Report from flight test RADAR

(1 appendix)

1 Summary

1.1 General

With the support of the Swedish Energy Agency (STEM), the Swedish Armed Forces (FM) and the Defence Materials Administration (FMV) have carried out an investigation into the problems of interference of coastal radar by offshore wind turbines. The investigation consisted of flight tests and simulations, as well as examination of work carried out abroad and experience drawn from this work. The results of these investigations show that the ability of radar to detect targets is reduced behind a wind turbine. The extent of the interference from a wind turbine correlates closely with results from simulations carried out by the Swedish Defence Research Agency (FOI). Calculations by the currently used planning tool *WRAP ObsMan* indicates results that correspond to a great extent with simulations and measurements.

The level of requirements, or rather the way of formulating requirements for FM to be able to give a positive opinion for the expansion of offshore wind turbines that is currently needed for an "approval" in *WRAP ObsMan*[1] is not appropriate however, since it does not provide sufficient flexibility. Current requirements result in almost all considerations so far giving negative results. Among other things, the size of the target (radar target area[2]) does not affect the result. A new way of formulating the requirement and a better presentation of the calculated results are required.

With the broadened and improved knowledge gained after tests carried out, there are now better conditions than earlier for determining the consequences of offshore wind turbines with respect to their influence on FM air and surface radar surveillance. With the aid of improved performance tools, calculated results can be better evaluated in the current operative[3] scenario, in which consideration is taken to other radar stations and other sources of information that can cover the "shadowed" areas.

[1] ObsMan (Obstruction Manager) is one of the tools in the computer-based spectrum planning tool WRAP. WRAP has been developed by WRAP International AB and ObsMan, and certain other tools have been developed by commission of FMV. Refer to www.wrap.se.

[2] Radar perceives the size of a target in the form of an equivalent target area. The radar target area is stated in m^2 and is related to the physical size of the target, but also to its form, construction and material. The frequency of the radar (wavelength) is significant for the radar target area. By shaping a craft so that radar energy is diffused instead of reflected in the direction of the radar, very small radar target areas obtained). A modern fighter aircraft that is completely designed on stealth technology such as the American F-117, can give rise to a radar target area of the same size as an average bird (as little as 0,01 m^2).

[3] In this document, the terms "tactical" and "operative" are used. In this context, the terms refer to management or operations levels. Tactical levels are at the unit, function or local level. Operative levels are more overall and refer to operations at FM headquarters (HQ).

Only using calculation tools as a basis for an opinion by FM regarding the development of offshore wind turbines in a certain area is not appropriate. The calculation result shall be included as part of the decision information. A presentation tool in which the influence on a radar's performance is indicated in a more reliable fashion, as well as a composite radar coverage image for the area, can provide the required decision information. Each case must be judged on its own merits, in which FM requirements are applied with consideration to the current operative situation.

In section 6 a description is given of how FM intends to handle referrals for consideration regarding the development of offshore wind turbines and which prioritised measures in the short and long term are either planned or proposed.

With the examination model for referrals for consideration that is now proposed, FM judges that most of the development of offshore wind turbines can be solved in terms of radar conflicts. One requirement for positive solutions is that a dialogue is established at an early stage with the operators, and that the requisite adaptation measures are carried out when necessary. Such measures may include, for example, the adaptation of the number and location of turbines in a wind farm, the establishment of radar next to a wind farm or measures for existing coastal radar (supplements, moving, raising masts).

Costs related to measures for handling interference from wind turbines on FM sensor and communication systems that require FM to give a positive opinion shall be paid by the wind turbine project in question, or in another way outside FM's budget.

1.2 Project goals

The Swedish Energy Agency (STEM), in the paper mentioned, has decided to grant the Defence Materials Administration (FMV) financial support for carrying out the project "Flight test radar" during the time period 04/12/2006 – 31/12/2007 (later extended to 28/03/2008 due to technical problems that arose, and to 22/08/2008). FMV carried out the project in cooperation with the Swedish Armed Forces (FM).

In the STEM decision[4] on financial support for the project "Flight test radar" there are some sub-objectives for the results to be achieved after test operations carried out. These sub-objectives have been fulfilled or in most cases will be.

Facilitating a larger proportion of positive opinions from FM	
Goal formulation	"In the project, tests will be carried out to investigate what decisions will be made and what measures should be taken on the part of the Swedish Armed Forces to achieve an increase in approvals for the establishment of offshore wind turbines."
FM further details	FM tools for determining the extent of influence on radar stations are too blunt since they are completely concentrated on the signal/noise ratio. It is desired that FM investigate what tools are needed to determine what effects exist with more precision. There

[4] The Swedish Energy Agency 27/11/2006, D.nr. 2006-03635.

	is an expectation that improved tools, model adaptations and knowledge may lead to more positive opinions being given.
Results	The tests were carried out with the aid of simulations and practical tests. The results show that the correlation between theory and practice is good. Knowledge of the effect on radar capacity to detect targets is now sufficient to enable the development of aids that can provide information in a more reliable fashion for handling referrals for consideration. The probability of being able to provide approvals for the establishment of offshore wind turbines is thereby assessed to be higher.

Provide general rules for establishment	
Goal formulation	”In addition, the project will draw up proposals for how wind turbines can be established to minimise any interference effects on radar.”
FM further detail	With the aim of minimising interference, FM is expected to describe the general rules for how the establishment of wind turbines is to be carried out.
Results	In overall terms it can be said that the only generally applicable rule is ”the further away the better”. In general an assessment must be made in each individual case. The tactical[5] influence for FM may very well vary from place to place. The improved calculation and presentation tool will give better chances of testing alternative areas for the establishment of wind turbines.

Determining the size of the area affected	
Goal formulation	”The real area of interference of different types of radar caused by wind turbines shall be determined after the evaluation of flight tests.”
FM further detail	It must be possible to determine the size of the area interfered (bearing/distance/elevation) behind a wind turbine. The level of interference must also be determined.
Results	The area of interference behind a wind turbine tower is somewhat larger than the geometric shadow. The degree of interference corresponds largely with theoretical calculations. The proposed development of current calculation tools provides good conditions for judging the consequences in each individual case.

[5] In this document, the terms ”tactical” and ”operative” are used. In this context, the terms refer to management or operations levels. Tactical levels are at the unit, function or local level. Operative levels are more overall and refer to operations at FM headquarters (HQ).

Testing current requirement levels (signal/noise ratio)	
Goal formulation	”At present there are no investigations carried out that can establish whether the requirement level is realistic for currently applicable conditions regarding interference caused by offshore wind turbines.”
FM further detail	The investigation shall test whether the current level for signal/noise ratio is reasonable. The way of formulating the requirement should also be investigated.
Results	The project has led to a proposal for a new and more flexible way of formulating the requirement so that it can be adapted to the conditions for each test case in question. The statement of requirements should cover both technical requirements, such as the radar target area, as well as tactical/operative requirements. The starting point for the current requirement level is: ”radar capacity to detect targets shall not be reduced”. In principle, the result is a requirement for LOS (Line Of Sight) which means a rejection of most consideration cases for offshore development of wind turbines.

Map and take into consideration international experience	
Goal formulation	”International cooperation, with the aim of gaining information from earlier investigations, conclusions and measures – primarily from Great Britain.”
FM further detail	The execution of tests and reports shall be such that consideration is taken to the international knowledge that exists in this area.
Results	The risk of interference to radar from wind turbines is common knowledge. There are a number of reports that describe the problems and provide general guidelines for avoiding or minimising the risk of interference. Common to all of these is the LOS (Line Of Sight) criterion, i.e. that wind turbines must be located in such a fashion that they are not detected by radar, either through having sufficient separation distance or by drawing advantage of terrain shadowing. Some reports contain a more technical basis for how to calculate interference, and in certain cases the radar target area for wind turbines. There are no calculation tools equivalent to *WRAP ObsMan*. Possibly the most interesting development just now is a recently started project by the NATO[6] research and development organisation. In the project, which will continue until 2010, the effects of interference will be studied. The goal is to draw up a common view of how to analyse and calculate interference from wind turbines with respect to radar and radio links. In this case FM, FMV or FOI should be given the opportunity of participating in the work, not least to provide the competence currently acquired in conjunction with flight tests.

[6] North Atlantic Treaty Organisation

2 Technical investigation

2.1 FMV report

The FMV report ”*Testing the effects of offshore wind turbines on radar coverage. Tactical and technical analysis*” is enclosed as an appendix. The Swedish Armed Forces' headquarters (HQ) has participated in the evaluation of simulations and flight tests carried out, and in the drawing up of the FMV report. HQ therefore supports the conclusions and proposals expressed in the report.

In the light of the tactical and operative considerations that FM has made in conjunction with considerations for the development of wind power, FM submits its comments below on the FMV report and draws certain conclusions as a basis for the proposal of measures submitted in section 6.

2.2 Real interfered area

2.2.1 Shadowing effect (FMV 4.2.3-5, 7.1, 7.2.1)

The extent of the interfered area around and behind a wind turbine and a wind farm is investigated with the aid of simulations and flight tests. The area most clearly influenced is the shadowed sector that arises behind a wind turbine. Even though this area is small for each individual wind turbine and has a very limited vertical extent, a wind farm can have a significant influence on radar coverage for a radar station.

The interference level in the form of reduced detection probability or decreased detection distance is very dependent on the radar target area (refer to footnote on page 1).
Since even physically large objects such as aircraft or ships can show a smaller radar target area through their shape (“Stealth technology”), consideration must also be taken to physically large targets in the calculation of shadowing effects such as decreased range.

For surveillance of surrounding sea areas, FM has established a number of radar stations of the type PS-870 near to the coast. A continuous chain of small radar stations (PS-640) is under construction along the coast, primarily for surface surveillance of the proximity. These radar stations are of the civil type (Terma Scanter), and have limited range and lack specialised protection against interference. In many cases there are more than one individual radar station that cover a certain geographic area. The fixed established radar system can be supplemented by airborne radar surveillance (PS-890), which normally flies over land but may have its primary surveillance area over the surrounding sea areas. In a more crisis/warlike scenario, other airborne and seaborne radar stations will be able to contribute to create the “shared status image” in the network-based defence (NBF) that FM is striving towards. Other sources of information than radar, such as signal searching, will contribute to the total status picture.

The consequences of the shadowed area as a result of a wind farm, for example, may vary with the geographic area of establishment and what supplementary radar coverage exists.

The consequences may also vary over a certain time period in an operative scenario, depending on what mobile radar stations are available.

2.2.2 Other factors (FMV 7.2.2-4)

Unwanted detections (clutter) that arise around wind farms, such as ghost images caused by reflections from wind turbines in combination with real targets affect the tactical function of radar. Even though the geographical area affected is known by operators, the incorrectly generated targets will load the system when target tracking is started. The consequences of this will vary depending on the tactical and operative situation. In a ”calm” situation this influence may be negligible, but in conjunction with large-scale activities with many real targets, the consequences may be serious.

PS-870 is not 3D radar and therefore lacks the capability of distinguishing between targets at different heights. The function of clutter maps that exist in the context of aerial surveillance for removing unintentional targets that may arise due to ground echoes will also hide targets that are flying over a wind power area that cause clutter in radar stations. This is naturally a serious consequence.

Access to supplementary radar coverage or information from alternative sources of intelligence will of course affect the degree of the consequences, in the same way as for the shadowed sector.

Unwanted detections and ghost targets have not been further analysed in this investigation.

2.2.3 Conclusions

The real interfered area appears to be limited to the sector behind a wind farm, with a limited vertical dimension. In addition there is an effect directly adjacent to the wind farm. In the latter case this influence will exist in certain situations for all target heights. The consequences of this interference will vary in different geographical areas and at different periods in time. An assessment of the consequences must therefore be made for each individual test case. Decision information that presents, for example, available radar stations in the area as well as the interference areas will facilitate the assessment of operative consequences.

Further investigation of the use of clutter maps and how interference around wind farms can be calculated and presented is required before this can be included in calculation tools.

It is important that co-operation between wind power planners and FM is maintained during the entire development of a wind power project. Changes to the location of the wind farm and its configuration may mean that a new impact assessment is required. Changes to the plans of a wind power project may also result in a negative opinion from FM being changed into a positive opinion.

2.3 Requirements placed

2.3.1 Current situation (FMV 7.3.1-2)

The calculation of interference from wind turbines with respect to radar that was carried out with the aid of the planning tool *WRAP ObsMan* currently has great significance for the FM impact assessment of planned wind farms. The FMV investigation and flight tests carried out indicate that simulations correlate with real interference. After flight tests, a test of the calculations in *WRAP ObsMan* was carried out which indicates that the results correspond very closely to the simulations and measurements carried out in conjunction with flight tests. However, *WRAP ObsMan* only calculates how much the signal from the target decreases compared to a situation without wind turbines. In this calculation no consideration needs to be taken to the radar target area of the object, or interference effects from other factors as in section 2.2.2 above. There are no reports on influence on range, which requires further calculations, but these can be based on the interference calculations that currently take place in *WRAP ObsMan*.

Calculation of the interference effect results in a value for the ratio between power levels for two different target signals. These consist partly of the direct (unaffected) target signal and partly the target signal affected by the interference through reflection from wind turbines. This is called the *signal/noise ratio*, S/N.
The implementation of calculations in *WRAP ObsMan* is described in ref [11] as in the FMV report.

Applicable requirement levels for S/N are selected on the assumption that radar capacity to detect targets shall not be decreased in comparison with the case of non-interference. When these requirement levels were established, wind turbines were only built on land and since *WRAP ObsMan* takes terrain conditions into consideration, decisions after testing were often positive – except in those cases where wind turbines were planned in the vicinity of a radar station. In the case of land based wind turbines, there are often other reasons than the effects on radar that lie behind a negative opinion from FM. Reasons may include wind turbines being planned adjacent to a radio link path, signal surveillance by the National Defence Radio Establishment (FRA), a shooting range or other location of FM operations.

Since the offshore development of wind turbines started to be tested, partly in the form of real consultation applications and partly in the form of tests made for a certain indicated areas that were judged to be interesting for wind turbines, it was quickly apparent that in almost all cases the result was negative. The primary reason for this was that in the case of offshore development, Line Of Sight (LOS) conditions generally prevail, since PS-870 is based near the coast and located in positions that to a large extent allow free sight over adjacent sea areas, and that almost the entire wind turbine is close to 90° exposure to the radar, thus causing an obstacle with a maximum radar target area. Equivalent conditions apply to an even larger extent for PS-640, whose main objective is the surveillance of marine targets.

A clear disadvantage of the current method of calculating the signal/noise ratio is that the radar target area for the real target does not have any significance. Even if the starting

point is a scenario including targets with a large radar area, which in all probability will be detected by radar even in conditions of interference, calculations in most cases will provide a negative result.

2.3.2 Changes to requirements (FMV 7.3.3)

Simply reducing the requirements of the S/N ratio would appear to be an easy solution. However, the advantage of a reasonable change to the required S/N ratio is judged to be limited. The calculation may still result in rejections for targets with large radar areas, which in all probability can be detected by radar and even in the sector of interference. In addition, there is a risk that calculations will provide results for approval in cases where the detection probability for targets with small radar areas will be too low.

The current approval requirement has been determined for a certain radar type (PS-870). If the reporting of test results is given a more detailed formulation, it will be applicable to other radar types as well.

2.3.3 Extension of the calculation model (FMV 7.3.5)

The current examination model primarily uses the calculated radar target area of wind turbines to give the size of the interference signal. It is known that certain existing radar systems react to the rotor blades of a wind turbine in movement (Doppler effect) and certain (tactical) radar types are also specially designed to detect the rotor blades of helicopters.

Consideration is not taken to this in the examination model and the calculation tool thus cannot handle Doppler effects. It would be valuable to study so-called dynamic effects of rotor blades in movement and their influence on the interference situation (occurrence of false targets) and how this can be used for the calculation factor in the examination model.

2.3.4 Conclusions

The method of placing requirements for what FM considers to be acceptable interference of radar from wind turbines should be reviewed, not only with respect to the current requirements for S/N ratio but also the way of expressing the requirement. A more flexibly formulated requirement is needed that can be adapted to the operative situation in the geographical area in question, e.g. not the same consideration in all operative directions, possible supplementary coverage from other sensors, the radar's signal processing characteristics etc. For example, the requirement could be expressed as an acceptable decrease of range (or reduction of detection probability) in a certain percentage of cases, tied in with the "interference area" and different radar target areas representing different types of targets.

A calculation tool, currently *WRAP ObsMan*, that alone determines how FM will allow or reject the expansion of offshore wind power projects is not realistic. The calculations that are made shall be one part of decision information. The development of support for presenting calculations in a way that facilitates the decision process must be given priority. Together with a new way of formulating requirements for approval, this may

enable a more transparent basis for decisions. Impact assessment can be adapted to the conditions prevailing for each test. The requirements for approval may vary for different wind power projects depending on the geographical location, size and configuration of the wind farm, the operative significance of the area, alternative sources of information etc.

FM considers that such a solution would make it easier to give positive opinions, both through technical evaluation and FM's operative assessment, when investigating a proposed development of offshore wind turbines. The important point here is that it is a combination of technical assessments and operative judgements that are the basis of an opinion expressed by FM.

Continued specification of a tool for decision support and an analysis of the costs for the two alternative paths, of the further development of *WRAP ObsMan* or the use of the sensor planning system *EVA*[7], should be able to provide supporting information for which path should be chosen. It may be optimal to further develop both alternatives into a complementary system.

2.4 Modification of radar (FMV 7.4.3)

One possible technical measure is to adapt the radar stations affected to decrease the influence of false targets that occurs around a wind farm. This type of solution has been studied in Great Britain, among other countries. The experience from there is that certainly there are possibilities of decreasing this type of interference, but so far there is no solution that is acceptable to the military authorities and the cost of modifying 30 radar stations of a certain type is estimated at between SEK 150 and 300 million. The problem that occurs in the shaded area behind a wind farm, with reduced range as a consequence, is not solved by modification.

In order to determine what a technical solution may provide for Swedish conditions, a special technical investigation is necessary. In addition to the radar stations themselves, the entire functional chain should be studied, including operations centres where a large part of the target tracking functions and so on are located.

FM does not consider that the technical solution is realistic in the short term, for financial reasons as well as others. On the other hand, an investigation could illustrate what options there are in the long term for achieving improvements.

2.5 The possibility of moving a radar station (FMV 7.4.2)

One measure that could rectify potential interference is relocating the radar station in question. It must be clear, however, that this is not only a financial issue. It may also include new planning of a location in another geographical area. There are a number of different requirements that must be fulfilled for a move to be possible. A geographical location must be found that can provide sufficient radar coverage at the same time as

[7] EVA – Evolutionary Evaluation and Analysis. A computer-based planning tool for dimensioning radar coverage regarding grouping and radar performance. Developed by Combitech AB

requirements for communications, protection and guarding can be fulfilled. In addition, there are often demands for grouped systems, such as radio systems and radio linkage systems. Access to roads and electrical power are required as well as the possibility of the requisite agreement for the use of land. Land agreements are often difficult to make these days since a radar installation is often seen as a disadvantage for the property. In this context, FM/FMV may need to co-operate with the wind power developer in question.

Relocating a fixed radar station is a project that must be preceded by extensive investigations, reconnaissance and other planning, which places a large workload on the organisations, both FM and FMV. It is questionable whether such a procedure is realistic, at least to any major extent within a shorter time perspective, especially in the light of the ongoing re-organisation at FM. At present, FM is in a phase of strictly limited financial resources and cutbacks in personnel, at the same time as it is undergoing extensive organisational changes and military units are being phased out. However, the relocation of radar stations should not be rejected out of hand as a possible solution for allowing consultation on the development of wind power, at least not in the context of major wind power projects. If the solution should contain an alternative location for a radar station in order to make possible the development of the wind farm, one absolute requirement is that the entire cost of the relocation would be paid by the wind power project in question and not by FM.

2.6 How should wind power be developed?

It is difficult to provide any general directives for how a wind power area should be configured in order to minimise its effects on radar functions. The distance from the radar station (coast) influences the situation in a positive direction. From the point of view of FM, it is better to have large wind farms at a great distance than smaller wind farms nearer the coast.

The location of individual wind turbines does not only affect the size of the shadowed sector but also the capability of radar to differentiate between targets and measure distances. This is completely dependent on the position of the radar in relation to the wind farm and the geographical location of the radar is of primary importance, which may also create problems of security, not least if the wind farm has a foreign owner.

The conclusion is that directions for the suitable location of individual wind turbines within a wind farm must be investigated in every separate case. In the light of the significance of micro-location of wind turbines for energy production, FM judges that the possibilities of influencing the location of wind turbines to decrease the effects on radar functions is limited. An early dialogue with wind power developers should be established, however.

2.7 Other issues - FM sensor study

During autumn 2006 and spring 2007 a sensor study was carried out by HQ. This study is the basis for the structure (dimensioning) of FM’s future radar surveillance and the direction of sensor acquisitions. Among other methods, the sensor planning tool *EVA* for radar coverage calculations was used. Major development of wind farms may influence

the results of the study. An analysis of this should take place, possibly in the form of a further calculation stage in *EVA*, in which both existing and planned wind farms are included as a limiting factor.

3 International cooperation

3.1 Compilation

A compilation of certain foreign studies, tests and trials that have been reported in open sources is included in the FMV report, section 6. Representatives from the project group have also carried out two study visits to Great Britain at Qinetiq (the equivalent of FOI) and the RAF (air force). During these visits the supporting information in the FMV report section 6.2.1. was confirmed and discussed. The project group reported on the Swedish handling of wind turbines/radar issues, including the calculation tool that is used (*WRAP ObsMan*) and the investigations and practical trials that were ongoing or planned in Sweden.

3.2 Conclusions

After contact with people from other countries in conjunction with meetings and conferences, as well as a general search on the Internet, it can be stated that the risks of interference from wind turbines on radar is common knowledge. A number of reports exist that describe the problems and give general guidelines for avoiding or minimising the risks of interference. One factor that permeates these reports is that there is a LOS criterion, i.e. that wind turbines must be located in a way that means they are not visible to radar, either by having sufficient separation distance or using terrain to shadow them. The main reason for interference is the large radar target area of wind turbines.

Some reports contain a more technical basis for calculating interference and in certain cases the radar target area for wind turbines. There are no calculation tools that correspond to *WRAP ObsMan*. Possibly the most interesting development at the moment is the recently started project from the NATO research and development organisation. The issue will be studied until 2010 and the goal is to draw up a common view of how to analyse and calculate interference from wind turbines to radar and radio links. If possible, FM, FMV or FOI should be allowed the possibility of participating in this work.

4 Effects of other radio transmissions

4.1 Current status

All radio systems run the risk of unintentional interference from other radio transmitters. All occurring interference is cumulative and thus increases the risks of radar functions being affected. In the assessment of interference risks for radar in individual scenarios, some attention should thus be paid to decrease the interference protection margins depending on other sources of interference.

Naturally there is also a risk of interference between radar stations operating in the same frequency bandwidth. For this reason, detailed planning of fixed radar stations must be

established. Not only must radar stations be considered during this planning, but also civil and military fixed infrastructure such as radio link development. The purpose of planning is to decrease the risk of different stations or systems interfering with each other, i.e. that no telecommunications conflicts occur.

PS-870, which is the radar used as the basis for calculations in *WRAP ObsMan*, operates in the bandwidth 5-6 GHz (sometimes called the C bandwidth). The bandwidth is allocated for radar, but other services also use it. The Swedish authority for frequencies, PTS (Post and Telecom Agency) has issued an exemption from the obligation to obtain a permit for certain use of radio in one of their papers. This means that the equipment which fulfils certain established technical specifications can be acquired and used freely, without demands for permits or other registration of usage. The primary use within this area is the radio system for data transfer (WAS/RLAN/WLAN).

4.2 Development

Work has started within the EU on reviewing the requirements for frequency space for ”governmental use”, primarily concerning resources for military requirements. In Sweden a similar investigation is underway[8]. The aim is to release more frequency space for market needs through the increased use of auction procedures, for example. In addition to reallocating resources from military to civil usage, possibilities are being sought to share of the use of frequency bandwidths to a larger extent. Since there is a desire to allow the market to decide which services and systems the frequency bandwidths will be used for, there is increasing uncertainty in judging the risks of interference with military radar stations, for example.

4.3 Conclusion

The frequency bandwidth that is used for FM radar stations is increasingly in demand for other systems and services. The available frequency spectrum for radar will decrease and uncertainty about possible conflict situations will increase. Since a requirement is set on the level of ”permissible interference” from a specific source of interference (wind turbines) consideration must also be given to other unintentional interference situations that occur and influence the capacity of radar to detect targets.

5 Project finance

The project has been carried out within the stated financial frameworks of STEM. Detailed financial reporting is submitted by FMV in a special paper to STEM.

6 FM processing of wind power cases

6.1 Requirements on the operative capacity of FM

Operative capacity[9]

[8] Government decision 17/07/2007, Committee directive 207:111, ”Radio frequency use and electronic communication”
[9] Government decision 7, 19/12/2007 Fö2006/702/EPS – pages 2-3

”The goal for the area of operations is to develop the contributing organisation in accordance with the demands for operative capacity that the government has determined. The demands for operative capacity that are put on the Swedish Armed Forces are:

Capacity I – Assert Sweden's territorial integrity and contribute to preventing and managing crises in our surrounding world through participation in peace promoting measures.

This operative capacity puts requirements of the following sub-capacities.”

- *”The Swedish Armed Forces shall be able to detect violations of airspace and sea territory. Movements of aircraft and ships shall be able to be followed, with the purpose of detecting threats to security or infringements of national or international law. The Swedish Armed Forces shall be able to adapt their readiness in time and space, and shall be able to repel violations and handle incidents.”*

Environment issues[10]

”*The Swedish Armed Forces shall actively participate in the consultation process for wind power cases so that suitable locations can be identified at an early stage.*”

All examination of the development of wind turbines must take place within the background of the main commissions of FM as stated above. Maintaining the capacity to detect violations of airspace and sea territory requires in the first instance good and secure radar coverage. Maintaining radar coverage during a long time and over large areas is resource intensive and must therefore be based mainly on a fixed infrastructure (radar stations, operations centres and communication networks).

All forms of interference to the FM sensor chain have operative consequences for the ability to fulfil the remit that FM is given in accordance with the government appropriation paper and BerO (readiness order), i.e. to have the capacity to detect and identify targets around the clock. The capacity to monitor an accident area at sea and to lead rescue missions may be influenced. In certain cases this may result in negative consequences for the development of wind power. Requirements for radar range vary in different geographical areas, however. An examination must be carried out for each individual case. FM’s need for information varies in different geographical areas, the Baltic Sea and the North Sea having generally higher priority than the Norrland coast.[11]

In the light of the above, it is important that a dialogue is maintained between wind power developers and FM at an early stage in the planning of offshore wind turbines. FM judges that, despite the effects on the FM sensor chain, most problems associated with the development of offshore wind turbines can be solved regarding radar conflicts if there are tactical/operative or technical solutions. In certain cases this may involve demands on

[10] ibid. –Page 21
[11] HQ 2008-03-28 Task Force Staff comments on the report on flight test radar.

adaptation measures, such as the number and micro-location of wind turbines in a wind farm, the establishment of radar in the vicinity of the wind farm, or measures to existing coastal radar (supplements, relocation, extension of masts).

It is the opinion of FM that costs for measures to handle interference from wind turbines to FM sensor systems and communication systems that are required for FM to be able to give a positive opinion shall be paid for by the wind power project in question, or in another way outside the FM budget.

6.2 Goals for FM examination of wind power cases

There may be different reasons for why FM is not able to approve a development of offshore wind turbines, such as the intended location being part of a naval training area or lying close to a high-risk area for firing live ammunition or missiles. So far, however, the risk of interference with radio surveillance and along certain parts of the coast also with signal surveillance has completely limited the options for agreements, since the examination model has given negative results in practically all cases.

The goal for consideration activities shall therefore be to assess the impact on radar surveillance in a more flexible way, better adapted to the individual situation, by changing the way of formulating the requirements among other things. FM is expected to give a favourable opinion of offshore developments of wind turbines to a greater extent than previously. The risk of conflict with radar shall not in itself set limitations for FM opinions.

The technical calculation results (currently the signal/noise ratio) shall alone be decisive for a positive opinion. Every case for consideration shall be judged in the light of its operative context and the possibility of obtaining supplementary intelligence information in order to maintain an acceptable surveillance of the geographical area in question.

The option of compensating for reduced radar coverage behind a wind farm by radar stations being moved forward in the proximity of a wind farm should continue to be included in future impact assessments. Exactly how this will take place and what requirements must be put on installations and so on has not yet been studied. Experience from the ongoing expansion of the radar chain using the PS-640 indicates that the cost of installations may be significantly higher than previously assumed.

6.3 Measures proposed by the investigation (FMV 7.6)

6.3.1 Short term

A special preparation group should be created at HQ to prepare for FM decisions regarding referrals for consideration of marine and coastal wind power projects. This group should include representatives from production management and task force management as well as the Military Intelligence and Security Service (MUST). Such a group, with broad and long term representation of competence, is required to obtain a complete picture of the impact on radar surveillance. The unified assessment of wind power projects must be safeguarded in the long-term perspective as well.

Support for this preparatory group requires technical and operative information. This consists of calculations of major influence and compilation of existing and planned radar stations (and possibly other sources of intelligence) in the geographical area in question. Current planning support (*WRAP ObsMan*) must therefore be developed in accordance with the guidelines described in section 2.3 in order to make calculations of changes to range within the sector of interference and to provide a transparent presentation of the results.

The short-term measures proposed by the investigation are therefore (in order of priority):

a) Examination of the development and introduction of a calculation and presentation tool (FMV report 7.6.2, Measure 1). Such a tool, or a method for using an existing tool (*WRAP ObsMan* and *EVA*) after any supplements required, should be introduced as soon as possible to facilitate FM's consideration of cases.

b) Examination of the options of taking into consideration the occurrence of false radar information (clutter) (FMV report 7.6.3, Measure 3).

c) Charting the possibility of FM/FMV/FOI participating in the NATO research and development project SET-128 on the *Sensors and Electronic Technology Panel* (FMV report 7.6.5, Measure 5). The goal for participating shall be to exchange Swedish experience and results from tests carried out, and to work towards a common view among NATO/PFF[12] countries with respect to interference with radar from wind turbines and the development of common methods and calculation tools.

d) Examining the consequences of establishing radar stations close to wind farms. How should radar stations be grouped, what demands should be placed on installation and liaison communication, and what are the total costs? Carry out a trial installation.

e) Cooperating with national authorities (Civil Aviation Authority, Swedish Maritime Administration, Coastguard, Customs) with the intention of investigating differences and similarities in influence between civil and military applications (FMV report 7.6.5, Measures 6 and 7).

Activities outlined in a), b) and d) are judged to involve a considerable use of resources, both regarding finance and working hours, and these resources are not currently available at FM.

6.3.2 Long-term

The following activities have a lower priority than those described above, but are judged to involve a deeper technical examination. In the light of the labour involved (as well as finance) they may need to be executed over a longer time period.

[12] PFF stands for "Partnership for peace" in Swedish, and is a programme of co-operation between NATO and certain countries outside NATO.

f) Examining the extent of unwanted detections and ghost targets, and the possibility of handling problems through technical solutions. (FMV report 7.6.3, Measure 2).

g) Examining the problem of suppressed radar information from areas above wind turbines and proposed technical solutions or other measures (FMV report 7.6.4, Measure 4).

Activities outlined in f) and g) are judged to involve a considerable use of resources, both regarding finance and working hours, and these resources are not currently available at FM.

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