

Wind Energy Operations and Maintenance

Best Practices for Wind Power Facility Electrical Safety

This best practice guide outlines recommended practices to assist with the safe operation and maintenance of wind power generation facility electrical systems.

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1 Introduction

Purpose

This guideline has been written for wind energy generation facilities and provides a framework to develop and address safe work practices for electrical safety, in addition to those practices required by applicable health and safety laws. This guideline deals with safe work practices and not safe installation requirements. For guidance on safe installations practices, reference the Canadian Electrical Code and jurisdictional specific requirements.

Background

Wind energy generation is a form of renewable electricity generation comprised of individual generating units spread across an extensive area either offshore or onshore. Each individual generating unit consists of complex electrical and mechanical subcomponents that are mounted on tower structures and necessitates specialized maintenance practices during operations. During the operation, maintenance, and repair of such systems, qualified workers may be required to perform tasks at heights, in restricted spaces, isolated environments, extreme climates, and sometimes where emergency response facilities are not near to the work site. Workers may be exposed to hazards such as electric shock or electrocution, the hazards of arc flash, and arc blast unless appropriate electrical safe work practice measures (such as the preparation and hands-on training of workers) are taken. Therefore, it is beneficial for the wind energy sector to develop well-defined electrical safe work practices and procedures for maintaining and operating the associated wind farm equipment throughout the facility's operational life cycle.

2 Notice and Disclaimer

The Canadian Wind Energy Association ("CanWEA") assumes no liability or responsibility for reliance on the contents of this Best Practices for Wind Farm Electrical Safety (the "Materials"), which are intended for educational and informational purposes only. CanWEA makes no representation or warranty about the suitability of the information offered in these Materials, including for legal compliance or any other purpose. The Materials are offered only as general (and not site- or project-specific) guidance and do not constitute legal, engineering, medical, or professional advice.

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- These Materials are not intended to be a statement of the work practices and other precautions required by applicable health and safety laws, compliance with which is the sole responsibility of the user of the Materials.
- These Materials do not address every type or model of electrical equipment or component that may be used in connection with a wind energy generation facility. CanWEA members and their contractors should familiarize themselves with the specific equipment and components for each site and consider whether any additional precautions are warranted in the circumstances.
- CanWEA members and their contractors should be mindful that the Materials are not intended to be, and are not, a substitute for a health and safety management system, and that any suggested program elements herein should be evaluated on a case-by-case basis and may need to be revised or supplemented to ensure legal compliance.
- CanWEA members and their contractors should determine whether to seek legal or professional advice on all matters concerning health and safety compliance or any other issues implicated by the Materials where appropriate.
- Materials are not intended to offer, nor should they be construed as, medical advice. Health care professionals should be consulted where appropriate.

3 Limitations

This guideline has been developed with reference to industry related publications. However, it is not exhaustive and hence the reader should defer to published standards and applicable legislation for guidance. Furthermore, this document is neither written to be a compliance standard nor intended to be a protocol for the audit of an electrical safety program.

4 Regulations

Each province, territory and the federal government in Canada outlines a regulatory framework for Occupational Health and Safety (OH&S). In general, with some exceptions, the federal legislation applies to employees

of the federal government, federal corporations, as well as workers in federally regulated industries. The provincial or territorial legislation applies to most other workplaces. Many of the basic elements such as rights and responsibilities of workers, employers, and supervisors, are similar in all the jurisdictions across Canada. However, the details of the OH&S legislation and how the laws are enforced vary from one jurisdiction to another. In addition, provisions in the regulations may be "mandatory", "discretionary" or "as directed by the Minister".

Most provincial OH&S legislation contains general requirements for employers to identify hazards, which include electrocution/shock, arc flash, arc blast, and the requirement to take steps to protect workers from these hazards. Depending on the jurisdiction, there may be requirements that are applicable to an electrical safety program. For example, there may be requirements and limits for:

- Recommended personal protective equipment, special tools and equipment (e.g., use of non-conductive ladders)
- Working on or near energized electrical equipment
- Safe limits of approach to energized conductors
- Training requirements
- Working alone legislation
- Safe work procedure development

CanWEA members should review any changes to applicable health and safety laws to determine whether they require new or modified health and safety measures.

5 Definitions

Absence-of-voltage test – also known as test-before-touch testing, it is a process to verify the test instrument is working properly, test and verify its function on a known energized source, testing the equipment or circuit that is required to be de-energized and verifying the test instrument is still working properly on a known energized source. There are two primary types of voltage detectors; 1.) Direct-contact, which is used typically for voltages below 1,000 volts ac and 2.) Proximity, which is used for voltages above 1,000 volts. Proximity testers are not recommended for voltages below 1,000 volts, since they may not provide proper indication.

Arc flash hazard – a dangerous condition associated with the possible release of energy caused by an electric arc (CSA Z462).

Arc Flash Boundary – when an arc flash hazard exists, an approach limit at a distance from a prospective arc source within which a person could receive a second-degree burn if an electrical arc flash were to occur. Note: A second-degree burn is possible by an exposure of unprotected skin to an electric arc flash above the incident-energy level of 1.2 cal/ cm² (CSA Z462).

Electrical equipment – any apparatus, appliance, device, instrument, fitting, fixture, luminaire machinery, material, or thing used in or for, or capable of being used in or for, the generation, transformation, transmission, distribution, supply, or utilization of electric power or energy, and, without restricting the generality of the foregoing, includes any assemblage or combination of materials or things that is used, or is capable of being used or adapted, to serve or perform any particular purpose or function when connected to an electrical installation, notwithstanding that any of such materials or things may be mechanical, metallic, or non-electric in origin (CSA Z462).

Limited Approach Boundary – an approach limit at a distance from an exposed energized electrical conductor or circuit part within which a shock hazard exists (CSA Z462 Clause 4.3.4 and Annex C).

Lockout/Tagout – placement of a lock and a tag on an energy-isolating device in accordance with an established procedure (CSA Z462). Locks and tags should be used together; the lock to prevent the equipment from being operated and the tag to identify who is responsible for placing it. Locks used for lockout/tagout should be

individually keyed and tags should be resistant to the weather conditions they may be exposed to.

Tagout only – used where it is not possible to attach a lock to the disconnecting means. The disconnecting means shall not be used as the only means to put the circuit in an electrically safe work condition.

Proving Unit – a separate unit used to verify the volt-ohm meter is functional before and after absence-of-voltage testing. Proving units are usually low-voltage (up to 240 volts) and some are self-diagnosing, giving warning when they have lost their accuracy.

Qualified person (worker) – one who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify and avoid the hazards involved (CSA Z462).

Restricted Approach Boundary – an approach limit at a distance from an exposed energized electrical conductor or circuit part within which there is an increased likelihood of electric shock, due to electrical arc over combined with inadvertent movement, for personnel working in close proximity to the energized electrical conductor or circuit part (CSA Z46 Clause 4.3.4 and Annex C).

Risk – a combination of the likelihood of occurrence of injury or damage to health and the severity of injury or damage to health that results from a hazard based on (CSA Z462).

Shock hazard – a dangerous condition associated with the possible release of energy caused by contact with or approach to energized electrical conductors or circuit parts (CSA Z462).

Unqualified person – a person who is not a qualified person (CSA Z462).

Wind turbines – Wind turbines are structures that produce power by capturing the kinetic energy in surface winds created by the sun and converting it into energy in the form of electricity.

6 References

OH&S	Federal, Provincial, and Territorial Occupational Health & Safety Documents
CSA C22.1	Safety Standard for Installations
CSA C22.2	Safety Standards for Electrical Equipment
CSA C22.3	Electricity Distribution and Transmission (and communication)
CSA C22.4	Objective Based Industrial Electrical Code Safety Standards for Industrial/Institutional
CSA C22.5	Electrical Safety Management Systems Standards (WIP)
CSA C22.6	Electrical Inspection Code for Existing Residential Occupancies
CSA Z460	Control of hazardous energy – Lockout and other methods
CSA Z462	Workplace Electrical Safety
CSA Z463	Guideline On Maintenance Of Electrical Systems
CSA Z1000-06	Occupational health and safety management
CSA Z1002-12	Occupational Health and Safety – Hazard Identification and Elimination and Risk Assessment and Control
CSA Z1006-10	Management of work in confined spaces
CSA-Z94.1-05	Industrial Protective Head Wear – Performance, Selection, Care, and Use
CSA Z94.3-07	Eye and face protectors
CSA Z195-14	Protective footwear
CSA Z259	Series of Standards
CSA Z432-04	Safeguarding of machinery
IEEE 1584	Guide for Performing Arc Flash Hazard Calculations
IEEE 3007.1	Recommended Practice for the Operation and Management of Industrial and Commercial Power Systems
IEEE 3007.2	Recommended Practice for the Maintenance of Industrial and Commercial Power Systems
IEEE Std. 516	Guide For Maintenance Methods On Energized Power Lines
IEEE Std. 978	Guide For In-Service Maintenance And Electrical Testing Of Live-Line Tools
IEEE 3007.3	Recommended Practice for Electrical Safety in Industrial and Commercial Power Systems
NFPA 70B	Recommended Practice for Electrical Equipment Maintenance
NFPA 70E	Standard for Electrical Safety in the Workplace

CanWEA members should review any changes to applicable standards to determine whether they require new or modified health and safety measures.

7 Electrical Safe Work Practices

CSA Z462¹ provides relevant requirements for safe work practices. Additional applicable laws in each jurisdiction should also be met, at a minimum. It should be kept in mind that CSA standards and applicable laws set the minimum requirements only. The following document contains general safe work practices that are accepted within the wind industry, in addition to those standards and laws.

Wind turbines are, at their basic level electrical generators. They operate on the same principals that can be found at most power generation facilities around the world. There are some differences in components, and location but fundamentally, the turbine is rotated and electricity is produced. The hazards and risk associated with wind turbine testing and maintenance is very similar to the same tasks performed on other generation equipment and are well understood by the industry. It is recommended that the precautions and safe work practices contained in manufacturer's literature be adhered to when performing maintenance or testing.

7.1 Safe Work Practices vs. Safe Work Procedures

Safe work practices are positive guidelines helpful to the performance of a specific type of work that may not always be done in a specific way. It is not always practical to develop a standardized "safe work procedure" for a given task because the situation may require that employee to perform the job differently from time to time. In such cases, the employer may consider providing employees with safe work practices to control hazards allowing tasks to be performed with minimum risk to people and property.

Safe work practices are developed to cover a general range of procedures. As modes of work change, new safe work practices can be developed. If a new safe work practice is required due to legislation or industry change, employees and management can work together to re-

define the existing practice. Where possible, the new safe work practice should be a combined effort between employee, management and safety personnel. All new safe work practices, once completed and adopted, should supersede any previous practices.

7.2 General Safety Guidelines:

- Work to be performed on electrical equipment should always be prioritized to be in an electrically safe work condition, where the absence of electrical energy has been confirmed and where isolation points have been locked-out and tagged-out
- All parts and components used for repairs or replacements should be approved by the site operator.
- Employees should be trained to recognize and to avoid such hazards that they may encounter in their jobs and tasks.
- Workers should have the ability to descend on their own to mitigate the risk of any electrical incidents that may occur up tower, given the difficulty of recovering the worker for treatment if they cannot descend on their own.
- Workers performing work on energized conductors or circuit parts should be well-qualified and trained. Unqualified workers should not be exposed to electrical hazards.
- Exposed conductor or circuit parts that could become energized should be treated as energized.
- Safe work practices should include the knowledge of specialty protective wear (where required) such as hard hats, eye protection, arc-rated clothing and PPE, insulating blankets, covered line hoses, mats, and insulated gloves and sleeves.
 - PPE showing defects or damage that would affect its ability to protect should be turned in to a supervisor and not used.
- Short cuts and poor work performance should not be tolerated.
- The classification of an area speaks to the hazards present and the safety aspects of the electrical circuitry and equipment to be used.
 - Employers should inform the worker what the classification of the area his or her job assignment is in.

¹ CSA Z462-18 Workplace electrical safety is a standard developed by a panel representing many sectors of the electrical industry and provides one of the best minimum work practices and requirements currently available in Canada. It is updated on a three-year revision cycle to incorporate the latest findings and research to safe-guard human life from electrical hazards.

- An explosive atmosphere can be created by work procedures which require the use of chemicals, paints, solvents, etc.
- Before energizing any circuits or equipment, this hazard, among others, should be checked for.
- If a significant change that affects the safety of the scope of work occurs, a new job safety plan should be implemented.
- Lockout/tagout procedures should be developed for any equipment that has more than one source of power, more than one switch, circuit breaker or other energy control device or presents hazards or risk that is greater than normal.
 - Wind towers are one example of a device needing a lockout/tagout procedure developed for it. It may have voltage supplied from the generator, the slip rings, the control panel or the hub pitch batteries.
- Documentation is important and should be encouraged. Documentation allows supervisors to verify tasks were performed correctly and provides workers with checklists and forms that can keep them in conformance with the safety related work practices needed.

Incidents associated with electricity can be prevented through safe work practices and use of the hierarchy of risk control methods. Safe work practices include job risk assessments (shock and arc flash), de-energizing electric equipment prior to testing or repairing (absence-of-voltage/test-before-touch), applying lockout/tagout procedures whenever possible, keeping tools and equipment properly maintained, exercising caution when working near energized lines, and wearing appropriate PPE when needed. Elimination of the hazard (placing equipment in an electrically safe work condition) should always be the first option and the use of PPE should be the last.

7.3 Assessing Risk and the Hierarchy of Risk Control Methods

The 2018 edition of CSA Z462, Clause 4.1.6.8.4 requires the use of the hierarchy of risk control methods which were derived from ANSI Z10. These methods are arranged from the most effective to the least effective. Elimination of the hazard is most effective, while the use of PPE is the least effective. The hierarchy of risk control

methods is provided below with an example for reference:

1. Elimination – Placing equipment in an electrically safe condition
2. Substitution – Reducing energy by using low-voltage, low-energy circuits
3. Engineering controls – Use of guarding to isolate circuits and conductor parts
4. Awareness – Signs warning of hazard or risk
5. Administrative controls – Procedures and job planning tools
6. PPE – Shock and arc-rated PPE if other methods of risk reduction are not feasible

Before beginning any tasks involving electrical circuits or circuit parts a job hazard assessment or, as it is sometimes referred to, a job task assessment should be performed. The job steps should be planned, the equipment needed should be specified, the required tools and equipment should be specified, the hazards associated with the task should be identified and the steps taken to avoid them should be in place. These should be documented on the appropriate form and submitted for approval by the site supervisor prior to work beginning. CSA Z462-18 was used as a reference to develop these safe work practices. Workers and supervisors are encouraged to become familiar with the latest edition of Z462.

Assessing risk includes a shock risk assessment and an arc flash risk assessment. Refer to the latest edition of CSA Z462 and/or NFPA 70E for further information regarding conducting these risk assessments. Other items that should be assessed are the potential for human error and the methods that can be used to control it. This includes an assessment of potential errors left by the last person to work on that equipment.

It is recommended that barricades be set up at the farthest boundary from an energized source, either at the limited or arc flash boundary. For systems above 750 V some provinces specify a second worker be present, but regardless, a trained safety backup should be present for all work that presents electrical risk. The safety backup should wear the same PPE as the worker performing the task, have a rescue hook in his or her hands and be just beyond the safety barrier tape or barricade. Refer to Z462, Informative Annex F, *Risk assessment and risk control* for more information.

7.4 Job Safety Plans and Briefings

Job safety plans document the hazards and risk employees may face when performing work on electrical equipment or circuits. A sample job planning form or, as it is also known as, a Pre-Task Analysis (PTA) is provided in Annex C. Workers should have demonstrated the ability to gather task information and determine task limits, document hazards associated with each task, estimate the risk and hazards for each task(s), and assign a safety measure for each hazard and attain an acceptable or tolerable level of risk. The Energized Electrical Work Permit (EEWP), or a similar form, should be used to perform the shock and arc flash risk assessments, choose PPE and obtain the supervisor's authorization to begin task(s) on energized electrical equipment, whereas the PTA covers mostly general safety requirements. An example of an EEWP is shown in Informative Annex J, *Sample energized electrical work permit*.

7.4.1 General Job Briefing Recommendations

CSA Z462, Informative Annex I, *Sample job briefing and planning checklist* is another example of a checklist that can be modified for use to fit the needs of the task. Z462 states that before starting each job, the worker in charge conducts a job briefing with the workers involved. The briefing should cover such subjects as the following:

- Hazards associated with the job;
- Work procedures involved;
- Special precautions;
- Energy source controls;
- PPE requirements; and
- The information on the energized electrical work permit, if a permit is required.

Additional job briefings should be held if significant changes that might affect the safety of workers occur during the course of the work.

7.4.2 Qualified Electrical Worker

The employer should ensure that the Qualified Electrical Worker in charge performs a job safety plan and conducts a job briefing with the employees involved before they start each job. The briefing should cover at minimum the following subjects:

- Hazards associated with the job;
- Work procedures involved;

- Special precautions;
- Energy source controls;
- Personal protective equipment requirements; and
- Stop work triggers.

7.4.3 Number of Briefings

If the work or operations to be performed during the work day or shift are repetitive and similar, at least one job briefing should be conducted before the start of the first job of each day or shift. Additional job briefings should be held if significant changes, which might affect the safety of the employees, occur during the course of the work.

7.4.4 Extent of Briefings

A brief discussion is satisfactory if the work involved is routine and if the employee, by virtue of training and experience, can reasonably be expected to recognize and avoid the hazards involved in the job. A more extensive discussion should be conducted in certain circumstances, such as:

- If the work is complicated or particularly hazardous; or
- If the employee cannot reasonably be expected to recognize and avoid the particular hazards involved in the job.

7.4.5 Working Alone

Generally, due to the risk involved, it is recommended that electrical work not be performed by a lone worker. A "safety backup" should be used whenever work is performed on equipment or circuits that are or may become energized.

In certain circumstances where a lone worker is appropriate, it is recommended that supervisors should conduct a briefing with the lone worker and establish a communication method and check-in rate.

7.4.6 Lockout

The employer is referred to CSA Z460 for *Control of hazardous energy – lockout and other methods*.

Lockout means to physically neutralize all energies in a piece of equipment circuits before beginning any maintenance or repair work. In general, a lockout involves:

- Stopping all energy flows
- Locking switches and valves
- Securing the machine, equipment, or power transmission line in a de-energized state

When it is not reasonably practicable to lockout equipment to be serviced, repaired, tested, cleaned, maintained or adjusted, a specific safe work procedure should be developed and implemented which provides the same or greater level of safety provided by locking out equipment. All equipment should be tested to ensure lockout procedures are effective prior to permitting a worker to perform work on that equipment. No person should be allowed to remove a lock from locked out equipment, except the person who installed the lock. In the event of an emergency or the worker who installed the lock is no longer available, a person designated by the employer should remove the lock. In such cases, the employer should be sure that returning the equipment to operation will endanger no person.

When the lockout procedure uses a lock and key process, the employer should:

- Issue to each employee who is required or permitted to work on equipment, a lock that is operable only by that employee's key or a duplicate key
- Designate a person in charge to keep the duplicate key
- Ensure that the duplicate key is accessible only to the designated employee
- Ensure that the lock used has a unique mark or identification tag on it that identifies the employee to whom the lock is assigned
- Ensure that a logbook is kept to record the use of the duplicate key

Where it is not reasonably practicable to use an employee's key to remove a lock, the employer may permit the designated competent person to remove the lock, if the designated employee has determined that:

- The key used to lock the lock is not available; and
- It is safe to remove the lock and activate the machine.

When the lock has been removed, the employer should ensure that the employee who locked out the equipment is informed of the removal of the lock. Some sites require the approval of a senior manager to remove a lockout

lock. It is recommended that the site's specific requirements be reviewed prior to lock removal.

An alternative to normal lockout/tagout can be used to further ensure the security of the lockout/tagout process is by having only one key available for each worker's lockout lock. If the worker is unavailable to remove the lock and the equipment must be restored to service, all the steps above should be followed. If the worker cannot be contacted the lockout lock is to be cut off the equipment and returned to the worker the next day or the next time the worker is back on site with an explanation of why it was removed.

Tagout Only (Typically Utility Style Equipment) – An information tag and permit system without a lock may be used only where equipment design precludes the installation of a lock on energy-isolation device(s). When an information tag and permit system is employed, at least one additional safety measure should be employed. In such cases, a written procedure is recommended describing the information tag and permit system and to establish responsibilities and accountability for each person who might be exposed to electrical hazards.

7.4.7 Lightning

Lightning detection should be in place and active whenever entering or ascending a tower is being considered. Procedures should be established on-site to prescribe lightning proximities at a minimum for:

- Site workers placed on lightning warning
- In-tower stop work
- General on-site stop work

7.4.8 Approach Limits and Boundaries

The following Approach Limits should be used when working on or near electrical equipment that is or may be energized. Refer to the NFPA 70E 130.4 tables as shown. This information can also be found in CSA Z 462 Tables 1A (AC) and 1B (DC).

Table 130.4(D)(a) Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Alternating-Current Systems

(1) Nominal System Voltage Range, Phase to Phase ^a	(2) Limited Approach Boundary ^b		(4) Restricted Approach Boundary ^b ; Includes Inadvertent Movement Adder
	Exposed Movable Conductor ^c	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–150 V ^d	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
151 V–750 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
751 V–15 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–36 kV	3.0 m (10 ft 0 in.)	1.8 m (6 ft 0 in.)	0.8 m (2 ft 9 in.)
36.1 kV–46 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
46.1 kV–72.5 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
72.6 kV–121 kV	3.3 m (10 ft 8 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
121 kV–145 kV	3.4 m (11 ft 0 in.)	3.0 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
145 kV–161 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.3 m (4 ft 3 in.)
161 kV–230 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	1.7 m (5 ft 8 in.)
230 kV–242 kV	4.0 m (13 ft 0 in.)	4.0 m (13 ft 0 in.)	1.7 m (5 ft 8 in.)
242 kV–345 kV	4.7 m (15 ft 4 in.)	4.7 m (15 ft 4 in.)	2.8 m (9 ft 2 in.)
345 kV–500 kV	5.8 m (19 ft 0 in.)	5.8 m (19 ft 0 in.)	3.6 m (11 ft 8 in.)
500 kV–765 kV	7.2 m (23 ft 9 in.)	7.2 m (23 ft 9 in.)	4.9 m (15 ft 11 in.)

Notes:

(1) For arc flash boundary, see 130.5(A).

(2) All dimensions are distance from exposed energized electrical conductors or circuit part to employee.

^aFor single-phase systems above 250 volts, select the range that is equal to the system's maximum phase-to-ground voltage multiplied by 1.732.

^bSee definition in Article 100 and text in 130.4(D)(2) and Informative Annex C for elaboration.

^cExposed movable conductors describes a condition in which the distance between the conductor and a person is not under the control of the person.

The term is normally applied to overhead line conductors supported by poles.

^dThis includes circuits where the exposure does not exceed 120 volts nominal.

Table 130.4(D)(b) Shock Protection Approach Boundaries to Exposed Energized Electrical Conductors or Circuit Parts for Direct-Current Voltage Systems

(1) Nominal Potential Difference	(2) Limited Approach Boundary		(4) Restricted Approach Boundary; Includes Inadvertent Movement Adder
	Exposed Movable Conductor [*]	Exposed Fixed Circuit Part	
Less than 50 V	Not specified	Not specified	Not specified
50 V–300 V	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	Avoid contact
301 V–1 kV	3.0 m (10 ft 0 in.)	1.0 m (3 ft 6 in.)	0.3 m (1 ft 0 in.)
1.1 kV–5 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.5 m (1 ft 5 in.)
5 kV–15 kV	3.0 m (10 ft 0 in.)	1.5 m (5 ft 0 in.)	0.7 m (2 ft 2 in.)
15.1 kV–45 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	0.8 m (2 ft 9 in.)
45.1 kV–75 kV	3.0 m (10 ft 0 in.)	2.5 m (8 ft 0 in.)	1.0 m (3 ft 6 in.)
75.1 kV–150 kV	3.3 m (10 ft 8 in.)	3.0 m (10 ft 0 in.)	1.2 m (3 ft 10 in.)
150.1 kV–250 kV	3.6 m (11 ft 8 in.)	3.6 m (11 ft 8 in.)	1.6 m (5 ft 3 in.)
250.1 kV–500 kV	6.0 m (20 ft 0 in.)	6.0 m (20 ft 0 in.)	3.5 m (11 ft 6 in.)
500.1 kV–800 kV	8.0 m (26 ft 0 in.)	8.0 m (26 ft 0 in.)	5.0 m (16 ft 5 in.)

Note: All dimensions are distance from exposed energized electrical conductors or circuit parts to worker.

^{*}Exposed movable conductor describes a condition in which the distance between the conductor and a person is not under the control of the person.

The term is normally applied to overhead line conductors supported by poles.

7.4.9 Steps for Placing Equipment in an Electrically Safe Work Condition and Absence-of-Voltage Testing

Working on equipment or systems safely often involves placing it in an electrically safe work condition, which also includes absence-of-voltage testing. The following are recommended steps:

- Determine all possible sources of electrical supply to the specific equipment. Check applicable up-to-date drawings, diagrams, and identification tags.
- After properly interrupting the load current, open the disconnecting device(s) for each source.
- Wherever possible, visually verify that all blades of the disconnecting devices are fully open or that draw out-type circuit breakers are withdrawn to the fully disconnected position.
- Release stored electrical energy.
- Release or block stored mechanical energy.
- Apply lockout devices in accordance with a documented and established procedure.
- Use an adequately rated portable test instrument to test each phase conductor or circuit part to verify it is de-energized.
 - Test each phase conductor or circuit part both phase-to-phase and phase-to-ground.
 - Before and after each test, determine that the test instrument is operating satisfactorily through verification on any known voltage source.
- On electrical systems over 1000 V, noncontact test instruments may be used to test each phase conductor.
 - See CAN/CSA-C22.2 No. 61010-1-12 for rating, overvoltage category, and design requirements for voltage measurement and test instruments intended for use on electrical systems 1000 V and below.
 - For additional information on rating and design requirements for voltage detectors, see IEC 61243-1, IEC 61243-2, or IEC 61243-3.
- Where the possibility of induced voltages or stored electrical energy exists, ground the phase conductors or circuit parts before touching them. Some sites require grounding all conductors locally when the voltage exceeds 750 volts. It is recommended that the site's policies be verified before work is started.

- Where it could be reasonably anticipated that the conductors or circuit parts being de-energized could contact other exposed energized conductors or circuit parts, apply temporary protective grounding equipment in accordance with Z462, Clause 4.2.6.

7.4.10 General Safe Work Practices Guidelines for All Tasks

Specific tasks may have additional safe work practices associated with them, but in general all tasks will follow these guidelines. Some of these may be repeated with each task or equipment:

- Task(s) should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- The manufacturer's instructions should be consulted and understood prior to the start of the task.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- A written job safety plan should be developed before the start of the task(s).
- A job safety briefing should be conducted prior to the start of any task.
- The results of the absence-of-voltage tests, LOTO (lockout/tagout), the job risk assessments and job briefings should all be documented.
 - It is recommended, but not required, to check off the LOTO box on the Pre-Task form to signify that the absence-of-voltage test was satisfactory.
 - Digital meters used for the absence-of-voltage-test will not read "zero" volts, but will "flutter" a very small value. If unsure if the reading is satisfactory, it is recommended that a more experienced worker be consulted to confirm the reading.
- All work performed by the employees should be verified that it is in accordance with the safe work procedures for that specific equipment.
- Absence-of-voltage (also known as test-before-touch testing), testing of all conductors, phase-to-phase and phase-to-ground should be performed before contact is made with any tool or device.

8 Task-Specific Safe Work Practices

8.1 Up-Tower Wind Turbine Generation Equipment

8.1.1 General

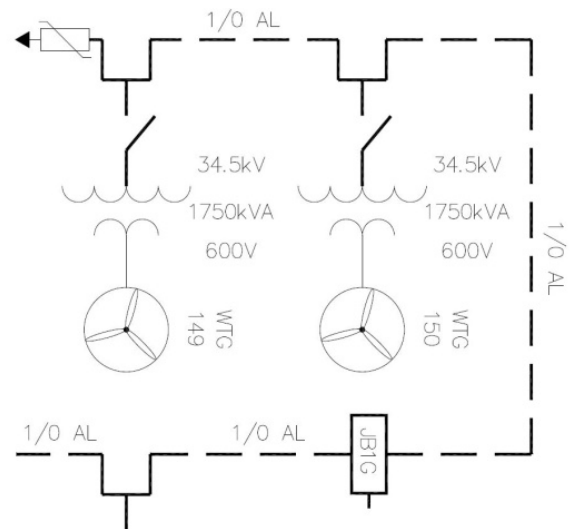
Below are the safe work practices that employers should consider implementing, in addition to compliance with applicable laws and standards, when performing any task associated with a wind generator:

- Tasks involving electrical hazards should only be performed by workers who are qualified and authorized or by a trained person under the direct supervision of a qualified and authorized worker.
- A written assessment of hazards associated to the task should be conducted prior to the start of work and provide the risk control method(s) to control the potential hazard(s).
- A written job safety plan should be developed before the start of the task(s)
- A job safety briefing should be conducted prior to the start of any task.
- Lockout/Tagout should be performed to isolate any power sources to the generator, its controls or its pad-mounted transformer, depending on the task to be done.
- The use of a Proving Unit is recommended to ensure the voltage tester is functioning (up to 700 V). Follow the manufacturer's specifications for each unit.
 - If the generator output voltage exceeds 750 V a Proving Unit should not be used, unless it is verified it can be used at the voltage being measured.
- When performing absence-of-voltage, full testing of all conductors, phase-to-phase and phase-to-ground should be performed.
- The results of the absence-of-voltage tests, LOTO (lockout/tagout), the job risk assessments and job briefings should all be documented.
- All work performed by the employees should be verified that it is in accordance with the safe work procedures for that specific equipment.

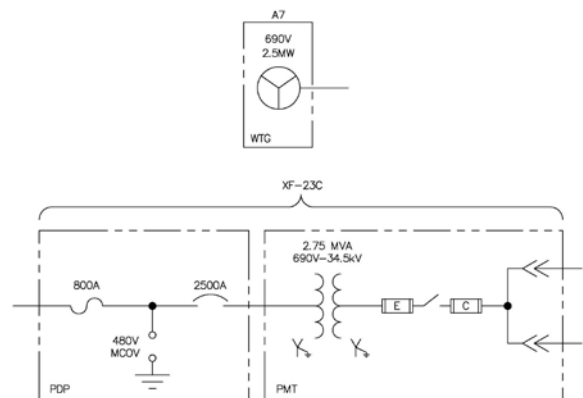
- Only insulated tools should be used when contact with energized conductors or circuit parts is possible.
- Workers should follow the appropriate fall protection guidelines at all times.

8.1.2 Generator/Wind Turbine

Generators on wind towers may present specific hazards relating to backfed generator types. Note in the schematic below that the generator could be producing power, or it could be backfed from the grid. Although it is rare, wind turbines can catch on fire, which present additional and unique hazards.



Generators present specific hazards due to the possibility of back feeding. Multiple generators are connected in series in a grid which increases the short circuit current that is available. The generators will often produce 690 V and the pad mounted transformer (PMT) steps the voltage up to 34.5 kV

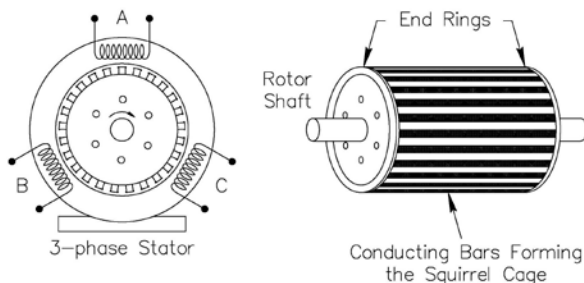


This is the symbol for a wind turbine/generator. This schematic shows the fuses, grounding, circuit breakers, pad-mounted transformer and fusible links

8.1.3 Conventional Generators

Turbines that use a blade, bearing, gearbox and generator are considered of a conventional design. Problems with the gearbox or bearings may cause damage to the generator. Alternative designs are being used in order to try to resolve potential gearbox and bearing issues and to make them more efficient. Some turbines will have the pad-mount transformer up tower in the nacelle, in which case there may be low- or medium-voltage cables that goes from the generator to the grid. Some designs may have those cables energized at 690 V, while some could be 34,500 V.

There are a variety of designs that manufacturers prefer, but conventional design wind turbines will be of the squirrel-cage induction design or the wound rotor induction design (also known as a doubly feed induction generator or DFIG). It is recommended that workers be instructed on the details of their units. In a conventional design turbine, the rotation of the blade causes the generator rotor to turn, which produces a magnetic field. When the rotor is not turning at design speed, the squirrel cage turbine can act like a motor, consuming power and not generating power. In a squirrel cage design the magnetic field is constant, while a DFIG generator can adjust the generator's speed by varying the power to the rotor through the use of slip rings.



Squirrel cage and DFIG generators produce power by rotating the rotor, which creates a magnetic field across the phase windings of the stator. The initial power to produce this magnetic field is drawn from the grid. Once the rotor reaches its proper speed, it begins producing power.

8.1.4 Direct Drive Generators

Direct drive generators are large diameter, multi-pole generators with the rotors connected directly to the main shaft with no gearbox. Typically, they operate at 17–19 RPM at full production. The electrical output is from the stator connected through a convertor or directly to the grid depending on design. It is possible that some designs also utilize the DFIG (doubly-fed induction generator)

concept where the rotor also generates at super-synchronous speed.

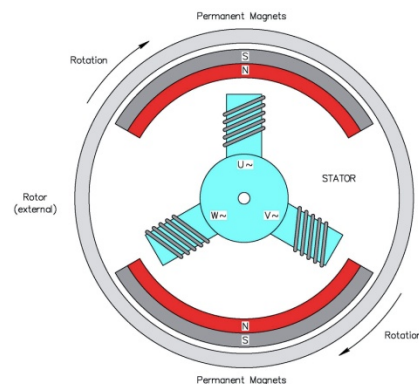
There are two styles of direct drive turbines;

1. Electrically excited generators that use external power to excite the rotation element, similar to a hydro power or conventional steam turbine and
2. Permanent magnet type generators (see below). The electrical safety issues for the conventionally excited generators are similar to any normal generator or motor.

8.1.5 Permanent Magnet Generators

Permanent magnet generators present the same primary safety issues as other types of generators; if the rotor turns, electricity is produced. Whether in direct drive machines or conventional gearbox driven generators, the magnets are always mounted on the moving component which could be the internal rotor in a conventional design or an external ring as in direct drive where the power generating coils are mounted in a stationary internal configuration. Locking the rotor and drive train is critical for mechanical safety, but in permanent magnet machines, it is also critical for electrical safety. Since turbines are generally considered to be mechanically safe when the locking pins are properly installed, then they would be generally safe electrically as well, particularly once the capacitance is discharged and grounds are properly installed.

Direct Drive Permanent Magnet example:



Regardless of the type of turbine, electrical power is produced and the general safety hazards and risks are the same. Workers are cautioned to wear appropriate safety equipment when performing any task involving electrical energy.

Permanent magnet generators for conventional design turbines look effectively the same as the electrically-excited or squirrel cage designs, but rotating the rotor creates the same safety issues. Permanent magnet generators are designed to operate at higher speeds (800+ RPM). Avoid any contact with the conductors if the rotor is turned, even if slowly.

8.1.6 General Guidelines for Working in or Up Tower

Pre-Task

Working safely depends on preparing to adequately prepare to do the task by completing Pre-Task steps. These may change somewhat with the specific task, but usually will have the same basic steps to ensure safe task performance. Please read all of the listed steps and consider implementing them as applicable to reduce the likelihood of a health and safety incident.

- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- Prior to the start of work, the manufacturer's instructions to lock the generator rotor in place should be reviewed and implemented.
 - If the generator output voltage exceeds 750 V a Proving Unit should not be used, unless it is verified it can be used at the voltage being measured.
- Locking the rotor will prevent the generator from producing power.
- Discharge any capacitive charge the generator's windings may have stored. The use of a grounding stick is recommended to slowly dissipate any charge.
- The use of a Proving Unit is recommended to ensure the voltage tester is functioning (up to 700 V). It is recommended to follow the manufacturer's specifications for each unit.
- Proper lockout/tagout procedures should be followed to isolate and de-energize the feeder cable from the generator, including the main circuit breaker.
- The location of all grounds, the results of the absence-of-voltage tests, LOTO (lockout/tagout), the job risk assessment and job briefings should be documented using the wind site's forms.

- The generator could be backfed from the pad-mounted transformer.
 - Single-line diagrams and schematics should be checked to verify the circuits.

Warning: Wind generators are connected to grids and feed pad-mounted transformers (PMTs). Generators are also backfed from the load-side of the main circuit breaker. Absence-of-voltage testing is especially important when working on generators, their components or circuits.

Performing the Task Safely

- For more information on up-tower risk refer to Decision Matrix number 3.
- Always understand the manufacturer's instructions and any cautions they may have.
- Best safe work practice is ask other experienced and qualified professionals if unsure of the appropriate safety protocol.

Post-Task

- When work is completed get the supervisor's approval before restarting, if required.
- Re-energize the generator by first reconnecting its control circuits, then its main circuit breaker and then its pad-mounted transformer.
 - The use of appropriate PPE and live-line tools is recommended.
 - The risk assessments, removal of locks, tags and grounds, where placed should be documented using the wind site's forms.
 - Release the turbine rotor for operation.
- All tests and inspections should be documented using the company's forms

Capacitors

The electrical system and grid can contain capacitors in various locations. Refer to capacitor section of down-tower task-specific safe work practices.

Cables

Power cables are a frequent source of issues of equipment failures at wind sites. Terminations also cause a substantial number of failures due to improper installation. Testing power cables can be particularly hazardous due to the high test voltage being applied. Minimum safe work practices that employers should considering implementing, in addition to applicable laws and standards, are:

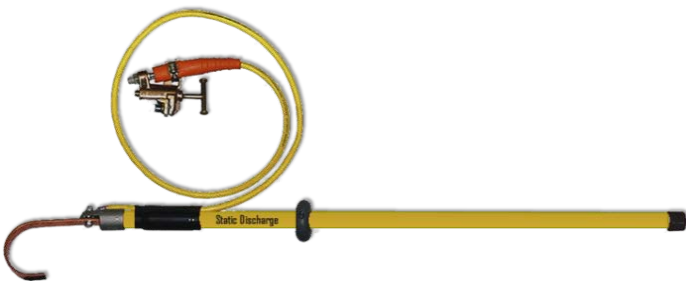
Pre-Task

- The cable should be isolated by placing it in an electrically safe work condition prior to the start of any task(s).
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be documented.
- Wind site generation is connected to a grid.
 - It may be necessary to operate the pad-mounted transformer bypass switch.
 - Operate the bypass switch using a freshly-inspected live-line tool while wearing appropriate PPE.
- Proper lockout/tagout using appropriate company procedures, tags and documentation should be performed.
- It is recommended to perform absence-of-voltage testing before making contact with any circuit or equipment.
- The location of all PTs, the results of the absence-of-voltage tests, LOTO (lockout/tagout), the job risk assessments and job briefings should be documented using the wind site's forms.

Cables Installed Up Tower

For cables routed up-tower, it is recommended to verify it is adequately secured and will not cause any additional safety risk.

- Cables can hold a hazardous capacitive charge;
 - Before any cable is touched, a ground should be applied to ensure the charge is removed.
 - The use of a grounding stick is recommended to discharge cables.



Grounding sticks are connected to ground and then touched to the cable. They have a 500M Ω resistor inside to prevent an arc flash from being discharged. (Courtesy W.H. Salisbury)

Warning: There is an increased risk of electrical shock when cables are first disconnected and after testing. Properly rated rubber insulating gloves and leather protector gloves should be worn.

- If any cables are disconnected they should be marked and identified.
- Cable shields should be tested first to ensure proper positioning.
 - A cable should not be tested without knowing where each end is.
 - Testing the shield is normally a good means to check for proper positioning before testing the cable. Use a megohmmeter connected from the shield to ground to verify the shields are connected to ground.
 - If the shield is not accessible on both ends, the main conductor can be used to verify phasing.

Performing the Task Safely

Before applying test voltage, both ends of the cable should be barricaded by personnel or red danger tape to ensure no one makes contact with the test voltage.

- Any worker in the area should be cautioned not to cross the safety barriers and to observe any warnings given by an attendant.
- Adequate clearance between the cable and any grounded object to prevent flashover during testing should be verified prior to the start of the test.



The above photos show improperly installed cables, as they have too small of a radius or insufficient clearance to ground. This is a common installation mistake that can lead to premature failure.

- During testing, all cables not under test should be grounded with a static ground.
- It is recommended that insulating rubber gloves and leather protector gloves be worn anytime the cable is handled. Although the capacitive charge is dissipated quickly by grounding, the di-pole molecules realign themselves after the test is completed. These can induce a charge into the cable for several minutes.
- After any over-potential test, the conductors should be grounded for at least two times as long as voltage was applied.
 - That may be inadequate based on the length of the cable. The time to dissipate the charge could be four times the test time for cables that are km long.
 - The use of a grounding stick is recommended for placing static grounds.

Post-Task

- Final inspection should be conducted on all connections before the covers are reinstalled.
- The person who disconnects any item is responsible for proper reconnection.
 - If that person moves to another area, he should inform another person of what must be reconnected.
- A final check should be performed for phasing parallel runs by checking for continuity phase-to-phase.
 - This is to verify none of the parallel runs are crossed.
- All tests and inspections should be documented using the company's forms

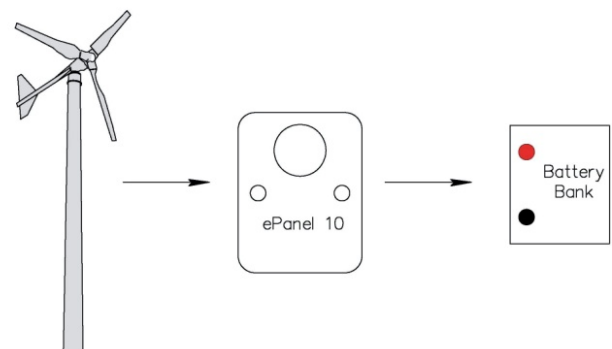
8.1.7 Control Panels

Wind turbine control panels regulate the speed of the turbine to prevent over speed conditions which could cause damage to the turbine. The following are the safe work practices that employers should consider implementing as a minimum safe work practice, in addition to applicable laws and standards, when testing a control panel:

Pre-Task

- All workers exposed to electrical hazards should wear appropriate PPE, including safety boots, hard hats and arc-rated clothing.
- A written job hazard assessment should be conducted and the hierarchy of risk control methods used to provide the method(s) to control the potential hazard(s).

Wind Renewable Energy Controller Block Diagram



Wind turbines use control panels between the turbine and the battery to regulate speed. This means both AC from the power system and DC from the battery system is present.

- Control panels may be backfed from the pad-mounted transformer.
 - Single-line diagrams and schematics should be checked to verify the circuits.
- The limits of approach to energized apparatus as specified in the current edition of Z462, Table 1A or 1B should be adhered to.
- Proper lockout/tagout and absence-of-voltage testing should be performed.
 - All conductors and equipment should be treated as energized until tested and proven to be de-energized.
- The results of the absence-of-voltage tests, LOTO (lockout/tagout), the job risk assessment and job briefing should be documented using the wind site's forms.

Performing the Task Safely

- Control wires that are removed should be labeled and documented before they are disconnected.
- When applying test voltage to any potential transformer (PT) circuit, the circuit should be isolated so the PT cannot be backfed.
- The safety guidelines for control panel maintenance and testing is the same for the generator, as the slip rings could become energized.

Post-Task

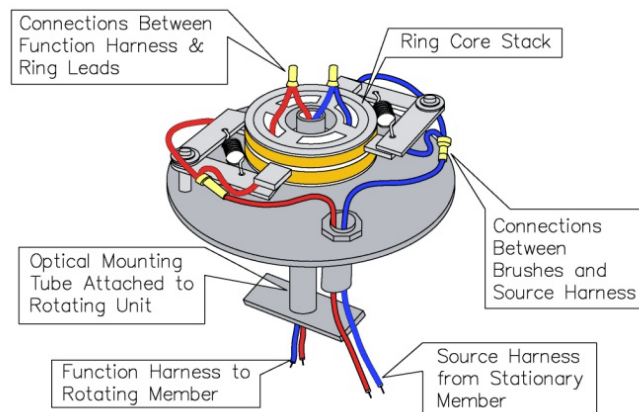
- Final inspection on all connections should be conducted before the covers are reinstalled.
- The person who disconnects any item is responsible for proper reconnection.
 - If that person moves to another area, they should inform another person of what must be reconnected.
- All tests and inspections should be documented using the wind site's forms.

8.1.8 Slip Rings

Slip rings are subject to the same type of safety issues as the generator. Slip rings transfer the electrical signal to the nacelle from controls. They are a method to transfer power and signals from a stationary object to one that rotates. Safe work practices that should be considered include:

Pre-Task

- The task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.



Slip rings are often "stacked" so they can transfer a number of different electrical signals. They require periodic maintenance to remove dust and repair wear.

- The manufacturer's instructions to lock the generator rotor in place should be followed. This will prevent the generator from producing power.
- Proper lockout/tagout procedures should be followed to isolate and de-energize the feeder cable from the generator, including the main circuit breaker.
 - The generator could be backfed from the pad-mounted transformer.
- The results of the absence-of-voltage tests, LOTO (lockout/tagout), the job risk assessment and job briefing should be documented using the wind site's forms.

Performing the Task Safely

For more information concerning slip ring safety, refer to Decision Matrix number 1.

Post-Task

- All tests and inspections should to be documented using the wind site's forms.
- Verify the work location is clear of any debris or extra parts or components.

8.1.9 Batteries (UPS and DC Controls)

EXPLOSIVE HAZARD: Lead-acid storage batteries give off a highly explosive mixture of hydrogen and oxygen when gassing. Gassing occurs when batteries are being charged (they have been under-charged and are now being brought back up to operating charge) or when they are over-charged. Sparks, open flame, or lighted cigarettes should not appear near a storage battery. "No Smoking" signs should be posted where they are clearly visible to anyone entering the battery room area.

ELECTROLYTE HAZARD: When handling electrolyte, face shields (face shields should not have metal reinforcing rims, which could cause a battery short if dropped), rubber aprons, and rubber gloves should be worn. Actions causing the electrolyte to splash should be avoided. The electrolyte is injurious to skin and clothing and should always be handled carefully. The eyes in particular should be guarded.



Batteries can be connected in "banks" to achieve a specific voltage for use. In this arrangement each battery produces about 1.75 Volts. Shown are wet-cell lead-acid batteries, but there are also nickel-cadmium, lithium-ion, sealed lead-acid and valve-regulated lead-acid (maintenance-free) and gel-cell batteries.

Batteries of various sizes and types can be used in and around the turbine, substation and computers. All have an electric shock hazard and should be maintained to ensure they can perform their function when called upon to do so. Often there is a UPS system to back the batteries up when power is removed, or a second set of batteries may be in place. It is recommended that the manufacturer's literature and instructions be consulted to ensure the batteries are properly maintained.

A non-hydraulic pitch control turbine also may contain batteries, typically referred to as hub pitch batteries. These batteries are intended to direct the turbine blade

edges into the wind during power outages or storms to limit their rotational speed to a safe value. They can operate for several hours, so care should be taken when handling or working in close proximity (close enough to make contact) to them. Pitch control can also be used to increase the efficiency of the turbine by adjusting blade angle and increase the area of the blade exposed to the wind. The batteries for the hub pitch control system are located in the nacelle (turbine cover) up tower or can be at the base of the tower. When installed up tower they can be subject to extreme conditions involving vibration and temperature/weather variations.

Although not powered by batteries, another commonly-used term is "yaw", which is rotating the entire wind turbine on a horizontal axis. Yaw control ensures the turbine is constantly facing into the wind to provide the maximum rotor area.



Hub pitch control systems that use batteries as their power supply will often use valve-regulated lead-acid (VRLA) or lithium-ion batteries. Both types of batteries require little maintenance, but also have a relatively short life.

Another up tower device that performs the same function as hub pitch batteries is the ultracapacitor. These have an advantage of producing short bursts of power, but can also add to the safety concerns of workers. Ensuring they are grounded and discharged is imperative.



Ultracapacitor used for supplying energy to the hub pitch control system. Photo courtesy of Moog, Inc.

Turbines may use hydraulic systems to control pitch and yaw. Their systems do not use hub batteries, but will use station batteries to supply power.

Batteries and battery banks offer unique hazards, as they are never de-energized, even when completely isolated. The safe work practices that an employer should consider implementing as a minimum, in addition to applicable laws and standards, are:

Pre-Task

- Task(s) should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- If working with other employees, a job safety briefing should be conducted.
- All materials and data should be verified as correct for the task(s).
- Access the battery location prior to examining the battery and connections.
- Identify Emergency Exits for rapid exit, if needed.
- Single-line and control drawings should be reviewed to ensure the battery system can be isolated, if needed.
- The battery should be placed on an equalize charge to ensure the quick operation of its overcurrent protective device.
- The condition of the battery as-found/as-left should be documented in the job risk assessment

and the job briefing should be documented using the wind site's forms.

Warning: When charging, the chemical reaction in batteries produces both toxic and explosive gasses. Workers should read the introduction at the beginning of this section for additional information and review the manufacturer's instructions.

- The sources of all ignition should be removed and the storage area ventilated.
 - In case of primary ventilation failure an auxiliary ventilation system should be in place to ventilate the area from the outside in.
 - Do not operate any electrical device (lights, fans or anything else) inside the battery storage area.

Performing the Task Safely

- The batteries should be examined for leaks or over charging.
- An eyewash station and safety shower should be within the proximity of the work area and operational when working on battery banks.
 - Eyewash stations should be within sight and have unobstructed access.
- A spill kit should be within close proximity (within line of sight) to the work area when working on battery banks.
- Tools used when working on or around battery banks should be an approved insulated tool. Taped tools should not be used as a substitute for insulated tools as tape is not an adequate insulator.
- Minimum PPE requirements should be met for tasks such as:
 - Taking voltage measurements.
 - Interaction with electrolyte – including specific gravity readings, adding water, moving individual battery cells, moving flame arrestors, etc., impedance measurements or performing load bank tests, torqueing or making connections.
- PPE may include the use and wearing of acid-resistant gloves and apron, face shield and goggles. If performing electrical tasks wear PPE appropriate for these hazards, as well.



Proper PPE is recommended when working on or maintaining batteries. Photo courtesy of IRONguard

- All connections should be inspected after work is completed.
- Any item disconnected is the responsibility of the person that disconnected it to ensure it is reconnected properly.
 - If the person who disconnected the item moves to another area, he/she should inform another person of what must be reconnected.
 - Any wires lifted or landed should be documented using the wind site's forms.
 - All connections should be made, properly torqued and verified.
- For more information on battery and UPS controls, refer to Decision Matrix number 5.

8.2 Transformers – Up-Tower or Down-Tower

8.2.1 Transformers

Whenever possible, a transformer should be de-energized before service operations. Transformers rated above 150 kVA should never be energized or de-energized by the use of disconnects not rated for load break. The load break capabilities of associated equipment should be confirmed prior to switching transformers to ensure they are adequate.

Some transformers have the ability to store a phase-to-ground and/or primary-to-secondary capacitive charge when de-energized. An absence-of-voltage test should be performed prior to the start of any task(s) and the windings

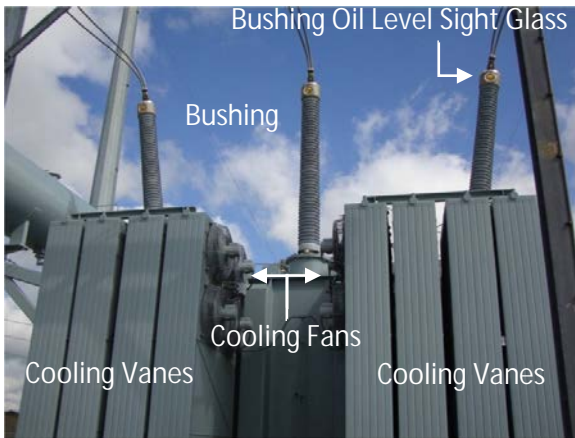
of a high voltage transformer between windings and to ground should be discharged before approaching or contacting normally energized parts. Prior to making contact with the transformer bushings with any part of the body or tools, it is recommended that the winding be grounded to discharge any capacitive charge they may have.

There are typically two types of power transformers at wind sites: pad-mounted transformers (PMTs) at the tower and the main transformers in the main substation. Pad-mounted transformers have fuses inside them for protection against faults.



Pad-mount transformers often use aluminum windings and have low-voltage internal fuses for protection against faults on the primary winding of the transformer

The second type of transformer is the main transformer in the substation. It is typically connected to the utility power system and is much larger than the pad-mounted transformers. These transformers take the voltage from the wind strings and steps it up to the utility's voltage, often 34.5 kV and above. The main transformer is protected by differential relays.



The main power transformer is connected to all the individual string transformers from the generators in the wind towers. It steps up the voltage to match the utility's voltage and will be positioned in the main substation.

The use of a high voltage grounding stick that uses a 500 M Ω resistor is recommended for personnel safety for discharging cables and generator or transformer windings. Many power and distribution transformer installations have potential transformers connected directly to the primary or secondary winding of the power or distribution transformer. Such potential transformers should have the primary and secondary protection devices withdrawn and secured against possible back feed.

Caution should be taken when adjusting off-load tap changers; it is best to do so only with the transformer fully de-energized. Even though they are commonly

referred to as no-load or off-load tap changers, these tap changers remain under load even when the transformer's secondary winding is disconnected due to the transformer's excitation current.



No-load or off-load tap changers are used to adjust the primary voltage, so the secondary voltage will match the system. Even though they primarily are used to adjust voltage, they also change the current.

Below are safe work practices that the employer should consider implementing, in addition to applicable laws and standards, as a minimum when testing all types of transformers:

Pre-Task (All Transformer Types)

- The task(s) should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- A safety barrier should be erected around the transformer under test to prevent unqualified persons from making contact with any component energized during the test. Safety barriers should be waist high with red danger safety barrier tape or an attendant.
- It is recommended to perform proper LOTO (lockout/tagout) and full absence-of-voltage testing before the start of testing.
- The location of all grounds, the results of the risk assessment, job briefing, LOTO (lockout/tagout) and absence-of-voltage tests should be documented using the company's forms.

- When possible, the transformer should be completely isolated and temporary personal protective grounds attached.
 - On pad-mounted transformers, the doors should be secured so they will not close unintentionally.
 - It is recommended to apply temporary personal protective grounds by using a live-line tool and not by hand.
 - The ground connection should be applied first, then the phase-to-ground connections.
 - If not totally disconnected the neutral ground strap should be disconnected at a minimum.
- Before disconnecting the transformer, all cables should be marked and documented properly.
- The individuals directly involved in the testing are the only ones who should be within the safety barrier, unless qualified a person(s) is being trained.
 - Persons being trained should be cautioned against making contact with the transformer under test, unless instructed to do so.

- The test set ground should be connected to the ground of the transformer under test.



The photo above, taken at a training facility, shows the proper PPE and live-line tool to be used for operating the bypass switch.

Performing the Test Safely

- Workers involved with moving the test leads should wear appropriate rubber insulating gloves and leather protector gloves to protect against shock.
- A pad-mounted transformer should be de-energized prior to operating the bypass switch.
 - If it cannot be de-energized, an appropriate live-line tool, arc-rated clothing and PPE should be used.
 - A 10-foot live-line tool and an arc flash suit with a 40 cal/cm² (arc flash category 4) are recommended as a minimum.
- Always follow the manufacturer's instructions for any test set used.
- For more information concerning working around transformers, refer to Decision Matrix number 3.
- DC testing can leave a stored charge on the transformer's windings, especially after a Winding Resistance test. This charge can be hazardous.
 - Discharge the transformer's windings after any DC test using a grounding stick.

- Each phase of the transformer should be tested to ensure it is operating properly.
 - The use of a live-line tool, adequate arc-rated and shock PPE are recommended.
 - Close doors on the cabinet for pad-mounted transformers and secure them.

Warning: If the ground clamps are not properly tightened the possibility exists that effective grounding will not be achieved and severe danger may exist due to clamps being blown off the bus or earth ground connections.

Post-Task

- All temporary personal protective grounds should be removed before re-energizing.
 - The phase-to-ground connections should be removed first, then the ground connection.
 - All workers not directly involved with switching should be cleared from the area.
- Before the transformer covers are reinstalled all jumpers should be accounted for.
- If there are missing jumper(s) the person in charge should be contacted and the issue resolved.

- The person who disconnects any item is responsible for proper reconnection.
 - If that person moves to another area, he should inform another person of what must be reconnected.
- A final inspection should be performed before the covers are reinstalled.

8.3 Down-Tower Equipment

8.3.1 Cables

Power cables distribute the electricity produced by each generator to the pad-mounted transformer, then to the string and then to the substation and eventually to the utility. Power cables can have voltages from 600 volts to 35,000 volts or greater, depending on their application, so failure of a cable will create safety and production issues. Some estimates associate the cause of failure for power cables at 95% due to installation mistakes. If the cable and terminations are properly installed, the cable should have a long life. The following are safe work practices that the employer should consider implementing, in addition to applicable laws and standards, at a minimum when testing a cable:

Pre-Task

- The task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- All phases should be verified to be visibly isolated and have adequate clearance from ground or grounded equipment to prevent flash over.
- Potential transformers should be connected to the line or cable side of the isolating disconnects.
 - Any such potential transformers should have the primary and secondary fuse withdrawn and secured against possible back feed. Disconnection of grounding constitutes “secure”.
 - Any load “tap offs” from the line or cable should be checked to verify it is adequately isolated and secured to prevent back feed from any emergency power source.

- Temporary portable generator power sources can be a hazard if back-fed circuits are not considered and secured.
- Proper LOTO (lockout/tagout) and full absence-of-voltage testing should be completed prior to the start of any tasks(s).
- It is recommended to document the location of all grounds, PTs, LOTO (lockout/tagout), location of any portable generators, the results of the absence-of-voltage/test, the risk assessment and the job safety briefing.
- Cables can hold a hazardous charge; therefore, before any cable is touched a ground should be applied to ensure the charge is removed. A grounding stick is recommended for this task.
- If any cables are disconnected, all cables should be marked and documented.

Performing the Task Safely

- Shields should be tested to ensure proper location.
 - For safety reasons, a cable should not be tested without knowing where each end is. This is normally a good means to check for proper location before testing.
 - If the shield is not accessible on both ends, the main conductor can be used to verify phasing.
- Before applying test voltage, both ends of the cable should be barricaded by using red danger tape waist high or an attendant to ensure no one makes contact with the test voltage.
 - The proper clearance from any ground or other conductors or circuit parts to prevent a flash over should be verified to prevent flashover.
- During testing, all cables not under test should be grounded with a static ground.
- For more information regarding power cable safety, refer to Decision Matrix number 4.

Post-Task

- After an over-potential test, the conductors should be grounded for a least as long as voltage was applied.
 - A grounding stick is recommended for this task.

- Long cable runs may require up to four times the test period.
- A final inspection should be conducted on all connections before the covers are reinstalled.
- The person who disconnects any item is responsible for proper reconnection. If that person moves to another area, he should inform another person of what must be reconnected.

8.3.2 Grounding

There are two primary types of grounding; temporary personal protective grounding and permanent grounding of equipment and power systems for safety. Temporary personal protective grounding is used to ensure power system equipment and power lines are de-energized; and if accidentally re-energized by reclosing, static or induced voltages, will not present a hazard to the worker. Inadequate ground clusters could melt or allow a shock risk. It may not be possible to apply locks and tags in the normal fashion. If locks and tags cannot be used, it is recommended that the Tag Only procedure be used (page 6).

Grounding for the power system has each tower and its equipment connected to a grounding system when the site is constructed. The substation will have its own ground system, known as a grounding grid and extends from the perimeter through the entire substation in a grid pattern. All equipment inside the substation, including the fence and gate are connected to the ground grid. Inside the substation at each switch will be a grounding mat. The grounding mat protects the worker in case the switch electrically fails when operated. Each part of the permanent ground system must be tested periodically and proven to be intact and have a low enough resistance to perform its function.

Temporary Personal Protective Grounds

For temporary personal protective grounds, the following are safe work practices that employers should consider implementing, in addition to applicable laws and standards, at a minimum:

Pre-Task

- The task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using

the hierarchy of risk control methods should be provided.

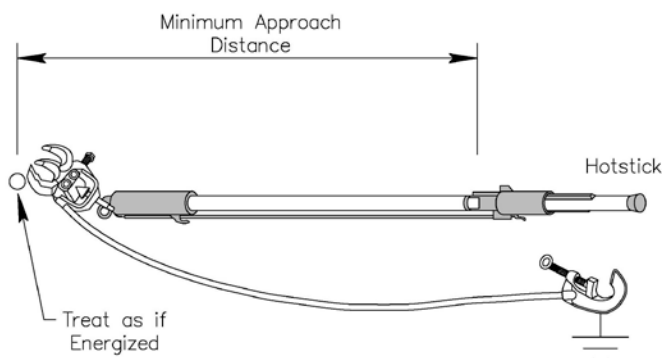
- The worker should assess the work area prior to commencing the work. They should be aware of any abnormal switching requirements.
- Clearance points should be visually verified, where practical.
- Authorization to install or remove temporary personal protective grounds on the line or electrical equipment should be obtained from the person in charge.
- The location, time of installation and number of temporary personal protective grounds installed or removed should be documented on the wind site's forms.
- When temporary personal protective grounds are installed inside a substation, the information should be recorded in the substation log book or permit to work.
- The person in charge should be informed when temporary personal protective grounds have been installed or removed.
- The equipment should be placed in an electrically safe work condition using adequately-rated shock and arc flash PPE.
 - Prior to use, the live-line tool and the gloves should be inspected.
 - The LOTO (lockout/tagout), absence-of-voltage/Test-Before-Touch tests, risk assessment, job briefing and any required site documentation for the location and marking of temporary personal protective grounds should be recorded.

Performing the Task Safely

Select and inspect temporary personal protective grounds using appropriate safe work practices:

- The appropriate conductor size for the location, available fault current and the appropriate conductor length to minimize whipping from accidental energization should be considered. Refer to ASTM standard F855 Table 1 for guidance on sizing.
- When repairing or constructing temporary personal protective grounds, components from different manufacturers should not be mixed. This has been shown to lead to failure.

- Grounds should not be coiled, either on a line truck or on the ground.
- A 20' maximum length is recommended for temporary personal protective grounds to prevent the impedance of the grounding from affecting employee safety.
- Grounds should be treated as being energized at all times. Induced voltage, which will be much lower than line voltage may appear on the line and can be a shock hazard.
- A live-line tool only should be used to install and remove temporary personal protective grounds.
- Temporary personal protective grounds should be applied quickly to eliminate arcing from induced voltages.
- If in doubt about the voltage detected on a line or equipment, do not place the ground; a fault could result.
- Ground clamps should be tightened adequately to ensure they will not be blown off in a fault.



Grounding of Conductor or Bus

Temporary personal protective grounds should be placed safely, or they can create more of a hazard than they resolve. Arms and the body should be kept outside the minimum approach boundary.

- The ground location should be verified that it is within clearance points and well outside of the limits of approach to all nearby energized apparatus.
- Live-line tools and grounding sticks should be inspected prior to their use. Refer to IEEE Standard 978, *Guide For In-Service Maintenance And Electrical Testing Of Live-Line Tools*.
- Prior to performing work using live-line tools it is recommended that IEEE Standard 516, *Guide For*

Maintenance Methods On Energized Power Lines be reviewed.

- Temporary personal protective grounds should be attached to an approved ground grid point using a live-line tool, not the hands.
- Proper body mechanics should be used to prevent strains and sprains; ask for assistance as needed.
- When working at elevations and where a ladder, aerial device, or scaffold are used, the appropriate elevating device procedures and instructions should be followed.
- One method of identifying the location of installed temporary personal protective grounds is by placing tags on the equipment and then entering them in a log.



Properly installed, adequately-sized temporary personal protective grounds ensure an area is safe to work in that otherwise would not be. Note the above technicians are wearing fall protection.

- If required, a mechanical lifting device, such as a manlift or bucket truck can be used to install the temporary personal protective grounds.
- If temporary personal protective grounds are too long, the excess should be tied off as required.

DANGER	Remember to Verify Equipment Name and Tag Number Check for Absence of Voltage and Apply Grounds using Arc Flash and Shock PPE Remove Grounds before Re-Energization
EQUIPMENT GROUNDED	
Equipment Tag:	
Reason:	
Print Name:	
Signed by:	
Date :	

Grounds Applied

Remove before Re-Energization

Best practice is to place warning signage on the equipment when placing temporary personal protective grounds on equipment or circuits. This will warn others that grounds are in place and need to be removed before the equipment is energized.

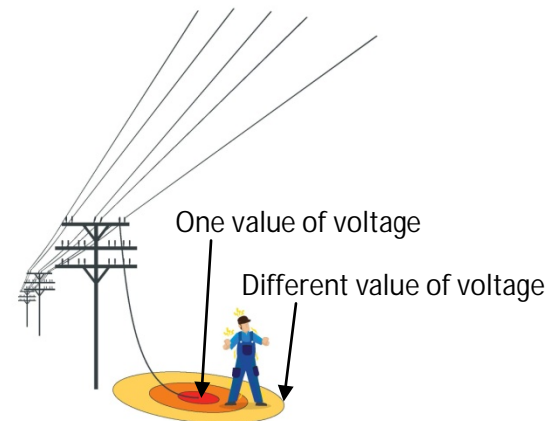
Post-Task

- When working at heights and where fall protection is required, the appropriate fall protection device procedures and either the manufacturer's instructions or site policies should be followed.
- Temporary personal protective grounds should be tested annually and tagged.
 - Any temporary personal protective grounds that are defective should be removed from service and tagged to show they are defective.
 - Temporary personal protective grounds should not be used again until they have been repaired, retested and certified as suitable for service.

8.3.3 Permanent Grounding

Permanent grounding connections can be seen at various locations throughout the wind site and substation. Each wind tower is connected to ground using a ground rod or

it is connected to the ground grid in the case of a substation.



Permanent grounding is used to prevent contact with inadvertently energized equipment and induced voltages. As substation voltages rise, so does the hazard caused by induced voltages. The picture above shows a step-voltage occurrence. Ground mats are used to protect employees from step voltage.

In the substation, ground mats can be observed connected to the overhead switches. These ground mats could be the only safe place if a switch should fail during operation. The ground mat keeps the switch operator at an equal potential to the system, reducing the difference in potential between the switch operator and the system. The hazard caused by electrical shock is not from a person receiving voltage, but from the difference in voltages between a source and ground.

Pre-Task

- LOTO (lockout/tagout), absence-of-voltage tests, risk assessment, job briefing, any required site documentation for the location and marking of temporary personal protective grounds should be documented on the wind site's forms. Prior to

operating any substation switch, its ground connection at the switch and ground mat should be verified to ensure it is tight.

- Loose connections could cause a hazardous potential difference.
- If the switch fails during operation, it is recommended not to step off the mat. The ground mat prevents a hazardous potential difference from occurring. This is often referred to as step voltage, where one foot is at one potential and the other foot is at another potential.
- Best safe work practice is to wear rubber insulating gloves and leather protector gloves when operating a substation switch.
- Prior to use, the gloves should be inspected.



Overhead switches can be hazardous if they fail during operation. A ground grid and ground mats limit the risk of injury to workers.

Performing the Task Safely

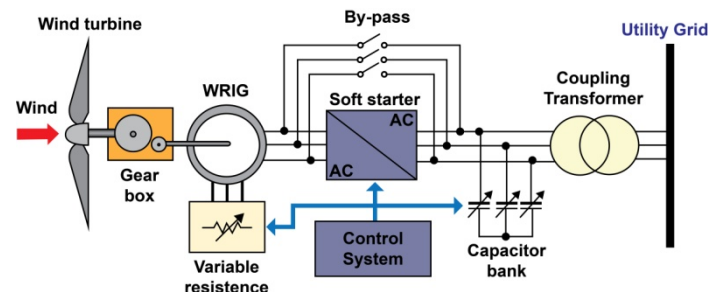
- There are two types of tests that can be performed; fall-of-potential and clamp-on meter testing.
 - Both can give equally accurate results.
 - The ground rod or ground grid is required to be disconnected from the equipment prior to testing when using the fall-of-potential method or the test will not be valid.
- The ground to be tested should be disconnected using adequately-rated shock and arc flash PPE.
- Refer to the manufacturer's instructions and specifications to determine which method is better for a specific site.

Warning: There is a risk of electrical shock when disconnecting the ground from the installed equipment. The use of rubber insulating gloves and leather protector gloves when connecting or disconnecting the ground is recommended.

Post-Task

- Temporary personal protective grounds and ground systems should be tested at a maximum of five-year intervals.
- The manufacturer's instructions for performing either of the Fall-of-Potential or clamp-on test should be followed for accurate test results.
 - The test results should be documented using the wind site's forms.
 - Test results that are too high should be reported to the wind site management for review.

8.3.4 Capacitors



Capacitors can be used to correct the system power factor (capacitor bank) or to smooth power fluctuations (soft starter). Although not shown in this figure, the "soft starter" (inverter) also contains capacitors.

Wind turbines can have a variable output due to changes in wind speed, pitch, etc. Fluctuations in power create difficulties in maintaining connection with the utility grid and can cause the wind site to be disconnected. Large power capacitors are used to dampen this fluctuation, providing a smoother output. Capacitors can be used for power factor correction, where the capacitor adjusts the phase angle of the voltage to current making it closer to being in-phase with each other. This results in more efficient operation of the system. Capacitors work with the inverter to control the output of the turbine and the main grid system.

Pre-Task

- The task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- The worker should assess the work area prior to commencing the work. They should be aware of any abnormal switching requirements.

Warning: Capacitors can store a high value of voltage and current which can, without appropriate precautions, result in severe shock injuries.

- Before contacting the capacitor with any part of your body or tools, they should be connected to ground using a line-line tool and temporary personal protective ground cluster.
- Authorization to connect or disconnect capacitors from power lines or electrical equipment should be obtained from the person in charge.
- The location, time of installation and number of capacitors installed or removed should be documented on the wind site's forms.
- The equipment should be placed in an electrically safe work condition using adequately-rated shock and arc flash PPE.
- Prior to use, the live-line tool, temporary personal protective ground cluster and the gloves should be inspected.
 - The LOTO (lockout/tagout), absence-of-voltage/Test-Before-Touch tests, risk assessment, job briefing and any required

site documentation for the location and testing should be recorded.

Performing the Task Safely

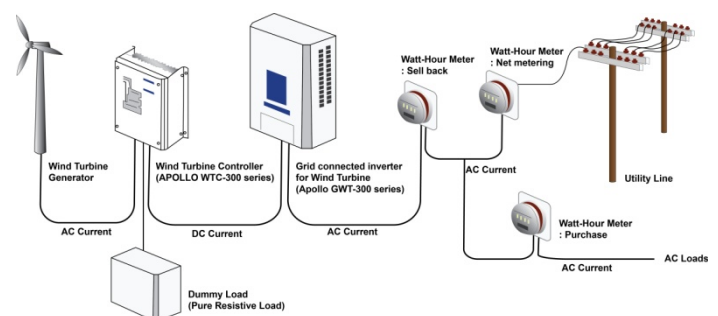
- In order to test capacitors they must be disconnected from ground. This could present inherent hazards. It is recommended that the test set be connected to the capacitor bushing before the temporary personal protective ground is removed.
- The manufacturer's instructions should be reviewed and followed in order to perform any test required.

Post-Task

- Temporary personal protective grounds should be removed from capacitors after they have been reconnected to the electrical system.
 - In order to avoid being avoid being shocked it is recommended to use caution and use proper rubber insulating gloves with leather protectors, and live-line tools.
- Test result should be documented on the wind site's forms and all information recorded.
 - Test results that are too high should be reported to the wind site management for review.

8.3.5 Inverters

The output from a generator has three electrical characteristics: voltage, current, and frequency. Because wind speed varies, a wind-driven generator would produce these at variable rates as well. Inverters are designed to convert DC to AC and will synchronize current fed to the main grid. An inverter can also be used to cut power to the grid if the main grid connection is lost. These allow raising or lowering voltage in ac transmission lines. The inverter will contain diodes, capacitors and resistors in order to convert the DC to AC.



The inverter controls the output waveform from the turbine.

Pre-Task

- The task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- The worker should assess the work area prior to commencing the work. They should be aware of any abnormal switching requirements.

Warning: Because inverters contain capacitors they can store a high value of voltage and current which can, without appropriate precautions, result in severe shock injuries.

- Before contacting the inverter with any part of your body or tools, they should be connected to ground using a line-line tool and temporary personal protective ground cluster.
- Authorization to connect or disconnect inverters from power lines or electrical equipment should be obtained from the person in charge.
- The location, time of installation and number of inverters installed or removed should be documented on the wind site's forms.
- The equipment should be placed in an electrically safe work condition using adequately-rated shock and arc flash PPE.
- Prior to use, the live-line tool, temporary personal protective ground cluster and the gloves should be inspected.

The LOTO (lockout/tagout), absence-of-voltage/Test-Before-Touch tests, risk assessment, job briefing and any required site documentation for the location and testing should be recorded.

Performing the Task Safely

- In order to test inverters they must be disconnected from ground. This could present inherent hazards. It is recommended that the test set be connected to the inverter before the temporary personal protective ground is removed.

- The manufacturer's instructions should be reviewed and followed in order to perform any test required.

Post-Task

- Temporary personal protective grounds should be removed from the inverter after they have been reconnected to the electrical system.
 - In order to avoid being shocked it is recommended to use caution and use proper rubber insulating gloves with leather protectors, and live-line tools.
- Test result should be documented on the wind site's forms and all information recorded.
 - Test results that are too high should be reported to the wind site management for review.

8.4 External Apparatus and Collection Network

8.4.1 Utility Poles

Utility poles are used to carry electrical power from one area to another, usually from the substation to the utility. Utility poles are typically treated wood with cross arms that the overhead wires are mounted to. Utilities typically do not allow others to maintain their poles or equipment, but if the wind site has utility poles that belong to them, the following safe work practices should be implemented:

Pre-Task

- The task(s) should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- Wooden utility poles are subject to weathering and rotting.
 - Before climbing a utility pole it should be inspected first to ensure it is safe to do so.
 - The results of the inspection should be documented on the wind site's forms.
 - Poles should not be worked on when they are at an excessive angle.

- Poles that are in danger of falling should have their lines de-energized at the earliest possible moment and a new pole installed.
- The wind site's employees should not make contact with any energized overhead line.
- All employees should maintain a minimum of 10' from their bodies or anything they are carrying to an energized overhead line.

Warning: Overhead power lines are not insulated to the voltage. They have a jacket that protects them from weathering, not insulating them. Do not break the 10' minimum approach distance.

- If using a bucket truck, it should be inspected prior to use to ensure it is safe to use.
 - The bucket truck should be grounded using appropriately sized temporary protective grounds.
 - The temporary personal protective grounds should be inspected for defects prior to installation.
 - The bucket should be kept a minimum of 10' from any energized power line or equipment.
 - The manufacturer's safety and operation procedures should be adhered to while the bucket truck is in use.
 - The inspection and tests performed on the bucket truck should be documented using the wind site's forms.
- The bucket truck should be electrically tested annually or according to provincial, federal or the manufacturer's specifications.
- The hydraulic fluid in the bucket truck lift mechanism should be tested in accordance with the provincial, federal or manufacturer's specifications.
- It is recommended to extend the rigging arms to stabilize the bucket truck.
 - If the rigging arms are not extended, the load capacity of the bucket truck should be decreased according to the manufacturer's instructions.
 - If there is a chance of the bucket making contact with an energized overhead line a spotter should be used to ensure the boom does not come closer than 10'.

- The spotter should be in constant two-way communication with the truck operator at all time using a walky-talky or hand-signal they both agree to.
- If insulators are to be replaced on utility poles, the lines should be de-energized first using the appropriate site LOTO (lockout/tagout) procedure and absence-of-voltage/Test-Before-Touch testing.

Post-Task

- All test results and the LOTO (lockout/tagout) procedure, risk assessment and job briefing should be documented using the wind site's forms.

8.4.2 Underground Cables

Most power cables at wind sites are located underground. If the cable and terminations are properly installed, the cable should have a long life. The followings are the safe work practices that the employer should consider implementing, in addition to applicable laws and standards, at a minimum when testing a cable:

Pre-Task

- The task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- Perform proper LOTO (lockout/tagout) and full absence-of-voltage testing prior to the start of any tasks(s).
- All grounds, PTs, LOTO (lockout/tagout), location of any portable generators, the results of the absence-of-voltage/Test-Before-Touch test, the risk assessment and the job safety briefing should be documented using the wind site's forms.
- Before applying test voltage, both ends of the cable should be barricaded by using red danger tape waist high or an attendant to ensure no one makes contact with the test voltage.
 - The proper clearance from any ground or other conductors or circuit parts should be verified to prevent a flash over.

- Check for potential transformers connected to the line or cable side of the isolating disconnects.
 - Any such transformers should have the primary and secondary fuse withdrawn and secured against possible back feed. Disconnection of grounding constitutes “secure”.
 - Any load “tap offs” from the line or cable should be verified it is adequately isolated and secured to prevent back feed from any emergency power source.
 - Temporary portable generator power sources can be hazardous if backfed circuits are not considered and secured.
- Cables can hold a hazardous capacitive charge; therefore, before any cable is touched a ground should be applied to ensure the charge is removed.
 - A grounding stick is recommended to discharge the cable.
- If any cables are disconnected, all cables should be marked and documented.

Performing the Task Safely

- Shields should be tested to ensure proper location.
 - For safety reasons, a cable should not be tested without knowing where each end is. This is normally a good means to check for proper location before testing.
 - If the shield is not accessible on both ends, the main conductor can be used to verify phasing.
- During testing, all cables not under test should be grounded with a static ground.
- For more information regarding cable safety, refer to Decision Matrix number 4.

Post-Task

- After an over-potential test, the conductors should be grounded for a least as long as voltage was applied.
 - A grounding stick is recommended for this task.
 - Long cable runs may require up to four times the test period.

- A final inspection should be conducted on all connections before the covers are reinstalled.
- Any load “tap offs” from the line or cable should be verified it is adequately isolated and secured to prevent feedback from an emergency power source. Temporary portable generator power sources can be a hazard if back feed circuits are not considered and secured.

8.4.3 Connections and Splices

Terminations (connections) and splices are typically made using kits designed for this purpose. They generally work well, but manufacturer’s instructions must be followed to ensure a long service life. The following are the safe work practices that the employer should consider implementing, in addition to applicable laws and standards, as a minimum when installing or testing connections and splices:

Pre-Task

- The task(s) should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- Proper LOTO (lockout/tagout) and absence-of-voltage/Test-Before-Touch testing should be performed prior to the start of work.
 - The results of the tests, the LOTO (lockout/tagout), risk assessment and job briefing should be documented using the wind site’s forms.
 - The cable to be worked on should be verified to be fully isolated from any source of energy.

Performing the Task Safely

- The manufacturer’s instructions for installing the kit should be followed to ensure a long-lasting termination or splice.
- All steps for testing the cable should be followed once the termination or splice has been completed.

Post-Task

- A final inspection should be made of the worksite to ensure no trash or left over components are in the area.
- The results of all tests should be documented using the wind site's forms.
 - Any test receiving questionable results should be turned in to the site supervisor for review.

8.4.4 Trenching

Trenching is important to the long life of underground power cable. Improper trenching causes “infant” cable failure and so it must be done properly. A resource for trenching rules is available online from Duke University, safety.duke.edu/sites/default/files/ig14.pdf. The following are the safe work practice that employers should consider implementing, in addition to applicable laws and standards, at a minimum when conducting trenching:

Pre-Task

- The task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- Most wind sites have a specific trenching specification to protect power cables that are buried at their sites.
 - Trenches should be dug using equipment specifically designed for that purpose.
 - Trenches require a minimum depth to protect the cable from the effects of cold and heat. It is suggested to verify that depth with local code enforcement.
 - Trenches should be inspected for rock, gravel or other objects that could damage the cable.

Post-Task

- Trash and debris should not be placed into trenches.
- Trenches should be filled with the appropriate fill that will not cause damage to the cable.

- Once trenches are dug, appropriate signage should be placed to warn others of the presence of the trench.

8.5 Substation and Collector System

8.5.1 Switchgear

The switchgear encloses circuit breakers and other power system equipment that must be shielded from dirt and other environmental contaminants and to protect workers from the risk of electrical shock. The switchgear receives power from the turbine and allows it to be switched on or off, manually or by the system protection. The switchgear used at wind sites ranges from 5 kV to 34.5 kV, depending on its purpose. Switchgear contain vacuum or SF₆ (sulfur-hexafluoride) circuit breakers, typically of the draw-out design.

Pre-Task

- Remote racking of circuit breakers into or out of their cubicles is encouraged. Even though the odds of a failure are small, the consequences may be severe.
 - If it is possible, it is recommended that circuit breakers be de-energized before racking them into or out of their cubicle.
- Two people should be involved in the racking operation; one performing the racking of the circuit breaker and the other acting as a safety backup.
- Task(s) should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.
- LOTO (lockout/tagout), absence-of-voltage/Test-Before-Touch tests, the risk assessment and the job briefing should be documented prior to the start of work using the wind site's forms.
- Prior to any work being performed on switchgear, it should be de-energized, if possible.
- All circuit breakers should be verified they are opened and racked out where possible before any test voltage is applied.

- Apply temporary personal protective grounds, as required and document ground locations, as specified in the grounding section.
- It is recommended that ground warning tags be placed on all equipment grounded to assist in locating grounds.



Switchgear provide a safe and easy to use method of distributing electrical power. Most wind sites use vacuum or SF₆ circuit breakers indoors and outdoors (station circuit breakers).

- If any cables are removed, it should be confirmed that all cables are marked and documented.

Performing the Task Safely

- When working on switchgear that is partially energized (e.g., tie cell hot on one side or generator cell hot on one side), they should be barricaded off with red danger tape
 - The shutters of a partially energized cell should never be opened.
- When applying test voltage, all switchgear should be barricaded or guarded off with tape and/or personnel to safeguard that no personal can come in contact with test voltage.

- If applying test voltage to any neutral conductor, all outgoing connections should be verified to ensure they are disconnected.

Post-Task

- All tests performed on the switchgear or circuit breakers should be documented using the wind site's forms.
- All personnel safety features that were disabled in switchgear should be replaced after work is completed and before equipment is energized.
- Two people should inspect all connections before the covers are reinstalled.
- The person who disconnects any item is responsible for proper reconnection. If that person moves to another area, he should inform another person of what must be reconnected.

SF₆ Warning (Indoor and Station Circuit Breakers): Employees working on gas-insulated cable systems or circuit breakers should be instructed concerning the special precautions required for possible presence of arcing by-products of sulfur-hexafluoride (SF₆). By-products resulting from arcing in sulfur-hexafluoride (SF₆) gas-insulated systems are generally toxic and an irritant. Gaseous by-products can be removed for maintenance to the compartments by purging with air or dry nitrogen. The solid residue that must be removed is likely mostly metallic fluoride. This fine powder absorbs moisture and produces fluorides of sulfur and hydrofluoric acid, which are toxic and corrosive.

8.5.2 Substation-Class Circuit Breakers

Substation-class circuit breakers are used in outdoor substation or other locations that require bulk transmission of power. They are often rated at 138 kV to 500 kV and connect the wind site generated power to the utility. Substation-class circuit breakers are usually vacuum or SF₆, but can be oil circuit breakers, also. The most common SF₆ circuit breaker at wind sites is the "dead tank" circuit breaker. "Live tank" circuit breakers are often used at higher voltages.

Before performing any work on substation-class circuit breakers the ground connections should be inspected to ensure they are in place and tight. At higher voltages the hazard of induced voltages becomes dangerous. Proper grounding of the equipment is highly recommended. Climbing on or trying to clean the circuit breaker bushings

when it is energized for any reason is strongly discouraged.



Above are two station-class SF₆ circuit breakers. The operating mechanism is on the front of the circuit breaker and can be hydraulic, pneumatic or spring operated. These are referred to as dead-tank circuit breakers. This is the typical type of SF₆ circuit breaker found at wind site main substations.

Pre-Task

- It is recommended the gas pressure be verified before any work is started.
 - SF₆ gas compresses as it gets colder.
 - There is a risk of the circuit breaker not functioning properly if the pressure of the SF₆ decreases too much.
 - The circuit breaker should not be operated if it has inadequate pressure.
- Task(s) should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person.
- A job risk assessment should be conducted and the method(s) to control the identified risk using the hierarchy of risk control methods should be provided.

Performing the Task Safely

- In addition to creating hazardous and toxic gases during a fault, SF₆ circuit breakers are a known environmental hazard.
 - Care should be used to prevent leakage when servicing the circuit breaker.

- The gas cart's manufacturer instructions on how to use it properly and safely should be consulted prior to use.
- Proper PPE and clothing when servicing SF₆ circuit breakers should be worn.
- The circuit breaker should be isolated from the system prior to the test.
- The circuit breaker should be tested for the absence-of-voltage (Test-Before-Touch) and a risk assessment performed, followed by a job briefing.
- The results of the absence-of-voltage (Test-Before-Touch) tests, the risk assessment and the job briefing should be documented using the wind site's forms.
- The circuit breaker should be isolated for testing. Workers should be made aware of the risk of induced voltage and static charges.
- The area around the circuit breaker should be barricaded using safety barrier tape placed waist high and/or an attendant.

Item	Open compartment before first SF ₆ filling	Open compartment which contained non-arced SF ₆	Open compartment which contained either normally arced or heavily arced SF ₆
Potential risk	<ul style="list-style-type: none"> • Fumes of cleaning material • O₂ starvation • Remaining SF₆ or other gas from production process 	<ul style="list-style-type: none"> • Fumes of cleaning material • O₂ starvation • Remaining gas 	<ul style="list-style-type: none"> • Fumes of cleaning material • O₂ starvation • Remaining gas • Residual reactive gaseous decomposition products • Switching dust and absorbers
Safety precautions	<ul style="list-style-type: none"> • Ventilation • Measurement of O₂ concentration when entering 	<ul style="list-style-type: none"> • Ventilation • Measurement of O₂ concentration when entering 	<ul style="list-style-type: none"> • Removal of switching dust and absorbers • Ventilation • Measurement of O₂ concentration when entering • Wear personal protective equipment
Safety equipment and tools	<ul style="list-style-type: none"> • Suction ventilator or vacuum cleaner • O₂ concentration measuring device 	<ul style="list-style-type: none"> • Suction ventilator or vacuum cleaner • O₂ concentration measuring device 	<ul style="list-style-type: none"> • Suction ventilator or vacuum cleaner • O₂ concentration measuring device • Single use protective clothes, shoe covers, hair cap • Acid-proof safety gloves • Full face mask (preferred) or, at least, breathing protective mask • Protective goggles

Safety equipment required for accessing SF₆ equipment compartments on electric equipment, from CIGRE 276, *Guide for the Preparation of Customized "Practical Handling Instructions"*

- The manufacturer's instructions and procedures should be reviewed and followed during the test.
- Testing SF₆ circuit breakers requires special equipment. Any worker performing such tests should be trained to prevent safety risk and prevent damage to the circuit breaker.
- No one should be in the test area that is not directly involved in the testing or is being trained to perform the tests. Such persons should be continuously escorted.

Post-Task

- Once the testing is completed, the circuit breaker should be reconnected to the system while wearing adequate rubber insulating gloves and leather protectors or allowing the static grounds to stay in place.
- Static grounds should be removed once the circuit breaker is reconnected to the system.
- The results of all tests should be recorded, and any out-of-specification results should be reported to the site supervisor.
- Prior to re-energizing the circuit breaker, it should be inspected for any grounds on its

bushings or other issue that could affect its operation.

- All employees should be warned to stay out of the area while the circuit breaker is being re-energized.

8.6 Test Equipment

Test equipment refers to any device used to inject a voltage or current (or other electrical signal) into an electrical device to verify it is satisfactory for continued service or any equipment used to measure such electrical quantities. Test equipment can have various outputs, such as variable voltages or current, frequencies or special waveforms to detect defects in equipment. Test equipment can cause serious health and safety incidents if it is used unsafely. The following guideline are recommended for the use of test equipment:

Pre-Task

- The manufacturer's instructions for the test equipment should be reviewed prior to the test equipment being used.
- Each employee should demonstrate the proper use of the test equipment prior to using it.

- Before use, the test equipment should be operated and verified its output will not cause injury during use.
- Before use, the test equipment should be inspected to verify all guards and other safety features are on the test equipment and operational.
- Prior to use, the test equipment should be inspected for any defect that would affect its safe use, especially output wiring and accessories.
 - Digital and mechanical volt-ohm meters should not have their leads wrapped around the body of the meter, as this over-stresses the lead at the connector to the meter.



The meter lead looked fine on the outside, but was separated when any stress was placed on it. This lead to a failure that severely injured a worker who was permanently disabled.

- Defective or unserviceable test equipment should be turned in for repair or to be discarded.
- The test equipment should be connected to a Ground-Fault Circuit Interrupter (GFCI), either a receptacle or through a pigtail designed for the purpose, unless the manufacturer does not approve of it.
- Before the test equipment is used, the GFCI should be tested and verified it is functional.

Performing the Task Safely

- The employee should wear the safety equipment recommended by the manufacturer or by the wind site when using any test equipment.
- The test equipment should only be used in the manner recommended by the manufacturer.
- The area where the test equipment is being used, and the equipment it is testing, should have access restricted to it by the use of safety barrier tape placed waist high and/or an attendant.
- Each employee should be provided training on the proper use of the test equipment prior to its use.
- If test equipment requires repair or servicing, it is recommended that a person or facility who is qualified to do such work be used.

Post-Task

- It is recommended that test equipment be inspected and tested annually to verify it is safe to use.
 - Test equipment that is tested and found to be satisfactory should have an approved sticker placed on them showing who performed the test, the date of the test and their initials.
- Test equipment used for measuring, such as voltmeters, ammeters or power quality meters should be used only as their manufacturer recommends.

9 Decision Matrix

Decision matrix sample table for specific tasks (General guidelines; not specific to any manufacturer).

Task	Pre-requisite	Potential Hazards Present	Personal Protective Equipment, Devices and Tools
1. Generator Slip Ring Maintenance for Unit Out of Service	<ul style="list-style-type: none"> This task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person. A written job plan should be completed and a tailboard conference should have taken place with all workers, as required. Be aware of congestion in the work area, the need for good housekeeping and proper body mechanics. Proper body mechanics should be used. Symptoms of a musculoskeletal injury can include pain, burning, swelling, numbness or tingling, color changes, and loss of movement or strength in a body part. It is recommended that you inform your supervisor if you are experiencing any of these symptoms so steps can be taken to avoid making the conditions worse. 	<ul style="list-style-type: none"> Electrical Contact Strains & Sprains Slips & Trips Airborne Particles Ergonomic Positioning Pinch Points Confined Space High Noise Level 	<ul style="list-style-type: none"> Hard Hat Safety Footwear Barricades Personal Fall Protection Atmospheric Monitoring System Safety Eyewear Working Gloves Low Voltage Rubber Insulated Gloves Hearing Protection Confined Space Retrieval System Respirator
2. Injured Man – Tower Rescue	<ul style="list-style-type: none"> This task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person. The rescue procedure should be reviewed in the written Job Safety Plan and during a tailboard conference with all workers. The limits of approach to energized apparatus and conductors should be observed. Employees should be aware of congestion in the work area, the need for good housekeeping and proper body mechanics. An employee's undivided attention should be given to this task. If an emergency situation occurs while conducting this task, the area 	<ul style="list-style-type: none"> Strains & Sprains Slips & Trips Airborne Particles Electrical Contact Ergonomic Positioning Pinch Points Confined Space High Noise Level 	<ul style="list-style-type: none"> Hard Hat Safety Footwear Barricades Personal Fall Protection Atmospheric Monitoring System Safety Eyewear Working Gloves Low Voltage Rubber Insulated Gloves Hearing Protection Confined Space Retrieval System Respirator

	<p>should be secured to prevent further injury or damage and emergency assistance should be called for immediately as identified in your job plan.</p>		
3. Power Generation Hardware – Installing and Removing Equipment from an Installed up-tower	<ul style="list-style-type: none"> • This task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person. • All workers conducting this job should be required to wear safety boots, hard hat, fall arrest, and safety glasses with UV/IR. • Wear your high visibility or flame resistant clothing as required. • When within limits of approach to energized apparatus appropriately rated rubber gloves and sleeves should be worn. • All personal protective equipment, FRP, cover-up, and rubber gloves and sleeves should be inspected prior to use. • A written job plan should have been completed and a tailboard conference should have taken place with all workers, as required. • Employees should be aware of congestion in the work area and the need for good housekeeping. • Proper body mechanics should be used. Symptoms of a musculoskeletal injury can include pain, burning, swelling, numbness/tingling, color changes, and loss of movement or strength in a body part. • It is recommended that you inform your supervisor if you are experiencing any of these symptoms so steps can be taken to avoid making the conditions worse. • This task requires your undivided attention, it is important to remain focused on the task at hand. 	<ul style="list-style-type: none"> • Poor Communication • Equipment Failure • Equipment Operation • Slips & Trips • Traffic, Pedestrian • Falling From Heights • Falling Objects • Electrical Arc • Electrical Shock • Rigging Failure 	<ul style="list-style-type: none"> • Clothing, High Visibility • Barricades • Fall Protection • Traffic Control • Signage • Temporary Protective Grounds & Flags • Hard Hat • Safety Footwear
4. Conductor – Installing, Trenching and Salvaging	<ul style="list-style-type: none"> • This task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person. 	<ul style="list-style-type: none"> • Falling from Heights • Weather • Unstable Ground • Miscommunication or 	<ul style="list-style-type: none"> • Fall Protection -arrest • Traffic Control • Grounding • Job Plan or Tailboard

	<ul style="list-style-type: none"> • All workers conducting this job should be required to wear safety footwear, hard hats, safety eyewear, and where required face shields, balaclava, flame resistant clothing, high visibility clothing and hearing protection. • A written job plan should have been completed and a tailboard conference should have taken place with all workers, as required. A route assessment to determine potential hazards should be included to identify possible hazards. • Limits of approach to energized apparatus should be observed. • Employees should be aware of congestion in the work area and the need for good housekeeping. • Proper body mechanics should be used. Symptoms of a musculoskeletal injury can include pain, burning, swelling, numbness/tingling, color changes, and loss of movement or strength in a body part. • It is recommended that you inform your supervisor if you are experiencing any of these symptoms so steps can be taken to avoid making the conditions worse. • Your undivided attention should be given to this task, it is important to remain focused on the task at hand. 	lack of communication	<ul style="list-style-type: none"> • Safety Hold Off • Limits of Approach • Proper Vehicle Setup
5. Batteries (UPS and DC Controls)	<ul style="list-style-type: none"> • This task should only be performed by qualified and authorized personnel or by a trained person under the direct supervision of a qualified and authorized person. • All workers conducting this job should be required to wear safety boots, safety glasses/goggles and hard hat. • Employees should be aware of congestion in the work area and the need for good housekeeping. • Proper body mechanics should be used. Symptoms of a musculoskeletal injury can include pain, burning, swelling, numbness/tingling, color changes, and loss of movement or strength in 	<ul style="list-style-type: none"> • DC Electric Shock • DC Arc Flash • Health Hazards • Chemical • Explosive Atmosphere • Gas, Leaks/ Migration • Strains, Sprains • Slips/Trips/ Falls • Housekeeping 	<ul style="list-style-type: none"> • Hard Hat • Safety Eyewear • Safety Footwear • Gloves, Leather Work

a body part.

- It is recommended that you inform your supervisor if you are experiencing any of these symptoms so steps can be taken to avoid making the conditions worse.
- Your undivided attention should be given to this task, it is important to remain focused on the task at hand.

10 Additional Resources

10.1 Emergency Response and Rescue

10.1.1 Purpose

To insure that all personnel performing elevated tower work are prepared in an emergency to provide assistance and/or remove an injured employee from an elevated workstation.

10.1.2 Rescue Plan

All equipment used for fall protection should comply with ANSI Z359.1 and applicable provincial and federal laws. All employees performing elevated tower work should have formal tower safety and rescue training as specified by the wind site management. Proof of certification for each climbing employee should be on site at all times.

Each wind site should have their own rescue plan, rescue procedures and post rescue procedure. These should be available at the site in a location that is visible to all employees.

To ensure all hazards, control measures and rescue information is communicated to each employee, the crew should review the wind site's emergency information and Job Site Assessment (JSA) that should include the following information:

- Rescue method and the equipment to be used.
- Location of first aid kit, phones and rescue equipment.
- Location information that provides specifics about the wind tower.
- Directions for emergency services to access the jobsite.
- All emergency numbers and available address to the nearest emergency services location.
- Prior to work, the tower crew should hold a tailgate meeting to discuss the information listed above in addition to the job hazards and the scope of work.

10.1.3 Safe Work Conditions

It is recommended that all sites conduct daily inspections to verify they have safe work conditions at their sites. Examples of safe or unsafe work conditions at wind sites include the following conditions:

- Towers and substations should be maintained in a clean and orderly fashion.
- Ladders and other means of ascending the tower should be kept clear of obstructions.
 - In inclement weather ice should be removed, if possible.
- If lightning is within the distance specified by the site operator of the site, it is recommended that up-tower work be suspended until it is safe.
- Office and warehouse areas should be kept free of debris or other tripping hazards.
- Any unsafe condition should be documented, photographed, if possible and reported to the site supervisor as soon as possible.
- Unsafe work conditions should be corrected as soon as possible.
- A risk analysis should be performed and documented for all tasks to ensure safe work conditions exist.
- Employees should not be permitted, or told, to perform tasks in which they are not qualified.
- If an employee believes an unsafe condition exists, he should be able to suspend work until the situation that causes that to be corrected or he is counseled.
- All mechanical equipment, such as crane and man lifts should be operated by a person qualified to do so.
- All employees not directly involved with tasks involving mechanical equipment should not be permitted to be in the work area.
- Only qualified persons should be permitted into the substation area.
 - Employees can be task-qualified for tasks such as housekeeping or weed control.

10.2 Qualified and Unqualified Electrical Worker Training

The guidelines in Annex A are recommended for training wind site employees, supervision and management. The Training Matrix is divided into four categories; unqualified (Level 0), qualified up to 1,000 V (Level 1), qualified above 1,000 V (Level 3) and supervision (Level 4).

10.2.1 Frequency of Training Requirements

The frequency of electrical safety training should occur, at a minimum, when a new worker enters the company or when there is a change in the worker's role. The CSA Z462 Clause 4.1.6.4.3 recommends that workers must undergo documented retraining in electrical safety at a minimum of every three years or if the conditions stated below are observed:

- Supervision or annual inspections indicate that the worker is not complying with safety-related work practices;
- New technology, new types of equipment, or changes in procedures necessitate the use of safety-related work practices that are different from those that the worker would normally use; or
- The worker needs to employ safety-related work practices that are not normally used during his or her regular duties.

Appendix A

11 Training Matrix for System Operators, Technicians and Supervisors of Wind Energy Generation Facilities

11.1 Workers Who are Not Qualified Persons

Defined as employees who work around energized electrical equipment and systems meeting the definition of "Normal Operating Equipment" and are not considered to be "Qualified" CSA 462-18, Clause 4.3.2.2.4:

- The equipment is properly installed;
- The equipment is properly maintained;
- The equipment is used in accordance with instructions included in the applicable *Canadian Electrical Code*, Part II Standard and in accordance with the manufacturer's instructions;
- The equipment doors are closed and secured;
- All equipment covers are in place and secured; and
- There is no evidence of impending failure.

CEC, Part II Defines The Requirements For Safe Electrical Installations

MAINTENANCE AS PER VENDORS LISTING OR NATIONAL CONSENSUS STANDARDS

As noted in CSA Z462-18 the condition of "properly installed" means the equipment is installed in accordance with applicable industry codes and standards and the manufacturer's recommendations. Proper maintenance means the equipment has been maintained in accordance with the manufacturer's recommendations and applicable industry codes and standards. Evidence of impending failure means that there is evidence such as arcing, overheating, loose or bound equipment parts, visible damage or deterioration.

An unqualified person should not enter a substation without continuous escort by a qualified person. In substations this is due to the hazardous voltages present, of uninsulated current carrying parts at vastly different voltages and clearances to ground or other potentials.

11.2 Qualified Person

Defined as employees who can work safely around energized electrical equipment and systems that are in "Normal and Abnormal Operating Conditions"

Abnormal Conditions exist when the worker is required to employ work practices that may expose the worker to electrical hazards or risk or that may not be implemented unless emergency/safety conditions exist. For the wind industry this could be considered any time the wind is blowing, and power is not being produced.

Z462 Requires "Competency"

SHOW ME YOU CAN DO THE JOB SAFELY

Electrical Hazards (shock, arc flash and blast) are employee exposures that result from working within the limited approach boundary or the arc flash boundary of exposed parts or conductors.

Z462 defines a qualified person as – *Qualified Person (worker) – one who has demonstrated skills and knowledge related to the construction and operation of electrical equipment and installations and has received safety training to identify the hazards and reduce the associated risk.*

It is noted in Clause 4.1.7.1.6 "Electrical safety training documentation" that:

The employer shall document that each worker has received the training required by Clause 4.1.7.1.1.

This documentation shall:

- a) be made when the worker demonstrates proficiency in the work practices involved;*
- b) be retained for the duration of the worker's employment; and*
- c) contain the content of the training, each worker's name, and dates of training.*

Notes:

- 1) Content of the training could include one or more of the following: course syllabus, course curriculum, outline, table of contents, or training objectives.
- 2) Employment records that indicate that a worker has received the required training are an acceptable means of meeting this requirement.

Retraining is required:

A worker shall receive periodic retraining in safety-related work practices and applicable changes in this Standard, at intervals not to exceed 3 years, to maintain an appropriate level of awareness and shall receive additional training if

- a) supervision or annual inspections indicate that the worker is not complying with safety-related work practices;*
- b) new technology, new types of equipment, or changes in procedures necessitate the use of safety related work practices that are different from those that the worker would normally use;*
- c) the worker needs to employ tasks that are performed less often than once per year;*
- d) the worker needs to employ safety-related work practices that are not normally used during his or her regular job duties; or*
- e) the worker's job duties change.*

Recommendations for Unqualified and Qualified Person Training

Due to the hazards involved with operating generation, transmission and distribution equipment, workers should have site and equipment-specific training and demonstration of skills in order to be considered qualified. In most cases an unqualified person will only be able to operate generation, transmission and distribution equipment removed from the electrical hazards where a failure will not expose them to electrical hazards.

12 Unqualified Person Training

Anyone who may be exposed to electrical hazards should understand how exposure could occur and how to avoid injury from that exposure, as required by Z462-18, which includes “equipment or system operators, technicians and others”. System design will limit unqualified persons from some areas, but not eliminate exposure to the hazards. In most cases these activities would be outside the fence line of a substation and therefore entry for inspection, data collection, or any other activity in the substation could not be performed by these unqualified workers.

The tables that follow were developed by Shermco Industries to meet the minimum requirements of performing tasks in the wind generation environment. They are based on Clause 4.1.6 and Clause 4.1.7 in the current edition of CSA Z462-18.

12.1 Level 0 – Electrical Safety – Unqualified Person

Regulatory Drivers	<ul style="list-style-type: none">• CSA Standard Z195-M1984, Protective Footwear, English 3/86, French 12/84, Section 12.5(1)• Z462, <i>Workplace Electrical Safety</i>• For other standards, refer to Appendix B, Regulations and Standards for Provinces
Core Competencies	<ul style="list-style-type: none">• Understand the electrical safety program, policies, procedures and emergency response criteria• Recognize electrical hazards• Understand how exposure can occur• Understand how to avoid injury• Understand approach boundaries• Understand simple Lockout/Tagout procedures• Understand proper use of receptacles and extension cords• Understand the appropriate use and application of PPE
Frequency of Training	<ul style="list-style-type: none">• Initial training.• Every three years in accordance with Z462• Workers who, in the judgment of responsible supervision, fail to demonstrate adequate skill, and knowledge (to be determined by the job supervisor) shall be retrained. The extent of retraining necessary shall be at the discretion of the supervisor.

13 Qualified Person – Less Than 1,000 VAC Installations

This program is the first part of the training to qualify electrical workers to perform tasks where they may be exposed to electrical hazards. These workers should be required to be technically competent to participate. The intent of the course is to provide the safety training skills and knowledge to perform tasks while exposed to low-voltage (<1,000 VAC) hazards and risks.

13.1 Level 1 – Electrical Safety – Qualified Person Less Than 1,000 VAC

Regulatory Drivers	<ul style="list-style-type: none">• CSA Standard Z195-M1984, Protective Footwear, English 3/86, French 12/84, Section 12.5(1)• Z462, Workplace Electrical Safety• For other standards, refer to Appendix B, <i>Regulations and Standards for Provinces</i>
Core Competencies	<ul style="list-style-type: none">• Understand corporate policies and procedures• Understand how electrical hazards affect body tissue• Identify typical electrical hazards found on company facilities• Identify and understand the degree of hazard (shock, arc flash and arc blast)• Understand how to minimize risk by body position• Understand the proper use and application of voltage testing equipment, including inspection and indications• Understand how to place electrical equipment and circuits in an electrically-safe work condition• Be able to select, use, inspect and maintain PPE• Understand techniques required to perform a risk assessment• Understand clearance requirements around equipment• Determine and understand the Limited and Restricted Approach Boundaries• Determine the Arc Flash Boundary• Be able to apply safety barriers and signage

14 Qualified Person Electrical Safety – Greater Than 1,000 VAC

This program is designed to qualify electrical workers in the risks, procedures and specific requirements when performing tasks around energized electrical equipment rated greater than 1,000 VAC. Some time for demonstration of skills has been included into this program, but additional time may be needed based upon site-specific requirements.

14.1 Level 2 – Electrical Safety – Qualified Person Greater Than 1,000 VAC

Regulatory Drivers	<ul style="list-style-type: none">• CSA Standard Z195-M1984, Protective Footwear, English 3/86, French 12/84, Section 12.5(1)• Z462, <i>Workplace Electrical Safety</i>• For other standards, refer to Appendix B, <i>Regulations and Standards for Provinces</i>
Core Competencies	<ul style="list-style-type: none">• Understand corporate policies and procedures• Understand how electrical hazards affect body tissue• Identify typical electrical hazards found on company facilities• Identify and understand the degree of hazard (shock, arc flash and arc blast)• Understand how to minimize risk by body position• Understand the proper use and application of voltage testing equipment, including inspection and indications• Understand how to place electrical equipment and circuits in an electrically-safe work condition• Be able to select, use, inspect and maintain PPE• Understand techniques required to perform a risk assessment• Understand clearance requirements around equipment• Determine and understand the Limited and Restricted Approach Boundaries• Determine the Arc Flash Boundary

	<ul style="list-style-type: none"> • Be able to apply safety barriers and signage • Operate high-voltage electrical power system equipment, such as switches and circuit breakers • Inspect electrical power system equipment to evaluate its condition of maintenance
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15 Electrical Safety for the Supervisor

Electrical supervisor training is more involved than for the technician or field service worker, since the supervisor must ensure his or her worker's safety. This program has no hands-on demonstration of skills and is seminar based, using practical exercises and participant interaction to help guide the content. The focus of this one-day program is on what the supervisor should know to ensure a safe workplace.

15.1 Level 3 – Electrical Safety – Supervisor Level

Regulatory Drivers	<ul style="list-style-type: none"> • CSA Standard Z195-M1984, <i>Protective Footwear</i>, English 3/86, French 12/84, Section 12.5(1) • Z462, <i>Workplace Electrical Safety</i> • For other standards, refer to Appendix B, <i>Regulations and Standards for Provinces</i>
Core Competencies	<p>Upon completion of this class, participants will be able to:</p> <ul style="list-style-type: none"> • Understand the role of the supervisor in the electrical safety program • Understand the Energized Electrical Work Permit and hierarchy of controls • Understand PPE program, their roles and responsibilities, including PPE inspection, selection, training and use for their employees • Perform and review risk assessments • Understand the difference between qualified and unqualified personnel and the responsibilities of each. • Understand the basics of LO/TO procedures and the requirement for annual audits • Understand their enforcement role for the electrical safety program (conducting and documenting inspections, etc.) • Understand their responsibility for developing basic rescue procedures • Understand the safety network structure at company facilities • Simple and complex LO/TO procedures • Understand clearance requirements around equipment • Understand the basic theory behind conducting an arc flash hazard analysis.

15.2 Additional Demonstration of Skills and Knowledge

Until qualified employees have demonstrated proficiency in the work practices involved, they should be considered to be employees undergoing on-the-job training and should be under the direct supervision of a qualified person at all times. According to the definition of "qualified employee," the employee should also demonstrate an ability to perform work safely at his or her level of training.

The hands-on lab sessions conducted during the training programs should be documented to comply with Z462's training requirements.

Appendix B

16 Federal and Provincial Laws

Applicable laws are subject to change. Supervisors should check for the latest revision of governing documents in the jurisdiction where work is being performed. Standards are not laws but may be incorporated or referenced in part or in whole by the statutes or regulations, in some cases making them legal requirements. The following references are provided to give the reader a general sense of the types of relevant requirements that exist but should not be treated as a comprehensive or up to date list of requirements. The statutes and regulations referenced below, as well as any other applicable laws, should be consulted directly for the exact requirements.

Federal / Provinces / Territories	Occupational Health and Safety Regulation Major Summary
Federal	Canada Occupational Health and Safety Regulations, SOR/86-304, Section 8.4(2) CSA Standard Z195-M1984, Protective Footwear, English 3/86, French 12/84, Section 12.5(1)
Alberta	Alberta Occupational Health and Safety Act 2009 , Section 232(1) Alberta Occupational Health and Safety Act 2009 , Section 233(2) Alberta Occupational Health and Safety Act 2009 , Section 804(1)
British Columbia	British Columbia Occupational Health and Safety Regulations (296/97) [Section 8.11(3)], [Section 8.14(2)(b)], [Section 8.22(3)], [Section 19.10(3)]
Manitoba	Manitoba Workplace Safety & Health Regulation (C.C.S.M. c. W210) , 1. [Section. 6.10(1)(b)], [Section. 6.14(2)], [Section. 38.14(2)(f)], [Section. 38.14(4)]
New Brunswick	Regulation 91-191 under the New Brunswick Occupational Health and Safety Act (O.C. 91-1035) , 1. [Section. 289(1)], [Section. 288], [Section. 294(2)(a)]
Newfoundland and Labrador	Regulation 5/12 under the Newfoundland and Labrador Occupational Health and Safety Act (O.C. 2012-005) , 1. [Section. 80(3)], [Section. 82(1)], [Section. 484(2)(b)], [Section. 490(2)(c)]
Nova Scotia	Occupational Safety General Regulations made under the Occupational Health and Safety Act, S.N.S. 1996, c. 6. , [Section. 123(1)], [Section. 123(2)], [Section. 124(2)]
Northwest Territories	Occupational Health and Safety Regulations , [Section. 94(2)], [Section. 98(3)], [Section. 460(8)(a)(iii)]
Nunavut	General Safety Regulations under the Safety Act , [Section. 44(1)]
Ontario	Industrial Establishments Regulation under the Occupational Health and Safety Act , [Section. 42.1(2)], [Section. 42.1(3)]
Prince Edward Island	General Regulations made under the Occupational Health and Safety Act , [Section. 36.5(2)], [Section. 36.5(3)], [Section. 36.5(4)], [Section. 36.5(5)], [Section. 36.10], [Section. 36.17(a)]
Quebec	Regulation respecting occupational health and safety , [Section. 344(2)]
Saskatchewan	The Occupational Health and Safety Regulations under the Occupational Health and Safety Act , [Section. 91(3)], [Section. 94(3)], [Section. 97(2)], [Section. 465(5)(a)(iii)]
Yukon	Yukon Occupational Health Regulations under the Occupational Health and Safety Act , [Section. 1.13(c)], [Section. 1.14], [Section. 1.18(a)], [Section. 1.22], [Section. 9.07(3)(a)], [Section. 9.09(2)(c)]

Appendix C

17 Pre-Task Analysis Form

The Pre-Task Analysis form shown in this appendix is just one suggested format. Each wind site can develop their own forms, as needed. The most important requirement is to ensure the form developed covers all the hazards that can be expected for typical tasks that may be performed. Task-specific forms may be needed for special tasks that are outside of the parameters of this example.

Pre-Task Analysis forms are completed prior to the start of any task involving hazards. They are used for the job briefing to alert the worker to hazards and risk that may be present and assist in building a stronger safety culture.

Pre - Task Analysis

Project Name: _____		Project #: _____		Date: _____	
Location: _____		Submitted By: _____			
<i>The PTA will be completed daily by the crew leader for all major tasks. Employees involved in the tasks will sign the PTA. At the end of the task, turn this form in to the ICU Medical project manager. Deviations from known safe work practices or procedures require work to be stopped immediately.</i>					
Task / Activity Description: _____					
AHA #: _____		Employees trained on the AHA? <input type="checkbox"/> Yes <input type="checkbox"/> No		Does task require special training? <input type="checkbox"/> Yes <input type="checkbox"/> No If Yes, note in certifications below, or Other: _____	
Communication plans: In place? <input type="checkbox"/> Yes <input type="checkbox"/> No		Communication Method(s): _____		Emergency Number: _____	
DAP - Designated Assembly Points		Primary _____		Secondary _____	
Safety Equipment:		Safety shower & Eyewash location(s): _____		First Aid Kit Location(s): _____ AED Location & #: _____	
Wind: Direction: _____ Speed: _____ mph/knots		Weather conditions: _____		Temperature: _____ °F Weather acceptable for task? <input type="checkbox"/> Yes <input type="checkbox"/> No	
Nearest Hospital: _____		Nearby Occupational Health Clinic: _____			
Contaminants of Concern: _____		EHS Department involved in planning this job? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> N/A			
Air Monitoring Equipment: <input type="checkbox"/> H2S Monitor <input type="checkbox"/> 4-Gas <input type="checkbox"/> Other: _____ <input type="checkbox"/> N/A		Calibration/Bump Test Date: _____			
Standard PPE is Required: safety-toed footwear w/ 6" upper & defined heel, shirt w/ 4" sleeve, long pants, safety glasses w/ side shields, hardhat and ARC clothing					
Additional job/task specific PPE required? <input type="checkbox"/> Yes <input type="checkbox"/> No If Yes, indicate below		Environmental PPE: <input type="checkbox"/> Level D (Std.) <input type="checkbox"/> Level D(modified) <input type="checkbox"/> Level C <input type="checkbox"/> Level B <input type="checkbox"/> Level A			
Fall Protection		<input type="checkbox"/> Full Body Harness <input type="checkbox"/> SA Lanyard <input type="checkbox"/> SR Lanyard <input type="checkbox"/> Roof clamps <input type="checkbox"/> Life Lines <input type="checkbox"/> Guardrails <input type="checkbox"/> Barricades <input type="checkbox"/> Hole Covers		<input type="checkbox"/> Other _____	
Eye/Head/Face		<input type="checkbox"/> Mono goggles <input type="checkbox"/> Full face shield <input type="checkbox"/> Chemical goggles <input type="checkbox"/> Welding/Cutting lenses <input type="checkbox"/> Welding hood		<input type="checkbox"/> Other _____	
Respirator		Air: <input type="checkbox"/> SCBA <input type="checkbox"/> Supplied APR: <input type="checkbox"/> Full Face <input type="checkbox"/> 1/2 face <input type="checkbox"/> Hood		Cartridges: <input type="checkbox"/> Particulate <input type="checkbox"/> HEPA <input type="checkbox"/> Chemical <input type="checkbox"/> Combination Cartridge <input type="checkbox"/> Other _____	
Foot		<input type="checkbox"/> Rubber boots <input type="checkbox"/> Chemical Boots <input type="checkbox"/> Ice cleats <input type="checkbox"/> Metatarsal guards <input type="checkbox"/> EH Rated		<input type="checkbox"/> Other _____	
Hand(Gloves)		<input type="checkbox"/> Leather general <input type="checkbox"/> Chemical Resistant <input type="checkbox"/> Cut resistant <input type="checkbox"/> Gripping <input type="checkbox"/> Driving <input type="checkbox"/> Welding <input type="checkbox"/> Cryogenic <input type="checkbox"/> Heat Resistant <input type="checkbox"/> Electrical		<input type="checkbox"/> Other _____	
Special Clothing		<input type="checkbox"/> Coveralls <input type="checkbox"/> Chemical Resistant <input type="checkbox"/> FRC Welding <input type="checkbox"/> ARC Electric <input type="checkbox"/> FRC Fire <input type="checkbox"/> Reflective Vest <input type="checkbox"/> Cooling Vest <input type="checkbox"/> Wind Resistant <input type="checkbox"/> Raincoat		<input type="checkbox"/> Other _____	
Daily inspections completed - <input type="checkbox"/> Yes <input type="checkbox"/> No		Utilities Contacted (One Call) <input type="checkbox"/> Yes <input type="checkbox"/> No Date: _____		Utility contact (Name) _____ Utilities Located <input type="checkbox"/> Yes <input type="checkbox"/> No	
Permits/Plans/Procedures/Programs - Required and IN-PLACE: <input type="checkbox"/> Yes <input type="checkbox"/> No; Check as appropriate		Name of competent person(s): _____			
<input type="checkbox"/> Excavation/Trenching <input type="checkbox"/> LOTO <input type="checkbox"/> Confined Space Entry <input type="checkbox"/> Cranes/Critical Lifts		<input type="checkbox"/> Abatement- Asbestos <input type="checkbox"/> System Testing <input type="checkbox"/> Lead Abatement			
<input type="checkbox"/> Hot Work <input type="checkbox"/> Steel Erection <input type="checkbox"/> Geo Drilling/Pushing <input type="checkbox"/> Materials Storage/Handling		<input type="checkbox"/> Heat/Cold Stress <input type="checkbox"/> Line Breaking/Hot Tapping <input type="checkbox"/> High Voltage Electrical			
<input type="checkbox"/> Fall Protection <input type="checkbox"/> Scaffolds <input type="checkbox"/> Signs/Barricades <input type="checkbox"/> Railway/Blue Flag/De-railer		<input type="checkbox"/> Demolition <input type="checkbox"/> Housekeeping <input type="checkbox"/> Blasting/Explosives			
<input type="checkbox"/> Decontamination <input type="checkbox"/> _____ <input type="checkbox"/> Hazardous Waste <input type="checkbox"/> Other (Specify) _____					
Employee Certification's Required: <input type="checkbox"/> Yes <input type="checkbox"/> No		<input type="checkbox"/> Crane Operator <input type="checkbox"/> Scaffold Erection <input type="checkbox"/> Mobile Equipment Operator <input type="checkbox"/> High Voltage <input type="checkbox"/> Lead or Asbestos <input type="checkbox"/> Safeland/gulf		<input type="checkbox"/> Rigger <input type="checkbox"/> Confined Space Entry <input type="checkbox"/> Forklift Operator <input type="checkbox"/> LOTO <input type="checkbox"/> HAZWOPER <input type="checkbox"/> CPR/First Aid	
<input type="checkbox"/> Signalman <input type="checkbox"/> Fall Protection <input type="checkbox"/> Powder Actuated Tool User <input type="checkbox"/> Welding & Cutting <input type="checkbox"/> Radiation					

Appendix D

18 Example Energized Electrical Work Permit Form

The Energized Electrical Work Permit (EEWP) form shown is an example that can be used when a worker is about to perform work and the equipment or circuit cannot be de-energized. The form is usually specific to electrical tasks, such as assessing the shock and arc flash hazard, determining the shock and arc flash boundaries, the PPE required and authorization to do energized work. This ensures unqualified persons do not perform tasks they should not.

The example form is taken from Informative Annex J, Figure J.1 of the CSA 2018 Z462 as required in Clause 4.3.2.3.2.

ENERGIZED ELECTRICAL WORK PERMIT	
PART I: TO BE COMPLETED BY THE REQUESTER	
Job/work order number: _____	
(1) Description of circuit/equipment/job location: _____	
(2) Description of work to be done: _____	
(3) Justification for why the circuit/equipment cannot be de-energized or the work deferred until the next scheduled outage: _____	
Requester/Title _____	Date _____
PART II: TO BE COMPLETED BY THE ELECTRICALLY QUALIFIED PERSONS DOING THE WORK	
Check when complete	
(1) Detailed description of the job procedures to be used in performing the above-detailed work: _____	<input type="checkbox"/>
(2) Description of the safe work practices to be employed: _____	<input type="checkbox"/>
(3) Results of the shock risk assessment:	
(a) Limited approach boundary _____	<input type="checkbox"/>
(b) Restricted approach boundary _____	<input type="checkbox"/>
(c) Necessary shock personal and other protective equipment to safely perform the assigned task _____	<input type="checkbox"/>
(4) Results of the arc flash risk assessment:	
(a) Available incident energy at the working distance or arc flash PPE category _____	<input type="checkbox"/>
(b) Arc flash boundary _____	<input type="checkbox"/>
(c) Necessary arc flash personal and other protective equipment to safely perform the assigned task _____	<input type="checkbox"/>
(5) Means employed to restrict the access of unqualified persons to the work area: _____	<input type="checkbox"/>
(6) Evidence of completion of a job briefing, including discussion of any job-related hazards: _____	<input type="checkbox"/>
(7) Do you agree the above described work can be done safely? <input type="checkbox"/> Yes <input type="checkbox"/> No (If no, return to requester)	
Electrically qualified person(s) _____	Date _____
Electrically qualified person(s) _____	Date _____
PART III: APPROVAL(S) TO PERFORM THE WORK WHILE ELECTRICALLY ENERGIZED	
Manufacturing manager _____	Maintenance/engineering manager _____
General manager _____	Electrically knowledgeable person _____
Safety manager _____	Date _____
Note: Once the work is complete, forward this form to the site safety department for review and retention	

