UL 6141

STANDARD FOR SAFETY

Wind Turbines Permitting Entry of Personnel

UL Standard for Safety for Wind Turbines Permitting Entry of Personnel, UL 6141

First Edition, Dated May 20, 2016

Summary of Topics

This revision of ANSI/UL 6141 dated July 30, 2021 includes the addition of reference to the Standard for Energy Storage Systems and Equipment, UL 9540, as UPS functionality; 4.21.1.10

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated January 8, 2021.

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Standard for Wind Turbines Permitting Entry of Personnel

First Edition

May 20, 2016

This ANSI/UL Standard for Safety consists of the First Edition including revisions through July 30, 2021.

The most recent designation of ANSI/UL 6141 as an American National Standard (ANSI) occurred on July 27, 2021. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements cover large wind turbine systems (WT) that are equipped with electrical subassemblies and permit the entry of personnel. With respect to this standard, WT permitting entry of personnel are considered to be wind turbines where a user or service person may, or is intended to, enter the turbine to operate it or perform maintenance. These WT are intended for use in utility-interactive, grid-tied applications that operate in parallel with an electric power system (EPS) to supply power to common or stand-alone loads. This standard includes requirements for WT intended for EPS grid connections at transmission, sub-transmission, and distribution levels depending on the specifications of the specific WT.

1.2 The WT power, control and protection systems are evaluated only to the extent that they function within the manufacturer's specified limits and response times. These control and protection functions are evaluated with respect to risk of electric shock and fire. It is intended that the electrical subassemblies that address power transfer and control and protection functions evaluated per this document are to be coordinated with the mechanical and structural evaluation of the WT in accordance with the IEC 61400 series of documents.

1.3 These requirements do not cover:

a) Wind turbine generating systems intended for offshore installation,

b) Mechanical or structural integrity of the WT or subassemblies,

c) Verification that the manufacturer-defined controls and protection limits maintain the WT within its safe mechanical and structural limits,

d) Compliance with specific grid interconnection standards or requirements.

1.4 The wind turbine products covered by these requirements are intended to be installed in multiple installation locations and jurisdictions which may include installation codes including, but not limited to, the National Electrical Code, ANSI/NFPA 70, the National Electrical Safety Code (NESC), and NFPA 79, Electrical Standard for Industrial Machinery.

1.5 The wind turbine products covered by this standard are considered to be machines that include inherent internal hazards that make them unsuitable for access by the general public.

1.6 The users, operators and service persons that enter this equipment are expected to have the necessary knowledge of its operation and reasonably foreseeable hazards. These individuals are expected to be equipped with the necessary equipment for the application and hazard.

1.7 The evaluation of products to this standard includes the evaluation of all features and functions incorporated in or available for the WT that can affect compliance of the WT with this standard. This includes references in the documentation for the WT.

1.8 Small WT and electrical subassemblies are defined as wind turbines where a user or service person is not intended or required to enter the WT to operate or perform maintenance on the WT. Small wind systems are covered in the Standard for Small Wind Turbine Systems, UL 6142.

2 General

2.1 Components

2.1.1 Except as indicated in 2.1.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendices A – C for a list of standards covering components used in the products covered by this standard.

2.1.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product or system covered by this standard,

b) Is superseded by a requirement in this standard, or

c) Is not relied upon for compliance with the National Electric Code, ANSI/NFPA 70, and other U.S. installation codes, provided the component addresses the performance and safety critical aspects necessary for the end application as determined by the evaluation in this standard.

Note: the following provides guidance for item (c) –

1) Integral WT components relied upon to interconnect with and/or protect system components, system wiring, loads, etc. shall be of the type(s) defined in the applicable portion of the National Electric Code and shall comply with the applicable portions of the UL standards or standards referenced in the National Electric Code and in Appendix A for that component type or function. They shall be suitable for the application within the end product application, including the end product ratings and including foreseeable abnormal conditions. Examples include, but are not limited to, branch overcurrent protection, switches, disconnects, wire, cable, connectors, contactors, etc.

2) External WT system components (not integral to the WT) shall comply with applicable UL standard for that component.

2.1.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.1.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.1.5 Components and subassemblies of the overall WT shall be evaluated and found suitable for their operation over the rated normal operating range of electrical and environmental conditions within the WT per the WT manufacturer's specifications.

2.1.6 These components and subassemblies shall also perform per the manufacturer's specifications during defined abnormal conditions, such as WT shutdown and abnormal electric utility grid conditions.

2.1.7 For additional requirements, reference Section 4, Special Components and Subassemblies of Wind Turbines.

2.2 Units of Measurement

2.2.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

2.2.2 All references to AC voltages within this standard shall be considered to be RMS unless otherwise specified.

2.2.3 All references to DC voltages within this standard shall be considered to be maximum cyclic voltages unless otherwise specified.

2.2.4 All references to voltages that are not specified as AC or DC shall be considered to be the nominal line-to-line AC RMS voltage.

2.3 Undated References

2.3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

3 Glossary

For the purpose of this standard, the following definitions apply.

3.1 DOWN TOWER – The space in and around a wind turbine location that is at or near ground level such as the base level of the turbine tower.

3.2 ELECTRIC POWER SYSTEM (EPS) – Equipment or facilities that deliver electric power to a load(s). The most common example of an EPS is an electric utility.

3.3 MAXIMUM CURRENT(S) – The maximum peak current(s) a wind turbine will produce. There may be several maximum current ratings defined for a product or system, such as alternator/generator output, inverter/converter output, and control output circuits.

3.4 MAXIMUM OUTPUT POWER – The maximum average power output a wind turbine in normal steady-state operation will produce over a one minute period of time. Note that the peak power output can be greater.

3.5 MAXIMUM VOLTAGE – The maximum peak voltage a wind turbine will produce during operation, including open circuit conditions.

3.6 MEDIUM VOLTAGE – More than 1000 Vac or 1500 Vdc.

3.7 NACELLE – The housing or enclosure for the alternator/generator and other wind turbine parts that is generally located at the top of the tower.

3.8 OVERVOLTAGE – Any voltage having a peak value exceeding the corresponding peak value of maximum steady-state voltage at normal operating conditions.

3.9 OVERVOLTAGE CATEGORY – A numeric classification that defines a transient overvoltage condition:

a) Overvoltage categories I, II, III, and IV are used per IEC 60664-1, Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests.

b) The term "overvoltage category" in this standard is synonymous with "impulse withstand category" used in IEC 60664-4-44, Low-voltage electrical installations – Part 4-44: Protection for safety – Protection against voltage disturbances and electromagnetic disturbances.

3.10 PERSONAL PROTECTION SYSTEM – Emergency stop system intended primarily to provide protection from moving, rotational, or electrical danger for personnel in the wind turbine.

3.11 POLLUTION – Any addition of contaminants, solid, liquid or gaseous (ionized gases), and moisture that may produce a reduction of dielectric strength or surface resistivity.

3.12 POLLUTION DEGREE – The level of pollution present at the location on or in a product where the clearance and creepage distance measurement is made and can be controlled by the design of the product. For example, enclosures can be used to achieve pollution degree 3, heaters within enclosures can help achieve pollution degree 2, and encapsulation can be used to achieve pollution degree 1:

a) Pollution Degree 1: No pollution or only dry, nonconductive pollution. The pollution has no influence.

b) Pollution Degree 2: Normally, only nonconductive pollution; however, a temporary conductivity caused by condensation may be expected.

c) Pollution Degree 3: Conductive pollution or dry, nonconductive pollution that becomes conductive due to condensation that is expected.

d) Pollution Degree 4: Pollution that generates persistent conductivity through conductive dust or rain and snow.

3.13 POLYMERIC MATERIAL – Materials that are either natural or synthetic and are primarily composed of chained molecules of monomers, combinations of monomers, combined polymers, crosslinking agents, fillers, colorants, and other materials.

3.14 RATED POWER – The output power of the wind turbine when operating at its rated wind speed in accordance with IEC 61400-12-1, Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines.

Note: The method for measuring wind turbine power output is specified in IEC 61400-12-1.

3.15 SAFETY RELATED CONTROLS SYSTEM (SRCS) – Assembly of equipment that includes the critical controls and protection functions that maintain the wind turbine within its mechanical and structural design limitations. This includes the evaluation of electrical control and protection functions, limits, operation, and response times during normal, abnormal, and failure conditions. The SRCS may include electromechanical components.

3.16 SWITCHGEAR – The combination of switching and interrupting devices that are used with associated control, instruments, metering, protective, and regulating accessories. Switchgear also includes associated interconnections and other electrical accessories, and supporting structures used primarily for the generation, transmission, distribution, and conversion of electric power.

3.17 SWITCHGEAR ASSEMBLY – Assembled indoor or outdoor equipment provided with a supporting structure, one or more enclosures, conductors, electrical interconnections and other accessories that includes switching, interrupting, control, instrumentation, metering, protective, and regulating devices.

3.18 TURBINE PROTECTION SYSTEM – System intended primarily to provide protection for a wind turbine structure in the event of the following conditions: short circuits, excessive vibration, rotor or generator overspeed, extreme temperature, or extreme wind.

3.19 UP TOWER – The space in and around a wind turbine location that is at or above the top of the tower such as in the nacelle and hub.

3.20 WIND TURBINE (WT) – A device or system of subassemblies that convert wind energy to electric power and typically consists of an overall structure including; tower, nacelle, hub and blades as well as the associated internal equipment.

3.21 WIND TURBINE OUTPUT CIRCUIT – The circuit conductors or equipment connected to the turbine output terminals or conductors where the turbine is intended to be connected to the electric power system (EPS).

WIND TURBINE EQUIPMENT AND SUBASSEMBLIES

4 Special Components and Subassemblies of Wind Turbines

4.1 General

4.1.1 For the purpose of this standard, the medium voltage requirements are to be applied to circuits that operate at greater than 1000Vac / 1500 Vdc nominal.

4.1.2 WT equipment and subassemblies, other than those noted in this section and 2.1, Components, shall comply with (at minimum) one of the following standards:

a) The Standard for Industrial Control Panels, UL 508A;

b) The Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1, or

c) UL 60947 Low-Voltage Switchgear and Controlgear – Part 1: General Rules along with any of the following UL 60947 part 2 standards:

1) UL 60947-4-1, Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters;

2) UL 60947-4-2, Low-Voltage Switchgear and Controlgear – Part 4-2: AC Semiconductor Motor Controllers and Starters I Contactors and Motor-Starters;

3) UL 60947-5-1, Low-Voltage Switchgear and Controlgear – Part 5-1: Control Circuit Devices and Switching Elements – Electromechanical Control Circuit Devices;

4) UL 60947-5-2, Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements - Proximity Switches;

5) UL 60947-7-1, Low-Voltage Switchgear And Controlgear – Part 7-1: Ancillary Equipment – Terminal Blocks for Copper Conductors;

6) UL 60947-7-2, Low-Voltage Switchgear and Controlgear – Part 7-2: Ancillary Equipment – Protective Conductor Terminal Blocks for Copper Conductors

7) UL 60947-7-3, Low-Voltage Switchgear and Controlgear – Part 7-3: Ancillary Equipment – Safety Requirements for Fuse Terminal Blocks.

4.1.3 Regarding 4.1.2 (a) when used outside the scope parameters of the Standard for Industrial Control Panels, UL 508A, an evaluation shall be performed on the means to keep the internal temperature within the limits of UL 508A. If not feasible, testing per the Standard for Industrial Control Equipment, UL 508 shall be performed for the worst case normal rated equipment use application.

Exception: Equipment and subassemblies not covered by Section 8, Safety Related Control Systems, that include components rated for at least the evaluated rated ambient temperature need not be tested per UL 508.

4.1.4 Where the standards referenced in 4.1.2 do not address the needs of the equipment or subassembly, NFPA 79, Electrical Standard for Industrial Machinery, shall be applied.

4.1.5 Equipment and subassemblies shall be rated for the electrical an environmental installation location of the component inside or outside the turbine. Internal turbine environmental conditions may include exposure to water, corrosive, non-corrosive liquids, falling dust, dirt, and other debris that might occur. For WTs where oil films or leaks may be expected based on the normal operation or maintenance tasks, enclosures, including gaskets, shall be suitably rated for ingress of the expected type and amount of oil.

4.1.6 The acceptable WT enclosure rating shall be determined from the manufacturer's instructions and description of the intended use during manufacturing, transport, installation, operation and maintenance. Enclosures shall be rated using:

a) Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E,

b) IEC 60529, Degrees of Protection Provided by Enclosures (IP Code), or

c) NEMA 250, Enclosures for Electrical Equipment (100 Volts Maximum)

Note: NEMA 250 or UL 50E Types 3R, 3RS, 5 or 12 enclosure ratings or IEC 60529 enclosure ratings of IP43, IP54, or IP65 address the environment of most internal wind turbine components and enclosures.

4.1.7 Equipment enclosures shall be constructed of sufficient mechanical strength to withstand the foreseeable mechanical forces during normal operation and service of the turbine. Such forces include, but are not limited to, rotation, rotational sway, yaw, and foreseeable forces imparted by personnel or equipment on the enclosures.

4.1.8 Enclosures or equipment that may be used by operators or service personnel, such as a step, hand hold, or lean support, shall have the mechanical strength and rigidity to maintain the enclosure's required properties as defined in this section including, but not limited to, electrical spacings and access to live parts.

4.1.9 For internal areas of the WT where users or service persons are intended to enter the turbine to operate or service it, polymeric materials such as polymeric enclosures, polymeric access barriers, walls of a nacelle, or insulation on the walls of a turbine shall be rated as follows. Any single unbroken section greater than 10 square feet (0.93 m^2) or a single linear dimension greater than 6 feet (1.83 m), shall have a maximum flame spread index and smoke developed index as shown in Table 4.1 as tested in accordance with the Standard for Test for Surface Burning Characteristics of Building Materials, UL 723.

Exception No. 1: The following are not required to comply with this requirement:

a) Wire and cables,

b) Materials less than 0.036 inch (0.9 mm) thick directly applied to walls, floors, or ceiling surfaces,

c) Elevators complying with 4.26.

Exception No. 2: Turbines with automatic fire suppression are allowed to use Up Tower limits for all turbine locations.

Table 4.1
Large area polymeric smoke and flame ratings

Tower location	Flame spread index	Smoke developed index
Down tower and tower[a]	25	450
Up tower	200	450
[a] Applies to enclosed assemblies and does not apply to open lattice constructed.		

4.1.10 A material with a flame-spread rating higher than that specified in 4.1.9 may be used as the exterior finish or covering on any portion of the enclosure if the rating of the combination of the base material and finish or covering complies with 4.1.9.

4.1.11 Brake systems shall prevent ignition of adjacent combustible materials and potential fluids (contained or leaked) through coordination of design features.

4.2 Wiring

4.2.1 General requirements

4.2.1.1 Internal wiring within subassemblies and components that are not covered by component standards shall comply with the Standard for Industrial Control Equipment, UL 508, or IEC 60204-1, Safety of machinery – Electrical equipment of machines – Part 1: General requirements (Chapter 12 and 13), or NFPA 79, Electrical Standard for Industrial Machinery (Chapters 12 and 13) in addition to the requirements in this section.

4.2.1.2 Wiring that is subject to movement, flexing, or twisting during operation of the wind turbine shall be investigated in accordance with 4.4, Cable drip loop, for suitability in the conditions of use and rated life or cycle time.

4.2.1.3 All wiring within a WT that is accessible to users or service personnel or runs vertically up the tower shall be either in a raceway or be rated for tray cable usage. The following meets the intent of this requirement:

a) Multiconductor cable complying with the Outline of Investigation for Flexible Motor Supply Cable and Wind Turbine Tray Cable, UL 2277, and marked for wind turbine usage;

b) Power-limited circuit cabling complying with the Standard for Power-Limited Circuit Cables, UL 13, suitable for Tray Cable usage (Types CMG, CM, CL2, CL3, PLTC, CMR, CL2R, CL3R, CMP, CL2P, CL3P);

c) Optical fiber circuits complying with the Standard for Optical Fiber Cable, UL 1651;

d) Power cabling complying with the Standard for Thermoplastic-Insulated Wires and Cables, UL 83, or the Standard for Thermoset-Insulated Wires and Cables, UL 44, and additionally marked for cable tray usage (“CT”, “For Cable Tray Use”, “For CT Use”, or “For Use in Cable Trays”) or marked "FT4";

e) For voltages greater than 2kV, cabling complying with the Standard for Medium Voltage Power Cables, UL 1072, and additionally marked for cable tray usage (“CT”, “For Cable Tray Use”, “For CT Use”, or “For Use in Cable Trays”) or marked "FT4";

f) Extra hard usage cord that complies with the Standard for Flexible Cords and Cables, UL 62;

g) Cables that comply with the Standard for Cables for Non-Power-Limited Fire-Alarm Circuits, UL 1425;

h) Metal-clad cables that comply with the Standard for Metal-Clad Cables, UL 1569.

Exception: Wiring within a component need only meet the requirements for the component.

4.2.1.4 Wiring within the turbine shall comply with the NEC-based wiring requirements in 4.2.2 or IEC-based wiring requirements specified in 4.2.3.

4.2.2 NEC-based wiring requirements

4.2.2.1 Wiring within the WT shall be compliant with applicable articles of the National Electrical Code, ANSI/NFPA 70, such as:

a) Article 215.2 for minimum rating and size of feeders;

b) Article 300.3(C) for minimum rating of conductors of different systems in same raceway;

c) Article 392 for tray cables;

d) Article 445.13 for ampacity of conductors for generators;

e) Article 455.6 for conductors of phase converters.

4.2.2.2 The designs specified in 4.2.2.1 that are used shall be referenced on the turbine marking plate.

4.2.3 IEC-based wiring requirements

4.2.3.1 Wiring supplied with the WT and installed by the manufacturer or installed by qualified personnel in accordance with the manufacturer's installation procedures shall be referenced on the turbine's marking plate and shall be comply with the following:

a) Wiring integral to the WT shall be of the types specified in 4.2.1.3, and shall be sized in accordance with IEC 60364-5-52:2009, Low-voltage electrical installations – Part 5-52: Selection and erection of electrical equipment – Wiring systems;

b) Current-carrying rating shall be based on IEC 60364-5-52:2009, Table B.52.1 to and including Table B.52.13;

c) Derating factors for temperatures different that 30°C shall be based on IEC 60364-5-52:2009, Table B.52.14;

d) Derating factors for a group of cable or multi-conductor cables shall be based on IIEC 60364-5-52:2009, Table B.52.17, Table B.52.20, and Table B.52.21.

4.2.4 Wiring ampacity verification

4.2.4.1 If the methods of verifying ampacity cannot be established, a temperature evaluation shall be performed.

4.2.4.2 The evaluation specified in 4.2.4.1 shall be an engineering calculation based on proven techniques or a test performed under the conditions specified in 4.2.4.3 – 4.2.4.5. At the conclusion of the evaluation, the temperature recorded shall not:

a) Be so high as to constitute a risk of fire;

b) Be so high as to adversely affect any materials employed in the equipment;

c) Exceed the temperature limit for any individual component within the equipment.

4.2.4.3 Protective devices or circuitry shall not trip during the test.

4.2.4.4 For equipment provided with a thermostat or other thermal protective device, temperatures are to be measured with all parts operating simultaneously since the heating of one part may affect the heating of another part.

4.2.4.5 The operating conditions shall include, but are not limited to:

a) Normal conditions,

b) Carrying rated current continuously,

c) Worst case voltage range specified by the manufacturer,

d) Mounted as intended in end use, considering worst case scenarios,

e) Maximum surrounding temperature specified by the manufacturer,

f) Until temperatures are constant.

4.2.5 Separation of wiring

4.2.5.1 For the separation of wiring circuits, one of the following methods shall be used when more than one circuit is operating at the same or different voltages in the same cable run and cable duct:

a) All conductors shall be insulated at the highest operation voltage;

b) The wiring of different voltages shall be grouped and these groups shall be separated by barriers – either grounded conductive barriers or polymeric barriers complying with requirements in 37.3, Insulating Barriers, of the Standard for Industrial Control Equipment, UL 508;

c) Wiring operating at different voltages shall be physically separated by distance, where the separation distance is obtained from the highest voltage for two groups (see section 5, Spacings); or

d) The highest rated voltage system cables shall be provided with a grounded conductive shield or jacket capable of carrying the maximum fault current in the cable system for the required time to trip the short circuit protective device. Compliance with the requirement shall be demonstrated or verified by calculation.

4.2.5.2 The combination of a component and wiring shall not result in the component or wiring exceeding their thermal ratings.

4.2.5.3 Wiring subjected to water or oil exposure during normal or abnormal conditions, such as a gasket or seal leak, shall be suitably rated for the condition.

4.2.5.4 Wiring subjected to UV exposure during operation shall be rated for exposure to sunlight.

4.2.5.5 Wiring exposed or subjected to wear, abrasion, impact from operation of the turbine, or located in a user or service person traffic area shall be provided with additional protection to prevent damage to the electrical insulation.

4.2.5.6 Wiring or cables subjected to cold temperature flexing or twisting shall be rated or evaluated for the application and operating temperature.

4.2.6 Wiring identification

4.2.6.1 General

4.2.6.1.1 All conductors shall be identified at each termination by coding such as, but not limited to, letter(s) and or number(s) corresponding with the wiring diagrams provided with the wind turbine.

4.2.6.1.2 If color coding is used to identify wiring, one of the color coding systems in 4.2.6.2 or 4.2.6.3 shall be used, and the color coding system shall be referenced in the wind turbine marking:

4.2.6.1.3 Where conductor colors are used for identification and insulated conductors are not readily accessible, color coding throughout the entire length is not required, but each end and accessible locations shall be clearly identified, using marking tape or other suitable means that is durable.

Exception: A conductor identified by color as a protective conductor shall never be re-marked to a different color or used for other purposes.

4.2.6.2 North American color system

4.2.6.2.1 Colors are coded as follows:

a) Black – all ungrounded power circuit conductors;

b) Red – ungrounded ac control circuits operating at a voltage less than the main operation voltage;

c) Blue – ungrounded dc control circuits;

d) Yellow or orange – ungrounded control circuits or other wiring, that remain energized when the main disconnect(s) is in the "off" position;

e) White, gray, or three white stripes on a color other than green, blue, orange, or yellow – grounded ac current-carrying control circuit conductor regardless of voltage;

f) White with blue stripe – grounded dc current-carrying control circuit conductor;

g) White with yellow stripe or white with orange stripe – grounded ac control circuit current carrying conductor that remains energized when main disconnect switch(s) is in the "off" position;

h) Green – Protective conductor.

4.2.6.3 International color system

4.2.6.3.1 Colors are coded as follows:

a) Green-yellow combination – protective conductor;

b) Light blue – neutral conductor;

c) Black – all ac and dc power circuits;

d) Red – all ac control circuits;

e) Dark blue – all dc control circuits;

f) Orange – all control and power circuits that remain energized when the main disconnect(s) is in the "off" position.

4.3 Splices and connections in power cables

4.3.1 Splices in power circuit cables shall be provided with insulation suitable for the circuit in which it is used, including voltage rating, thermal rating, and mechanical protection.

4.3.2 Conductor splices shall be rated for the size, type, and number of conductors to which they are connected.

4.3.3 For connections or splices that do not include a strain relief, a strain relief shall be provided within 24 inches of the spliced connection to prevent tensile forces on the conductors and splice.

4.3.4 Spliced connections in WT power circuits operating at 1000V or less shall be assembled in accordance with the splice manufacturer's instructions using the tool specified by the splice connector manufacturer. The tool shall be calibrated per the manufacturer's specifications. The assembly operation shall be performed within the rated installation ambient temperature range as specified by the connector manufacturer.

4.3.5 For splice connections in power circuits operating at 1000V or less, the finished assembly shall comply with the applicable testing requirements of the Standard for Wire Connectors, UL 486A-486B, regardless of the applied voltage. Splice connections operating between 600V and 1000V, shall be subjected to the insulation puncture tests at a test voltage of 2000V plus 2.25 times circuit operation voltage. The flashover tests shall be conducted in accordance with insulation puncture and flashover test voltages, Tests A and B (Table 28) of UL 486A-486B, for 600 and 1000 volts. The testing shall be performed using the same conductor type and style in the WT application.

4.3.6 Splice connectors used in power circuits above 1000V shall comply with the requirements of IEEE 404, Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV.

4.3.7 Termination connectors used in power circuits above 1000V shall comply with the requirements of:

a) IEEE 48, Standard for Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV, for high stress control terminations, or

b) IEEE 386, Standard for Separable Insulated Connector Systems for Power Distribution Systems Above 600 V, for equipment connections such as switchgear.

4.4 Cable twist loop

4.4.1 If operation of the wind turbine results in the potential twisting of cables – connecting cables between rotating parts (nacelle) and parts of the fixed structure (tower or foundation) – the operational conditions of use shall not cause damage to the conductors or their insulation.

4.4.2 Cables shall be used within the ratings stated by the cable manufacturer for rotation and temperature.

4.4.3 The cable manufacturer's ratings for torsion characteristics shall be used as a basis for determining the acceptability of the cable in the specific application. Where the cable manufacturer cannot provide these ratings, a sample that is deemed representative of the conditions to which the cable will be subjected in the specific application shall be tested.

4.4.4 Controls that prevent damage to conductors or their insulation, including rotational limits, shall be considered part of the Safety Related Controls System evaluation of this document. The control shall be designed so that resetting to the neutral position is possible. See Section 8, Safety Related Controls System (SRCS).

4.4.5 Where multiple cables are grouped and/or tied together, the assembly loading shall be distributed so that the individual cables and mounting devices are not subjected to loads that exceed their individual ratings.

4.4.6 Cable twist loop assembly shall prevent cable contact with and movement against other surfaces that would cause damage to the cables that could compromise the cable's mechanical and electrical integrity under all operational modes of the WT.

4.4.7 The support clamps or rings on a cable or cable assembly shall prevent strain and torque from being transferred to the electrical terminal/termination.

4.5 Bus bars

4.5.1 Bus bars shall comply with (at minimum) one of the following standards. The bus bar operating conditions shall be within the scope of the selected standard(s):

a) For bus rated 600 V or less: the Standard for Busways, UL 857

b) For bus rated more than 600 V: IEEE C37.23, Metal-Enclosed Bus.

c) For bus rated 1000 V or less:

1) IEC 61439-1, Low-voltage switchgear and controlgear assemblies – Part 1: General rules, and

2) IEC 61439-6, Low-voltage switchgear and controlgear assemblies – Part 6: Busbar trunking systems (busways).

4.5.2 The conductors and components shall comply with the applicable standard(s) selected in regards to operating temperature range, environmental conditions, electrical isolation, electrical impulse withstand, and short circuit withstand capabilities as necessary for the electrical and environmental conditions within the turbine.

4.5.3 Vertical power transmission equipment shall be constructed with sufficient mechanical strength to withstand the foreseeable mechanical forces (deflection, movement and loading) for its use in accordance with IEC 61400-1, Wind turbines – Part 1: Design requirements.

4.5.4 The evaluation of these vertical bus bar systems shall account for the following conditions:

a) Static loading on system components;

b) Expected deflection and forces on the transmissions, assemblies, and support structure resulting from bending of the tower under anticipated extreme conditions;

c) Expected force direction and magnitude of displacement of the assembly;

d) Component fatigue, loosening of fasteners;

e) Degradation, wear, deformation and creep of polymeric electrical insulating materials;

f) Loss of intended electrical conductivity or loss of electrical isolation;

Note: Loss of intended conductivity is often the result of loose electrical connections or broken conductors. Loss of insulation is often the result of worn or broken insulation materials or loss of electrical spacings.

g) Operation for the intended turbine life span or specified maintenance period for the assembly.

h) The assembly noted in (g) may be evaluated by testing, analysis or a combination of the two.

4.5.5 Scaled testing may be used to represent the complete system specified in 4.5.4.

4.5.6 The mechanical and structural suitability of the assembly and supporting members may be addressed via analysis per the design load case evaluation. In this case, the design load cases shall specifically include and address the forces on the assembly, subassemblies and components including insulating and conducting materials.

Note: If the analysis method does not include effects of abrasion/wear and material creep on the polymeric electrical insulation, testing may be necessary.

4.6 Switchgear

4.6.1 Switchgear and switchgear components shall comply with the applicable standard(s) noted below for the specific type of switchgear used:

a) Standard for Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear, UL 1558;

b) Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1;

c) Standard for Low-Voltage Switchgear and Controlgear – Part 4-1A: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters, UL 60947-4-1A;

d) Standard for Low-Voltage Switchgear and Controlgear – Part 5-2: Control Circuit Devices and Switching Elements – Proximity Switches, UL 60947-5-2;

e) Standard for Low-Voltage Switchgear and Controlgear – Part 7-1: Ancillary Equipment – Terminal Blocks for Copper Conductors, UL 60947-7-1;

f) Standard for Low-Voltage Switchgear and Controlgear – Part 7-2: Ancillary Equipment – Protective Conductor Terminal Blocks for Copper Conductors, UL 60947-7-2;

g) Standard for Low-Voltage Switchgear and Controlgear – Part 7-3: Ancillary Equipment – Safety Requirements for Fuse Terminal Blocks, UL 60947-7-3;

h) IEEE C37.20.2, Standard for Metal Clad Switchgear;

i) IEEE C37.20.3, Standard for Metal-Enclosed Interrupter Switchgear.

j) Standard for Switchboards, UL 891.

4.6.2 Switchgear shall be rated for the installation location of the component within or outside the turbine. Enclosures for switchgear shall not have openings on the top surface, unless such openings are protected from falling water and debris.

Exception: Compliance may be determined via the applicable end product test per the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50.

Note: Internal turbine environmental conditions often include dripping of water and other non-corrosive liquids, as well as falling dust, dirt, and other debris. Type 12 or 5 enclosure ratings address the internal environment of most wind turbines.

4.6.3 The service conditions within the tower assembly shall be considered with respect to the normal service conditions for the type of switchgear installed within the tower. Where the anticipated service conditions within the tower are more severe than the normal service conditions for the switchgear, these conditions shall be mitigated, or additional investigation of the switchgear may be required.

Note: As an example, the normal service conditions for metal-clad switchgear are defined in IEEE C37.20.2, Standard for Metal-Clad Switchgear, to include an ambient air temperature of minus 30 to 40°C. If the anticipated temperature within the tower assembly is less than minus 30°C, supplemental heating may be required.

4.7 Panelboards

4.7.1 Panelboards installed within the tower assembly shall comply with the Standard for Panelboards, UL 67.

4.8 Transformers

4.8.1 Power transformers rated 600 Vac or less shall comply with one of the following standards that is applicable for the application:

a) Standard for Specialty Transformers, UL 506;

b) Standard for Dry-Type General Purpose and Power Transformers, UL 1561;

c) Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1;

d) Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2;

e) Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

4.8.2 Dry-type power transformers rated greater than 600 Vac shall comply with the requirements in

a) Standard for Transformers, Distribution, Dry-Type – Over 600 Volts, UL 1562, or

b) IEC 60076-11 Power transformers – Part 11: Dry-type transformers.

4.8.3 Overcurrent protection for power transformers shall comply with Article 240 Part IX, Overcurrent Protection Over 600 V Nominal, of the National Electrical Code, ANSI/NFPA 70.

4.8.4 Instrument transformers shall comply with one or more of the following standards where applicable:

a) IEEE C57.13, Standard Requirements for Instrument Transformers,

b) IEEE C57.13.2, Standard Conformance Test Procedures for Instrument Transformers,

c) IEEE C57.13.6, Standard Requirements for High Accuracy Instrument Transformers, and

d) IEC 61869-1, Instrument Transformers – Part 1: General requirements, and applicable part 2 standards noted below:

1) IEC 61869-2, Instrument Transformers – Part 2: Additional requirements for current transformers;

2) IEC 61869-3, Instrument Transformers – Part 3: Additional requirements for inductive voltage transformers;

3) IEC 61869-4, Instrument Transformers – Part 4: Additional requirements for combined transformers;

4) IEC 61869-5, Instrument Transformers – Part 5: Additional requirements for capacitor voltage transformers;

5) IEC 61869-102, Instrument Transformers – Part 102: Ferroresonance oscillations in substations with inductive voltage transformers;

6) IEC 61869-103, Instrument Transformers – Part 103: The use of instrument transformers for power quality measurement.

4.8.5 Cast core transformers shall comply with IEEE C57.12.60, Test Procedure for Thermal Evaluation of Insulation Systems for Dry-Type Power and Distribution Transformers, Including Open-Wound, Solid-Cast, and Resin-Encapsulated Transformers.

Note: the IEC 60085 (Electrical insulation – Thermal evaluation and designation) alternative use of relative thermal endurance index (RTE) to assign a temperature rating shall not be used in place of the long term aging testing.

4.8.6 Oil-filled transformers shall comply with:

a) IEEE C57.12.00, General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers or

b) IEC 60076-1, Power transformers – Part 1: General; and

c) The applicable IEC 60076 part 2 standards identified below:.

1) IEC 60076-2, Power Transformers – Part 2: Temperature rise for liquid-immersed transformers;

2) IEC 60076-3, Power Transformers – Part 3: Insulation levels, dielectric tests and external clearances in air;

3) IEC 60076-4, Power Transformers – Part 4: Guide to the Lightning Impulse and Switching Impulse Testing - Power Transformers and Reactors;

4) IEC 60076-5, Power Transformers – Part 5: Ability to Withstand Short Circuit;

5) IEC 60076-6, Power Transformers – Part 6: Reactors;

6) IEC 60076-7, Power Transformers – Part 7: Loading guide for oil-immersed power transformers;

7) IEC 60076-10, Power Transformers – Part 10: Determination of Sound Levels;

8) IEC 60076-11, Power Transformers – Part 11: Dry-type transformers;

9) IEC 60076-12, Power Transformers – Part 12: Loading guide for dry-type power transformers;

10) IEC 60076-13, Power Transformers – Part 13: Self-protected liquid-filled transformers;

11) IEC 60076-14, Power Transformers – Part 14: Liquid-immersed power transformers using high-temperature insulation materials;

12) IEC 60076-15, Power Transformers – Part 15: Gas-filled power transformers;

13) IEC 60076-16, Power Transformers – Part 16: Transformers for wind turbine applications;

14) IEC 60076-18, Power Transformers – Part 18: Measurement of frequency response;

15) IEC 60076-21, Power Transformers – Part 21: Standard requirements, terminology, and test code for step-voltage regulators.

4.8.7 Autotransformers shall comply with the applicable standard:

a) Standard for Dry-Type General Purpose and Power Transformers, UL 1561;

b) Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1;

c) Standard for Low Voltage Transformers – Part 2: General Purpose Transformers, UL 5085-2;

d) Standard for Industrial Control Equipment, UL 508.

e) IEC 60076-1, Power transformers – Part 1: General; and the applicable IEC 60076 part 2 standards identified in 4.8.6 (c).

4.9 Hub

4.9.1 Assemblies and components subjected to forces of rotation, acceleration, and deceleration shall be constructed of sufficient mechanical strength to withstand the foreseeable mechanical forces to which they may be subjected under normal and abnormal operation, including emergency shutdown. The design load case calculations from IEC 61400-1, Wind turbines – Part 1: Design requirements, may be used to address this requirement provided the calculations specifically include the rotational forces imparted on the hub components.

4.9.2 To prevent damage by loose materials, electrical components shall be housed in electrical cabinets within the hub. The enclosures shall comply with the applicable enclosure requirements of the:

a) Standard for Industrial Control Equipment, UL 508,

b) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy, UL 61800-5-1, or

c) Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741.

4.10 Converter/inverter

4.10.1 The low voltage converter or inverter that performs functions directly related to WT power generation shall comply with one of the standards noted in (b) – (f) below but shall also include multiple source aspects. Medium voltage converters shall comply with (g) or (h). Where a converter or inverter has connections to multiple power sources, such as but not limited to the EPS, the turbine generation, and energy storage, the converter or inverter shall be tested to include those multiple sources under normal and abnormal conditions. A connection to a power source that cannot result in fault current into an inverter or converter (during inverter or converter internal faults) may be excluded. One example of such a connection is a control circuit to a power generation device.

a) *Deleted*;

b) Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741;

c) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1;

d) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-2: Safety Requirements – Functional, UL 61800-5-2;

e) Standard for Safety of power converters for use in photovoltaic power systems – Part 1: General requirements, UL 62109-1; or

f) IEC 62477-1, Safety requirements for power electronic converter systems and equipment – Part 1: General.

g) IEC 62477-1, Safety requirements for power electronic converter systems and equipment – Part 1: General, and IEC 62477-2, Safety requirements for power electronic converter systems and equipment – Part 2: Power electronic converters from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC; or

h) Standard for Safety for Medium Voltage Power Conversion Equipment, UL 347A.

Exception: UL 1741 requirements specified for compliance with IEEE 1547, Interconnecting Distributed Resources with Electric Power Systems, and IEEE 1547.1, Conformance Test Procedures for Interconnecting Distributed Resources with Electric Power Systems are not required to be addressed.

4.11 Lightning protection systems

4.11.1 Lightning protection systems on a WT shall comply with Chapter 9, Wind Turbine Generator Systems, of NFPA 780, Standard for Installation of Lightning Protection Systems or IEC 61400-24, Wind Turbines – Part 24: Lightning protection.

4.11.2 Surge suppression components shall comply with the Standard for Surge Protective Devices, UL 1449, or IEC 61643-11, Low-voltage surge protection devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods.

Note 1: These devices should have a maximum continuous operating voltage (MCOV) equal to or greater than the highest circuit operating voltage, including voltage ride through voltages.

Note 2: Main power circuits are typically protected by IEC 61643-11 (Class 1 or Class 2) and UL1449 (Type 1 or Type 2) and these devices have a 20KA rating. Some of these devices require the use of specific overcurrent protection.

4.12 Slip rings

4.12.1 General

4.12.1.1 Slip rings used for transmission of power, control, or signal circuits within rotating elements of the wind turbine shall be evaluated to the requirements of the Standard for Industrial Control Equipment, UL 508, or IEC 60204-1, Safety of machinery – Electrical equipment of machines – Part 1: General requirements.

Exception: Motor and generator slip rings shall be evaluated to the specific component standard and are excluded from this section.

4.12.1.2 Slip rings rated above 1500V shall be evaluated by either:

a) Construction using the spacings requirements from the Standard for Medium-Voltage AC Contactors, Controllers, and Control Centers, UL 347, and the test requirements from the Standard for Industrial Control Equipment, UL 508, based upon the intended operating voltage; or

b) IEC 60204-11, Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV.

4.12.1.3 Temperature tests specified in the standards referenced in 4.12.1.2 shall be conducted with the unit rotating as intended in its end-use installation as well as in a fixed position.

4.12.1.4 The slip ring circuits and ground paths shall have short circuit ratings equal to or greater than the overcurrent protection provided in the end-use installation or shall withstand fault current levels in accordance with the following standards:

a) Standard for Industrial Control Equipment, UL 508,

b) IEC 60204-1, Safety of machinery – Electrical equipment of machines – Part 1: general requirements,

c) IEC 60204-11, Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV.

4.12.2 Slip ring overload

4.12.2.1 The slip ring is to be mounted and enclosed to represent its end application, and the unit is to be tested with a load current and time duration as indicated in 4.12.2.2. The unit shall be tested at rated voltage ±15 percent. The slip ring shall not show evidence of ignition, sealant leakage, cracking, breakage, or similar physical damage.

4.12.2.2 For a slip ring with overcurrent protection, the overload current is to be tied to the “overload” rating for the specific overcurrent protective device rating. The overload test current is to be applied for a duration equal to the maximum clearing time permitted for the overcurrent protective device type used to protect the slip ring circuit. The integral overcurrent protective device is to be shunted out of the circuit for this test.

Note: Typical U.S. overcurrent devices have a 135 percent overload rating, and IEC overcurrent devices often have a 1.45 overload rating. The maximum clearing time permitted for most overcurrent protective devices is commonly 1 hour or 2 hours and depends upon the device type, current rating, and applicable standard.

4.12.2.3 If no integral or external overcurrent protection is provided, the test in 4.12.2.2 shall be conducted using a current value that can be supplied to the unit continuously by the WT source circuit, plus 10 percent. The test shall be conducted until ultimate results occur but shall not last more than 7 hours.

4.12.2.4 Following the overload conditioning, the slip ring shall again be subjected to the Dielectric Withstand Test specified in the Standard for Industrial Control Equipment, UL 508. There shall be no breakdown between conductors or between conductors and dead metal parts.

4.13 Gearboxes

4.13.1 The electrical features of a gearbox assembly shall comply with the requirements of the Standard for Industrial Control Equipment, UL 508. This may include, but is not limited to, heaters, coolant pumps, fans, sensors, and their interconnection.

4.13.2 Gearbox wiring shall comply with the Standard for Industrial Control Equipment, UL 508, or 4.2, Wiring.

4.14 Hoists and winches

4.14.1 Hoists and winches shall comply with the requirements of the Standard for Hoists, UL 1340, which is applicable only to hoists and winches for tools, supplies, and materials.

4.15 Fire protection

4.15.1 Control panels that incorporate fire alarm functions shall comply with the Standard for Control Units and Accessories for Fire Alarm Systems, UL 864. Unless otherwise characterized by the WT manufacturer’s specifications, the fire alarm systems of a WT are considered to be for the purpose of property protection only, as defined by NFPA 72, National Fire Alarm and Signaling Code.

Note: NFPA 850, Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations, Chapter 10, Identification and Protection of Hazards for Wind Turbine Generating Facilities, provides guidance for WT fire protection systems.

4.16 Emergency stop functionality for personnel protection

4.16.1 Emergency stop functionality for personnel protection shall be provided and comply with the requirements of:

a) Section 8, "Control and protection system," in IEC 61400-1, Wind turbines – Part 1: Design requirements, and

b) Section 9.2.5.4, "Emergency Operations (Emergency Stop Emergency Switching Off)", in NFPA 79, Electrical Standard for Industrial Machinery.

4.16.2 Activation of the emergency stop shall initiate the shutdown sequence that will bring all movement of the WT to a standstill per IEC 61400-1, Wind turbines – Part 1: Design requirements.

Note: Activation of the brake may be applied at any convenient time when such activation does not increase the hazard level in the WT or for the WT structure.

4.16.3 The WT shall be provided with a suitable disconnect switch function that can be operated to isolate the WT from the EPS. Disconnection from the EPS may be initiated as part of the emergency stop for personnel and/or turbine protection. The disconnection from the EPS, as initiated by the emergency stop, shall not rely on the control system as defined in Section 8, Safety Related Controls System (SRCS). The switch function may be implemented via multiple contactors or switching devices.

Exception: The EPS disconnect is not required to be a part of the WT if the WT is marked to indicate:

a) That the EPS disconnect means is required to be provided and installed by the field assembler/installer,

b) The location of the EPS disconnect means, and

c) That the electrical requirements for the EPS disconnect means shall be provided.

4.16.4 An actuator may be provided to de-energize and isolate the WT power production circuits from the EPS connection. If provided, these actuators shall be clearly marked and shall be located both down tower and up tower. When activated, the EPS disconnect actuator shall de-energize all main power to the WT. As a part of this functionality, all electrical power to power production circuits and equipment shall be deactivated except lighting, communications, and SRCS circuits, which may remain energized if they are isolated from the power production circuits.

4.16.5 The emergency stop shall meet the following requirements:

a) It shall override all other functions and operations in all modes,

b) Power or energy to the moving parts, which causes a hazardous condition(s), shall be removed as quickly as possible without creating other hazards (e.g., rotors pitching to reduce hub rotation), and

c) The reset of the command shall not restart the machinery but only permit restarting.

4.16.6 The reset of the stop function shall not initiate any hazardous conditions.

4.16.7 It shall not be possible to restart the WT until all emergency stop or emergency off commands have been manually reset.

4.16.8 The emergency stop actuator shall comply with:

a) Standard for Industrial Control Equipment, UL 508, and

b) IEC 60947-5-5, Low-voltage switchgear and control gear, Part 5-5: Control circuit devices and switching elements – Electrical emergency stop device with mechanical latching function.

4.16.9 Emergency stop actuators shall comply with Category 0 or Category 1 stop function requirements for a machine control system as defined in NFPA 79, Electrical Standard for Industrial Machinery. They shall be rated for minimum 10,000 operations.

4.16.10 Following engagement, the emergency push button/actuator shall remain in the engaged position.

Note: this is the IEC definition of self-latching type.

4.16.11 Actuators of emergency stop devices shall be colored RED. The background immediately around pushbuttons and disconnect switch actuators used as emergency stop devices shall be colored YELLOW. The actuator of a pushbutton-operated device shall be of the palm or mushroom-head type and shall affect an emergency stop when depressed. The RED/YELLOW color combination shall be reserved exclusively for emergency stop or emergency off applications.

4.17 Cable trays and wireways

4.17.1 Cable trays shall comply with Article 392, and wireways shall comply with Article 376 or Article 378 of the National Electrical Code, ANSI/NFPA 70.

Exception: Separation per NEC Article 392.20 is not required if the wiring method complies with 4.2.5.

4.17.2 Metallic cable tray and wireway assemblies shall be investigated for bonding between sections and shall comply with the mechanical evaluation for bus bars in 4.5.1.

4.18 Hydraulic electromechanical components

4.18.1 Hydraulic electromechanical components shall be rated for the normal and foreseeable abnormal pressures of operation.

4.18.2 There shall be no risk of fire, electric shock, or injury to persons as a result of the pressure relief means operation. Pressure relief means and system drains shall be located so as not to allow released hydraulic fluid to fall, spray, leak, or drip on electrical components and systems, unless these components and systems are rated for exposure to the hydraulic fluid including the foreseeable range of release pressure conditions.

4.19 Alternators, generators and motors

4.19.1 Rotating machines shall comply with one of the following:

a) Standard for Rotating Electrical Machines – General Requirements, UL 1004-1;

b) Standard for Impedance Protected Motors, UL 1004-2;

c) Standard for Thermally Protected Motors, UL 1004-3;

d) Standard for Electric Generators, UL 1004-4;

e) Standard for Servo and Stepper Motors, UL 1004-6;

f) Standard for Electronically Protected Motors, UL 1004-7;

g) Standard for Inverter Duty Motors, UL 1004-8;

h) IEC 60034-1, Rotating Electrical Machines – Part 1: Rating and performance, and the applicable part 2 standards:

1) IEC 60034-2-1, Rotating Electrical Machines – Part 2-1: Standard methods for determining losses and efficiency from tests (excluding machines for traction vehicles);

2) IEC 60034-2-2, Rotating Electrical Machines – Part 2-2: Specific methods for determining separate losses of large machines from tests;

3) IEC 60034-2A, Rotating Electrical Machines – Part 2: Methods for determining losses and efficiency of rotating electrical machinery from tests (excluding machines for traction vehicles) Measurement of losses by the calorimetric method;

4) IEC 60034-3, Rotating Electrical Machines – Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines;

5) IEC 60034-4, Rotating Electrical Machines – Part 4: Methods for determining synchronous machine quantities from tests;

6) IEC 60034-5, Rotating Electrical Machines – Part 5: Degrees of protection provided by the integral design of rotating electrical machines (IP code);

7) IEC 60034-6, Rotating Electrical Machines – Part 6: Methods of Cooling (IC Code);

8) IEC 60034-7, Rotating Electrical Machines – Part 7: Classification of Types of Construction, Mounting Arrangements and Terminal Box Position (IM Code);

9) IEC 60034-11, Rotating Electrical Machines – Part 11: Thermal protection;

10) IEC 60034-12, Rotating Electrical Machines – Part 12: Starting performance of single-speed three-phase cage induction motors;

11) IEC 60034-14, Rotating Electrical Machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity,;

12) IEC 60034-15, Rotating Electrical Machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines;

13) IEC 60034-16, Rotating Electrical Machines – Part 16: Excitation systems for synchronous machines – Definitions;

14) IEC 60034-18-1, Rotating Electrical Machines – Part 18-1 Functional evaluation of insulation systems – General guidelines;

15) IEC 60034-18-21, Rotating Electrical Machines – Part 18-21 Test procedures for wire-wound windings – Thermal evaluation and classification;

16) IEC 60076-18-31, Rotating Electrical Machines – Part 18-31: Functional evaluation of insulation systems – Test procedures for form-wound windings – Thermal evaluation and classification of insulation systems used in rotating machines;

17) IEC 60034-18-32, Rotating Electrical Machines – Part 18-32: Functional evaluation of insulation systems – Test procedures for form-wound windings – Evaluation by electrical endurance.

18) IEC 60034-18-34, Rotating Electrical Machines – Part 18-34: Functional evaluation of insulation systems – Test procedures for form-wound windings – Evaluation of thermomechanical endurance of insulation systems;

19) IEC 60034-18-41, Rotating Electrical Machines – Part 18-41: Partial discharge free electrical insulation systems (Type I) used in rotating electrical machines fed from voltage converters – Qualification and quality control tests;

20) IEC 60034-19, Rotating Electrical Machines – Part 19: Specific test methods for d.c. machines on conventional and rectifier-fed supplies;

21) IEC 60034-26, Rotating Electrical Machines – Part 26: Effects of unbalanced voltages on the performance of three-phase cage induction motors;

22) IEC 60034-28, Rotating Electrical Machines – Part 28: Test methods for determining quantities of equivalent circuit diagrams for three-phase low-voltage cage induction motors;

23) IEC 60034-29, Rotating Electrical Machines – Part 29: Equivalent loading and superposition techniques – Indirect testing to determine temperature rise;

24) IEC TS 60034-17, Rotating Electrical Machines – Part 17: Cage induction motors when fed from converters – Application guide.

4.20 Motor drives

4.20.1 A motor drive assembly that supplies power to control a motor(s) operating at a frequency or voltage different than that of the input supply shall have electrical and environmental ratings for the intended application and comply with one of the following standards:

a) *Deleted*

b) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1;

c) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-2: Safety Requirements – Functional UL 61800-5-2;

d) IEC 62477-1, Safety requirements for power electronic converter systems and equipment – Part 1: General.

e) IEC 62477-1, Safety requirements for power electronic converter systems and equipment – Part 1: General, and IEC 62477-2, Safety requirements for power electronic converter systems and equipment – Part 2: Power electronic converters from 1 000 V AC or 1 500 V DC up to 36 kV AC or 54 kV DC; or

f) Outline of Investigation for Medium Voltage Stator Switching Assemblies for Wind Applications, Up to 15KV, UL 347D.

Note: Motor drives are not considered to be directly related to WT power generation, which is addressed in Converters/inverters, 4.10.

4.20.2 Motor drives that perform safety-related functions may be subjected to additional requirements as defined in Section 8, Safety Related Controls System (SRCS).

4.21 Energy storage units

Note: This section addresses equipment safety issues and does not address the worker safety requirements that are covered by other documents.

4.21.1 General

4.21.1.1 Batteries used as energy storage shall comply with the requirements in one of the following standards as applicable:

a) Standard for Standby Batteries, UL 1989, or

b) Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications, UL 1973.

4.21.1.2 Energy storage capacitors shall comply with the applicable requirements of the Standard for Electrochemical Capacitors, UL 810A.

4.21.1.3 Lithium batteries shall comply with the applicable requirements of the Standard for Household and Commercial Batteries, UL 2054.

4.21.1.4 Vented or wet-cell type batteries shall be used in orientations that prevent electrolyte loss from normal and foreseen abnormal, motion vibration and rotation.

4.21.1.5 Vented or wet-cell type batteries shall be mounted within ventilated areas complying with the Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications, UL 1973.

4.21.1.6 Energy storage devices mounted in moving parts of the WT (e.g., nacelle or hub) shall be of a type not adversely affected by the anticipated motion and conditions of use.

4.21.1.7 Energy storage devices intended to provide power for protective functions or braking systems shall comply with the Capacity Test in the Standard for Standby Batteries, UL 1989, and demonstrate sufficient capacity to perform the protective function or braking action.

4.21.1.8 The energy storage unit intended to be used inside a WT shall be provided with the WT.

4.21.1.9 A battery supply contained in a remote cabinet that is investigated separately – that is not included in the investigation of a WT – shall comply with the applicable requirements of the Standard for Uninterruptible Power Supplies, UL 1778, or Standard for Safety of power converters for use in photovoltaic power systems – Part 1: General requirements, UL 62109-1. An input or output of a WT intended for the connection of a separate, external battery supply shall be provided with overcurrent protection in accordance with the requirements of UL 1778.

4.21.1.10 Subassemblies providing uninterruptible power supply functions shall comply with the applicable requirements of:

a) Standard for Uninterruptible Power Supplies, UL 1778, or

b) Standard for Safety of power converters for use in photovoltaic power systems – Part 1: General requirements, UL 62109-1, or

c) IEC 62040-1, Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS, or

d) Standard for Energy Storage Systems and Equipment, UL 9540.

The energy storage system shall be evaluated for special environments, if required in the intended end use application. The energy storage system shall be evaluated for safety related functions, if other safety related functions in the WT is dependent on the power provided by the energy storage system to ensure the overall safety performance of the WT.

4.21.2 Battery mounting

4.21.2.1 A battery shall be located and mounted so that its terminals are prevented from contacting the terminals of adjacent batteries or metal parts of the battery compartment should the battery shift.

4.21.2.2 The casing of a battery installed in a rotating hub shall comply with the requirements of an electrical enclosure, or the battery shall be mounted inside an electrical enclosure to prevent damage to the battery from loose parts in the rotating hub.

4.21.2.3 To reduce the risk of electrolyte leakage resulting from battery case damage by a battery mounting means, a battery mounting means shall not cause undue stress to the battery case. See 4.21.2.4 and 4.21.2.5.

4.21.2.4 A battery mounting means consisting of a bracket, strap, or similar means that extends around the top, sides, or both of the battery shall not cause undue compression to the walls of the battery. While other constructions may be accepted if they are determined to be equivalent, the following types of brackets or straps meet the intent of this requirement:

a) A bracket or strap constructed of a nonrigid polymeric material,

b) A metal bracket or strap with a flexible, foamed, or similar material between the bracket or strap and the battery walls, and

c) A metal bracket, which when tightened as intended, provides a clearance (minimum not specified) between the bracket and the battery walls. See 4.21.2.5.

4.21.2.5 Where determining the adequacy of the clearance for the mounting means described in 4.21.2.4 (c), the following factors shall be taken into consideration:

a) Dimensional tolerances of the bracket and overall dimensions of the battery case, and

b) Slight increase of the overall dimensions of the battery after use.

4.21.2.6 A metal case or container of a battery, such as an alkaline battery, shall be insulated or spaced away from contact with uninsulated live parts of the assembly if such contact may result in a short circuit.

4.21.2.7 An enclosure or compartment housing batteries employing metal containers or cases that are conductively connected to a battery electrode shall be constructed so that the batteries are insulated or spaced from each other, or otherwise physically arranged, to prevent short-circuiting of part or all of the battery supply after installation.

4.22 Disconnect devices

4.22.1 Each supply source of the WT shall be provided with a lockable disconnect that positively prevents the startup and operation of the circuit. Sources typically include the Area EPS or Local EPS and generator.

Note: A rotor lock is considered a suitable means to lockout and de-energize the generator. Some turbine types may require multiple disconnects to de-energize the system and all of its components.

4.22.2 In addition to the requirements of 4.22.1, a system-by-system review shall be completed to determine if additional lockable disconnects are necessary. Systems that require lockable disconnects are those that require repair or maintenance with the main supplies energized, such as motors and heaters. A review of the service and maintenance manuals shall be used to assist in this review.

4.22.3 When a disconnection device is provided, it shall:

a) Open all ungrounded conductors,

b) Be a manually-operated switch or a motor-operated switch with provisions for manual operation,

c) Require provisions for locking in the open position, and

d) Be marked to identify the disconnect device, switch, or breaker for the specific power circuits.

4.23 Battery charge controllers

4.23.1 Battery charge controllers shall comply with one of the following standards:

a) Standard for Power Units Other Than Class 2, UL 1012,

b) Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741, or

c) Standard for Batteries for Use in Light Electric Rail (LER) Applications and Stationary Applications, UL 1973.

4.24 Medium voltage disconnection means

4.24.1 As noted in 4.1.1, for the purpose of this standard the medium voltage requirements are to be applied to circuits that operate at greater than 1000 Vac and 1500 Vdc nominal.

4.24.2 A wind turbine that is large enough for service personnel to enter the structure and contains medium voltage equipment shall incorporate provisions for disconnection of the medium voltage supply.

4.24.3 An electrical actuator, lock out device, or similar type equipment that opens and prevents electrical closing of the medium voltage disconnect, shall be located in the nacelle if medium voltage equipment is present either in the nacelle or in the tower of the wind turbine.

Note 1: This requirement is intended to provide a means, located within the nacelle, to disconnect medium voltage supplies or actuate a disconnect device not located in the nacelle.

Note 2: The Standard for Electrical Safety in the Workplace, NFPA 70E, includes worker safety requirements including prevention of access to energized medium voltage equipment. The most common protection methods include mechanical captive keys. These interlock requirements are intended to prevent access or service in medium voltage compartments when the equipment is energized. Circuits that can be electrically fed from two or more sources may need additional protection.

4.24.4 De-energizing the medium voltage equipment shall also discontinue the wind turbine power production.

4.25 Heating and cooling equipment

4.25.1 Heating and cooling equipment shall comply with the Standard for Heating and Cooling Equipment, UL 1995.

4.26 Wind turbine tower elevators

4.26.1 Wind turbine tower elevators shall comply with:

a) ASME A17.1-2013/CSA B44-13, Safety Code for Elevators and Escalators – Includes Requirements for Elevators, Escalators, Dumbwaiters, Moving Walks, Material Lifts, and Dumbwaiters With Automatic Transfer Devices, or

b) The electrical requirements in 5.7.19, Operating Devices and Control Equipment, of ASME A17.1-2010/CSA B44-10, Safety code for elevators and escalators.

5 Spacings

5.1 Spacings within components or equipment shall be in accordance with the requirements of the standard for those specific components or equipment. The spacings requirements in 5.2 – 5.5 are applicable for components and equipment within the WT equipment.

5.2 Notwithstanding 5.1, the electrical spacings within WT equipment rated 1500 V or less shall comply with the spacings requirements in the:

a) Standard for Industrial Control Equipment, UL 508, or

b) Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal and Energy, UL 61800-5-1.

5.3 Paragraph 5.2 references the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, and IEC 61800-5-1, Adjustable speed electrical power drive systems – Part 5-2: Safety requirements – Functional, as a means to determine alternative spacings requirements that account for product, installation, and application-specific conditions. The requirements in 5.4 and 5.5 define the base line Pollution Degree and Overvoltage Category for WT that shall be used when applying UL 840 or the IEC 60664, (Insulation coordination for equipment within low-voltage systems) series of standards.

5.4 Pollution Degree 3 is to be applied to determine creepage spacings in general locations within a wind turbine. Pollution Degree 4 shall be applied to creepage spacings where conductive pollution such as brush dust or brake dust may be present.

Exception: Steps can be taken to control or reduce the pollution degree at the creepage distance by design features or the consideration of the operating characteristics of the product. Pollution degree 2 can be achieved by reducing the possibilities of debris accumulation and condensation or high humidity at the creepage distance. Pollution Degree 2 can also be achieved through filtered ventilation and a means to prevent condensation. Continuous application of heat, through the use of heaters or continuous energizing of the equipment when it is in use, can be used to control condensation. Continuous energizing is considered to exist when the equipment is operated without interruption every day and 24 hours per day or when the equipment is operated with interruptions of duration which do not permit cooling to the point that condensation occurs.

5.5 Overvoltage Category IV shall be applied to determine clearance spacings unless supplemental surge protection is employed as described in 5.6.

Note: Direct or nearby lightning strikes can induce high over voltage conditions in EPS circuits and wind turbine circuits throughout the hub, nacelle, and tower. Surge protective devices, if used, shall be installed in close proximity to the equipment being protected.

5.6 In accordance with 6.3 and as defined by the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, or IEC 60664-1, Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests, clearance distances may be reduced through the use of surge protective devices (SPDS) that limit overvoltage circuit conditions. When an overvoltage protective device is used, it shall comply with the requirements in the Standard for Surge Protective Devices, UL 1449. To reduce circuits below Overvoltage

Category IV, surge protective devices shall be provided both down-tower to protect from EPS surges and up-tower to protect from atmospheric discharges. The WT shall incorporate a means to indicate the failure of surge protective devices relied upon to reduce clearances.

5.7 Where the operating voltage is not apparent due to switching circuits or buck boost circuits, the product spacings shall comply with the worst case operating voltages for that portion of the circuit as determined by the Maximum-Voltage Measurements Test in the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741.

5.8 For circuits operating above 1500 Vac to 7200 Vac, the electrical through-air and over surface spacings shall be not less than those indicated in the Standard for Medium-Voltage AC Contactors, Controllers, and Control Centers, UL 347.

5.9 For circuits operating above 7200 Vac, the electrical through-air and over surface spacings shall be not less than those indicated in the Standard for Medium-Voltage AC Contactors, Controllers, and Control Centers, UL 347. Spacings shall be increased to meet the required dielectric voltage and impulse withstand tests based on the voltage of the circuit.

5.10 As an alternative to 5.8 and 5.9, and unless otherwise specified by specific component requirements within this standard, the following standards shall be used for evaluating the insulation coordination requirements for specific wind turbine equipment:

a) IEC 60071-1, Insulation co-ordination – Part 1: Definitions, principals and rules, and

b) IEC 60071-2, Insulation co-ordination – Part 2: Application guide.

5.11 Where field-fabricated installations are to be made for circuits rated 2400 V or more, provision for such installation shall be made so that the minimum air spacings between uninsulated live parts and between uninsulated live parts and grounded parts is not less than the values in Table 490.24, Minimum Clearance of Live Parts, of the National Electrical Code, ANSI/NFPA 70.

6 Components and Circuits Rated or Operating between 601V and 1000V

Note: This section is intended to provide guidance for the evaluation of components operating between 601 Vac and 1000 Vac:

a) When using standards complying with the applicable UL equipment and component standards that include a scope limit of 600V, and

b) Where existing UL standards do not already exist for the application.

6.1 Components for use in WT applications operating between 601 Vac and 1000 Vac shall be evaluated per 6.2 – 6.4 when:

a) There is an absence of a component standard for greater than 600V use, and

b) There are published component requirements for 600V use, and they are applied as defined by this section.

6.2 Spacings for components operating between 600 Vac and 1000 Vac shall comply with Table 6.1 unless the individual 600V component standard spacings are greater than the values in the table. If so, the individual 600V component standard spacings shall be applied.

Note: This requirement addresses components such as circuit breakers with larger service spacings.

Table 6.1
Minimum spacings

Potential involved, 601 — 1000 volts	Location	Minimum spacings, inches	(mm)
Between any uninsulated live part and an uninsulated live part of opposite polarity, an uninsulated grounded part other than the enclosure, or an exposed metal part	Through air	0.55	(14.0)
	Through oil	0.45	(11.4)
	Over surface air	0.85	(21.6)
	Over surface oil	0.62	(15.7)
Between any uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable	Through air or oil	0.80	(20.3)
	Over surface	1.00	(25.4)

6.3 If spacings in the individual 600V component standard (for components operating between 601 and 1000 volts) are less than the values indicated in Table 6.1:

a) The spacings in Table 6.1 shall be applied, or

b) The individual 600V component standard spacings shall be applied, if the Overvoltage Category and Pollution Degree of the component installation location (within the wind turbine equipment), are such that the 600V component standard spacings are equal to or greater than the 601 – 1000V system specific spacings required in 5.3.

Note: This requirement addresses components such as heaters with smaller industrial-control based spacings.

6.4 All tests shall be performed as required by the individual component standard except the applied input voltage shall be based on the component nominal operating voltage.

7 Grounding

7.1 WT and subassemblies shall be provided with a field grounding connection means that is compliant with both the National Electrical Code, ANSI/NFPA 70, and the Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741.

7.2 Grounding within the WT shall be compliant with the standards applied for the construction evaluation specified in 4.1.2.

8 Safety Related Controls System (SRCS)

Note: IEC 61400-1, Wind turbines – Part 1: Design requirements, defines several critical controls and protection functions that require evaluation to maintain the turbine within its mechanical and structural limitations. This includes the evaluation of electrical control and protection functions, limits, operation, and response times during normal, abnormal, and failure conditions that are specified in 8.2 and 8.3.

8.1 General

8.1.1 The Safety Related Controls System (SRCS) described and addressed within this document embodies the "Controls System" and "Protection System" functions defined in IEC 61400-1, Wind turbines – Part 1: Design requirements. The SRCS functions and evaluation required for the control system and protection system, shall include the electrical controls and actuation circuits and components associated with the "Braking System" as defined in IEC 61400-1 up to and including the electro-mechanical interface components. As required by UL 6141 and also IEC 61400-1, these electrical control and protection functions shall be evaluated for proper operation during normal and abnormal failure conditions.

8.1.2 The WT controls functions identified in IEC 61400-1 shall additionally be evaluated to any safety critical parameters identified through the risk analysis to maintain the turbine within the structural mechanical limits identified through the IEC 61400-1 evaluation. A control or protection system response is required to occur when the WT operating parameters reach a specific limit or activation level. The operational limits are programmed into the WT SRCS, and the operational parameters are specified in the manufacturer’s documented ratings for the equipment.

8.2 Protection functions

8.2.1 The WT protection functions identified in IEC 61400-1, Wind turbines – Part 1: Design requirements, shall be evaluated in addition to any safety critical parameters identified through the risk analysis to maintain the turbine within the structural mechanical limits identified through the IEC 61400-1 evaluation.

8.2.2 Additional protection functions that are determined necessary to mitigate a risk of electric shock or fire shall be evaluated in accordance with the requirements of this section.

8.2.3 Compliance with 8.2.1 and 8.2.2 shall be achieved by demonstrating compliance with either (a) or (b) below:

a) One of the following:

1) IEC 62061, Safety of machinery – Functional safety of safety-related electrical, electronic and programmable electronic control systems;

2) IEC 61508, Functional safety of electrical/electronic/programmable electronic safety-related systems – Part 1: General requirements; or

3) ISO 13849, Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design.

b) Redundant systems complying with 8.2.4 – 8.2.6.

8.2.4 In accordance with 8.2.3, redundant systems shall be diverse, independent, and have all possible combinations of firmware/software version(s) and intended hardware platform(s) subject to functional testing. By diverse and independent, it is meant that "faults with a common cause" shall be prohibited. The operation of the control system and protection system shall be evaluated independently. Lightning is a common cause that shall be specifically addressed under this evaluation.

8.2.5 Each combination of microprocessor model, manufacturer and firmware/software version used in the production of a WT shall be evaluated in accordance with 8.2.4. Revisions to any portion of the combination of software and/or critical hardware shall require re-evaluation of the WT protection system.

8.2.6 Revisions may be entitled to a limited re-evaluation in accordance with risks identified in this section and as addressed by the subsequent functional safety evaluation of the revised firmware or software. The scope of the re-evaluation shall be defined by the potential impact of the firmware or software revisions on the SRCS or WT.

8.3 Abnormal conditions for safety related controls system

8.3.1 The turbine SRCS risk analysis shall include consideration of the following operational conditions:

a) Complete loss of control power,

b) Loss of one power conductor of a polyphase control power circuit,

c) Control power undervoltage and overvoltage conditions,

d) Component single faults,

e) Vibration amplitude and frequency expected for the application,

f) Failure of critical wiring insulation, isolation and/or continuity.

8.3.2 As a result of the requirements specified in 8.3.1, the (SRCS) system shall initiate a safe and controlled shutdown of the turbine and cessation of output power.

9 Manual Shutdown

9.1 Turbines shall be provided with a manual shutdown button/switch and a shutdown procedure.

9.2 Shutdown of the turbine shall:

a) Result in a controlled rapid transition from rotation and power production to standstill of the rotor and yaw motion, and

b) De-energize or interrupt the turbine output power circuit.

9.3 The manual shutdown shall not result in the disconnection of power to lighting, communications, or SRSC circuits.

9.4 An emergency stop, if provided, that complies with 4.16 of this document is considered to comply with the manual shutdown requirement.

10 Self-Excitation

10.1 WT shall be protected from unintentional self-excitation during all foreseeable loading and unloading conditions including loss of grid connection for grid tied turbines. Verification of compliance with this requirement shall consider both normal and single-fault conditions.

11 Ratings

11.1 WT shall be provided with the following ratings and be validated via compliance to IEC 61400-12-1, Power Performance Measurements of Electricity Producing Wind Turbines:

a) Rated load amperes, whether for ac, dc, or both;

b) Number of phases;

c) Rated output current;

d) Overcurrent protection values provided by the wind turbine generator for stator and rotor (if applicable);

e) Short circuit current rating (SCCR);

f) Maximum output short circuit current;

g) A brief system description, including the type of generator (synchronous or induction);

h) Evidence of approval or other markings necessary to ensure safe and proper operation;

i) Rated power;

j) Reference wind speed, V_{ref};

k) Hub height operating wind speed range, $V_{in} – V_{out}$;

l) Operating ambient temperature range;

m) IEC Turbine Class (from Table 1 of IEC 61400-1, Wind turbines – Part 1: Design requirements);

n) Rated voltage at wind turbine terminals;

o) Frequency at the wind turbine terminals or frequency range in case the nominal variation is greater than 2 percent.

11.2 WT system level major components and subassemblies such as generators, converters, transformers, etc. shall include the applicable ratings in accordance with the applicable standard for the component or subassembly.

11.3 A WT generator assembly that is intended to be connected to an external converter or inverter, external control system or unit, or both (that is not provided with the WT system), shall include ratings for:

a) Rated output power,

b) Rated output voltage,

c) Rated output current,

d) Frequency or frequency range at the wind turbine output circuit,

e) WT short circuit current rating. (marked on the WT or within the manual).

SERVICE PERSONNEL SAFETY

12 Working Space

Note: While the scope of NFPA 79, Electrical Standard for Industrial Machinery, is limited to 600V, UL 6141 will apply the NFPA 79 requirements and practices up to nominal 1000V-rated wind turbines.

12.1 Electrical enclosures, compartments or specific areas within the WT that are likely to require a service person to enter the enclosure or housing to wire, examine, adjust, or perform maintenance, shall comply with Article 11.5, Spaces Around Control Cabinets and Compartments, of NFPA 79, Electrical Standard for Industrial Machinery.

Exception: In special areas where the required working spaces cannot be provided (e.g. hub), special working procedures shall be provided to address worker safety, including consideration of the specific hazards within the special area, as well as the scope of the work. The special working procedures shall comply with local codes.

12.2 Areas within a turbine that require a lockout provision for worker safety shall be provided with a disconnecting means for the turbine that shall:

a) Be at the point of connection of electric power to the WT or the affected circuit,

b) Be readily accessible, and,

c) Be capable of being locked in the open position.

12.3 A locking device shall be provided for use with the disconnecting means specified in 4.22. It shall be installed on or at the switch or circuit breaker (the disconnect) and shall remain in place (whether locked or unlocked).

MARKINGS

13 System and Subassembly Components

13.1 Unless otherwise stated, all markings shall be permanent. The following types of markings or the equivalent meet this requirement:

a) Molded,

b) Die-stamped,

c) Paint-stenciled,

d) Stamped or etched metal that is permanently secured, or

e) Indelibly stamped on a pressure-sensitive label complying with the Standard for Marking and Labeling Systems, UL 969.

13.2 A unit shall be plainly and permanently marked where it is readily visible after installation with:

a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is able to be identified – hereinafter referred to as the manufacturer's name;

b) A distinctive Model number or the equivalent;

c) Product specific serial number;

d) The date or other dating period of manufacture not exceeding any three consecutive months. The repetition time cycle of a date code shall not be less than 20 years. The date code shall not require reference to the manufacturer's records to determine when the unit was manufactured.

Exception No. 1: The manufacturer's identification is able to be in a traceable code when the unit is identified by the brand or trademark of a private labeler.

Exception No. 2: The date of manufacture is able to be abbreviated in a nationally accepted conventional code, or in a code affirmed by the manufacturer.

13.3 A WT shall be marked with the electrical ratings defined in section 11.

13.4 A WT shall be provided with a plaque that includes basic instructions on how to disable the turbine.

Exception: This is not necessary for turbines that can be shutdown via the emergency stop button.

13.5 Each WT disconnect device shall be marked to indicate it is a disconnect and also marked for the specific circuit it controls.

13.6 The symbols described in items (a) – (c) shall be used as specified:

a) A circuit intended to be connected to a dc circuit shall be identified by markings indicating that the circuit shall be dc. The symbol illustrated in Figure 13.1 meets the requirement for this marking. See 13.7.

b) A circuit intended to be connected to an ac circuit shall be identified by markings indicating that the circuit shall be ac. The markings shall include the supply-circuit frequency or supply-circuit frequency-range rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz). The symbol illustrated in Figure 13.2 meets the requirement for this marking. See 13.7.

c) The number of phases shall be indicated when the unit is designed for use on a polyphase circuit. The symbol illustrated in Figure 13.3 is equivalent to the word "phase." See 13.9.

Figure 13.1

Direct current supply symbol

(IEC Publication 417, Symbol 5031)

Figure 13.2

Alternating current supply symbol

(IEC Publication 417, Symbol 5032)

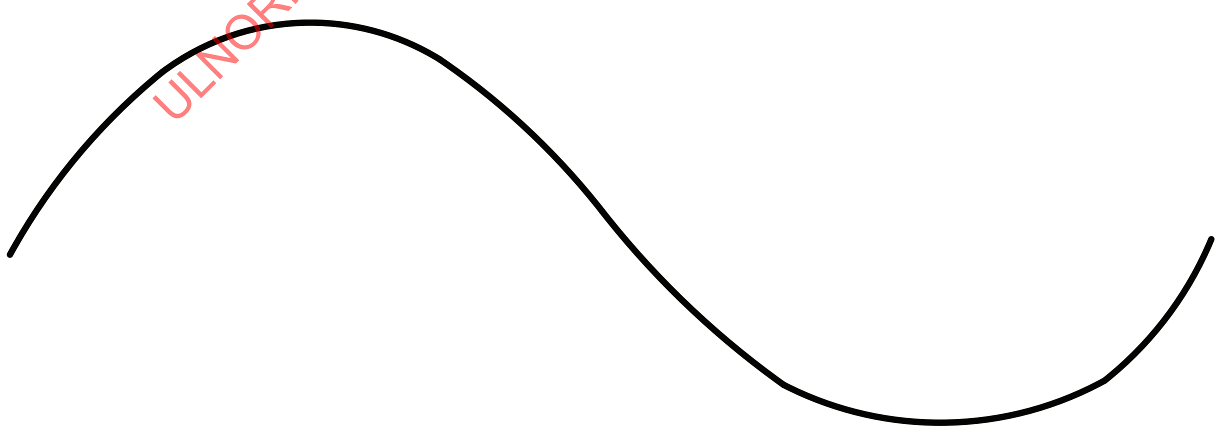
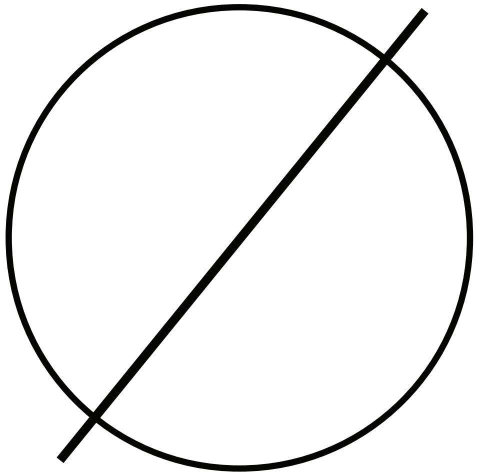


Figure 13.3

Phase symbol



13.7 When a symbol referenced in 13.6 (a), (b), and (c) is used, the important safety instructions shall identify the symbol.

13.8 The operating positions of a handle, knob, or other means intended for manual operation by the user shall be marked.

13.9 Wiring terminals shall be marked to indicate the intended connections for the unit, or a wiring diagram coded to the terminal marking shall be securely attached to the unit.

Exception: The terminal markings are not required when the wire connections are evident.

13.10 Field-wiring terminals shall be marked to indicate the appropriate wire conductor type (e.g., copper, aluminum), wire sizes, tightening torque, and wire insulation temperature rating.

Exception: When tightening torque ratings are included in the installation instructions provided with the unit, they are not required to be marked on the unit.

13.11 A pressure wire connector or stud-and-nut type terminal intended for connection of an equipment-grounding conductor shall be identified by:

a) The marking "G", "GR", "GND", "Ground", "Grounding", or equivalent;

b) A marking on a wiring diagram attached to the unit, or

c) The symbol illustrated in Figure 13.4 on or adjacent to the connector or on a wiring diagram provided on the unit. See 13.14.