacity.

Due to the different configurations, materials used and the specific conditions of each radar position, it is not possible to accurately determine a minimum distance from which the interaction between the radar and the wind turbines occurs. However, it is possible to determine the minimum distance from which the effects of the wind turbines should not be observable. For this, it has to be checked if the distance between the wind turbines and the radar distance is greater than the radio horizon, in which case the effects of the physical structure of the wind turbine or the Doppler Effect caused by the rotation of the blades should not be observable.

Because of their large reflective surfaces and moving components, the turbines can cause false targets on primary radar. If the highest point of the turbine is within the radio-horizon of the primary radar it is assumed that the turbine will be detected by it. Also, if the number of false targets generated by the reflections from the wind turbines is too high, so it exceeds the processing capacity of the radar, the radar's operational capacity will suffer. Note that in this situation, the affected area does not depend on where the turbines are located but on the internal configuration of the system.

When a wind turbine is located close to radar (less than 15 km for primary radar and less than 16 km for secondary radar) a detailed assessment is necessary. This impact assessment should consider the following aspects: the coverings that may appear, the false targets that are generated, the errors in determining the distance and the azimuth, exceeding the processing capacity and saturation of the receptor for the primary radar, and for the secondary radar, the probability of detection, the false target appearance and the accuracy in determining the coordinates of the targets.

The coverings and the receiver saturation will be approached from the perspective of the discovery probability described above.

A detailed evaluation of the occurrence of false targets should include:

- the calculation of the amount of energy reflected by the wind turbine taking into account the different orientations of the nacelle, the blade positions, the radar frequencies, the environmental conditions and the reflections from the surrounding area;
- the impact of the turbines in terms of fixed targets display taking into account the following: the sensitivity of the receiver, the automatic tuning of the gain in time, the type of the antenna, the Doppler filtering, and the minimum power at the reception.

In addition, another mechanism that can generate false targets is the reception of signals from the real target but reflected by the turbine or wind turbine reflections which then get reflected by the aircraft.

As for the primary radar, the secondary radar is affected by regions which present coverage. If a wind turbine is located close to secondary radar, it can affect the possibility of discovery of an aircraft flying on the same azimuth as the turbine. The impact on the secondary radar should be estimated separately for the interrogation signal and the response signal. In the case of the response signal, determining the aircraft position may not be affected, while the reception of signals in modes A and C can be affected. This assumption was made for a single wind turbine. If there are more wind turbines in the radar antenna's main lobe width, the resulting shading will be higher. However, the distance of 16 km is considered as the boundary between the two SSR (detailed assessment) and the 4 SSR (requiring no assessment). Due to the reflections on the surface of the wind turbine of the query signal, the response signal or both signals, false targets may occur.

Due to the implementation the ISLS (Secondary Lobe Suppression Query), the aircrafts' transponders have a lock period of 35 μs form receiving an interrogation signal through the secondary lobes. Thus, any transponder located at a distance less than 5250 m (half the distance corresponding to the 35 μs time interval) will not respond to the interrogation signals reflected because the difference in time between the direct and the reflected signals will always be less than 35 μs. Therefore, if the wind turbine is located at a distance of 16 km from the SSRand the distance between the transponder and the wind turbine is less than 5250 m, the transponder will not respond to the query signal reflected by the wind turbine due to the use of ISLS. Also, the transponder will not respond if the distance between the transponder and the wind turbine is greater than 5250 m because the power of the reflected query signal received by the transponder is less than the minimum power at the reception. When the response signal is reflected on the surface of the wind turbine, there will appear errors in determining the coordinates of the SSR.

The ratio between the direct response signal and the reflected response signal can be calculated taking into account the following:

- the attenuation of the propagation of the signal from the secondary radar to the turbine and to the aircraft are similar;
- the attenuation of the propagation of the signal between the transponder and the turbine, and between the transponder and the secondary radar are similar;
- the transponder antenna gain is the same as the direction of the wind turbine and the secondary radar;
- the gain of the secondary radar antenna is the same on the direction of the wind turbine and on the direction of the transponder.

Given the previous reasoning, we can say that when the distance between the SSR and the wind turbine is greater than 16 km, the impact on the radar's accuracy in determining the azimuth is acceptable regardless the time difference between the direct and the reflected signal. It should be noted that in the case of a wind park, all the calculations presented here have to be made for each turbine in part.

The Impact of the Wind Farms on Air Surveillance Systems

From June to December 2010, the Romanian Air Force Headquarters formed a team that analyzed the influence of the wind farms on the performance of the radars of the air surveillance system, using the mathematical calculus and the analysis of the results of the available studies developed by countries like the United Kingdom, the Netherlands and especially the United States, studies that were based on multiple flight tests conducted in areas where wind farms were located.

The results of the above mentioned analysis have shown that the utility class wind turbines can have a significant impact on the operational capabilities of the military radars of the air defence system and the civilian radars used for the air traffic management. The empirical results and the mathematical calculus made by the team that developed the study showed that the large reflective surface of a wind turbine combined with the Doppler frequency shift produced by the rotating blades can reduce the capacity of the radar to make a distinction between the wind turbine and the aircraft.

Based on the coverage angles, we will determine the hypothetical values of the discovery distances of the different types of radars of the Romanian Air Force in the case when a wind turbine is located within their surveillance area. We will consider a wind turbine with an average height of 150 m (the height of the nacelle and the length of the blade having different locations in several points at various distances from the radar (DRT).

The formula used to determine the discovery distances on the azimuth of the wind turbine is:

$$D_{desc} = K_u\left(-2{,}47\alpha + \sqrt{(2{,}47\alpha)^2 + 17H}\right),$$

Where:

- K_u is the coefficient of radio-horizon usage (the ratio between the maximum discovery distance and distance of the radio-horizon),
- α is the coverage angle (measured in minutes),
- H is the height for which the possibilities are calculated.

It can be noticed that the discovery distances decrease from the maximum discovery distance when a wind turbine is located in the surveillance area of the radar. The most dramatic decreases occur at lower altitudes where certain sectors in which the radar cannot detect any aircraft may occur.

The Results of the Flight Tests

To validate the findings and mathematical calculus above, the Romanian Air Force have planned the GREEN ENERGY exercise between 08 – 08.12.2011. During this exercise, the radar has been deployed near the SĂCELE village in the proximity of the COGEALAC-FÂNTÂNELE wind farm and aircrafts and helicopters have conducted test flights using different flight profiles to determine the influence of the reflections generated by the wind farm on the performance of the radar.

The objectives of this exercise aimed to determine the probability of discovering air targets which fly in the covered area behind the wind farm (and the space above and around the turbines), when the wind turbines are located at a distance between 5 to 15 km from the radar, as well as to asses the impact of the reflective surface of the wind turbines, combined with Doppler frequency shift caused by the rotation of their blades, on the ability of the radar to tell the difference between the reflections from wind turbines and those from an aircraft.

Based on the surveillance of the air space and the tracking of the planned aircrafts and other targets of opportunity, the following conclusions were revealed:

• The radar is strongly influenced by the reflections generated by the reflective surface of the wind turbines, combined with the Doppler frequency shift produced by the rotation of their blades. This influence is shown on the Doppler map provided by the radar where the wind farm appears as a terrain feature which could not be removed by increasing the signal processing threshold;

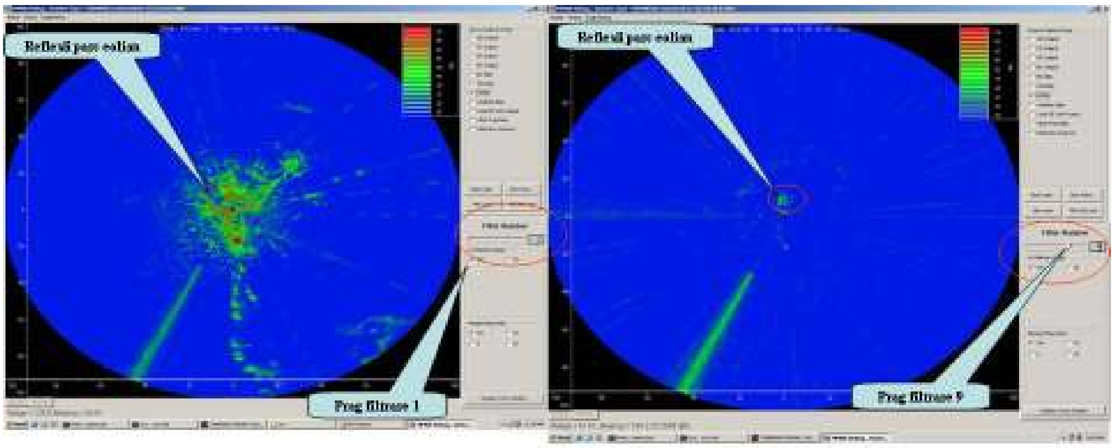

Fig. 2 *The Doppler map made by the radar in the presence of the reflections from Cogealac – Fântânele wind farm*

• The intensity of the reflections is influenced by the rotation speed of the wind turbine blades (which is determined by the speed and the power of the wind) and the number of the wind turbines operating at that time;

• On the displays of the radar located near the wind farm, primary plots (PSR) were initialized and maintained during several periods of scanning (antenna rotations); also, there have been initialized even tracks that have had variable speeds (from 150 to 850 km/h) and altitudes ranging from 100 m to 6500 m, the evolution in azimuth, distance, altitude and speed for the same track being totally random. The number of these tracks was influenced by the rotation speed of the blades (wind speed and power) and the number of the wind turbines operating at that time;

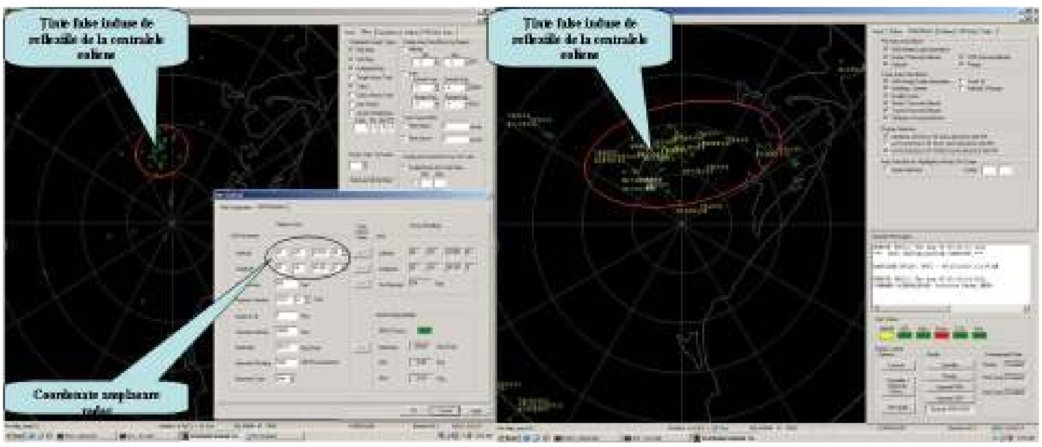

Fig. 3 *"False targets" induced on radar, generated by the reflections from Cogealac– Fântânele wind farm*

- When the air targets flew at altitudes higher than 500 m above and behind the wind farm, there were discontinuities in their tracking; the signal was lost during several rotations of the antenna (3 to 10/30 seconds to 100 seconds), mainly on the primary radar;

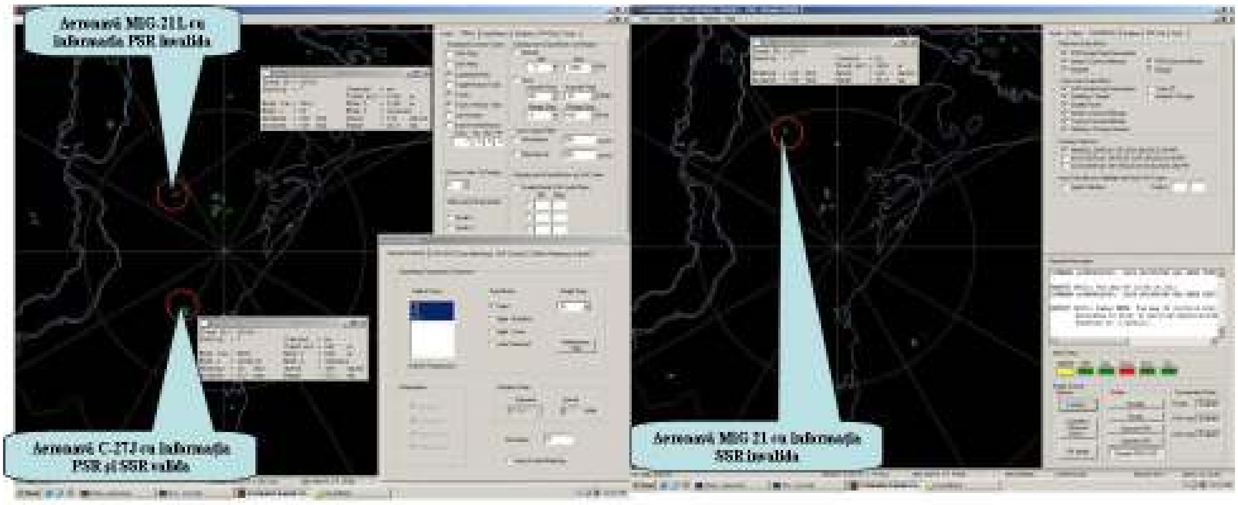

Fig. 4 *The alteration of the SSR and PSR information on the radar induced by the reflections of the Cogealac – Fântânele windfarm*

- The air targets that flew lower than 400 m above and behind the wind farm could not be tracked due to the reflections from wind turbines.

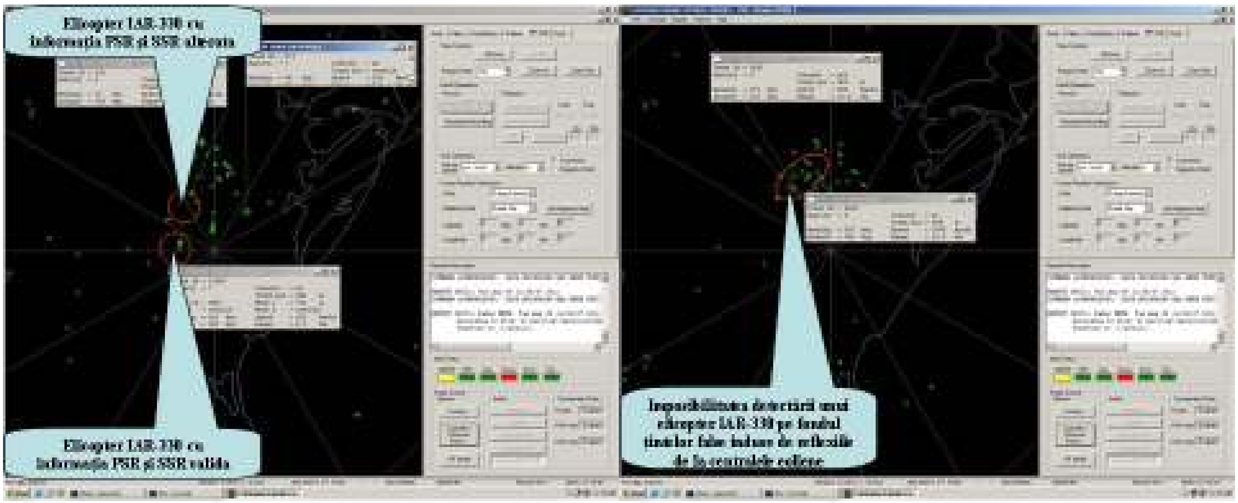

Fig. 5 *An helicopter couldn't be tracked by the radar due to the false targets induced by the reflections caused by the Cogealac – Fântânele windfarm*

Conclusions

Based on the analysis of the influence of the wind farms on the performance of radars, we can unequivocally conclude that they have a negative impact on the radar's ability to fulfill its basic functions when the wind farms are located in the surveillance area of the radar. The extent of this impact will depend on several factors such as: the position of the turbine and its blades from the radar beam, the number of the wind turbines and the distances between them. The wind turbines have a different impact on the primary radar and secondary radar due to the construction particularities of these two types of radars. Thus, in the case of the primary radar (PSR), when the wind turbine is located at a distance less than the radio-horizon, the following effects occur:

1. Decreasing of the likelihood of targets detection due to the following factors:

•The shadows behind the wind turbine, respectively the area which extends to the maximum discovery distance of the radar, because the wind turbine is an obstacle for the propagation of the electromagnetic waves;

•The increasing of the false alarm threshold (CFAR) in the azimuth-distance resolution cell where the turbine is located and in its adjacent cells, and especially in a number of 1 to 16 resolutions cells above the cell in which the wind turbine is located due to the high level of the signal reflected by the wind turbine. The size of this azimuth-distance cell depends on the type of the radar and the algorithm used to process the received signal.

2. The occurrence of false targets on the azimuth of the wind turbine due to the reflection of the radar signal by the physical structure of the wind turbine. These targets can be:

• The fixed targets due to reflections from the tower or nacelle of the wind turbine - they can be removed only by radars fitted with a moving targets selection system (STM or MTI);

• The moving targets due to the reflections from turbine blades, which due to their size at normal working speed, produce reflected signals whose Doppler frequencies correspond to speeds between 100-300 km/h. Because of this, the moving targets cannot be entirely removed by the MTI system of the radar; the mobile false targets which cannot be removed will be displayed and will form random tracks in the area where the wind turbines are located.

3. The occurrence of false moving targets (target picture of a real target) on the azimuth of the wind turbine due to the reflection by the wind turbine of the echo signal of a real target when the real target is near the wind turbine or near the radar.

4. The occurrence of false moving targets on the azimuth of a real target due to reflection by the wind turbine of the query signal of the radar survey when the real target is near the wind turbine or near the radar.

5. The overloading of the radar data processor. This overflow occurs when the total number of plots (including those from the reflections due to the wind turbines) is greater than the processing capacity of the radar data processor, which actually makes the radar data processor to apply specific methods to avoid the overloading. This has a major impact on the operational capability of the radar and does not depend on the location of the wind turbines.

6. The occurrence of errors in determining the distance and the azimuth of the real targets. When there is a small difference between the direct signal and the reflected signal, the received signal will be a combination of these signals which leads to errors in determining the coordinates (azimuth and distance) of the real targets. This effect occurs when the targets are on the same azimuth sector as the wind turbine and at a distance from the radar greater than the distance from the wind turbine to the radar.

7. The saturation of the radar receiver. In some cases, when the wind turbine is located close to the radar location, the amount of energy reflected by the wind turbine is very high, which may lead to the saturation of the radar receiver, which cause major damage to the probability of targets detection.

Conversely, in the case of the secondary radar (SSR), when the wind turbine is located at a distance smaller than the radio-horizon, the following effects can occur:

1. The diminishing of the probability of target detection and the probability of detection of the responses in A and C modes due to the shadow area behind the wind turbine, area which is small when the distance between the SSR and the wind turbine is greater than 16 km, thus affecting only the targets located on the same azimuth with the wind turbine and close to it.

2. The occurrence of false targets due to the reflection on the surface of the wind turbine of the query signal, of the response signal or of the both signals. Although most SSR systems use fixed targets maps (the reflections from the terrain) to suppress the response signals of the target reflected by them, due to the structural features of the wind turbines, this method is not effective because they are not seen as fixed objects by the SSR. This effect is removed by placing the wind turbine at a distance greater than 16 km from the radar location and the implementation of the ISLS mechanism to aircraft transponders.

3. The occurrence of errors in determining the distance and the azimuth of the real targets. When there is a small difference between the direct signal and the reflected signal, the received signal will be a combination of these two signals, leading to errors in determining the

coordinates (azimuth and distance) of the real targets. Due to the construction features of the SSR radar, the impact on the accuracy of determination of the coordinates is considered tolerable if the distance between the radar and the wind turbine is greater than 16 km, regardless of the difference between the direct signal and the reflected signal.

Locating the wind farms near the radars makes it almost impossible to discover air targets flying at lower altitudes, thus affecting the execution of missions by the radar units subordinated to the Romanian Air Force Headquarters.

Beyond the radio horizon there are no restrictions in locating the wind farms because, in this case, they do not affect the operational capability of the radars.

These conclusions took into account only the coverings generated by the wind turbines, but as we have seen throughout the paper, there could be other negative effects arising from their location within the radar surveillance area. These effects should be determined on a case by case basis using both theoretical calculus and practical measurements in the respective areas.

On the other hand, we should consider the wind potential of Romania that will cause major investment of billions of euros in the production and exploitation of electricity from renewable sources. The development trend in the E.U. indicates an adequate use of the areas with renewable energy potential (wind and solar) in order to ensure the implementation of the 1997 Kyoto agreement on reducing greenhouse effect gas emissions.

If we analyze the wind map of Romania, we find that the areas with potential for wind energy generation correspond to the areas of interest for the air surveillance system. According to the above study, the location of the wind farms in these areas will significantly affect the airspace surveillance and air targets tracking capacity of the ground based radars. This will result in diminishing the ability to defend the Romanian airspace against aggressions from the direction of the wind farms. This will not only affect the responsiveness of Romania, but also of NATO, given the fact that the Romania's air surveillance system is the first line of air surveillance of the NATO's Eastern border.

The prohibition of locating wind turbines within a range of 15 km from a radar will result in an area with a surface between 300 and 700 km^2 (calculated with the formula $S = \pi R^2$). According to the above study, the prohibition of locating the wind farms will include areas that would allow the installation of hundreds of wind turbines that could generate thousands of MW. This would affect in a negative way the billions of euros direct investments in the energy sector. Taking into account these issues and Romania's increasing need for more electrical energy, we can say that there is a contradiction between the main mission of the air surveillance system – preserving the air sovereignty of Romania – and the need for economic development of the country, in accordance with the requirements generated by Romania's status as member of the EU.

BIBLIOGRAPHY

European Guidance Material on Managing Building Restricted Areas, The European and North Atlantic Office of ICAO, 2009.

Guidelines on How to Assess the Potential Impact of Wind Turbines on Surveillance Sensors, Eurocontrol Headquarters, Brussels, 2009.

FA/Rdlc.-1, Manualul pentru întrebuințarea Centrului de Supraveghere Aeriană, Bucharest, 2010.

Memoratorul trupelor radiotehnice, Ministry of National Defense, Bucharest, 1982.

FA-8/3, Manualul specialistului de radiolocație, Air Force Staff, Bucharest, 2006.

FA/Rdlc-2, Manualul pentru întrebuințarea radarului FPS-117, Air Force Staff, Bucharest, 2002.

CAA Policy and Guidelines on Wind Turbines, UK Civil Aviation Authority, London, 2010.

Assessment of the Effects of Wind Turbines on Air Traffic Control Radars - NTIA Technical Report TR-08-454, National Telecommunication and Information Administration, July 2008, http://www.its.bldrdoc.gov/pub/ntia- rpt/08-454/08-454.pdf;