centre for sustainable energy

Common concerns about wind power (2nd edn)

Chapter 13
Shadow flicker and epilepsy risk

This is one of a series of chapters of evidence-based analysis drawing on peer-reviewed academic research and publicly funded studies.

For other chapters, see
www.cse.org.uk/concerns-wind-power-2017

Centre for Sustainable Energy, June 2017

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The first edition of Common Concerns about Wind Power was published in 2011 to provide factual information about wind energy, in part to counter the many myths and misconceptions surrounding this technology.

Since 2011, much has changed in the legal and economic sphere, and a second edition became necessary. Research has been carried out for this edition since 2014. Therefore, this edition is formatted as a series of individual chapters available for download at www.cse.org.uk/concerns-wind-power-2017

All chapters written and researched by Iain Cox.

Centre for Sustainable Energy, June 2017
Written and researched: 2015

The Centre for Sustainable Energy is a national charity committed to ending the misery of cold homes and fighting climate change.

We share our knowledge and practical experience to empower people to change the way they think and act about energy.

We are based in Bristol although most of our work has relevance and impact across the UK. Our clients and funders include national, regional and local government agencies, energy companies and charitable sources.

Chapter 13

Shadow flicker and epilepsy risk

Summary

At certain angles the blades of a wind turbine will rotate in front of the sun, casting a moving shadow that may be seen by observers in nearby dwellings. When there is a narrow opening, such as a door or window, these moving shadows can be of sufficient contrast to project a flickering effect known as 'shadow flicker'. Despite early fears that wind turbines may cause photo-epileptic seizures, studies have shown that modern wind turbines rotate at a rate well below the threshold that would potentially be of risk for vulnerable persons. Whilst it poses no threat to safety, shadow flicker from turbines may be an annoyance factor for observers who are subjected to it for longer than a certain time. However, due to the geometries involved, shadow flicker is an easily modelled property and can be accounted for during planning and development of a wind farm; indeed, even existing wind turbines that are found to cause an issue can easily implement measures to remove the occurrence of shadow flicker. UK government planning regulations stipulate that the possibility of shadow flicker must be considered during wind farm development, and there are a number of software packages that can model the phenomenon consistently and accurately.

What is this based on?

Wind turbines are tall structures, and present an open disc in the form of rotating blades. Depending on the sun's bearing in relation to observers (this is the sun's azimuth) and the sun's altitude in the sky, wind turbines will cast a shadow over nearby ground – this shadow can be a significant length at certain times of the day and at certain times of the year. An important factor in the case of wind turbines is that the rotating blades will pass in front of the sun's azimuth, giving rise to moving shadows that are particularly noticeable through windows and doors where the contrast between light and shade is most apparent. This shadow flicker effect could certainly present an annoyance to exposed residents, and some critics have predicted (wrongly) that sufferers of photosensitive epilepsy would be prone to seizures as a result.

What is the evidence?

A number of different factors must coincide to result in shadow flicker, and the magnitude of the effect can also vary greatly in response to changing conditions.[1] Crucially, the position of the wind turbine in relation to a constrained opening – a window or door – determines whether the flicker effect will be observed. The height and position of the sun, i.e. its azimuth, must also be such that the rotating blades cast a long enough shadow that falls on the critical area; the wind speed must be enough that the turbine is operating during these periods when such shadows may be cast. Finally, the contrast of light and dark, which will determine the magnitude of the effect, is dependent upon prevailing cloud cover and time of year. Due to the latitude of the UK, only dwellings sitting within 130° either side of north relative to the turbines can be affected (going clockwise, that is 230° to 130° from true north); no long shadows are cast southwards by turbines in northern latitudes.[2]

Research carried out at early wind farm developments in the UK showed that shadow flicker only occurs when the shadow is sufficiently in focus and lasts a certain duration, both properties that diminish rapidly with distance from the rotating blades. This led to the '10× diameter' rule, whereby distances that fall within ten times the rotor diameter can create the right circumstances to give rise to shadow flicker.[3,4] For example, a rotor diameter of 80m will potentially give rise to shadow flicker up to 800m away, if conditions are right. This ratio is used as part of the planning regulation guidelines for the siting of wind turbines in the UK.[2]

Since it is possible to predict this phenomenon it is relatively simple to include an assessment of potential shadow flicker when developing a site for a wind turbine. Even if residences may potentially fall within a shadow flicker area this does not necessarily mean a development should be excluded. There are several relatively simply mitigation measures developers can take, such as 'micrositing' to adjust the position of problem turbines within a wind farm, programming the relevant turbines to stop operation in the brief window of time during which shadow flicker has been predicted to affect certain dwellings, and planting a screen of trees between the turbines and the affected properties to disperse the light.[1]

Although the leading software used as standard in the industry gives consistent results between different programs, the lack of real climatic data that is modelled means the predictions are 'astronomical worst case' scenarios.[1] This is meant in relation to the simplifications of the general model, which treats the sun as a point source of light, presents the turbine rotor face as a solid disc formed from perfectly rectangular blades, and assumes the atmospheric conditions are completely clear. Conditions in reality combine so that shadow flicker is not apparent during many of the times when it is predicted to occur. Sunlight hitting the Earth radiates from the disc of the sun, not a point source; the blades of a turbine are trapezoid, so different parts of the blade will cause different levels of shadowing; and on many days the intensity of sunlight is diminished due to atmospheric scattering and the presence of aerosols like water droplets and particulate matter.[5]

Seasonal variation is also important, since the shadow effect is more far reaching in winter when the sun is lower in the sky, but winter also corresponds with more frequent cloud cover so the light is muted (winter also happens to coincide with higher average wind speeds, when turbines will operate closer to their maximum rating for longer).[1] So, in the UK winter months although the sun is lower in the sky and casts longer shadows, 80% of the time the sunlight is not bright enough to create the necessary contrast for shadow flicker to be apparent;[*] even in summertime, the sunlight is not bright enough 60% of the time. The sun must also be at the correct bearing in relation to the turbine rotor face to cast a shadow across an exposed dwelling. Due to this combination of sunlight and bearing, these circumstances in reality only occur together for a fraction of the theoretical maximum calculated by the astronomical worst case scenarios: 15% in winter and 30% in summer. All of these variables have led some to suggest that the shut-down strategy of mitigation, a popular solution for wind farm operators, may be overused in many cases because these real-world conditions are not taken into account.[1,5]

Prolonged exposure to shadow flicker of around 60 minutes or more has been documented to cause transient symptoms relating to stress, such as reduced concentration span and elevated heart rate.[6] Whilst generally not harmful due to the temporary nature of the symptoms, a regard to minimise these effects led German planning authorities to stipulate shadow flicker on exposed buildings is limited to a maximum of 30 hours in the course of a year or 30 minutes per day on the worst affected day.[1] Other planning authorities have adopted similar guidelines, such as Northern Ireland and the Republic of Ireland. In rare cases where repeated exposure has occurred, most often due to office building situated near wind farms, simple mitigation measures have been successfully implemented.[1]

It has also been suggested that shadow flicker poses a threat to the small percentage of epileptics who suffer from photosensitive epilepsy, in which seizures are triggered by flashing lights or contrasting patterns of light and dark.[7] In the UK, the National Society for Epilepsy states that 1 in 100 people suffer from epilepsy during their lifetime, and about 5% of this group will have photosensitive epilepsy.[8] Flashing or flickering at frequencies between 3–30 hertz (Hz) are the most common form of photic stimuli known to cause photo-epileptic seizures, and concern regarding wind turbines was due largely to the fact that rotation frequencies in this range are found in small, building-mounted turbines, not the commercial scale turbines found in wind farms. These smaller turbines have the dual problems of greater blade numbers and faster rotation speeds that create flicker above the critical frequency.[9] Commercial turbines with a three blade design – the industry norm – would have to rotate at 60 revolutions per minute (rpm) to generate a flicker effect of 3 Hz or more, but in fact turbines of this kind rotate at much slower speeds and will not pose a threat to photosensitive epilepsy sufferers during operation.[7,10] Speeds of some representative commercial turbines are illustrated in Table 14.1. Even for smaller 'domestic-size' turbines (up to a rating of about 10 kW) that may possess the potential to induce photo-epileptic seizures, typical atmospheric conditions result in a contrast threshold between light and dark that is significantly reduced such that any observed flicker will not have the capacity to induce epileptic seizures at distances greater than 1.2 times the height of the turbine rotor.[10]

There are some concerns that the flicker effect caused by reflected light from turbine blades can be apparent at greater distances than is taken into account by planners. Note that this strobe effect is different from shadow flicker. However, the same principle with regards to frequency of flicker and the exact positioning of an

Table 13.1 Representative commercial-scale wind turbines and typical rotation speeds during operation

Manufacturer	Model	Rating	Typical rpm
General Electric	GE 1.6-100	1.5 MW	10–16
REpower	MM92	2.0 MW	8–15
Siemens	SWT-2.3	2.3 MW	6–16
Vestas	V112-3.0	3.0 MW	6–17

Figures for rotation speed as stated in ref.7. MW, megawatt; rpm, revolutions per minute

* As light is increasingly scattered by atmospheric conditions it creates a more even ambient light through diffuse radiation; hence, the 'beam' effect of direct sunlight that creates the sharpest constrast shadows is mitigated. On days with complete cloud cover, for instance, the result is muted light levels with no shadows cast.

observer with relation to the turbine are applicable, even though reflected light can affect areas not reached by shadow.[9] Government guidelines advise developers to minimise the specular properties of turbine blades to avoid light reflecting off the blades unduly; indeed minimising reflectiveness of the blades is something the industry has been carrying out for several decades already, and it is typically no longer an issue.[1,2,11]

Conclusion

Shadow flicker from the rotating blades of a wind turbine is a known, quantifiable effect. Large commercial turbines can potentially create a flicker effect at frequencies below 2 Hz, safely below the threshold that can cause photo-epileptic seizures, and there is no evidence that the operating characteristics of commercial wind turbines can induce seizures in the vulnerable population of epilepsy sufferers. If endured continuously for prolonged periods, the annoyance factor of shadow flicker can lead to temporary stress-related symptoms in observers, but planning guidelines and mitigation measures can ensure this situation does not occur.

Due to the precipitating factors, which involve turbine position in relation to the solar azimuth and sun's altitude above the horizon relative to an observer, this phenomenon can be accurately modelled and predicted. In practice, shadow flicker occurs within narrow spatio-temporal limits. This means that even if it is predicted to affect certain dwellings, shadow flicker is only apparent when the intensity of sunlight and angle of the blades to an observer combine with the sun's position in the sky to create a noticeable effect – this is effectively for short periods in any single day affecting those particular dwellings that are vulnerable during such periods.

The predictability and infrequency makes shadow flicker an eminently manageable problem: it can be curtailed by the introduction of various mitigation measures, among them re-siting of individual turbines, creating screening features such as treelines (or using existing ones), and programming the turbines to cease operation for the short time during which offices or dwellings are affected.

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