PROPERTY

COMMENTARY PAPER

Bolts from the blue: A crash course on lightning's striking power and dangers

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Lightning — powerful natural phenomenon — is a sudden electrostatic discharge that releases massive amounts of electrical energy between the atmosphere and an earth-bound object. According to the National Oceanic and Atmospheric Administration, on average, lightning strikes Earth 8.6 million times a day, making it one of the most common weather occurrences on our planet. While fascinating to observe, lightning can also be extremely dangerous and cause damage to property. This commentary aims to provide a technical yet accessible overview of lightning, including where it is most common in North America, how it damages equipment and susceptible targets.

The science behind lightning

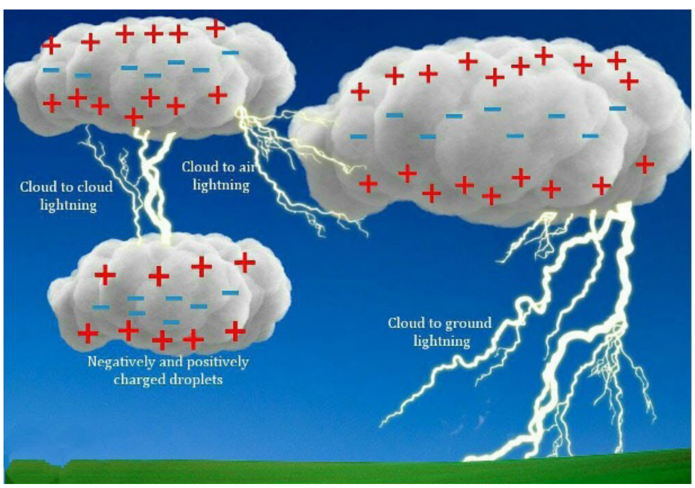


Illustration credit: ScienceABC

Lightning begins when strong updrafts and downdrafts of wind occur during thunderstorm formation. Water and ice particles collide, causing a separation of electrical charges. Positively charged ice crystals rise to the top of the thunderstorm cloud while negatively charged ice particles and hail sink to the middle and lower portions of the cloud. This separation of charges establishes an enormous electrical potential difference between the top and bottom of the cloud, as well as between the cloud and ground.

When the electrical potential becomes sufficiently strong, a conductive path is formed and lightning is discharged. There are several types of lightning including:

- Cloud-to-ground
- Intra-cloud
- Cloud-to-cloud
- Cloud-to-air

From an equipment perspective, the most dangerous type of lightning is cloud-to-ground, which originates from the negatively charged bottom of the thundercloud and strikes an earthbound object like a building or tree. A typical cloud-to-ground lightning bolt discharges a current of 20,000 to over 100,000 amps and can reach temperatures hotter than the surface of the sun.

Lightning in North America

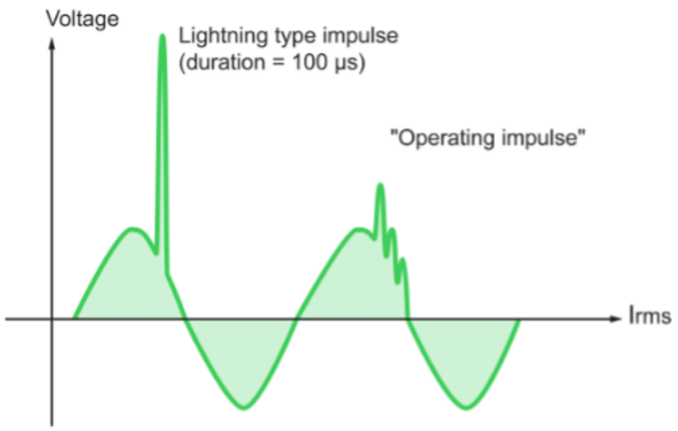
In the United States, Central and Southern Florida experience the highest frequency of lightning activity, with over 100 strikes per square mile per year. Other high activity areas include the Gulf Coast states, the Mississippi Valley, the Southeast and the Rocky Mountains. In Canada, southern Ontario and Quebec see frequent lightning from thunderstorms originating in the Great Lakes region. The Northwest Territories and Nunavut also experience dry lightning strikes associated with forest fires.

Susceptible targets

When lightning strikes a building, home, or power line, the massive surge of electricity can damage appliances, electronics and wiring. Direct strikes can also ignite fires or cause explosions if flammable materials are present. Some equipment and infrastructure that are vulnerable to lightning damage include:

- Electrical and electronic devices like computers, network switches, routers and phone systems.
- Appliances such as air conditioners, stoves and refrigerators.
- Electrical wiring and power distribution systems.
- Telecommunication networks and antennas.
- Buildings with metallic construction and wiring.
- Oil drilling rigs and refineries.

Mechanisms by which lightning damages susceptible targets



Lightning overvoltage creates a huge spike in voltage on power lines, but it only lasts for a very brief moment. Operating impulses or surges occur regularly in normal operation of electrical equipment. Graph credit: Lightning and Surge Protection

Overvoltage

When lightning strikes an object, the enormous electrical current creates a massive surge of power that can be conducted through wires, circuits and components. This extreme overvoltage can exceed the tolerances of electronic devices and cause internal components like semiconductor junctions, transistors and integrated circuits to burn out or fracture.

Overvoltage therefore results from the massive electrical potential difference between a thundercloud and ground that discharges via the lightning channel. Voltages can exceed 100 million volts. Currents can surpass 100,000 amps. Overvoltage is primarily an issue when lightning directly strikes equipment or a connected transmission line. Such a strike causes immediate electrical damage to components due to extreme current/voltage.

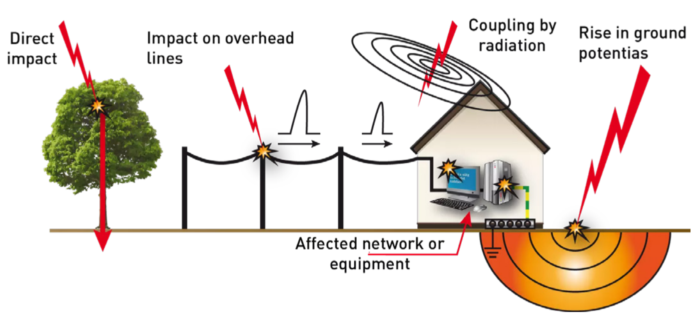


Illustration credit: CITEL Inc.

Inductive coupling

Inductive coupling refers to the phenomenon where a lightning strike can induce voltage and currents spikes in nearby electrical conductors through electromagnetic induction, even if those conductors are not directly struck.

Here is a more detailed explanation of how inductive coupling works: When lightning travels through the air, it generates extremely rapid changes in electric and magnetic fields in the area surrounding the lightning channel. These changing electromagnetic fields will induce voltages and currents in metallic conductors that are located within the field region. This process of electromagnetic induction is called coupling.

If the metallic conductor loops form a closed circuit, the induced voltages can cause large currents to flow through the conductors. Nearby wires, power lines, cables, etc. act as antennas that "pick up" these induced voltages when they intercept changing lightning electromagnetic fields. The longer the conductor loops and the stronger/closer the lightning strike, the higher the induced voltage can be.

Voltages induced in electronics or electrical systems via inductive coupling can damage components or exceed safe operating limits, even if the lightning does not strike them directly. Lightning current flows prefer to couple into conductive loops, so wiring acts like inadvertent loop antennas, allowing connected devices to experience hazardous surges.

> *Inductive coupling allows hazardous lightning electromagnetic energy to be transferred into conductors and electronics through non-contact induction.*

Transient power surge

An off-premise lightning bolt that strikes electrical power lines or building wiring can cause a hazardous power surge inside connected equipment. Devices plugged into outlets or wired into a structure's electrical system can experience these potentially damaging surges through conduction. A surge protector helps dampen but may not fully protect from a direct lightning strike. Power surge on the other hand, refers to a rapid increase in voltage or current in an electrical circuit. The surge intensity is lower than a direct strike (overvoltage), often 1,000-10,000 volts, which is still hazardous to electronics. Other sources of transient power surges include damage to power lines and transformers, short circuits, faults, and switching on the electrical grid by the utility company.

Heat/fire

Lightning strikes can vaporize materials and ignite fires. The extreme heat from high current arcing and discharge through circuits can melt plastics and burn flammable electronic components. Fuel sources like ruptured gas lines can ignite from the heat.

Physical damage

When lightning directly hits equipment like antennas and electric poles, the massive energy can physically deform, crack or shatter materials. Nearby lightning induced power surges can also cause physical impacts like warping of conductive electronics chassis. The kinetic energy can render devices completely inoperable.

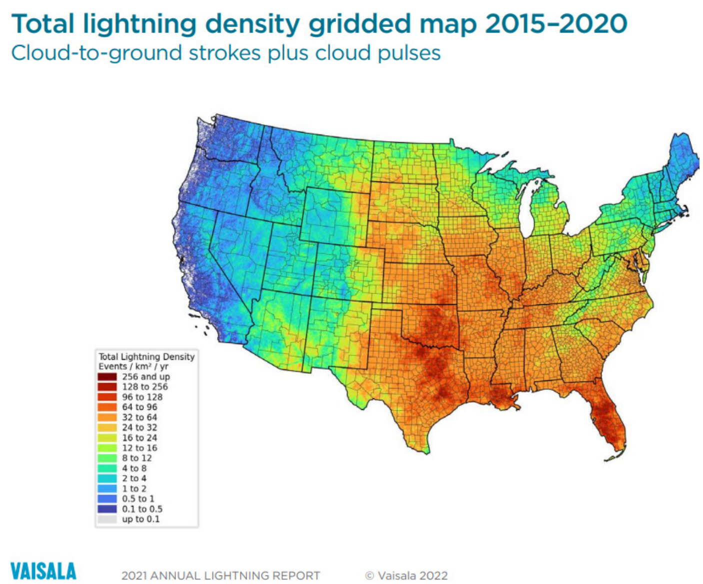
Can a circuit breaker protect against lightning?

There are a few key reasons why a standard circuit breaker may not be able to sense and trip from a lightning-induced power surge, even though it can handle a more typical power surge:

- **Speed -** Lightning surges happen extremely fast, in microseconds or less. Circuit breakers are designed to trip based on current over time. They may not react fast enough to cut power during a lightning event.
- **Magnitude -** The voltage and current spike from a close lightning strike can be exponentially higher than a small wiring fault surge that breakers are sized for. The massive overload can effectively "weld" the breaker contacts together before tripping occurs.
- **Frequency -** Lightning surges contain very high frequency components as the current changes rapidly. Circuit breakers aren't tuned for this frequency range, so high frequency surges can sneak through without detection.
- **Lack of ground reference -** Circuit breakers use current transformers that need a ground reference. During a lightning strike, the ground reference can shift, confusing the sensing circuitry.
- **One-time event -** Lightning surges are single impulse events versus an ongoing operating impulse fault. The breaker may not release fast enough for a one-time spike.
- **Multiple paths -** Lightning can induce surges across multiple connected paths. Breakers in one location won't see the whole picture of the strike coupling.

Lightning detection networks

Lightning detection networks use a system of ground-based sensors to detect electromagnetic signals given off when lightning strikes occur. The data is transmitted to central processors to determine the location, time and characteristics of each strike. Lightning detection networks have existed since the 1950s, with continual improvements in technology allowing for greater detection efficiency, accuracy and coverage over time. Today, organizations like Vaisala and Earth Networks operate extensive real-time lightning detection networks with thousands of sensors across the U.S. When investigating potential lightning-related claims, there are pros and cons to relying solely on lightning detection network data versus contacting an expert.



Vaisala lightning statistics 2021 annual report. Illustration credit: Vaisala

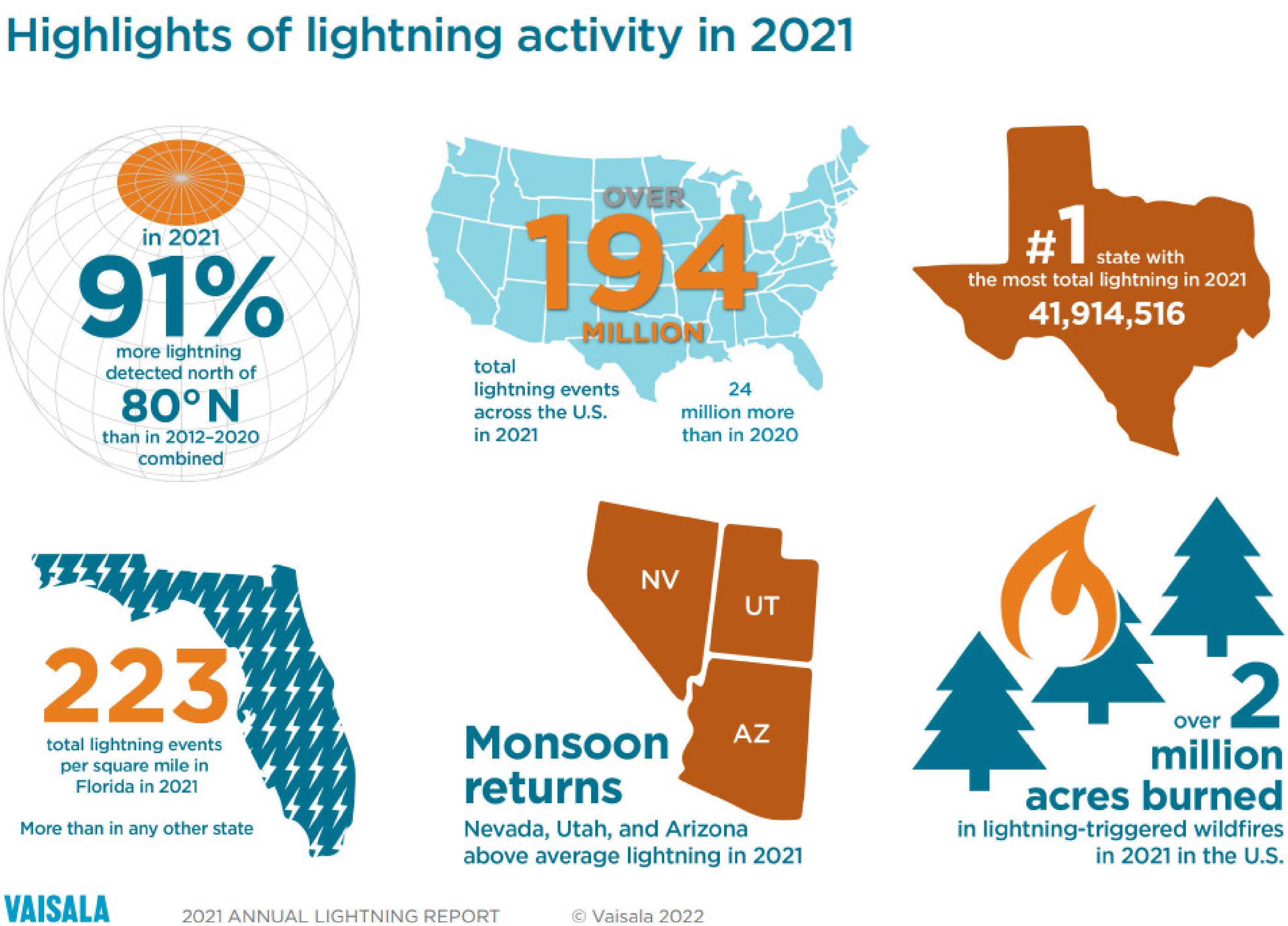
Potential benefits of using lightning detection network data:

- Provides data that lightning was either present or not in the vicinity at the time of the equipment damage.
- Detection networks have strong accuracy for cloud-to-ground strikes so location data is generally reliable within the published ellipticals of confidence.
- Lightning density maps reveal if multiple strikes occurred nearby.
- The data is convenient, low cost and easily accessed.

Potential limitations:

- Detection efficiency is lower for intra-cloud and cloud-to-cloud strikes. Some causative lightning may be missed.
- Proximity alone does not prove that lightning damaged the equipment. Other causal factors may be involved.
- An expert can provide additional on-site forensic analysis to correlate damage patterns with lightning or other non-lightning related electrical or mechanical faults.
- Experts have specialized knowledge for judging if the characteristics and intensity of nearby strikes were sufficient to reasonably cause the observed damage.

Lightning detection data is therefore useful supporting evidence but leveraging the expertise of a lightning damage expert can provide additional investigative insights and strengthen claim determinations. The most prudent approach is likely combining lightning strike data with an objective expert forensic analysis.



Vaisala lightning statistics 2021 annual report. Illustration credit: Vaisala

Case study – Lightning claim to HVAC equipment

A city library branch experienced a lightning strike during a storm. A claim was filed stating that the heating, ventilation and air conditioning (HVAC) system was damaged beyond repair. A $225,000 quote to fully replace two HVAC units and electricals was submitted as part of the claim.

Cutout of a commercial HVAC unit. The compressor is the black sealed metal cylinder shown at the bottom/front of the unit. Illustration credit: Galgon HVAC

Claim details:

- Lightning struck the building's rooftop during a storm.
- The library has two rooftop HVAC units that were installed 2013.
- An HVAC repair contractor assessed the damage and advised that both compressors burnt out due to a lightning strike.
- The contractor quoted $225,000 to replace both HVAC units and impacted electrical components.

Investigation:

- An engineer was dispatched to inspect the building and HVAC systems.
- The engineer confirmed evidence of a lightning strike.
- The engineer also agreed that lightning caused damage to both HVAC system components.
- The engineers report advised that the existing systems could be restored to a pre-loss condition, via replacement of damaged components followed by comprehensive testing.
- A recommendation was made to replace the damaged compressors and controllers, but existing coils, ducts, etc., could be reused.

Additional research:

The engineer discussed the proposed restoration with the library's HVAC contractor. The contractor furnished a quote with the following breakdown:

1. New compressors: **$15,000**
2. New controls: **$12,000**
3. Electrical repairs: **$10,000**
4. Total: **$37,000**

Conclusion:

There was evidence that lightning caused damage to both HVAC systems, but a full replacement was not warranted given the extent of repairable damage. The engineer recommended settling the claim based on the contractors quote for $37,000 in repairs. The proposed cost covered the lightning-damaged components but avoided unnecessary replacement of undamaged parts.

About EFI Global

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Get in touch with an expert

Christopher Swan – PE, Senior Forensic Electrical Engineer
Christopher has over 35 years of professional experience in the electrical consulting industry. He has practiced electrical engineering for new and remodeled residential, commercial, light industrial, and public projects for over three decades. He has experience in forensic investigations, insurance claims, lightning and fire investigations, equipment failures, litigation support, accidents, injuries, fatalities, shock and electrocutions, arc flash, illumination level analysis, construction cost disputes, arc flash studies, power quality, equipment evaluations, code reviews, peer reviews, engineering studies, and other engineering services. For more information, contact **Christopher.Swan@efiglobal.com**.

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