quietrevolution™

qr5 VAWT Airport Safety

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1. Introduction

The MoD, CAA and airport operators have genuine concerns that wind turbines could impact on their safety systems.

We should stress that quiet**revolution** is **not** an expert in the impact of VAWTs on radar and other safety systems. This is an introductory note on the subject, summarising our experience and understanding to date. We will make available more extensive assessments as our knowledge of this subject develops.

All airports have "airport safeguarding zones", that affect structures that would be above a contoured surface rising with a gentle slope from the instruments and runway. The closer one is to the airport instrument systems and runway[s] the lower the elevation of the safeguarded zone.

Our current knowledge is based primarily on two reports :

1. QinetiQ, July 2008: Including a real test of the visibility of the QR5 turbine to typical radar systems as used by civilian and military airports]
   This report is available on request from quiet**revolution**
2. Cyrrus, 11 April 2008: An impact study of quiet**revolution**'s turbines on Filton Airport systems
   This report was commissioned by a client of quiet**revolution** and can only be released upon receiving their written approval.

Airports have radar and other navigation systems, they are used to safely control the movement, landing and take off of aircraft. The main systems are: Instrument Landing Systems [ILS]; Distance Measuring Equipment [DME], Primary Surveillance Radar [PSR] and Doppler Radio Direction Finder [DRDF]. Airports do not all use the same equipment, nor is the quality of the equipment consistent at all airport sites. An evaluation will be required on a site by site basis.

The impact a wind turbine might have on airport and aircraft systems will depend on a number of factors:

Scale: The larger the turbine, the larger the likely impact on airport and aircraft systems.
Materials: some materials produce a more visible return than others.
Technology type: HAWTs vs VAWTs. A HAWT yaws depending on wind direction, causing a change in the signal seen by the radar, whereas a VAWT will have a constant shape regardless of wind direction.

Below is a brief summary of each of these types of equipment and the potential impacts that a quiet**revolution** Vertical Axis Wind Turbine could have on them.

2. Airport Equipment Summary

ILS – INSTRUMENT LANDING SYSTEM

- Standard precision approach landing system in civilian airports
- Ground based air-interpreted instrument approach system
- Precision guidance using combination of radio signals
- Used in poor weather and reduced visibility conditions

There are two types of ILS, 'single' and 'two' frequency systems. Single frequency types are more likely to be susceptible to reflections than two frequency types.

ILS's tend to operate with tone frequencies of 90Hz or higher, the qr5 turbine's rotational frequency is 5Hz to 15 Hz and the effects from the turbines on an IL System are therefore likely to be unmeasurable.

ILS's are not likely to be affected by the central mast or central turbine tube. The only parts of the rotor that could potentially affect an ILS are the rotating parts.

Any disturbance to an ILS is likely to be extremely small [or probably non existent], even if the turbine is located within the airport safeguarding zones.
Should the rotor be outside the safeguarding zones or if there is no line of sight between turbine[s] and ILS the likely level risk of any disturbance to the ILS is very small.

DME – DISTANCE MEASURING EQUIPMENT

- Used to measure aircraft distances as they approach for landing
- Typically considered as a back-up system
- Various types : Omni-directional or multi-path; can have single or bi-directional antenna
- Typically located 3m above ground level
- Typically 1no. or 2no. DME's on each airport runway
- Sensitive to degradation by building development in line or close to line of aircraft approach
- Only susceptible to interference if there is a line of sight between DME and turbine

The DME systems may be affected if the turbines are located within the line of sight DME <u>and</u> when within the safeguarding zones of an airport.

DME systems can be omni-directional or multi-path, omni direction are more susceptible to interference than multi-path DMEs.
DME's can also be installed with Bi-directional antenna which would also minimise the effect of a turbine on DME's.

Single, omni-direction DME's with single direction antenna are more susceptible to interference from wind turbines than more advanced multi-path systems. More advanced systems will probably cope with turbines that are located within the safeguarded zones and within line of site of the DME.

PSR – PRIMARY SURVEILLANCE RADAR

- Long-range, low or high frequency systems
- Typically located on elevated ground
- System incorporates Moving Target Identification [MTI] to discriminate wanted moving targets [aircraft] from static objects and ground clutter.
- Turbines must be in direct line of sight of PSR for the radar to be affected

3. Potential Impact from a qr Wind Turbines

1.
Mast and blades may act as a reflector and are presented as a static target. This is no different to any other ground clutter, however it is a permanent effect.
The 'reflectivity' of mast and rotor may be several orders larger than that of an aircraft and there is a risk that the radar receiver could be swamped, making it blind to aircraft in the area beyond the turbines. However, this effect can only occur when there is a direct line of sight between the PSR and the turbines.

If there is an effect from the rotors on the radar, the impact will depend on relative locations of turbines to the radar, the runways and the flight paths.

2.
The rotating blades impart a Doppler frequency shift to the reflected radar pulse which the radar sees as a moving target.

This effect is common in Horizontal Axis Wind Turbines where the profile - as seen by the radar - changes with wind direction. However the profile of a Vertical Axis Wind Turbine is constant. Again this effect is also only relevant when there is direct line of sight between the radar and the turbine rotor.

Probability of detection of a quietrevolution Vertical Axis Wind Turbine

The QinetiQ report on qr5 VAWT, published Nov 2008, summarised the impact of the qr5 turbine on radar as follows, (see appendix 1 for full executive summary):

"…. urban clutter attributed to cars and trucks, which have a comparable RCS [Radar Cross Section] return, would have already created similar clutter levels. Therefore, the addition of a [quietrevolution] VAWT to this clutter would have limited impact."

" MTI [moving target indicator] filters are used within the radar. This effectively cancels out the RCS from the static parts of the VAWT, leaving just the RCS of the moving components. Therefore, despite being readily detectable, the RCS due to the static components of the VAWT are unlikely to show up on the radar display."

"Taking into account the use of moving target indicator (MTI) filters in radar, and the likely clutter levels and obscuration associated with the urban environment, it is highly unlikely that a [quietrevolution] VAWT will add any additional clutter levels to that already seen and dealt with by a radar."

"… it should be noted that this RCS [Radar Cross Section] would be no more visible than that of other objects such as houses and telegraph poles or lampposts. The VAWT is primarily designed to be placed in urban areas, which will be surrounded by trees, houses and lampposts. So a [quietrevolution] VAWT is unlikely to add any more static clutter to an operators screen than is already present."

TABLE 1 : TYPICAL RADAR CROSS SECTIONS OF VARIOUS OBJECTS INCLUDING QR5 VAWT

Targets	RCS (m^2)	RCS (dBsm)	Example Speed (ms^{-1})
Bird	0.01	-20	9-13
Man	1	0	0.8
Micro turbine	3.8	5.8	10-100
Small wind turbine	5	7	40
Cabin cruiser	10	10	8-13
VAWT	72.4	18.6	10-20
Car	100	20	13-30
Truck	200	23	13-26
Enercon E66 wind turbine	1995	33	30-70
Corner reflector	20379	43.1	0

Table 4-1 Comparison of the RCS values and speeds of a VAWT with other real world objects [7]

quiet**revolution**'s interpretation of Qinetiq's report on the qr5 turbine is that a Primary radar System will detect the turbine, however it will be filtered out in the same way filtering occurs of other background clutter such as structures and vehicles within and without the airport safeguarded zones.

It is our conclusion that even with airport safeguarded zones a quiet**revolution** VAWT is unlikely to have any effect on the Primary Radar System.

DRDF – DOPPLER RADIO DIRECTION FINDER

- Received VHF communications from aircraft.

The turbines might affect a DRDF system if the turbines are within the safeguarded zones. The turbines are unlikely to have any significant effect on the signal strength however the potential risk is that bearing errors are introduced. The level of risk is likely to be very low, however it will greatly depend on the existing individual airport systems and how far they have already been degredated by existing 'clutter'.

quiet**revolution** would recommend that rotors are sited to avoid positioning between aircraft approach paths [and emergency exit paths] and air traffic communication locations to minimise the risk of introducing any addition bearing errors.

3. Summary

The two key parameters in determining whether a Vertical Axis Wind Turbine will have an effect on airport navigation and radar equipment are:

1. Whether the turbine(s) are within the airport safeguarding zones
2. Whether the turbine(s) are in direct line of sight of the equipment

If neither of these is the case, then the likelihood of there being any issues from installation of turbine(s) is small.

Even when one or both of these conditions exist there is a high probability that the sophistication of modern airport systems will filter out all effects of the turbines and ignore them in the same way that airport buildings, structures and airport ground vehicles etc are ignored.

If there is concern as to whether either of these conditions are likely to exist, then a discussion should be had with the airport.

If in doubt we would recommend contact being made with the airport in question. quiet**revolution** will provide all reasonable technical information to support such a discussion.

Appendix 1 : QinetiQ Executive Summary Quoted in Full

"Executive summary"

"QinetiQ was contracted by the Air Defence and Air Traffic Services Integrated Project Team to predict and measure the radar cross section (RCS) of a vertical axis wind turbine (VAWT), as well as assess the potential impact it would have on radar. The VAWT used for the study was the Quiet Revolution (QR) qr5, a 7kW turbine that is roughly 5 metres high and 3 metres in width.

To predict the RCS of the VAWT, a computer aided design (CAD) model was created, with a finite element mesh applied to it. The RCS predictions were calculated using the QinetiQ RCS prediction tool, Spectre®. The configuration tool was set up to run at frequencies of 1.3GHz and 2.9GHz, to represent L-Band and S-Band radars, at elevation angles of 0 and 1 degrees for a perfect electric conductor (PEC) material turbine assembly in free space.

The analysis showed that the dominant source of RCS was the central vertical axis of the VAWT, with a peak RCS of 20.5dBsm depending on the frequency and elevation angle, which masked some of the reflections from the blades. The RCS predictions were repeated with a radar absorbent material (RAM) applied to the vertical axis, which reduced the peak RCS to 11.5dBsm.

A spectrogram analysis was carried out, allowing Doppler velocity information to be extracted from the RCS data. Identifying the RCS of the moving components is important since many types of radar in the United Kingdom use filters to remove signals from static, or slow moving, objects. Therefore, it is the RCS from the moving parts of the turbine, with speeds roughly greater than 10 metres per second, that is likely to have the greatest impact on radar. The peak RCS from a moving component was predicted to be of the order of 4.8dBsm.

A real radar measurement trial was also undertaken by installing a QR qr5 VAWT at the QinetiQ Funtington measurement range on the south coast of England. The final set up of the turbine meant that the radar elevation angle with respect to the turbine was 1.6 degrees, slightly more than was originally modelled with Spectre. Measurements were taken at both 1.3GHz and 2.9GHz using vertical and horizontal polarisations. The peak RCS measured was found to be 18.8dBsm, with a peak RCS from a moving component of 1.1dBsm.

Comparing the measured data to that of the modelled data showed some good agreement when using the 1 degree elevation RAM axis data set. It was decided to run additional Spectre modelling to assess the RCS of the VAWT at 1.6 degrees. Comparing these additional results yielded better agreement between the modelled and measured data sets. It was found that the RCS of the VAWT was extremely sensitive to elevation angle, particularly at 2.9GHz. At 1.6 degrees elevation angle there appeared to be minimal reflection from the vertical axis of the VAWT, which was the dominant feature at 0 and 1 degrees, and explains why the RAM modelled data compared better against the real data than the PEC modelling.

Further analysis showed that overall, the measured data seemed to be slightly higher in RCS than the modelled data, but the high level of background noise in the real measurements made it difficult to pick out some of the blade structure in the Doppler spectra. When comparing images of the real VAWT installed at Funtington to that of the CAD used in the modelling, differences were found which were likely to account for the variations in the data.

The last part of this study examined the detection ranges and cumulative effects for a VAWT. At certain elevation angles, the radar has the potential to see the static component of the turbine out to a range of 32-138km. However, these detection ranges have been calculated in a free space environment without terrain clutter or multipath effects. The static clutter created by the VAWT would be set amongst other real world objects such as houses or lampposts, typical of an urban area At certain elevation angles, the radar has the potential to see the moving component of the turbine out to a range of approximately 51km. Again, urban clutter attributed to cars and trucks, which have a comparable RCS return, would have already created similar clutter levels. Therefore, the addition of a VAWT to this clutter would have limited impact.

Taking into account the use of moving target indicator (MTI) filters in radar, and the likely clutter levels and obscuration associated with the urban environment, it is highly unlikely that a VAWT will add any additional clutter levels to that already seen and dealt with by a radar."