Arnold Schwarzenegger
Governor

FAA OBSTRUCTION LIGHTING STANDARDS FOR WIND ENERGY PLANTS

PIER INTERIM PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

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California Wind Energy Collaborative

December 2005
CEC-500-2005-180

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Davis, California
Contract No. 500-02-004
Work Authorization MR-017

Prepared For:
California Energy Commission
Public Interest Energy Research (PIER) Program

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FAA Obstruction Lighting Standards for Wind Energy Plants

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DATE

May 2005

REPORT NUMBER

CWEC-2005-003

PREPARED FOR

California Wind Energy Collaborative,
sponsored by the California Energy Commission
Public Interest Energy Research (PIER) program

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1 Summary

With heights of modern utility-scale wind turbines exceeding 200 ft (61 m), wind energy developers in recent years have had to submit lighting proposals for wind plants to the Federal Aviation Administration (FAA). The current FAA guidelines for wind plant obstruction lighting have not been developed to a level where developers can know with some certainty what lighting scheme the FAA will approve for proposed construction. The California Wind Energy Collaborative (CWEC) initiated a study of FAA obstruction lighting for wind plants to determine the issues surrounding the subject. A literature survey and interviews on the subject were conducted. During the period of investigation, the CWEC was able to observe flight tests with the FAA of a wind farm configured for new lighting standards. Key elements of the proposed standards are synchronization of the flashing lights and maximum 0.5 mi. (0.8 km) spacing between lighted turbines. It is expected that the new standards will improve flight safety and streamline the FAA recommendation and permitting processes for wind plant developments.

2 Nomenclature

Specific terms and acronyms used throughout this paper are defined as follows:

Acronym	Definition
AGL	Above Ground Level
AWEA	American Wind Energy Association
CanWEA	Canadian Wind Energy Association
CFR	Code of Federal Regulations
CWEC	California Wind Energy Collaborative
DOE	U.S. Department of Energy
EIR	Environmental Impact Report
FAA	Federal Aviation Administration
NAD	North American Datum
NWCC	National Wind Coordinating Committee
UTM	Universal Transverse Mercator
WECS	Wind Energy Conversion System

3 Introduction

Proposed structures that exceed 200 ft (61 m) above ground level (AGL) in height in the United States are considered obstructions to navigable airspace according to the Code of Federal Regulations (CFR, United States 2005a). Although these structures are not specifically regulated by the Federal Aviation Administration (FAA), the FAA must be notified of proposed construction. Other authorities, such as the Federal Communications Commission (for antenna structures), and local Counties, provide regulatory language that FAA recommendations for obstruction lighting must be followed.

Although early stand-alone MOD-series wind turbines exceeded 200 ft (61 m) in total height (see Figure 1 for dimensions) and required obstruction lighting, only in the last decade has there been large-scale manufacturing of turbines over 200 ft. Nearly every utility scale wind turbine sold today exceeds 200 ft (61 m) in height. Wind plants are now constructed with up to 200 of these large turbines. Obstruction lighting now becomes a formidable permitting issue, which impacts the scheduling and economics of the development, and will have a community visual impact.

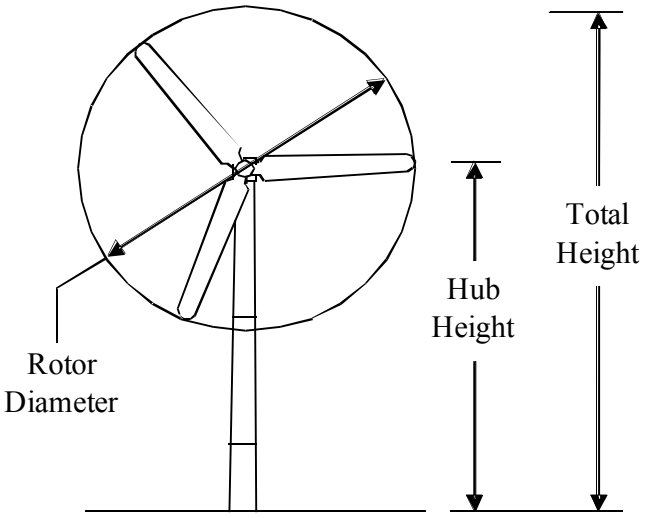

Figure 1. Wind Turbine Dimensions

The primary goal of the FAA recommendations is to ensure pilot safety. In the United States, there are no known incidents of an aircraft striking a utility-grade wind turbine. There is one reported case of an aircraft striking a farmers wind turbine (Maller 2000), however the accident report for the crash does not mention the aircraft crashing into the turbine (NTSB 2000).

The California Wind Energy Collaborative (CWEC) has undertaken a study of wind turbine obstruction lighting under its Windplant Optimization task. Obstruction lighting

was determined to be an issue of concern for California wind plant developers and operators. By studying the issues of obstruction lighting, perhaps solutions to overcome the issues could be determined.

The scope of this study is limited to obstruction lighting of wind plants away from airports where different considerations can take effect. This boundary is a 20,000 ft (6096 m) according to the CFR (United States 2005a). Low flying military operations are also not discussed; for this topic the reader is referred to a report by the British Department of Trade and Industry (Department of Trade and Industry 2002) on this subject.

4 Obstruction Lighting and Marking Advisory Circular

4.1 Purpose

The *Obstruction Marking and Lighting* Advisory Circular (FAA 2000) is the current document that offers guidance for the lighting of wind turbines. Developers also submit to the FAA a *Notice of Proposed Construction or Alteration* (FAA 1999), describing the structures to be lit. The Advisory Circular is not a regulation; however binding language to follow FAA recommendations exist for the FCC for radio towers and in some California county ordinances as listed in Table 1. Counties with no current binding language are Alameda, Contra Costa, Kern, and Merced.

Table 1. Obstruction Lighting References in California County Ordinances

	Internet Site	Ordinance	Obstruction Lighting Reference
Riverside	http://www.tlma.co.riverside.ca.us/planning/ord348.html	Ordinance 348, Section 18.41, Commercial Wind Energy Conversion Systems Permits	Section 18.41.c.(10) Application; Section 18.41.d.(20) Standards
Solano	code for wind energy not available on internet	Wind Turbine Siting Plan and Environmental Impact Report 1987	Page 33 Public Safety; Page 123 Air Traffic Safety; not in conditions for approval

As an example, the language in the Riverside Ordinance (Riverside County California 2001, §18.41.c.10) is as follows:

"If the application includes any WECS [Wind Energy Conversion System] *with a total height over 200 feet or any WECS which is located within 20,000 feet of the runway of any airport, the application shall be accompanied by a copy of written notification to the Federal Aviation Administration."*

The 200 ft (61 m) height restriction for unlit structures provides a buffer for aircraft flying according to the federal regulations. These can be found in the Aeronautics and Space Title 14 of the CFR (United States 2005b, §91.119). It states that for other than congested areas, 500 ft (152 m) altitude must be maintained from the surface, except in sparsely populated areas. At all times a 500 ft distance must be maintained from any person, vessel or structure. The 200 ft (61 m) threshold on lighting allows for at least a 300 ft (91 m) safety buffer for unlit structures in populated areas. Figure 2 shows the 500 ft level compared to a typical wind turbine height. The regulation also states the aircraft speed below 10,000 ft (3048 m) must be less than 250 knots. (129 m/s).

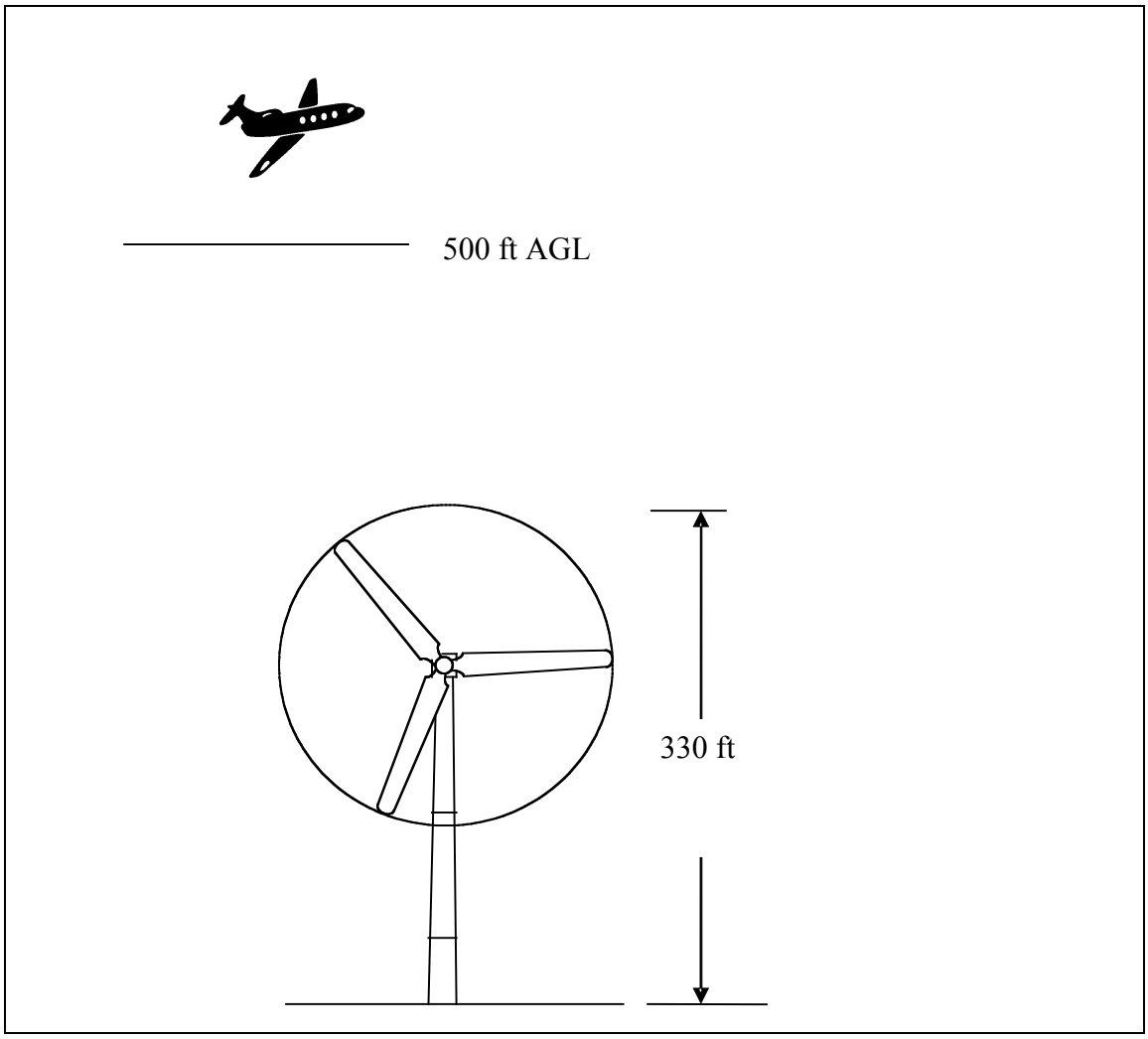

Figure 2. Typical Wind Turbine Height Comparison to 500 ft AGL

4.2 Wind Turbine Marking

Marking is a method for making structures conspicuous to pilots during daylight hours. Alternating bands of orange and white are recommended for wind turbines. An example scheme is shown in Figure 3.

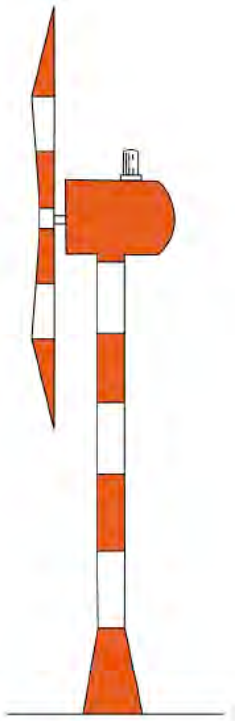

Figure 3. Wind turbine marking (FAA 2000)

The author is unaware of any current turbines with such markings in the United States; however three MOD-2s installed in Goldendale, Washington, and the WTS-4 turbine installed in Wyoming were painted in this manner (Spera 1994, p. 129 and 143). Several turbines in Europe are also marked in this scheme (Gasch and Twele 2002, pp. 45, 51, and 53). It is unlikely that marking will be used again in the U.S. due to cost and community opposition. The Advisory Circular allows for white flashing lights for daytime conditions, discussed in section 4.3, which omits the need for marking.

4.3 Wind Turbine Lighting

Lighting recommendations are for both conspicuousness in daylight and nighttime. Three types of lights are mentioned for wind turbines (see Table 2). Lights must be approved by the FAA following the *Airport Lighting Equipment Certification Program* Advisory Circular (FAA 1998a). Specifications for the lights specific to wind turbines can be found in the *Specification for Obstruction Lighting Equipment* Advisory Circular (FAA 1995). Typically a wind turbine manufacturer will buy equipment from an FAA-approved supplier. An example obstruction lighting installation can be found on the nacelle in Figure 4. Although there are some innovative solutions for wind turbine obstruction lighting, such as blade tip lighting from Enertrag (http://www.enertrag.de/index_en.php), they have not pursued FAA certifications in the United States.

Table 2. FAA obstruction lighting types for wind turbines

Lighting Type	FAA Designation	Flashes per minute	Peak Intensity (candela)
Flashing Red	L-864	20-40	2,000
Medium Intensity Flashing White	L-865	40	20,000 (day) 2,000 (night)
Dual Lighting with Red/Medium Intensity Flashing White	L-864/L-865	20-40/40	2,000/20,000

Figure 4. Nacelle installation of obstruction light (photo courtesy of Jim Patterson)

Red lights are for nighttime conditions, whereas white lights can be used for both day and night conditions. Wind turbines are not mentioned in the sections for steady red (L-810) or for high intensity flashing white (L-856). Some steady red lights are included in recommendations for wind plant layouts (for example, see section 7.3). The most commonly used lights for wind turbines are dual-lighting with red/medium-intensity flashing white. This is probably to avoid the community visual impact of nighttime flashing white lights.

All of the lights in Table 2 have a minimum vertical beam spread of 3° in order for the light to be most visible to oncoming aircraft. A diagram of the vertical beam spread with the expected low-visibility maximum range (FAA 2000) is shown in Figure 5. Lights can be designed to minimize the intensity at angles beyond this range, thus reducing the community visual impact.

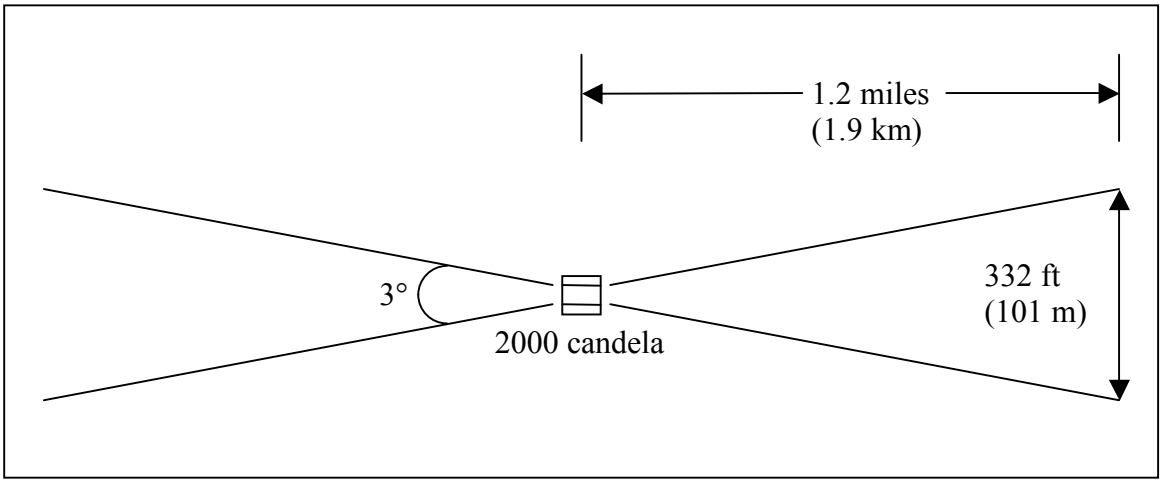

Figure 5. Vertical beam spread with expected low-visibility maximum range (not to scale)

Justification for the light intensity is provided in the advisory circular (FAA 2000, Appendix 2), and is based on minimum visibility in various conditions. A pilot should be able to see the obstruction lights in sufficient time to avoid the structure. This requirement is balanced by public acceptance, and Montgomerie (2004) suggests the possibility of a breakeven point represented in Figure 6.

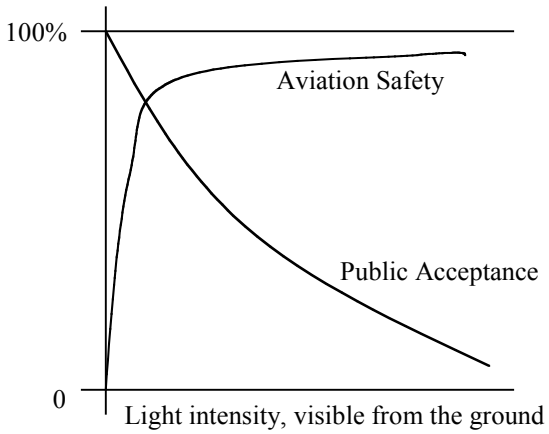

Figure 6. Aviation safety and public acceptance for light intensity (Montgomerie 2004)

The other specific recommendation in the Advisory Circular (FAA 2000) is that wind turbines should be lit by two lights on top of the nacelle (see Figure 7). The horizontal separation of the two lights should be such to ensure an unobstructed view of at least one fixture by a pilot approaching from any direction. There is no lighting requirement for the upper extremity of the turbine, which would be the blade tip at the 12 o'clock position.

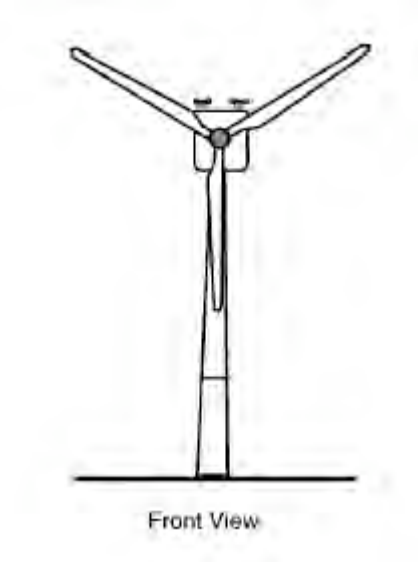

Figure 7. Dual Lighting Representation (FAA 2000)

4.4 Wind Plant Lighting

Original rules for the marking and lighting of wind turbine plants were to be based on standards developed for "antenna farms" (United States 2005a, §77.77-1100) that never came to fruition. Wind plants are mentioned in the circular (FAA 2000); however, no guidance is provided for lighting of an entire wind plant. One prominent mention is that groups of wind turbines are excluded from the exception that only the prominent structure within the group needs to be lit. Language from the document regarding wind plants is as follows:

"Recommendations on marking and/or lighting structures can vary depending on terrain features, weather patterns, geographic location, and in the case of wind turbines, number of structures and overall layout of design."

The process for obtaining FAA recommendations on a proposed wind plant lighting scheme is described in Section 5.

5 FAA Recommendation Process

The *Notice of Proposed Construction or Alteration* (FAA 1999) is submitted by the sponsor (wind plant developer) to the Manager of the FAA Regional Air Traffic Division office. California is in the jurisdiction of the Pacific Regional Office, located in Los Angeles. There are two representatives in the office, dividing California at the 36° parallel (just north of Tehachapi). Coordinates for the turbines are required in latitude and longitude using either North American Datum NAD 27 or NAD 83. The application process is outlined in Figure 8.

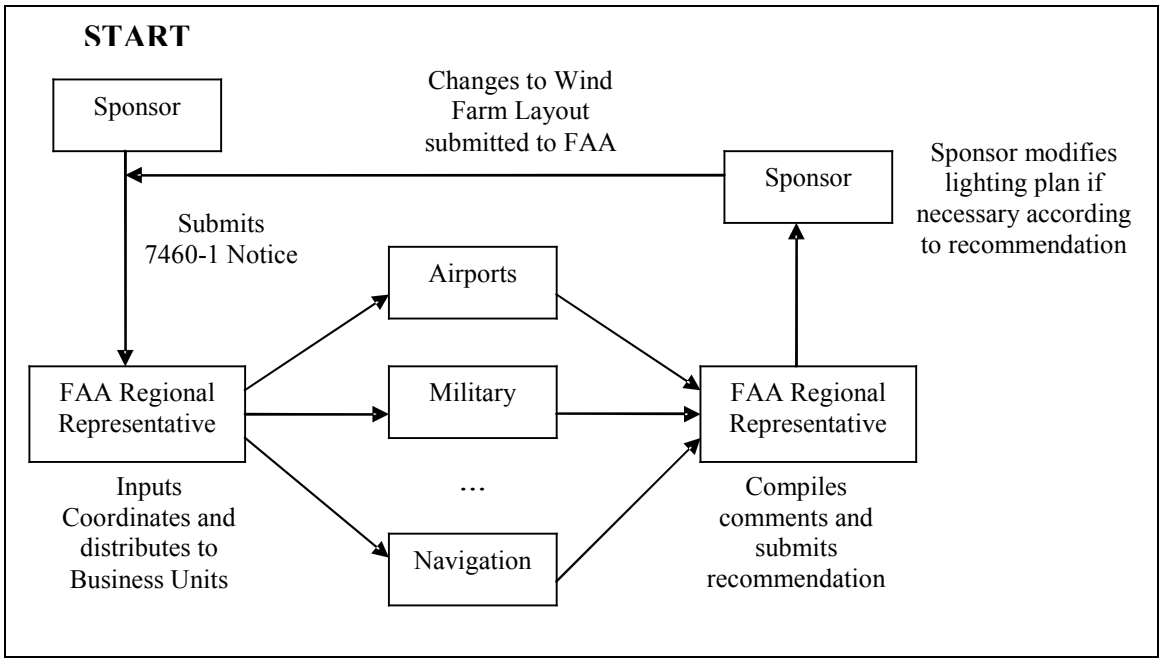

Figure 8. FAA Obstruction Lighting Application Process

The sponsor proposes the lighting pattern, usually based on prior experience and economics. When the form is received the coordinates are entered into mapping software by the FAA representative and submitted to seven business units to comment on the layout. At this point the FAA representative becomes a manager of the project, compiling the recommendations from the business units and submitting an overall recommendation back to the sponsor. The process repeats if turbines must be re-sited for any reason. At the completion of construction the *Notice of Actual Construction or Alteration* form (FAA 1998b) must be submitted to document the existing condition of the layout.

A wind plant developer would have to propose a lighting plan based on previous experience, or, by default, light every turbine within the wind plant. The developer would then have to wait for the FAA response without knowing if the recommendations would require changes to the lighting scheme. In the meantime, permitting and environmental impact reports for the wind plant would be based on the proposed lighting

scheme. This process has become an area of uncertainty for the wind industry. A statement to this effect is found in the Altamont Repowering Environmental Impact Report (Alameda County 1998):

"With regard to the Repowering Program, analysis of night lighting impacts is not feasible since turbine placement and turbine height for future projects is unknown and would be essential data required for an FAA decision. Further, the FAA does not provide abstract advisory opinions and responds only to site specific construction proposals. Since FAA decisions are site specific and fact-driven, any attempt by the counties to predict the variety of potential FAA decisions for a multiplicity of possible development proposals in the APWRA [Altamont Pass Wind Resource Area] would be speculative."

In speaking to developers, a common concern was a lack of consistent recommendations from the FAA Regional Offices nationwide. An example is a farm in Iowa where the FAA recommended lighting every turbine, compared to a project in Southern California where the recommendation came back with spacing between lights at 0.5 miles (0.8 km) with lighting at the end of the rows. In this comparison the flat terrain project had 100% lighting, whereas the project in complex terrain had 25% lighting.

Another concern voice by developers was the sometimes long length (up to one year) of evaluations of projects. This can be especially detrimental if changes need to be made in turbine positions in the life of the project.

These issues point to a lack of consistent standards for lighting of wind plants, leading to uncertainty for both the sponsor and the FAA. Only recently, perhaps in the past five years, has there been large-scale development of wind plants that require obstruction lighting. Not only was this a new workload for the FAA, with hundreds of new applications, but a completely different flight safety issue emerged with multiple obstacles within a large region. Because of these problems, the United States Department of Energy (DOE) and the FAA began a program to specifically develop new standards wind plant obstruction lighting.

6 Development of Obstruction Lighting for Wind Turbine Farms

6.1 Background

In 2002 the DOE set aside funds for an interagency agreement with the FAA to test new standards for wind plant obstruction lighting. The project was titled "Development of Obstruction Lighting for Wind Turbine Farms." In context the industry had been moving beyond the 200 ft (61 m) height for wind turbines, and the amount of notices to the FAA for evaluation had been increasing every year.

The FAA Technical Center in Atlantic City, New Jersey, became the technical lead for the project. An overview of the project can be found in the references (Patterson 2004). In initial discussions with the American Wind Energy Association (AWEA), the FAA decided to conduct flight evaluations at four sites spread throughout the country. The sites would be representative of typical wind farm terrain. The sites evaluated are listed in Table 3.

Table 3. FAA Evaluation Wind Plant Sites

Wind Plant Name or Area	State	Turbine Type	Terrain
Big Spring	Texas	Vestas V47 and V65	mesa top
Clear Lake	Iowa	NEG Micon 750 kW	flat agricultural
Somerset	Pennsylvania	Enron Wind 1.5 MW	rolling agricultural
Tehachapi	California	various	multiple ridgelines

The sites were evaluated from the ground and the air in a general aviation aircraft by lighting experts from the FAA Technical Center. An additional seven sites were evaluated that were in close proximity to the four sites. The preliminary findings were issued in an internal FAA report in January 2003. Key findings from the flight evaluations (Patterson 2004) are discussed in sections 6.2 to 6.4.

6.2 Lighting Type

The evaluations showed that daytime lighting with flashing white (L-865) went unnoticed. The wind turbines were seen well before the lights were. The typical white-painted turbines provide a dramatic contrast to virtually all varying terrain that was observed during the site visits, even in poor visibility conditions. This recommendation to omit daytime lighting would improve community visual impact in addition to reducing wind plant capital costs.

For nighttime lighting, red lights were the preferred over white lights. However, steady burning red lights (L-810) were virtually invisible until the aircraft was upon the turbine. Eliminating steady red lights might improve the wildlife impact according to the policy on wind energy from the American Bird Conservancy (2004). However research in the area of wildlife impact and lighting is not currently conclusive according to the National Wind Coordinating Committee (NWCC 2004).

The requirement to equip the lighted wind turbines with two light fixtures (see Figure 7) was determined redundant for a wind plant. Stand-alone turbines should remain with dual-lighting. This recommendation would decrease capital costs. However, light fixtures mounted flush to the turbine nacelle should be positioned higher than rotor hub, so as not to obscure the forward view (see Figure 9). This requirement is not spelled out in the Advisory Circular (FAA 2000), probably because turbine designs with large hub spinners were not envisioned.

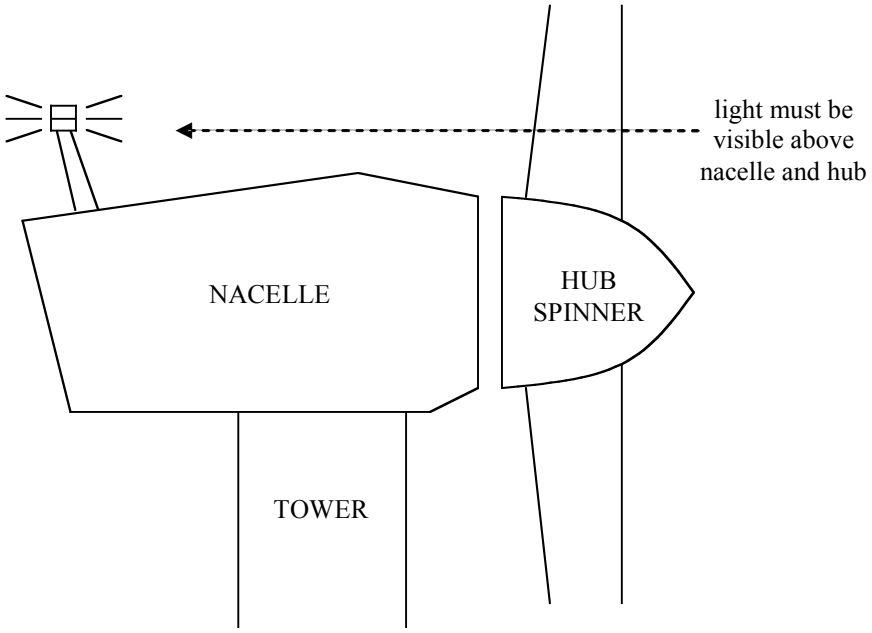

Figure 9. Position of light on turbine nacelle for unobstructed view

It was also determined that meteorological towers, which have the same lighting requirements and are typically prolific in wind plants, were an effective platform on which lights could be mounted.

6.3 Wind Plant Lighting Patterns

The evaluations determined that lighting on the interior of clusters was not necessary and lighting should be positioned on outer turbines. This would reduce the capital costs of the wind plant. However, there might be some objection to this recommendation if the interior of the cluster includes a ridgeline.

A mixture of lighting types in a wind plant was found to be confusing. White flashers, when used in conjunction with red flashing or steady burning, created a distraction. Also, steady reds combined with flashers were washed out. By recommending a single type of light, community visual impact would improve in addition to reducing capital costs.

One fortuitous finding was determined during the chance synchronization of lights in the Tehachapi wind resource area. Synchronization of lights showed great promise in allowing pilots to gauge the extent of the wind plant. This synchronization is similar to that found on bridge towers, where the simultaneous flashing of lights implies a connection. This finding for wind plants provides a great benefit to flight safety. Although the control for synchronization would increase capital costs, the infrastructure (fiber optic control lines to each turbine) for implementing this scheme is usually in place in wind farms. For several wind plants in one area, the question remains whether all obstruction lights within the area should be synchronized.

Currently there are no known studies on community acceptance with obstruction lighting. However, there might be a benefit of community acceptance with synchronized lights. With a large amount of unsynchronized lights, there is always a possibility that at least one light will be on at all times, and at different locations. For a ground observer this could be a visual distraction, in comparison to the continuous pattern of synchronized lights.

6.4 Separation between Lighted Turbines

Acceptable separation gaps for unlit turbines were determined to be around 0.5 mi. (804 m) based on the flight evaluations. This is an area of controversy, because it has a direct impact on the capital costs of the wind plant. Transport Canada had proposed spacing of 900 m (0.56 mi.) in their new rules; the Canadian Wind Energy Association (CanWEA 2003) countered with a 2000 m (1.24 mi) spacing standard.

For flight safety, the separation gap should be set low enough that a pilot will determine that the objects are in a group and take evasive action to avoid flying between them. Unpublished laboratory tests in Japan determined under low visibility conditions that pilots evaluated two lit objects as belonging to a group with approximately 0.10 mi. (160 m) spacing. It might be expected that this gap would increase with more neighboring lit objects.

7 Blue Canyon Wind Farm Evaluations

7.1 Background

The FAA was looking for a new wind farm where the findings of the flight evaluations could be implemented. At the same time, Zilkha Renewables was proposing a wind plant obstruction lighting scheme for their Blue Canyon Wind Farm that would reduce the number and types of lights and introduce synchronization. The FAA and Zilkha came to an agreement on the new lighting scheme, in which the FAA used the wind plant as a test case for new recommendations.

7.2 Description of the wind plant

The Blue Canyon Wind Farm (http://www.zilkha.com/whatweredoing.asp?id=34) is located 15 miles north of Lawton, Oklahoma, in the southwest corner of the state. Construction was completed in the spring of 2004. The site consists of 45 NEG Micon NM72 1.65 MW turbines in east-west strings. The turbine hub height is 70 m (230 ft) with an overall height of 105 m (345 ft). See Figure 1 for dimensions. The power is produced for the Western Farmers Electrical Cooperative (http://www.wfec.com/operations/blue_canyon.asp). A layout of the wind farm with positions of turbines with obstruction lighting is in Figure 10. An aerial view from the southwest can be seen in Figure 11. The turbines are distributed in one long row in the south with three groups of rows in the north. The substation is located west of the last turbine (lower left hand corner of Figure 11) and has a capacity for 300 MW. The project is expected to expand to this size once power-purchase agreements are in place.

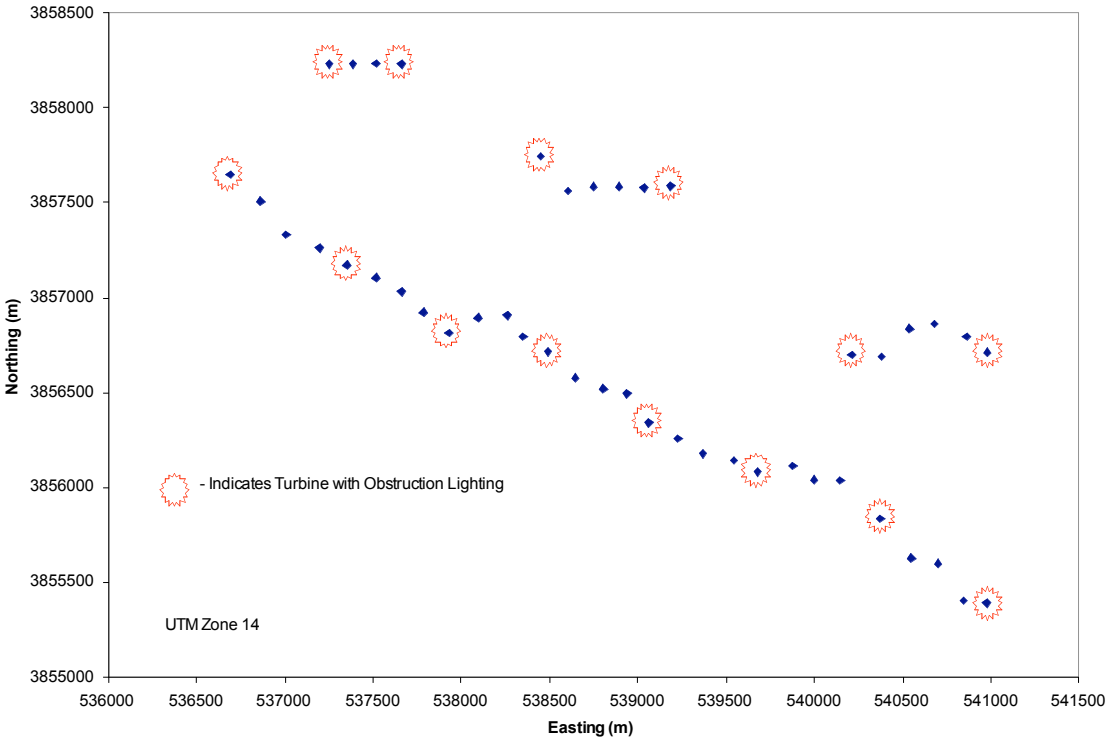

Figure 10. Blue Canyon Wind Farm Layout

Figure 11. Blue Canyon Wind Plant (photo courtesy of Jim Patterson)

An along-row view of the wind farm can be seen in Figure 12. The minimum separation between turbines on the front row on the right and the long row on the left is 0.42 mi. (674 m).

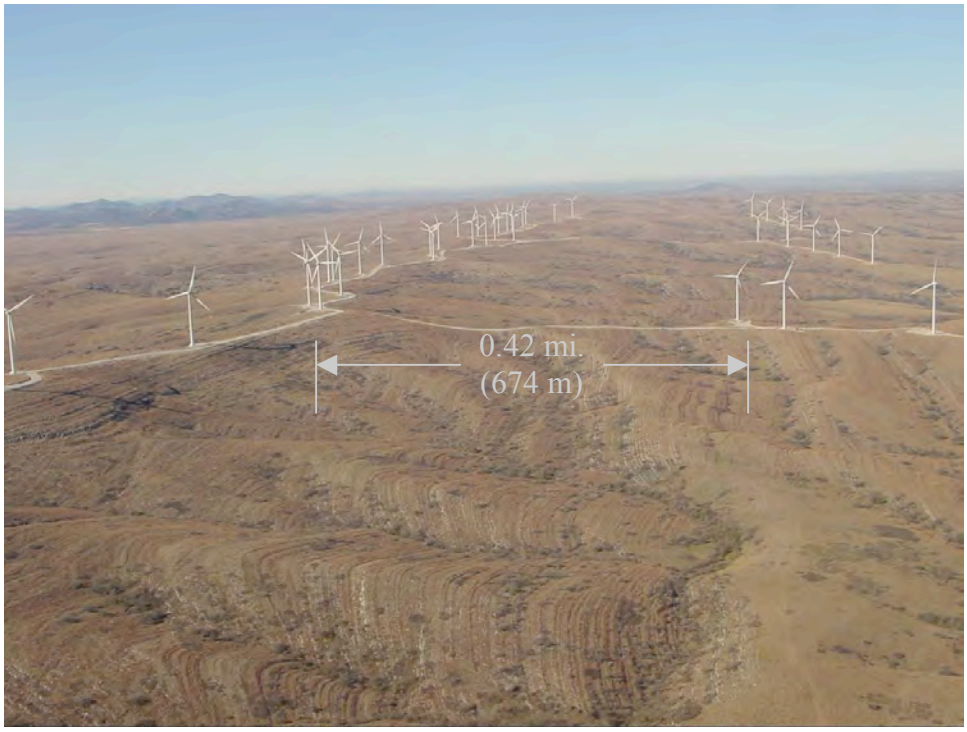

Figure 12. Along-row view of Blue Canyon Wind Plant (photo courtesy of Jim Patterson)

The obstruction lights are placed at the ends of each northern row and at every fourth turbine in the long southern row. The largest spacing between lights in a row is 0.51 mi. (816 meters).

The lights are synchronized with a central controller located in the substation. An additional fiber in the standard turbine control fiber-optic cable was available for the lighting control signal. Synchronization can be turned on or off and the controller can expand to control lights on 99 turbines. The lights and controller are supplied by Orga (http://www.orga-aviation.com/). Although this lighting scheme requires centralized control, there are alternate solutions to achieve synchronization, such as precision timing with GPS clocks on every light.

7.3 FAA Evaluations at Blue Canyon

7.3.1 Original Lighting Plan

The FAA Regional Office for the Blue Canyon location is in Dallas. The original lighting proposal for the farm was every other turbine had a day/night white/red medium intensity flasher; with every other turbine outfitted with a nighttime constant red LED. Zilkha and the FAA then agreed upon using the farm as a test case and the lighting proposal changed to synchronized nighttime-only lighting scheme.

7.3.2 Ground Evaluations August 2004

The initial evaluations of the lighting took place in August of 2004. The author was in attendance as an observer. The plan was to observe the wind plant with the lights unsynchronized and synchronized. Flight evaluations were cancelled due to continuous thunderstorm activity, so evaluations were limited to ground observations.

During the ground observations the lighting was initially unsynchronized. My impression was that the unsynchronized lights were a nuisance; there was always at least one light on at different positions. When the lights were synchronized I was initially not impressed with the effect, you could not get a sense of the wind plant size. However the light intensity was set at its lowest intensity initially. When the intensity was brought up to standard my peripheral vision seemed to trigger and immediately the size of the wind plant was realizable. We also stepped through light intensity, up to the required 2000 candela, and the impression was that the standard setting (2,000 candelas) was superior to the lower settings. This impression was similar to the "Aviation Safety" curve of Figure 6. It is unlikely that the FAA will allow a lower light intensity; however, I am not certain if we were viewing within the standard vertical beam spread. It was not the intention of the FAA to study modifications to the lighting intensity for this program.

The initial impressions of the FAA were that synchronized lights were superior to unsynchronized lights, and the 0.5 mile maximum spacing was adequate and should not be expanded.

7.3.3 Flight Evaluations December 2004

The FAA returned to Blue Canyon in December 2004 for more evaluations. Flight evaluations were possible because of favorable weather and impressions from the ground were strengthened in the flight observations. Again, the author was present. The flights commenced out of the Lawton airfield and proceeded north with special permission over the Fort Sill Army Artillery Range. Upon arriving at the wind plant, several approaches were made from all directions. Near the plant we flew at approximately 1000 ft AGL.

As before, the wind plant lights were unsynchronized at the beginning of the evaluations. My impression during approach was that it was impossible to determine the extent of the windfarm at fifteen miles inbound with unsynchronized lights. Another impression was that I could imagine a desperate pilot attempting to pass through the wind farm because

the spacing can not be adequately determined. Very rarely did two adjacent lights flash giving the minimum spacing reference. When the lights were synchronized, an immediate cue of connection amongst the lit objects and the overall extent of the obstacle could be determined with one glance.

The following day a representative from the Dallas FAA regional office was present to act as an observer for FAA Air Traffic headquartered in Washington D.C. This is the organization that releases the marking and lighting advisory circular. At the completion of the evaluations, the FAA was satisfied with the implementation of the new lighting recommendations.

8 Conclusions

Recommendations for wind plant obstruction lighting have been determined on a case-by-case basis leading to difficulties in the planning process for wind energy developers. Although there are no reported accidents between wind turbines and aircraft, the varying approach to wind plant lighting probably would have led to confusion for pilots. Through proactive efforts of the FAA Technical Center and Zilkha Renewables, a new scheme of light synchronization has been tested in Oklahoma to the approval of FAA management. The new scheme for wind plant lighting is expected to improve flight safety and reduce uncertainty in the planning process for wind energy development.

8.1 Proposed Wind Plant Lighting Recommendations

The FAA expects to submit a revised circular for wind turbines and wind farms based on the outcomes of the flight evaluations (Patterson 2004). The new advisory circular is expected to be available in summer 2005. The proposed guidelines are as follows:

- Maximum separation gap between lights along a row to be 0.5 mi. (0.8 km)
- Omission of lights within clusters
- Synchronization of lights for entire project
- No daytime lighting
- Use of red or white flashing lights possible
- Lighting of end of rows
- Single light mounted above hub radius (Figure 9)
- Omit steady burning lights

8.2 Recommendations for Further Study

It is likely that the primary issue of obstruction lighting with wind developers, uncertainty in the planning process, will be resolved with the new advisory circular. However, a few issues remain to be resolved with obstruction lighting for wind plants. These are listed and discussed below:

- Should all operators within an area be synchronized? The FAA will not require this; however, large wind resource areas will look like groups of unsynchronized lights. Would complete synchronization offer better flight safety and community acceptance?
- Should a ridgeline be lit if it is within a cluster of turbines? It seems that turbines at the highest levels in the wind plant should have lighting.
- Can the light intensity be lowered to balance flight safety and community acceptance (Montgomerie 2004)? This was not a subject of the current FAA evaluations, and the Advisory Circular (FAA 2000) provides background on the intensity levels. This subject should be revisited if community acceptance due to light intensity becomes a problem.
- Can the separation gap be increased to reduce costs without comprising flight safety? Technical research on this issue would be required to modify this number, but it seems unlikely that the 0.5 mi. value would be increased.

- Is there more community acceptance with synchronized lights? Surveys of communities within sight of wind plants should determine impressions regarding obstruction lighting.
- What lighting scheme minimizes the impact on wildlife? Surveys of avian and bat mortality should include wind plant lighting as a factor.

8.3 Acknowledgements

The author would like to thank Jim Patterson at the FAA Technical Center for allowing me to witness the FAA evaluations of the Blue Canyon Wind Farm. The observation flights were very helpful in gaining a pilot's perspective of a wind farm at night. The author would like to thank Jamie Curtis of Zilkha Renewables for providing access to the wind farm during the FAA observations and for providing the turbine coordinates for Figure 10.

9 References

Alameda County (1998). *Repowering a Portion of the Altamont Pass Wind Resource Area (Final EIR)*. Hayward, CA; Alameda County Community Development Agency. State Clearinghouse #98022024.

American Bird Conservancy (2004, 30 March 2005). American Bird Conservancy Wind Energy Policy [online]. Available: http://www.abcbirds.org/policy/windpolicy.htm.

CanWEA (2003, 30 March 2005). CanWEA Response to Draft 621.19.12 (Marking and Lighting of Wind Turbines) [online]. Available: http://www.canwea.ca/downloads/en/PDFS/LTR_TransportCan_Nov03.pdf.

Department of Trade and Industry (2002). *Wind Energy and Aviation Interests- Interim Guidelings*. Great Britain; Wind Energy, Defence and Civil Aviation Interests Working Group. ETSU W/14/00626/REP. 62 p.

FAA (1995, 29 March 2005). Advisory Circular AC 150/5345-43E Specification for Obstruction Lighting Equipment [online]. Available: http://www.faa.gov/arp/pdf/5345-43e.pdf.

FAA (1998a, 24 February 2004). Advisory Circular 150/5345-53B, Airport Lighting Equipment Certification Program [online]. Available: http://www.faa.gov/arp/pdf/5345-53b.pdf.

FAA (1998b, 24 Feb 05). FAA Form 7460-2, Notice of Actual Construction or Alteration [online]. Available: http://forms.faa.gov/forms/faa7460-2.pdf.

FAA (1999, 26 Feb 04). FAA Form 7460-1, Notice of Proposed Construction or Alteration [online]. Available: http://www.faa.gov/ats/ata/ata400/7460-1f.pdf.

FAA (2000). *Obstruction Marking and Lighting*. Federal Aviation Administration. Advisory Circular AC 70/7460-1K. 54 p.

Gasch, R. and J. Twele (2002). *Wind Power Plants*. Berlin, Solarpraxis.

Maller, P. (2000, July 29). "Plane crash kills 4 men southwest of Baraboo", *Milwaukee Journal Sentinel*.

Montgomerie, B. (2004). *Obstacle Markings on Wind Turbines for Safe Aviation and Marine Navigation*. FOI Swedish Defence Research Agency. FOI Memorandum 979. 10 p.

NTSB (2000). *Factual Report Aviation*. National Transportation Safety Board. NTSB ID: CHI00FA227.

NWCC (2004, 30 March 2005). Wind Turbine Interactions with Birds and Bats: A Summary of Research Results and Remaining Questions [online]. Available: http://www.nationalwind.org/publications/avian/wildlife_factsheet.pdf.

Patterson, J. (2004, 25 February 2005). Obstruction Lighting for Wind Generators [online]. Available: http://cwec.ucdavis.edu/forum2004/proceedings/index.html#presentations.

Riverside County California (2001, 16 March 2004). Land Use Ordinance #348 [online]. Available: http://www.tlma.co.riverside.ca.us/ordinances/ord348c.pdf.

Spera, D. A. (1994). *Wind turbine technology : fundamental concepts of wind turbine engineering*. New York, ASME Press.

United States (2005a). Code of Federal Regulations, Title 14: Aeronautics and Space, Part 77-Objects Affecting Navigable Airspace.

United States (2005b). Code of Federal Regulations, Title 14: Aeronautics and Space, Part 91-General Operating and Flight Rules.