A case of shadow flicker/flashing: assessment and solution

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SYNOPSIS

A short study was carried out investigating a reported problem of shadow flicker and flashing from the blades of a turbine. The incidence of this phenomenon was confirmed and the duration and frequency of occurrence assessed. The shadow flicker period would be short and only occur at certain times, but could cause irritation. A device to stop the turbine when shadow flicker occurred was recommended and is described. A recommendation was made that turbines should be sited at least ten diameters distance from habitations, and more if sited to the East/ Southeast or West/ Southwest, and the shadow path identified.

1 INTRODUCTION

Wind turbines are large structures, which can cast long shadows when the sun is low in the sky. The large rotating blades cast moving shadows which can fall on persons or habitations and cause a flickering or strobing effect. The effect can be pronounced in rooms in buildings facing the turbine, especially if the window is the sole source of light for a room.

There are very few references in the literature to the problem of shadow flicker in relation to wind turbines, although the problem is well known in other fields. To the author´s knowledge, the only substantial study that has been carried out in this area is the study of shadow hindrance from wind turbines by Verkuijen and Westra (1).

However there have been several reports from Denmark and the Netherlands of incidents of shadow flicker disturbance and apparently in one case this has been enough of a nuisance to have the turbine stopped (2).
Although shadow flicker may be thought of as a minor impact of limited duration, it is a disturbance that can cause irritation and lead to complaints. Shadow flicker disturbance will be greatest in the vicinity of the turbine and can be a significant problem where turbines are sited near habitations.

2 EFFECTS OF LIGHT FLICKER

Light flicker effects have been recognised in various fields, such as road tunnel lighting, helicopter aviation, television and film , and studies of epileptic convulsions (3). It has been found that the frequencies of flicker that produce disturbance are between 2.5 Hz and 40 Hz. About 10% of all adults and 15-30% of all children suffer some effects from light flicker (4). 2% of the population are epileptic, and 5% of epileptics show reactions to light flicker of 2.5 Hz to 3 Hz. In extreme cases flicker can induce disorientation or even convulsions in those who are vulnerable. Verkuijlen and Westra consider that frequencies of between 5 and 20 Hz should be absolutely avoided. Certainly, flicker can cause considerable irritation.

3 SHADOW FLICKER FROM WIND TURBINES

Most medium and large wind turbines have a rotation rate of between 30 r/min and 60 r/min, and smaller turbines often have a faster rotation. Most turbines in use today are two or three bladed, constant speed types, producing shadow flicker rates in the range of 1-3 Hz. Variable speed turbines may produce a 2-6 Hz flicker rate. Therefore the shadow flicker from turbines has frequencies that could in the right conditions produce light flicker effects to susceptible persons.

For shadow flicker to occur, the orientation of the turbine and its angle of elevation to the observer or the building must coincide with the angle and position of the sun to the building so that the shadow falls on the building. This will only occur at certain times of the year and day for the location. Additionally, the sun must be shining and the turbine operating at those times for flicker to occur. The shadow will be most pronounced when the blades of the turbine face the building and present the largest shadow area. As the sun moves in the sky, the shadow moves and the flicker period will be limited in duration.

The path of the shadow and its size can be predicted accurately given the location, and turbine dimensions, and so the occurrence, time and duration of flicker periods can be predicted.

4 A CASE OF SHADOW FLICKER

Residents of a neighbouring house claimed that shadow flicker and reflected sunlight from the turbine blades were causing disturbance to them (5). After complaints were made to the local Planning Authority, a study was carried out to investigate the problem.

Firstly confirmation of the incidence of shadow flicker was required and secondly an assessment of the duration and frequency of occurrence. A third objective was to suggest measures to reduce disturbance and lastly how to avoid such situations in the future.

4.1 Assessment

The precise bearings and angles of elevation were obtained from drawings and plans of the turbine and the two houses that are affected by shadow flicker, referred to as house A and house B, (6). See figs 1, 2 and 3.

Sun path diagrams were obtained for 52 degrees N latitude (7) and adjusted for the slightly higher latitude. The study by Verkuijlen and Westra produced a programme to predict the shadow tracks and describe the duration and frequency, but it was not possible to use this programme. Calculation of the precise shadow track would have been possible but within the scope of this short study an easier method was to use existing sun path diagrams to provide a quicker and more approximate result.

The turbine´s dimensions and data were obtained:

- turbine rating: 200kW
- blade diameter: 25m
- tower height: 30m
- swept area: 491m square
- rotation rate: 44 r/min & 33 r/min in light winds
- number of blades: 3
- flicker frequency: 2.2 Hz & 1.65 Hz

The orientation and range of angles of orientation from the two buildings´ windows to the turbine were obtained, and then these angle ranges were marked on the sun path diagrams. The incidence and approximate duration of the shadow tracks can be read from the diagrams.

It was found that the orientation range of the turbine to house A when blades were facing or perpendicular was 142-154 degrees SE. The range of angle of elevation from house A to the turbine blades was 5.2-13.9 degrees.

In the case of house B, the orientation range to the turbine with blades facing the building was 123-112 degrees ESE.
The range of angle of elevation from house B to turbine blades was 2.7-11.6 degrees.

From the sunpath diagram adjusted for the latitude, the sun´s path is at 142-154 degrees SE from house A and between 5.2 and 13.9 degrees elevation in the second half of November, December and early half of January, between the hours of 09-10 and 10-05 am, depending on the exact time of the year.
Therefore flicker was predicted to occur for a period of not more than about 20 minutes between these times but mainly between 09-20 and 09-50 am between Nov. 15 and Jan 15, at house A.

For house B the sun´s path is at 112-123 degrees ESE and between 2.7-11.6 degrees elevation in the months of October (later 2/3rds approx.) and November, first week and January (last week) and February (first two and a half weeks), between the hours of 07-10 and 08-50 am depending on the exact time of the year.
Flicker was therefore predicted to occur for a period of not more than 20 minutes between these times, but mainly between 07-20 and 07-55 am in October after the 10th, through to approx. November 8th and also in the last two weeks of January and first two and a half weeks of February, at house B.

4.2 Shadow Flicker Recommendations

It was recommended that a timer plus photo cell should be employed to automatically switch off the turbine for the duration of the flicker period, which will not be more than about 20 minutes, if the sun is shining and the wind blowing.

In addition it was recommended that the duration and time of year, and day of the flicker period should be confirmed by independent observation, because the accuracy of the Sun path diagram was not known. Since the duration of the shadow flicker period is short, little electricity generation will be lost.

In addition, the number of sunny hours is likely to be small in late October, November, December, January and early February when flicker is predicted to occur, although this will be in the windiest period.

Other solutions that have been suggested are that the turbine should be stopped at those hours when shadow flicker is likely to occur, or that blinds should be fitted. In one reported case the neighbours have been equipped with a switch to shut down the turbine if they are disturbed by shadow flicker.

Clearly it is best to avoid the problem in the first place by attention to careful siting. Wind turbines close to habitations, eg. ten diameters distance should not be sited to the East or South East, or West or South West of habitations, unless the shadow path has been identified and does not fall on windows of habitations or occupied buildings. Verkuijlen and Westra published useful diagrams showing maximum shadow duration contours,shadow tracks and maximum duration curves. Two other alternatives are that the turbine is stopped by a device such as the one described, or that it is sited well beyond the normal separation distance of ten diameters, as the shadow will then no longer be in sharp focus. This distance has not yet been identified.

4.3 Flashing

This is caused by the reflection of sunlight from gloss surfaced light toned blades, when the blades are at a certain angle. The occurrence of this reflection will depend on the time of day, direction of the wind and thus the turbine orientation, and also on the blade pitch. The size of the blades and the swept area will affect the degree of flashing to be expected.

Flashing will occur at the same frequency as shadow flicker ie. 2.2 Hz or 1.65 Hz. It could be a source of irritation and possibly a nuisance. This may occur at any time of the year provided that the sun is shining the turbine operating, and the orientation of the blades is at the right angle. This incidence could not be predicted from the available information.

It was recommended that the blades are coated in a non reflective, non gloss surface to avoid the flashing effect. The effect of atmospheric discolouring and dirt on the white gloss resin blades was observed. Though this discolouring may reduce the effect, flashing still occurred. The turbine manufacturer had claimed that there was no alternative to a gloss finish due to the requirements for an aerodynamic surface (8).

5 GENERAL COMMENTS ON THE SITING OF TURBINES

The minimum separation distance for wind turbines from habitations should be approximately 10 blade diameters. This is emerging from experience and research as a standard guideline, in order to reduce problems of visual impact, noise, shadow disturbance, and safety.

Clearly the turbine in this case does not conform to this general guideline, and this must contribute to the problem here, as well as the siting South East of the houses. The turbine is 7.36 diameters from the house, almost 3/4 of the recommended distance.

6 DESCRIPTION OF A PHOTO CELL/TIMER TO STOP TURBINE CAUSING SHADOW FLICKER AT A BUILDING OR SPECIFIC LOCATION

After discussion with the manufacturer of the turbine, a preference was expressed for a simple non electronic device, rather than any modification to the turbine control programme. The simplest device that can be suggested is a photovoltaic cell, mounted within a box with apertures that can be set to have the same angles and orientation as the sun´s when shadow flicker occurs at the buildings. The photovoltaic cell could then only operate a those times of the year and day when the sun was at the right angle. The voltage from the cell would trip a switch to close down the turbine for the short period of flicker.

Postscript
The shadow flicker has not as yet been confirmed by independent observation, but the objectors have been recording incidents and duration which accord with the predictions but are claimed to be of longer duration, up to one hour. The occurrence of flashing has been independently confirmed.

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(4) WILKIN A.J., BINNIE C.D. DARBY C.E. Visually induced seizures, Progress in Neurobiology, 1980, 15 85-117.

(5) Names of the parties involved and the location have been omitted as the matter is awaiting a planning decision.

(6) Private communication with the Local Planning Authority.

(7) DICKINSON W.C. CHEREMISINOFF P.N. Ed Solar Engineering Technology Handbook 1980 Pt A Engineering Fundamentals, Pub Butterworth, also Sunlight Basic Data.

(8) Private communication with the turbine manufacturer.

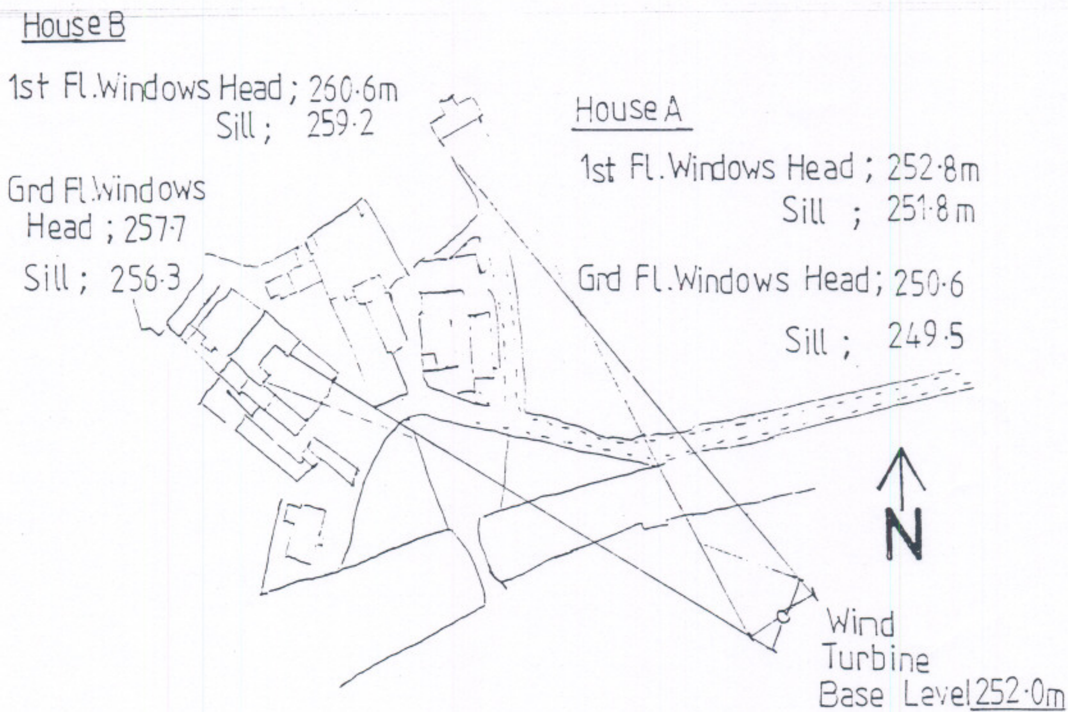

Fig 1 Plan of houses and turbine showing orientation to turbine

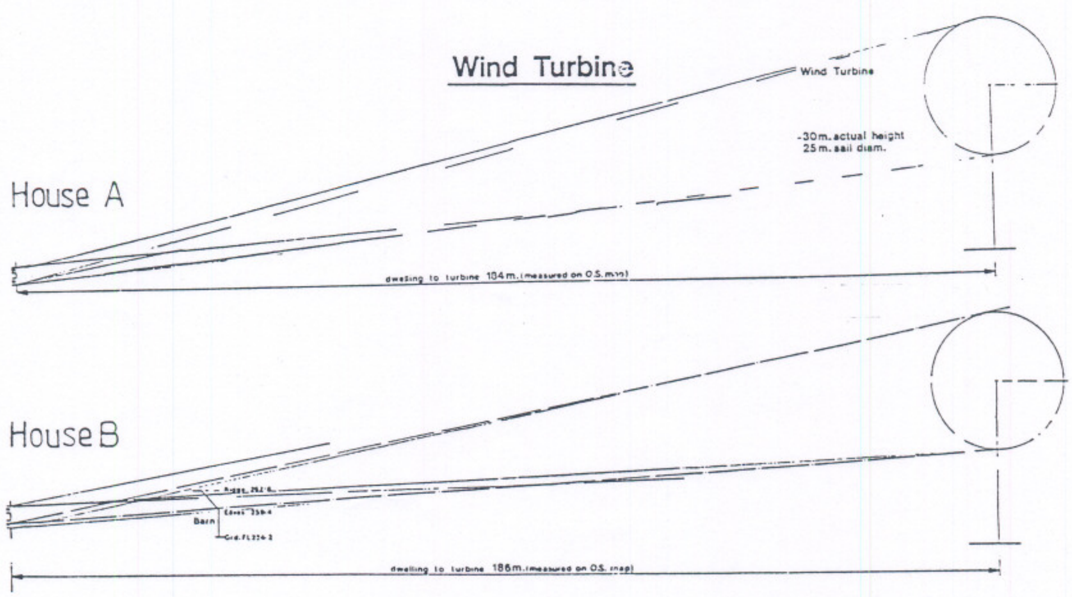

Fig 2 Diagram showing angles of elevation from each house to turbine

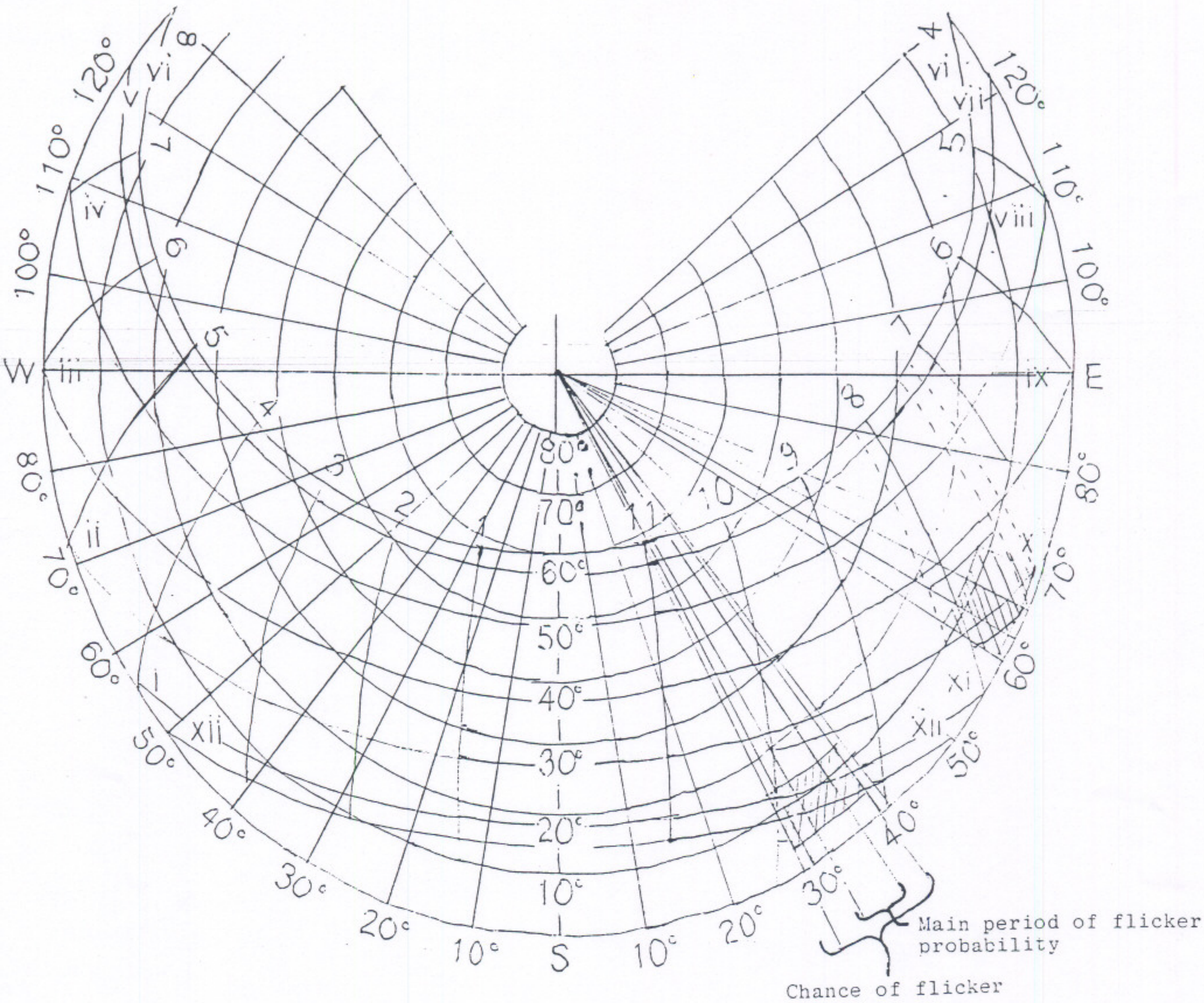

Fig 3 Example of part of the sun path diagram. The shaded area shows the duration and frequency of shadow flicker period