Wind Turbine Safety

Developing a Technician Training Course

By Isaac Slaven and Ed Dennis

The growth of the wind energy industry in the U.S. has created the need for qualified technicians to perform maintenance and operation activities. American Wind Energy Association (AWEA, 2010) has identified several wind turbine technician training programs in the U.S. The AWEA Seal of Approval for these programs looks to be an important step in their standardization (Interstate Renewable Energy Council, 2009).

IN BRIEF
- The wind turbine industry has grown significantly in recent years, and projections say it will continue to do so.
- Many training programs for wind turbine technicians have begun across the U.S.
- This article examines the development of a safety course for prospective wind technicians. The goal was to increase student interest in safety topics related to the wind turbine industry and to maintain the material within the OSHA-10 topics guidelines.

The importance of training is mentioned more than 850 times in OSHA standards. The agency's authority to enforce safety regulations dates back to the 1970s, yet fatalities and citations occur every day due to factors such as failure to properly execute risk assessment and use PPE. In 2010, 4,547 people died in the workplace (Bureau of Labor Statistics, 2011). Of these, nearly 2,000 were classified as contact with equipment; falls; exposure to harmful substances or environments; and fires or explosions.

This article describes how a course was adapted to be more specific to the high-risk nature of wind turbine work while covering OSHA-10 general industry and OSHA-10 construction topics.

Specifically, the authors share the experience of developing a wind power course at Ivy Tech Community College in Lafayette, IN. The course serves as an introduction to the wind industry and wind turbine safety. It was designed to ensure that the topics and activities presented are relevant to the wind technician field and to increase student interest in safety.

Wind Turbine Safety

The four leading causes of death during construction activities in the U.S. are falls, hit by/struck by, caught between and electrical injuries. These hazards account for 90% of workplace fatalities. As a result, OSHA has adopted a focused inspection initiative. All four of these dangers are inherent to work

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Photo 1: A wind technician climbs into the single access location for the wind turbine hub. Some models have access inside the nacelle.

that wind turbine technicians perform each day.

As wind energy installations increase across the U.S., so does the demand for technicians to maintain and operate the turbines. Although much turbine operation can be performed remotely using supervisory control and data acquisition technology, much of the work requires technicians be in physical contact with the turbines. Technicians regularly climb towers that are usually 197 to 328 ft (60 to 100 m) to the hub. They routinely place themselves at risk when working at height in and on these elevated structures.

Multiple activities require work or travel on top of the nacelle and hub (see "Key Terms" sidebar on p. 46). Generators typically produce between 500 and 700 V AC, and grid connection at each tower is in the range of 36,000 V AC. Hydraulic tool pumps used in the tower and nacelle can operate at pressures up to and exceeding 650 bar (9,400 psi). Furthermore, the entire structure, including the tower, nacelle and hub, falls under OSHA's definition of a confined space [29 CFR 1910.146(a)].

Under the OSH Act, OSHA requires that employers provide a workplace free of known or recognized hazards that are causing or have the potential to cause injury or death. A typical OSHA-10 course for general industry or construction does not adequately address the specific topics technicians would need to know in order to better recognize hazards applicable to wind turbine work. This coincides with NIOSH's (2010) hierarchy of controls, which contains five key elements: 1) hazard elimination; 2) substitution; 3) engineering controls; 4) administrative controls; and 5) PPE.

Table 1 (p. 46) outlines the time requirements for each topic for standard OSHA-10 courses for general industry or construction. Because these times are minimums, it is possible that only 2 hours are spent on the "Focus Four" hazards. This means that participants could receive an OSHA-10 certificate as a part of a wind turbine technician training program with only 30 minutes exposure to fall protection.

Mandatory times for each topic in the OSHA-10 classes must be met regardless of any modification to the training's emphasis. So, elective and optional times are the best opportunities for focused training. For example, scaffolds are not likely to be found on a wind turbine site and, therefore, the elective time for the construction training would be more effectively spent on a topic such as stairways and ladders.

Optional time presents another opportunity to integrate wind turbine safety topics; generally, this is the last 2 hours in the general industry course and 4 hours in the construction course. Training for fall protection and electrical safety, respectively, introduces ANSI Z359 and NPFA 70E as a necessary point of reference. Further descriptions and exercises in these topics are applicable to wind turbine work as well. During this optional time, additional exercises can be developed to address and practice activities related to these hazards.

Barriers

Although all barriers can be categorized as financial in some respect, key concerns include liability; appropriate and applicable equipment and structures; facilities and space to house and handle equipment and structures; competent/qualified instructors and instructor expense; time within current curriculum; and pressure to develop online curriculum.

Liability

Since the school provides the opportunity for students to climb, it is exposing them to a known hazard: gravity. Hold-harmless and release of liability forms are essential to the training process. Ivy Tech requires one hold-harmless and release of liability for each semester, and a signed inspection form for each activity on the towers. In addition, job safety analysis (JSA) worksheets are filed for the group before each activity.

Equipment

Using the appropriate equipment is essential to successful implementation of a wind-turbine-specific training program. In addition to correct equipment that can pass competent inspection, old equipment which has been retired adds value to the tactile experience. Table 2 (p. 47) outlines the equipment used at Ivy Tech. A setup with required PPE, indoor climbing apparatus and an outdoor climbing tower that can reasonably accommodate the variety of potential participants can easily cost more than $100,000. Since many PPE items are small and often desirable for personal use, an accounting system is needed for each item.

Facilities

To house climbing towers, the institution must dedicate adequate space for them. For example, the indoor climbing apparatus at Ivy Tech requires a permanent footprint of approximately 6x6 ft. When apparatus are used for climbing exercises, a larger space is required. Therefore, any items stored under the tower must not be permanently installed.

In this case, the outdoor tower was custom designed for training purposes. It is a three-legged, self-support tower of lattice construction. Each leg has removable climbing pegs (to reduce the tower vertical trespassing potential as an "attractive nuisance") and wire rope safety climbs. Since the tower is 80 ft above ground level, a circular free space with 100-ft radius was chosen. In addition to removable climbing pegs, a chain-link fence was installed to reduce trespassing.

As a self-support tower, a reinforced concrete foundation was necessary. At this site, the foundation is a pad and pier design of approximately 12×12×6 ft (L×W×D) with engineered reinforcement. The foundation design is dependent on site-specific geotechnical data.

Once the soil samples have been collected from a proposed site for geotechnical analysis, a qualified civil engineer can determine the foundation design that best meets the desired level of safety. Designers should also know that the tower will be used to instruct nonprofessional climbers in climbing and rescue. Often, they will increase the design's safety factors to improve the tower's rigidity.

Competent & Qualified Instructors

An OSHA-10 course must be taught by trainers authorized by DOL's Directorate of Training and Education (OSHA, 2010). To be an instructor for general industry and construction, an individual must have 5 years' verifiable experience in the applicable training area, or s/he must hold a CSP or CIH designation, with 3 years' experience in the applicable safety field (OSH). In addition, continuing education is required every 4 years to keep instructors updated.

In addition to being authorized by OSHA to teach the classes, the instructor of a wind energy course must have experience with wind turbines as s/he must have a thorough and complete understanding of the consequences of applicable work-

Key Terms

Nacelle: The complete up-tower housing containing the gearbox, generator and other components in a wind turbine (label 1 in Photo 2).

Hub: The part of a wind turbine that connects the blades to the nacelle (label 2 in Photo 2).

Tower: A vertical apparatus. In the wind energy industry, this term can be used to describe the vertical support system for the wind turbine or the entire wind turbine assembly (label 3 in Photo 2).

V AC: Volts of alternating current.

Wind turbine: Term that generally describes a utility-scale wind energy conversion system.

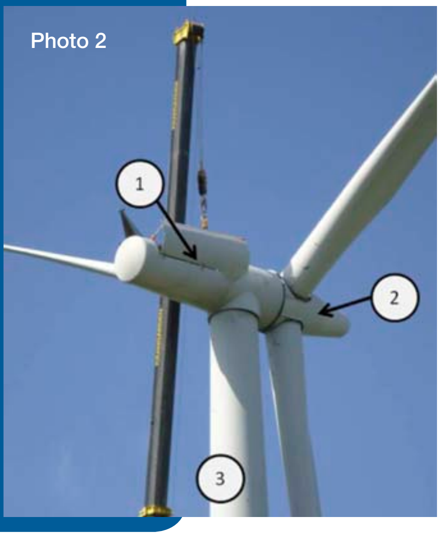


Photo 2

Table 1

OSHA-10 General Industry & Construction Topics

Required time	General industry topic	Required time	Construction topic
2 hours mandatory	Introduction to OSHA •OSH Act •Rights •Inspections, citation, penalties •General duty clause •OSHA website and phone number •Value of safety and health	2 hours mandatory	Introduction to OSHA •OSH Act •Rights •Inspections, citation, penalties •General duty clause •OSHA website and phone number •Value of safety and health
1 hour mandatory	Walking working surfaces/fall protection	2 hours mandatory	"Focus Four" hazards •Fall protection •Electrical •Struck by •Caught in/between
1 hour mandatory	Emergency action plans, fire, exits	30 minutes mandatory	PPE
1 hour mandatory	Electrical	30 minutes mandatory	Health hazards in construction
1 hour mandatory	PPE	2 hours elective	Two of: •Material handling •Tools •Scaffolds •Cranes, derricks, etc. •Excavations •Stairways and ladders
1 hour mandatory	Hazard communication	4 hours optional	Teach any other construction industry hazard or expand on the mandatory or electives
2 hours elective	Two of: •Hazardous materials •Materials handling •Machine guarding •Industrial hygiene •Bloodborne pathogens •Ergonomics •Safety and health programs •Fall protection		
2 hours optional	Teach any other general industry hazards or policies and/or expand on the mandatory		

place hazards. Beyond the inherent believability of first-hand knowledge, research has shown that instructors who have practical experience in the courses they teach are better received by students (Scott, 1996).

Competent climber and competent rescuer training is generally operated through specific manufacturers or training organizations. The training selected must be applicable to wind turbines and wind turbine hazards.

OSHA defines a competent person as "one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous or dangerous to employees." Without wind turbine experience, it would be difficult for an instructor to convey a working knowledge related to the specific hazards of a wind turbine.

Online Curriculum

As institutions compete for student enrollment, accommodations are being made to make education more available for students. Often, this includes the availability of online or web-based instruction. Benefits of online courses or, at minimum, mixed-mode (sometimes called blended learning or hybrid instruction) courses include asynchronous group interaction, location independence and multimedia interactions (Harasim, 2000).

However, research has shown that many students feel courses suffer without real-time, face-to-face, classroom interaction (Flowers, 2001; Schmidt & Gallegos, 2001). In the case of a climbing safety and fall protection course, certain learning objectives cannot be reasonably met using online technologies exclusively. The effectiveness of hands-on training on learning retention has been validated in many studies (Korwin & Jones, 1990).

Table 2

Equipment List

Item	Standard	Explanation
Indoor practice tower	Tower: Engineered with stamp; safety climb	Climbable lattice. Height: 18 ft
Outdoor tower	Tower: Engineered with stamp; safety climb	Climbable lattice with corner climbing pegs. Height: 80 ft
PPE: Full body harness	ANSI Z359 (2007)	Dorsal D-ring minimum. Sternal and hip D-rings also required on site. Tower harness with attached seat preferred for exercises
PPE: Twin leg safety lanyard	ANSI Z359 (2007)	Used for safety tie-off exercises
PPE: Cable sleeve	ANSI Z359 (2007)	Used on the wire-rope safety climb apparatus
PPE: Helmet	ANSI Z89 (2003) Type I	Chin strap required for swing fall scenarios
PPE: Eye protection	ANSI Z87.1 (2003)	Eye injury protection from falling or deflecting objects
PPE: Positioning lanyard	3,000 lb. minimum breaking strength	For on-tower positioning
PPE: Self-retracting lanyard	ANSI Z359 (2007)	Back-up fall protection for indoor exercises
PPE: Vertical lifeline	ANSI Z359 (2007)	Back-up fall protection for outdoor exercises
PPE: Rope grab	ANSI Z359 (2007)	Back-up fall protection for outdoor exercises
Rescue equipment	ANSI Z359 (2007)	Chosen rescue system is light, meets standard and is reusable
Miscellaneous connectors	ANSI Z359 (2007)	Carabiners, blocks/pulleys, choker slings, etc.

Table 3

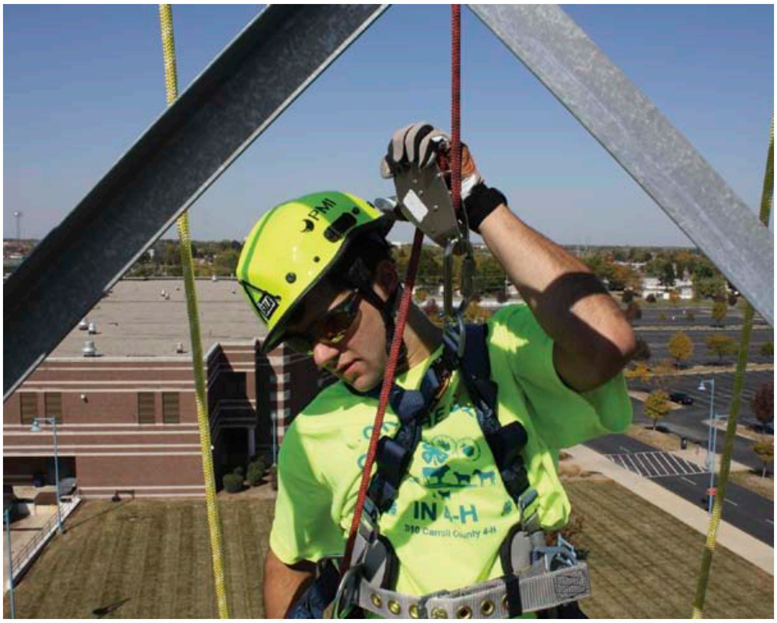
General Industry Safety Course With Wind Turbine Emphasis

Time spent	OSHA-10 general industry topic	Additional learning objectives for wind turbine emphasis
2 hours	Introduction to OSHA •OSH Act •Rights •Inspections, citation, penalties •General duty clause •OSHA website and phone number •Value of safety and health	•Research case studies specific to wind turbine accident investigation •Investigate history and evolution of fall protection •Explain the importance of the general duty clause with regards to wind turbine work
2 hours	Walking working surfaces/fall protection	•Identify the walking working surfaces in a wind turbine •Analyze "certified" anchor points on a ladder in a wind turbine •Evaluate a wind park fall protection plan •Create a fall protection plan for the training site
2 hours	Emergency action plans, fire, exits	•Describe the confined space hazards at various locations in a wind turbine •Differentiate situations resulting in in-tower and outside-tower exits •Evaluate a wind parks emergency action plan •Summarize heat/cold stress symptoms and prevention
2 hours	Electrical	•Identify electrical locations in a wind turbine •Apply NFPA 70E guidelines for various electrical applications in a wind turbine
2 hours	PPE	•Identify the ANSI Z359.1-2007 components of a personal fall arrest system (PFAS) •Inspect PFAS equipment for defects, nonconformities or other noncompliance. •Demonstrate the safe use of PFAS in a tower-climbing exercise •Evaluate noncomplaint PFAS PPE
1 hour	Hazard communication	•Identify materials that are present in a wind turbine •Analyze MSDS for various fluids, cleaners or greases commonly found in wind turbines
1 hour	Confined spaces	•Identify confined spaces related to wind turbine work •Evaluate a permit-required confined space scenarios

Opportunities

Although the OSHA-10 training courses are designed to be classroom-based experiences, this training is a good bridge into higher cognitive levels of the learning dimensions. OSHA regulations serve as the guideline, but they do not provide a method for implementing practices. Analyzing and evaluation, as functions of higher levels of cognition, can be achieved through exercises and activities. Among others, these can focus on NFPA 70E, JSA worksheets, and climbing and rescue activities. As noted, research shows that hands-on activities increase the effectiveness of cognitive retention (Korwin & Jones, 1990).

Photo 3: A student performs a controlled descent on the training tower.



One distinct difference between classroom teaching and on-the-job training (OJT) is the immediacy of application. Since OJT is typically performed using the actual equipment that will be used, the training is quickly applied. If it is the first time that a student/new employee has seen the concepts, the construction of knowledge (i.e., development of cognitive, psychomotor and affective knowledge) may be difficult. Additionally, due to the expense of time, OJT is often specific to equipment or a particular site, and its effectiveness relies heavily on a trainee's previous experience (van der Klink & Streumer, 2002). In addition, it has been shown that workplace tenure and career satisfaction are positively influenced by focused training (Wayne, Liden, Kraimer, et al., 1999).

Classroom learning is effective when students have sufficient transfer of prior knowledge to the new setting. However, without the foundations of knowledge, construction of knowledge, such as that through OJT, is more difficult, and long-term retention is reduced (Halpern & Hakel, 2003). More practice and group interaction in activities, such as climbing, can yield further cognitive development (Glasersfeld, 1989). Skills resulting from higher levels of cognitive development include differentiation, investigating, critiquing and adapting (Gronlund, 2003).

Table 4

Construction Safety Course With Wind Turbine Emphasis

Time spent	OSHA-10 construction topic	Additional learning objectives for wind turbine emphasis
2 hours	Introduction to OSHA •OSH Act •Rights •Inspections, citation, penalties •General duty clause •OSHA website and phone number •Value of safety and health	•Research case studies specific to wind turbine accident investigation •Investigate history and evolution of fall protection •Explain the importance of the general duty clause with regards to wind turbine work
3.5 hours	"Focus Four" hazards •Fall protection •Electrical •Struck by •Caught in/between	•Determine locations on a wind turbine that are directly related to the "Focus Four" hazards •Identify features of crane and rigging equipment that requires a competent inspection •Apply NFPA 70E guidelines for various electrical applications in a wind turbine •Explain the importance of a prework JSA for safe communication and actions
3.5 hours	PPE	•Identify the ANSI Z359.1-2007 components of a personal fall arrest system (PFAS) •Inspect PFAS equipment for defects, nonconformities or other noncompliance. •Demonstrate the safe use of PFAS in a tower-climbing exercise •Evaluate noncomplaint PFAS PPE
1 hour	Health hazards in construction	•Identify materials that are present in a wind turbine •Analyze MSDS for various fluids, cleaners or greases commonly found in wind turbines •Summarize heat/cold stress symptoms and prevention
1 hour	Confined spaces	•Identify confined spaces related to wind turbine work •Evaluate a permit-required confined space scenarios

Liability as an Opportunity

Although liability may present a minor barrier to the development of a wind turbine safety curriculum, it is an experience the instructor can use as a teaching mechanism. The importance of required documentation, such as a site-specific fall plan, JSA, PPE inspection logs, tower maintenance logs and postactivity worksheets can be shared with students. This helps students understand that such documentation is a necessary component of safety management as required by OSHA, ANSI and manufacturers.

In the case of Ivy Tech, in addition to the liability waiver students must complete before each semester, they must maintain inspection logs, JSA worksheets and postactivity worksheets for their own records. This is an added safety measure for the students and the school. When students are asked to discuss an activity, such as climbing prior to the event through a JSA, they are more mentally prepared for the activity. When students perform their own inspections, there is more certainty that the equipment is, in fact, fit for use. Additionally, the students develop a tactile comfort in the condition of their equipment.

Training Time

As noted, the course developed covers safety in wind turbines while maintaining the time requirements for OSHA-10 general industry and construction courses. Tables 3 (p. 47) and 4 list the distribution of time for elective and optional topics.

Although these tables indicate minimum times adjusted to meet OSHA time requirements, much more time is spent on many sections to accommodate the time necessary for hands-on activities. For example, a minimum of 3.5 hours must be spent on PPE. However, for supervised activities with PPE, such as inspection and use on the tower, a more realistic amount of time would be 16 classroom hours.

Increasing Student Interest

The authors examined the effectiveness of this training in increasing student interest in safety ex post facto. As a result of the increased interest in the job-specific, hands-on approach to the training, a new course (advanced wind turbine safety) was developed. It opened for enrollment 2 weeks before the first day of the semester, and was offered as a Saturday class (meeting eight consecutive Saturdays for 8 hours each). The class had 13 enrolled students, and many students have inquired about the continuation of the course in future semesters.

Conclusion

Development of a safety course specific to wind turbines is resource-consuming and intensive. Although issues such as liability, space and equipment present barriers, there are opportunities and teachable moments through the administrative experience. Documentation of safety protocol, inspection and incident reporting introduces students to scenarios in which these documents are required.

An instructor or administrator should never sacrifice the quality of a safety course in order to inflate numbers in a class or program; it is dangerous and can result in legal issues for the instructor and institution. In any case, completing a safety training course is not an end, it is a starting point. In wind energy, as in any industry, equipment and processes constantly evolve. With this, hazards change. Worker training should adapt with it. **PS**

Green Job Hazards

OSHA has identified the wind energy industry as a major source of green jobs. According to OSHA, "A key concept for all industries, but especially those that are just beginning to grow, is prevention through design (PTD)—designing the process/equipment in a way that eliminates hazards to the workers who use them. Employers should have a system in place where safety and health professionals work with design engineers in designing out hazards throughout the design phase of their products." Read more from OSHA at **www.osha.gov/dep/greenjobs/index.html**. Learn more about NIOSH's PTD efforts at **www.cdc.gov/niosh/topics/PTD** and its green jobs initiatives at **www.cdc.gov/niosh/topics/PtD/green jobs.html**.

References

American Wind Energy Association. (2010, Nov. 22). Wind industry unveils "Seal of Approval" for job training for wind turbine service technicians [Press release]. Washington, DC: Author. Retrieved Jan. 6, 2012, from **www.awea.org/newsroom/inthenews/release_112210a.cfm**.

Bureau of Labor Statistics. (2011). Census of fatal occupational injuries. Washington, DC: U.S. DOL, Author. Retrieved Sept. 1, 2011, from **www.bls.gov/iif/oshwc/cfoi/cftb0250.pdf**.

Flowers, J. (2001). Online learning needs in technology education. *Journal of Technology Education*, *13*(1), 17-30.

Glasersfeld, E.V. (1989). Cognition, construction of knowledge and teaching. *Synthese*, 121-140.

Gronlund, N.E. (2003). *Writing instructional objectives for teaching and assessment.* Upper Saddle River, NJ: Prentice Hall.

Halpern, D.F. & Hakel, M.D. (2003). Applying the science of learning. *Change*, 36-41.

Harasim, L. (2000). Shift happens: Online education as a new paradigm in learning. *Internet and Higher Education*, *3*, 41-61.

Interstate Renewable Energy Council. (2009, Dec. 17). AWEA's "Seal of Approval" for wind technician training programs. Retrieved Feb. 25, 2010, from **http://irecusa.org/2009/12/aweas-seal-of-approval-for-wind-technician-training-programs**.

Korwin, A.R. & Jones, R.E. (1990). Do hands-on activities, technology-based activities enhance learning by reinforcing cognitive knowledge and retention. *Journal of Technology Education*, *1*(2), 14-20.

NIOSH. (2010, June 25). Engineering controls: NIOSH workplace safety and health topic. Washington, DC: U.S. Department of Health and Human Services, CDC, Author. Retrieved Sept. 1, 2011, from **www.cdc.gov/niosh/topics/engcontrols**.

Schmidt, E.K. & Gallegos, A. (2001). Distance learning: Issues and concerns with distance learners. *Journal of Industrial Technology*, *17*(3), 2-5.

Scott, P.A. (1996). Attributes of high-quality intensive course learning experiences: Student voices and experiences. *College Student Journal*, *30*, 69-77.

OSHA. (2010, March 10). How to become an authorized trainer. Washington, DC: U.S. DOL, Author. Retrieved July 28, 2010, from **www.osha.gov/dte/outreach/construction_generalindustry/authorized.html**.

van der Klink, M.R. & Streumer, J.N. (2002). Effectiveness of on-the-job training. *Journal of European Industrial Training*, *26*, 196-199.

Wayne, S.J., Liden, R.C., Kraimer, M.L., et al. (1999). The role of human capital, motivation and supervisor sponsorship in predicting career success. *Journal of Organizational Behavior*, *20*(5), 577-595.