VAISALA

PWD20W Visibility Measurement Solution

Visibility Measurement for Wind Turbine Obstruction Light Control

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Just imagine how bright red and white flashing lights shining in the windows of your home could distract you from your daily tasks or make sleeping difficult. This is the reality faced by many people living or working near wind farms. Over 80 countries globally are now using wind power commercially, leading to project development closer to population centers. Given the challenging permitting and construction process, it is in the best interest of wind farm project developers to have the support of the local community. Vaisala is helping wind farm developers and their nearby constituents better manage the effects of wind turbine obstruction lights by using its visibility measurement technology to dim the lights in clear weather conditions. Germany has had a regulation in place since 2004 supporting the use of visibility controlled obstruction light intensity and many other countries are considering its adoption.

Introduction to Obstruction Lights

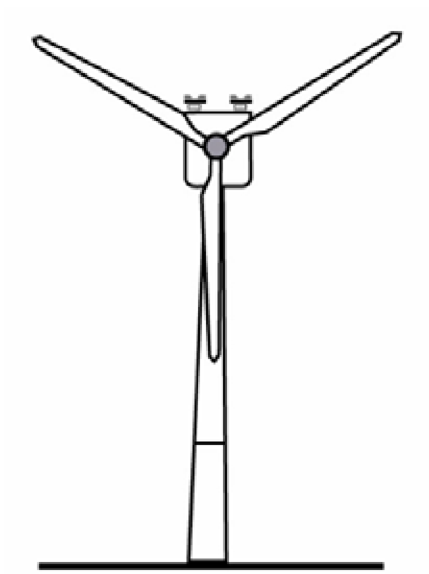
Obstruction lights are high-intensity lighting devices that are attached to tall structures to make them more visible to passing aircraft for collision avoidance. They generally are seen as red or white lights that are constantly illuminated, flashed, or strobed. In the past, red lights used incandescent filament bulbs and white lights used xenon but the recent development of high-power LED (light emitting diode) arrays with sufficient brightness has lowered power consumption and improved reliability. Dual lighting of a structure is common to avoid painting requirements, with white strobes used during the daytime and red beacons/strobes during nighttime.

Wind Turbine Obstruction Lighting Requirements

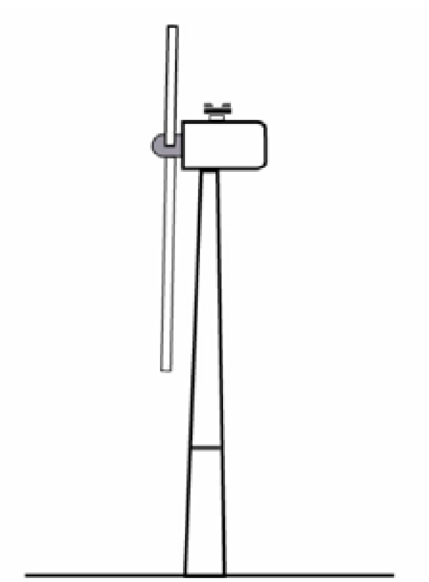
The United States FAA (Federal Aviation Administration) Obstruction Marking and Lighting Advisory Circular (AC 70/7460-1K) and Germany AVV (General Administrative Regulation) for the Marking and Lighting of Obstacles to Air Navigation provide recommendations for wind turbine farms. The FAA defines a wind turbine farm as a “wind farm development that contains more than three (3) turbines of heights over 61 meters (200 feet) above ground level”. Not every wind turbine must be lighted, but the FAA requires unlit gaps of no more than 805 meters (0.5 statute miles). The German AVV advises that all wind turbines be equipped with obstruction lights, but interior turbines can be omitted on a case-by-case basis. Light fixtures should be placed as high as possible on the turbine nacelle so they are visible from 360 degrees and not obscured by the rotating blades. Any array of flashing or pulsed obstruction lighting should be synchronized or flash simultaneously. Nighttime wind turbine obstruction lighting should consist of the preferred aviation red-colored flashing lights. Daytime lighting of wind turbine farms is not required, as long as the turbine structures are painted in a bright white color or light off-white color. Otherwise, medium intensity flashing white obstruction lights are recommended for daytime use.

Rationale for Obstruction Light Intensities

The United States FAA General Operating and Flight Rules (FAR Part 91) prescribe aircraft speed restrictions, minimum safe flying altitudes, and VFR (visual flight rules) weather minimums for governing the operation of aircraft within the U.S.



Front View



Side View

Figure 1. Typical lighting of a stand-alone wind turbine as shown in the U.S. FAA Advisory Circular AC 70/7460-1K

Distance/Intensity Table

Time Period	Meteorological Visibility Statue Miles	Distance Statue Miles	Intensity Candelas
		2.9 (4.7km)	1,500 (+/-25%)
Night	3 (4.8km)	3.1 (4.9km)	2,000 (+/-25%)
		1.4 (2.2km)	32
		1.5 (2.4km)	200,000
Day	1 (1.6km)	1.4 (2.2km)	100,000
		1.0 (1.6km)	20,000 (+/-25%)
		3.0 (4.8km)	200,000
Day	3 (4.8km)	2.7 (4.3km)	100,000
		1.8 (2.9km)	20,000 (+/-25%)
Twilight	1 (1.6km)	1.0 (1.6km) to 1.5 (2.4km)	20,000 (+/-25%)?
Twilight	3 (4.8km)	1.8 (2.9km) to 4.2 (6.7km)	20,000 (+/-25%)?

Table 1. Minimum obstruction light intensities given meteorological visibility in different conditions under U.S. FAA FAR Part 91 operating standards (FAA 1989). Note: Distance calculated for North Sky Illuminance

Flight visibility is the average forward horizontal distance, from the cockpit of an aircraft in flight, at which prominent unlighted objects may be seen and identified by day and prominent lighted objects may be seen and identified by night. Whereas, meteorological visibility denotes the greatest distance that selected objects (visibility markers) or lights of moderate intensity (25 candelas) can be seen and identified under specified conditions of observation.

Pilots of aircraft traveling at 165 knots (190 mph / 306 kph) or less should be able to see obstruction lights in sufficient time to avoid a wind turbine by at least 610 meters (2,000 feet) horizontally under all conditions of operation, provided the pilot is operating in accordance with FAR Part 91. Pilots operating between 165 knots (190 mph / 306 kph) and 250 knots (288 mph / 463 kph) should be able to see the obstruction lights unless the weather deteriorates to 4.8 kilometers (3 statute miles) visibility at night, during which time period 2,000 candelas would be required to see the lights at 1.9 kilometers (1.2 statute miles). A higher intensity, with 4.8 kilometers (3 statute miles) visibility at night, could generate a residential annoyance factor. In addition, aircraft at these speed ranges can normally be expected to operate under IFR (instrument flight rules) at night when the visibility is 1.6 kilometers (1 statute mile).

Local Acceptance of Wind Turbines

Studies conducted in 2010 and 2012 by Hübner and Pohl analyzed feedback from over 400 people living near 13 wind farms in Germany. Sixteen percent (16%) of the respondents indicated strong annoyance with wind farm obstruction lights, with discernible stress effects evident. Under certain weather conditions, such as clear nights, obstruction lights were more of a disturbance. The results showed that people living near wind farms without visibility-adjusted obstruction light intensity were more frequently using window blinds, spent less time in their bedroom, and took more sleeping pills. This study and others similarly conducted have shown that red LED lights are effective in reducing impacts on neighboring communities, as the lights' exposure time is minimal, thus creating less of a nuisance. Synchronization of the lights also limits the disturbance to those surrounding a wind farm.

The IEA Wind Social Acceptance of Wind Energy Projects recommends to minimize the light intensity of wind turbine obstruction lights by the following:

1. Abandon xenon white lights
2. Synchronize the lights in a wind farm
3. Apply light intensity adjustment using visibility measurements
4. Create less stressful planning and construction periods
5. Allow and use demand-oriented obstruction lights

Germany Regulation for Visibility Controlled Wind Turbine Obstruction Lights

The German national administration (AVV 2007) established regulations for the marking of wind turbines in 2004 in accordance with existing aviation obstacle guidelines. White flashing lights are permitted for daytime marking use and red flashing lights for nighttime use. If the visual range is better than 5 kilometers (3.1 miles), the light intensity may be reduced to 30%, and if the visual range is better than 10 kilometers (6.2 miles), it may be reduced to 10%. Visual range is determined as meteorological visibility by means of a device certified by the German meteorological service (DWD). In a wind farm, the distance between a wind turbine with visual range measuring equipment and those without shall not be more than 1.5 kilometers (0.9 miles). The measuring devices shall be installed close to the generator housing (nacelle). The worst visibility measurement taken by one of the devices shall be used for the entire wind farm. In the case of visibility measurement failure of at least one of the devices, all lights shall be operated at an intensity of 100%. The data concerning the correct operation and the results of the measuring devices shall be continuously recorded and retained for a minimum of four weeks.

Vaisala PWD20W Visibility Measurement Solution

Vaisala Visibility Sensor PWD20W for Wind Energy uses the proven forward-scatter measurement principle to measure Meteorological Optical Range (MOR). Its measurement range of 10 meters to 20 kilometers supports the visibility requirements established for wind turbine obstruction light control. The sensor is calibrated with reference to a highly accurate transmissometer during the manufacturing process. The sensor is well-protected against contamination with the optical components oriented downward and hoods protecting the lenses against precipitation, spray and dust. Hood heaters are also standard to prevent ice and snow accumulation.

The PWD20W measures light scattered at an angle of 45 degrees. This angle produces a stable response in various types of natural fog. Precipitation droplets scatter light in a different manner as fog and their contribution to visibility must be analyzed separately. PWD20W can detect and measure precipitation droplets from the optical signal and use this information in processing the scatter measurement results.

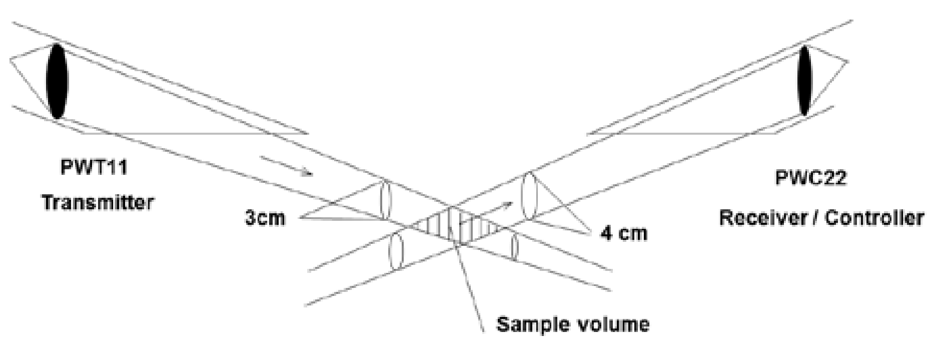


Figure 2. Visualization of the Vaisala PWD20W operating principle where the transmitted signal is backscattered into the receiver to measure meteorological visibility

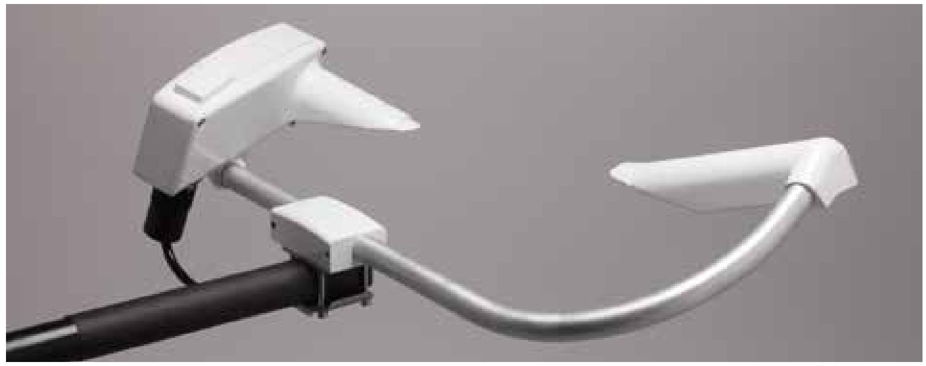


Figure 3. Vaisala Visibility Sensor PWD20W

Most visibility sensors operate in the near infrared wavelengths. Whenever the obstruction lights contain these wavelengths, the flashes may interfere with the measurements. Vaisala has developed specific algorithms for PWD20W to identify and eliminate the possible interference caused by the flashing obstruction light.

Before commercial launch of the solution in 2006, field testing was conducted on a wind turbine in Germany with hub height of 85 meters and a rotor diameter of 77 meters to verify that the visibility measurement performance is not influenced by the installed obstruction lights. Different mounting configurations were evaluated along with obstruction light filtering software. The results showed that installing the PWD20W at a height level below the obstruction light on the nacelle significantly limits its influence on the visibility measurement. Care should be taken to ensure that the PWD20W is mounted high enough above the nacelle surface that no reflection from the transmitter signal beam will reach the receiver. The visibility measurements were in accordance with the observed meteorological conditions.

Visibility Measurement Complements New Industry Solutions

The wind power industry is actively testing new demand-oriented solutions to improve the local acceptance of wind turbine obstruction lights. One such concept is an aircraft surveillance radar system installed at the wind farm that activates the wind turbine obstruction lights only when an aircraft is the vicinity of the wind farm. Another alternative concept requires aircrafts to have a transponder that sends a signal to activate the obstruction lights when near the wind farm. Visibility measurement can still complement these solutions by providing the supporting information to ensure that the obstruction light intensity is appropriate for the meteorological conditions when they need to be activated.

Figure 4. The Vaisala PWD20W installed on a wind turbine in the recommended location below the obstruction light on the nacelle.

Citations

- AVV (2007). General Administrative Regulation for the Marking and Lighting of Obstacles to Air Navigation. (24 May 2007).

  Allgemeine Verwaltungsvorschrift zur Kennzeichnung von Luftfahrthindernissen. Deutsche Flugsicherung – FfL I 143 / 07 NACHRICHTEN FÜR LUFTFAHRER – TEIL I – Langen, 24.Mai.2007 / Nichtamtliche Übersetzung erstellt durch den Bundesverband WindEnergie e.V.

- FAA (1989). U.S. Department of Transportation Federal Aviation Administration. FAR 91, General Operating and Flight Rules. (18 August 1989).

- FAA (2007). U.S. Department of Transportation Federal Aviation Administration. Advisory Circular, Obstruction Marking and Lighting AC 70/7460-1K. (February, 2007).

- Hübner and Pohl (2010 and 2012). Acceptance and stress effects of aircraft obstruction markings of wind turbines. Energy Policy, Vol 50, pgs. 592-600 (November, 2012).

  Akzeptanz und Umweltverträglichkeit der Hinderniskennzeichnung von Windenergieanlagen. http://sozpsy-forschung.psych.uni-halle.de/HKworkshop/projektbericht/HK_Abschlussbericht_MLU_04_05_10.pdf

- IEA Wind (2013). Expert Group Summary on Recommended Practice, 14. Social Acceptance of Wind Energy Projects 1. Edition 2013. (January 2013).

- Rudolph, Andy (2012). Wind Turbine Obstruction Lighting. Wind Systems Magazine, pgs. 68-72 (June, 2012).

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