Blade Lightning Protection for Wind Turbines
The dynamic phase of lightning commences in the form of a downward leader from the base of a cloud and grows into a series of steps and branches toward the ground. The protrusion of ground objects, such as wind turbine blades, into the ambient electric field of the lightning downward leader increases the electric field at the tip of the blade and/or other protruding parts of the turbine.

As the downleader approaches the tip of the ground objects, the electric field increases rapidly and small upward streamers form from the elevated points. Under the right conditions, these upward streamers compete as they propagate toward the approaching downleader. In order for one point on the turbine structure to develop an upward intercepting leader and become the preferred strike point, it must complete an ionized path between cloud and ground.

This main lightning discharge is characterized by a rapidly rising current (averaging about 30,000 Amps) with maximum values exceeding 200,000 Amps (Table 1). The whole process is extremely rapid and typically occurs within milliseconds. The average energy released in a single discharge may be 55 kW hours. The danger lies in the extremely high rate of current rise, which can generate very high voltages within and along the blade, and also from the continuing current following the peak.

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<td><strong>Current parameters</strong></td>
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<td>Symbol</td>
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<td>Peak current</td>
<td>kA</td>
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<td>Short stroke charge</td>
<td>C</td>
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<td>Specific energy</td>
<td>MJ/Ω</td>
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<td>Time parameters</td>
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<th>Subsequent short stroke</th>
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(Source: IEC 61400-24)

Blades with ineffective lightning protection design can sustain catastrophic damage. A coordinated system is critical to help ensure effective capture and to control the passage of lightning energy to ground.

The most effective techniques to provide reliable protection for wind turbine blades remain the subject of international research and standardization. nVent ERICO’s role in this research, in addition to years of service on related lightning-protection standards, have helped make the company a trusted authority within the industry.
WE FOCUS ON BLADE PROTECTION AS PART OF THE ENTIRE LIGHTNING PROTECTION SYSTEM FOR THE WIND TURBINE.

nVent ERICO offers a complete range of grounding, surge and lightning protection products for the wind energy industry. In addition to our extensive product offering, our engineers and designers are ready to provide design assistance for grounding and lightning protection for your facilities worldwide.
Critical Elements of a Blade Lightning Protection System

CONDUCTOR TECHNOLOGY

Lightning protection conductors are designed and manufactured to meet specific criteria for an effective and reliable conduction of lightning currents. For optimal performance, the conductors must maintain the following characteristics:

• Low inductance per unit length
• Low surge impedance
• Current-carrying capability to withstand, without degradation, the thermal and mechanical effects of lightning
• Resistance to environmental effects

When applied to applications with wind turbine blades, the construction and design of the blade may require additional characteristics for the conductors:

• Insulation, splicing and termination methods adequate to contain the lightning energy under current impulse conditions
• Ability to withstand mechanical fatigue over time

The application of optimal conductors within wind turbine blades is both unique and often complicated, and varies from one blade design and construction to another. nVent ERICO’s extensive knowledge and experience within this industry make it ideally suited to face these challenges. By manufacturing a wide selection of lightning conductor solutions in multiple facilities around the world, nVent ERICO can provide the high-quality, innovative products and services you require to consistently meet your needs.
Critical Elements of a Blade Lightning Protection System

PERMANENT, LOW-IMPEDANCE CONNECTIONS
IT IS WHO WE ARE

Connections are often considered the weakest point of an electrical circuit and this is especially true in the protection scheme within a wind turbine blade. They are subject to constant vibration and corrosion, as well as the thermal and mechanical stresses that are present during a lightning event. In addition, it is difficult to inspect or test the electrical connections within a blade after the system has been installed.

Experience has shown that the most effective protection schemes over time are designed and manufactured with permanent connections, which helps to ensure the system can handle a variety of adverse conditions.

Since 1938, nVent ERICO has specialized in making electrical connections that will never loosen, corrode or increase in resistance. Because of the affordability, success and superiority of the Cadweld welded electrical connection, nVent ERICO is considered a world leader in the development of high-current electrical grounding connections that are suitable for the harshest environments.

nVent ERICO also manufactures a vast array of methods that are used to connect conductors within wind turbine blades. These methods are designed and tested to meet the CENELEC EN50561 standard and other national standards, such as UL ® 96. Whether the protection scheme requires an insulated connection, connections to receptors, or connections from conductor to conductor, you can trust nVent ERICO to have the right connection method for your specific application.
Critical Elements of a Blade Lightning Protection System

RECEPTOR ATTACHMENT

To continuously enhance its lightning protection process, nVent ERICO has conducted years of research involving long-term field studies and has performed laboratory testing using some of the largest outdoor test laboratories available. Countless research study programs, including joint ventures with accomplished scientists in the field, have also been used in its research process. This extensive research program has resulted in some of the most up-to-date, published technical papers and journals, including patents in this area. nVent ERICO is also committed to the development and harmonization of lightning protection standards around the world.

The placement of receptors on structures, such as wind turbine blades, is performed using statistical models. A risk management approach is required to determine the receptor number and placement to provide optimum protection. The design of the receptor itself also influences its ability to capture lightning. nVent ERICO can provide receptors based on the material type, design and size of the blade.

Years of experience and knowledge in the field of lightning protection, combined with global manufacturing capabilities, make nVent ERICO a premier source for providing comprehensive protection solutions. nVent ERICO can also manufacture the required products and hardware to update existing systems.
Wind Power Solutions
nVent offers a complete range of foundation grounding and construction, bonding, power connections, surge protection, and lightning protection products for the wind energy industry. In addition to our extensive product offering, our engineers and designers are ready to provide design assistance for your facilities worldwide.

- nVent ERICO Blade Lightning Protection Components and Assemblies
- Bolt Couplers
- Cable to Rebar Connections
- nVent ERICO Ground Enhancement Material (GEM)
- nVent ERICO Cadweld Connections
- nVent ERIFLEX Flexibar Advanced
- Low-Voltage Insulators
- Power Blocks
- Grounding and MBJ Braids
- Standard Couplers and Position Couplers
- nVent ERICO Terminator Rebar End Anchors
- nVent LENTON Terminator Rebar End Anchors
- Cable to Rebar, Cable to Cable, Cable to Ground Rod
- Power and Control Surge Protection

nVent.com/ERICO
nVent ERICO System 3000 Lightning Protection

Fence and Gate Jumper Assemblies

Power Surge Protection

Equipotential Ground Bars

nVent ERICO Hammerlock and Ground Rod

Ground Rods
- Copper-bonded Steel
- Galvanized Steel
- Stainless Steel

Power and Control Surge Protection for SCADA and Power Connections

Universal Transient Barrier (UTB)

Prefabricated Mesh for Switch Shaft and Operating Handle Grounding
Introduction

Years of experience in the fields of grounding and bonding, lightning protection, low voltage power distribution and reinforced concrete construction, combined with global manufacturing capabilities, allow nVent to provide comprehensive solutions for the wind energy industry. We offer a full range of solutions including facility electrical protection products, low-voltage power distribution products and concrete reinforcement products.

BLADE

Lightning protection assemblies have been installed on thousands of wind turbine blades worldwide. Components cover a range of nVent ERICO products, including receptors, Cadweld exothermically welded connections, conductors, lightning event counters/lightning registration systems.

NACELLE

To help protect the electrical components housed within the nacelle, nVent ERIFLEX supplies products, such as grounding braids, insulators, Flexibar Advanced, power blocks and conductors.

TOWER

Tower lightning protection products include grounding braids, insulators, conductors, Flexibar Advanced and copper busbar.

FOUNDATION GROUNDING AND CONSTRUCTION

Grounding products include Cadweld exothermically welded connections, rebar clamps, ground/earth testers, nVent ERICO Ground Enhancement Material (GEM) and ground rods. Foundation construction products include bolt couplers, nVent LENTON Terminator rebar end anchors and standard couplers.

SURGE PROTECTION

nVent offers a complete line of surge protective devices that can be coordinated into an effectively staged electrical protection plan.

POWER CONNECTIONS

Products recommended for power distribution throughout the nacelle, tower and power hut include: splice blocks, power shunts, distribution blocks, Flexibar Advanced and busbar supports.

SUPPORT AND TRAINING

nVent project managers, engineers and researchers have decades of domain expertise and continue to develop new products for improved performance and installation efficiency for the ever-evolving wind power industry. We are trusted to deliver cost-effective, long-term solutions through turn-key, rapid-response engineering, design and integration services for the unique demands of the wind energy industry.

nVent ERICO specializes in:

- Custom design and packaging of lightning protection assemblies for wind turbine blades
- Grounding and bonding applications of the nacelle and tower
- Design and manufacture of lightning protection downconductors and connection systems
- Computer grounding layouts and analysis for the foundation

nVent provides extensive training and consultative services to OEMs, engineers and contractors on our product capabilities and installation techniques to help ensure optimum performance.
nVent lightning protection assembly kits for wind turbine blades are designed and manufactured to meet or exceed OEM specifications. In addition, nVent product development teams continue to work closely with OEMs to tailor the level of assurance you need to mitigate risks, refine component designs for improved reliability and enhance lightning protection performance.

1. CONDUCTORS

Designed and manufactured to meet specific criteria for effective and reliable conduction, lightning conductors should have:

- Low inductance per unit length and low surge impedance
- Current-carrying capability to withstand, without degradation, the thermal and mechanical effects of lightning
- Resistance to environmental effects and mechanical fatigue

Conductors offered include:
- Aluminum, copper and stainless steel
- Insulated and non-insulated
- Solid and woven conductors in both flat and rounded configurations

2. RECEPTORS

As a world leader in the design of strike termination devices, nVent applies this expertise to the design of its lightning receptors. Important factors include:

- Blade material and manufacturing process
- Ease of receptor installation and insulation requirements
- Attachment method to lightning protection conductor
- Attracting the lightning strike to a preferred attachment point
- Field serviceability

3. CONNECTIONS

Blade lightning protection connections may range from a Cadweld welded connection to a mechanically bolted connection. Considerations include:

- Lightning protection conductor material
- Resistance to vibration and corrosion
- Material impedance
- National/international standard requirements
- Costs and benefits

4. LIGHTNING REGISTRATION CARDS

nVent provides the ability to collect data for the analysis of lightning strikes. The lightning registration system is ideal for use on land and offshore.
nVent offers a full line of nVent ERIFLEX low-voltage products to protect the electrical components housed within the nacelle from the devastating effects of lightning strikes. Products include:

- Power blocks designed to provide a safe entry point for incoming power generated by the wind turbine
- Grounding braids for any grounding and bonding power connection
- Flexibar Advanced to help improve power density within the nacelle, tower and power hut
- Conductors to withstand the electromechanical effects of lightning
- Low-voltage insulators to promote stability of electrical and mechanical parameters

1. GROUNDING BRAIDS

Grounding braids consist of tinned, electrolytic, woven copper wire. Each braid has solid hole-punched ends for easy connection. Grounding braids are the first cost-effective alternative to grounding cables with crimped lugs.

Grounding braids can be used for any grounding and bonding power connection. Because of their low contact resistance, they are particularly adapted to decrease EMC problems.

nVent can provide Made-to-order (MTO) custom configurations to your drawing specifications. Copper braids can be made to custom lengths, widths, thicknesses and hole patterns, with PVC insulation, in flat or tubular shapes, in continuous coils or with soldered studs or crimped lugs.

2. FLEXIBAR ADVANCED

Flexibar Advanced is an effective alternative to using cables and lugs to help improve power density within the nacelle, tower and power hut and improve safety of your installation due to its unique and safer Advanced insulation. It offers space and weight savings of up to 70 percent (improving power density).

By eliminating the need for compression lugs, Flexibar Advanced improves the reliability of the power connection and reduces the number of power connections that are needed. It also extends power density to even greater levels within the nacelle, tower and power hut using MTO Flexibar Advanced and MTO braids. MTO products from nVent can be configured to your specifications, helping to reduce equipment and packaging sizes.

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- Insulated and non-insulated
- Solid and woven conductors in both flat and rounded configurations

4. POWER AND DISTRIBUTION BLOCKS

A complete power block range are the entry point for incoming power generated by the wind turbine, carried to the inverter.

5. SURGE PROTECTION

DIN rail mounted components

- UL and IEC Listed
- Enhanced temporary over voltage (TOV) withstand capability
- Retaining clip ensures enhanced vibration and shock resistance performance

6. LOW-VOLTAGE INSULATORS

nVent offers nVent ERIFLEX brand of low-voltage insulators.

- Manufactured of rugged, polyamide, halogen-free nylon material, which is reinforced with glass fiber
- Low-voltage insulators, from 15 mm to 100 mm height, for indoor use
- Very high resistance to leakage current
- Great stability of electrical and mechanical parameters
- Meets the requirements of UL 94 V-0 for self-extinguishing materials
- Working temperature -40ºC to +130ºC
- UL Recognized

7. LIGHTNING PROTECTION

Isolated Down Conductor provides a low impedance insulated path past critical equipment.

Lightning Registration Cards

nVent provides the ability to monitor data for the analysis of lightning strikes. The devices are ideal for both land-based and offshore turbines.
nVent offers a variety of products to help create effective lightning protection and power distribution systems for the wind turbine tower. Designed to meet the current IEC, NFPA or a proprietary design method, lightning protection and power distribution systems from nVent are ideal for use with the three styles of tower design:

- Tubular steel towers
- Precast concrete towers
- Lattice towers

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2. COPPER BUSBAR

nVent offers a variety of electrolytic copper bars – plain, punched or threaded. Busbar/connectors are also available.

- Threaded Busbars
  - Electrolytic copper
  - Rounded corners
  - Thickness from 2 to 10 mm
  - Length from 1,000 to 2,000 mm
- Punched and Plain Busbars
  - Design and assembly time-saving
  - Current up to 7400 A
  - Thickness from 4 to 40 mm
  - Length from 1,000 to 4,000 mm
- Busbar Connectors
  - Quick and easy connections
  - Large and versatile range
  - Connections from 2.5 to 35 mm²

3. FLEXIBAR ADVANCED AND BRAIDS

Flexibar Advanced is an effective alternative to using cables and lugs to help improve power density within the nacelle, tower and power hut. This innovative flexible insulated busbar offers space and weight savings of up to 70 percent (improving power density).

By eliminating the need for compression lugs, Flexibar Advanced improves the reliability of the power connection and reduces the number of power connections that are needed. It also extends power density to even greater levels within the nacelle, tower and power hut using MTO Flexibar and MTO braids. MTO products from nVent can be configured to your specifications, helping to reduce equipment and packaging sizes.

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 Conductors offered include:

- Aluminum, copper and stainless steel
- Insulated and non-insulated
- Solid and woven conductors in both flat and rounded configurations

5. POWER BLOCKS

High conductivity tinned copper blocks provide a good solution to interconnect two elements of the tower. They can be mounted directly inside the tower or pre-assembled in junction panels.
Tower

1. Grounding Braids
2. Copper Busbars
3. Braids
4. Conductors
5. Power Blocks

Flexibar Advanced
Foundation Grounding and Construction

Site location is critical to capture the wind and often involves areas of high soil resistivity. The increasing height of newer wind turbines enhances the threat of lightning strikes. Proper design and integrity of a grounding grid facilitates long-term safety and operation of any wind turbine site during both lightning and fault current events.

Wind turbine grounding system design has to meet three main criteria:
- Satisfy the step-and-touch potential requirements regarding the safety of personnel
- Provide sufficient ground reference potential to assure proper functionality of electrical equipment
- Effectively dissipate the lightning energy

The application engineering team at nVent can analyze and provide grounding system design assistance for tower and power substation grounding using the latest grounding design software. nVent also offers an extensive line of grounding products to meet your specific foundation grounding needs.

CONSTRUCTION

1. BOLT COUPLERS
Bolt couplers, part of the nVent LENTON line of concrete products, provide a full strength joint between a reinforcing bar and a standard parallel thread bolt. Both the S4 and S5 couplers are for use in North America and provide continuity between reinforcing bar and imperial UN or UNC all-thread rod or bolts. The S13 couplers provide continuity between reinforcing bar and ISO 965 metric all-thread rod and bolts. The bolt couplers are typically used to tie a pedestal base to the foundation and to anchor miscellaneous equipment to the foundation.

2. TERMINATOR
The Terminator is an over-sized end anchor that is secured to the end of a length of reinforcing steel, creating anchorage within the concrete. Terminator replaces hooked bars and provides anchorage, and also eases congestion.

3. STANDARD COUPLERS AND POSITION COUPLERS
Standard couplers are designed to splice the same diameter bars where one bar is free to move and can be rotated. Position couplers are designed to splice two curved, bent or straight bars when neither bar can be rotated.

GROUNDING

1. GROUND RODS
Copper-bonded steel ground rods exceed the requirements of ANSI®/UL and IEC. They are also highly corrosion resistant and provide at least a 30-year service life in most soils.

2. MECHANICAL CONNECTORS
The durable RC70/RC100 rebar clamps provide two connection points to rebar in the wind turbine grounding foundation and meet the NEC® standard requirement for bonding to rebar.

3. GROUND ENHANCEMENT MATERIAL (GEM®)
GEM is a low-resistance carbon concrete that improves grounding effectiveness in areas of poor conductivity. GEM is ideal for wind turbine foundations where limited space makes adequate grounding difficult by conventional methods.

4. EXOTHERMICALLY WELDED CONNECTIONS
The Cadweld molecular bonding process is superior in performance to any known mechanical or compression-type surface-to-surface contact connector. By virtue of the molecular bond, Cadweld connections provide current-carrying (fusing) capacity equal to that of the conductor and will not deteriorate with age.

Cadweld connections are UL Listed and satisfy IEEE® Standard (Standard for Permanent Connections Used in Substation Grounding).

5. GROUND/EARTH TESTERS
nVent offers a range of ground/earth testers that are lightweight and portable for ease of use in the field. The ground testers are ideal for determining soil resistivity prior to designing the wind turbine foundation ground system and for testing the final resistance of the ground system after installation.

6. CONDUCTORS
Below grade, nVent ERICO Cu-Bond Round Conductors are ideal as earthing and bonding conductors where copper theft may occur. The conductor can be used as an interconnecting grounding conductor between wind towers or as a grounding grid at the base of a wind tower.
Foundation Grounding and Construction

CONSTRUCTION

1. Bolt Couplers
2. Terminator
3. Standard Couplers & Position Couplers

GROUNDING

1. Ground Rods
2. Mechanical Connectors
3. Ground Enhancement Material (GEM)
4. Cadweld
5. Ground/Earth Testers
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