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Technical Whitepaper - November 2022

LoRaWAN® Gateways Lightning Protection

Description, Challenges and Best Practices for Industrial-grade Installation, Assets Protection, and Optimized Risk Management

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1 Introduction

Users of Low Power Wide Area Network (LPWAN) equipment, like many other outdoor electronic or telecommunication systems, shall face the problem of keeping their equipment in operation despite of the transient overvoltage induced by lightning.
There are several reasons for that:

- Integration of electronic components makes the equipment more vulnerable.
- Interruptions of service are unacceptable.
- LPWAN cover large areas and are exposed to more disturbances.

The need for a lightning protection system usually implies a risk analysis to determine the types of loss and subsequent consequences:

- Loss of, or risk to, human life,
- Loss of production or service execution to the public,
- Loss of economic value, and
- Loss of cultural heritage.

If the risk is assessed as low, lightning protection may be omitted, knowing however the potential consequences. If the risk is assessed as high, which is the case in most situations, then lightning protection is required.

This whitepaper provides some guidelines to understand the lightning phenomenon, its consequences and solutions to protect the electronic devices in general, and LoRaWAN® outdoor gateways more specifically.

Figure 1 : Lightning strike on a telecommunication tower – Source: CITEL

2 General considerations about lightning

2.1 The origin of overvoltage

Transient overvoltage has four main causes:

- Lightning,
- Industrial and switching surges,
- Electrostatic discharges (ESD), and
- Nuclear electromagnetic pulses (NEMP).

Overvoltage differs in amplitude, duration, and frequency. Lightning and industrial overvoltage have been with us for a long time, but ESD and NEMP disturbances are much more specific and arise from recent technological developments (massive use of semiconductors for the former, thermonuclear weapons for the latter).

2.2 Lightning and transient overvoltage

2.2.1 Lightning

Lightning, investigated since Benjamin Franklin's first research in 1749, has paradoxically become a growing threat to our highly electronic society. The lightning is a natural phenomenon, defined as electrical shock between two zones of opposite polarity, between the cloud and the ground. The flash may travel several miles, advancing toward the ground in successive leaps: the leader creates a highly ionized channel. When it reaches the ground, the real flash or return stroke takes place. A current in the tens of thousands of Amperes will then travel from ground to cloud or vice versa via the ionized channel.

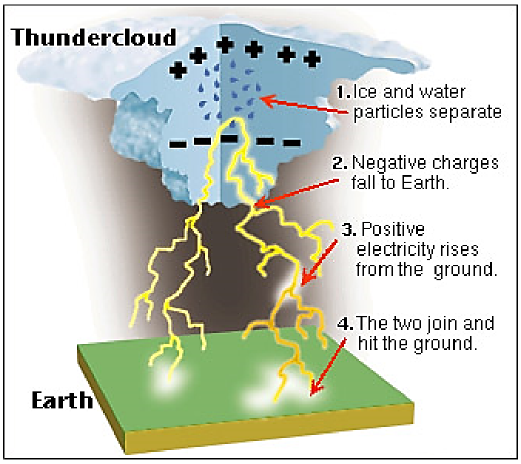

Figure 2 : Lightning phenomenon description – Source: Lightning Risk Assessments E&S Grounding Solutions

The result is a current lasting some tenths of microseconds which will generate side effects, transient overvoltage, which are much more destructive than the discharge itself. The development and the increasing brittleness of electronic equipment entail a bigger sensibility with surges. The lightning constitutes a real threat for companies' equipment but also for independent profession or even private individuals.

Against lightning itself, **the technique of protection consists in capturing the discharge to divert it from its initial target**. The lightning will be got, for example, according to the technique of the “lightning conductor” or the “meshed cage” and will save the site, however the electronic equipment will not be protected against the side effects.

Figure 3 : Thunderstorm over Geneva in June 2007 – © Christophe Suarez

2.2.1.1 Direct effects

At the time of the discharge, there is an impulse current flow that ranges from 1,000 to 200,000 Ampere peak, with a rise time of about few microseconds. This direct effect may be considered as a small factor in damaging electric and electronic systems, because it is highly localized. The best protection is still the classic lightning rod or Lightning Protection System (LPS), designed to capture the discharge current and conduct it to a particular point. For example, very high building, towers are equipped with lightning rods or LPS as shown below:

Figure 4 : Lightning strikes on the Burj Dubai building and Eiffel tower - © Christophe Suarez

2.2.1.2 Indirect effects

There are three types of indirect electrical effects:

- **Impact on overhead lines**: such lines are very exposed and may be struck directly by lightning, which will first partially or completely destroy the cables, then cause high surge voltages that travel naturally along the conductors to line-connected equipment. The extent of the damage depends on the distance between the strike and the equipment.
- **Rise in ground potential**: The flow of lightning in the ground causes earth potential increases that vary according to the current intensity and the local earth impedance. In an installation that may be connected to several grounds (e.g., a link between buildings), a strike will cause a very large potential difference and equipment connected to the affected networks will be destroyed or severely disrupted.
- **Electromagnetic radiation**: The flash may be regarded as an antenna several miles high carrying an impulse current of several tenth of kA, radiating intense electromagnetic fields (several kV/m at more than 1 km). These fields induce strong voltages and currents in lines near or on equipment. The values depend on the distance from the flash and the properties of the link.

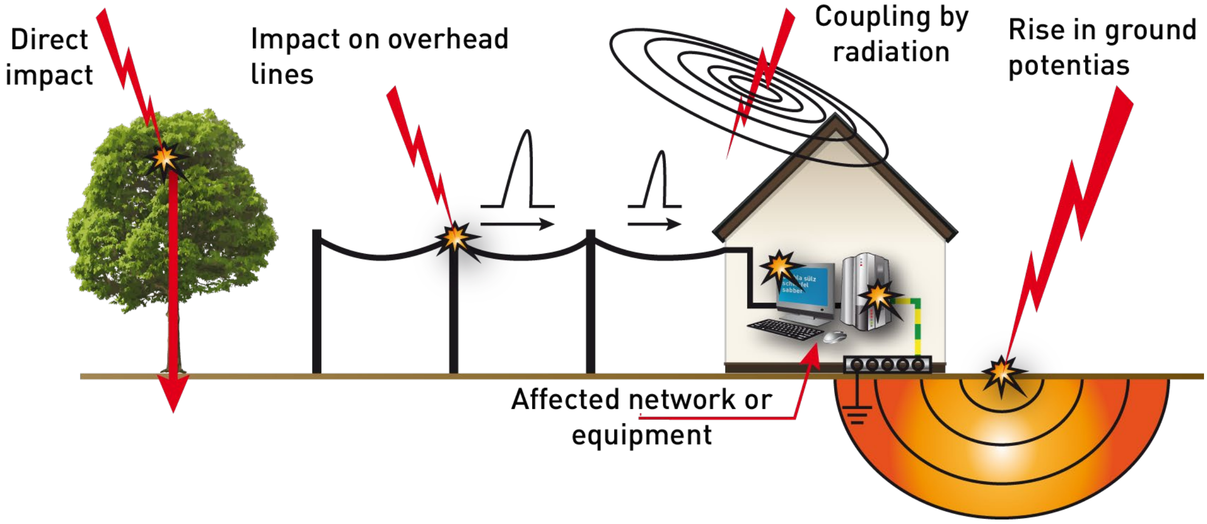

Figure 5 : Indirect effects of lightning strike - Source CITEL

2.2.2 Industrial Surges

This term covers phenomena caused by switching electric power sources on or off. Industrial surges are caused by:

- Starting motors or transformers,
- Neon and sodium light starters,
- Switching power networks,
- Switch «bounce» in an inductive circuit,
- Operation of fuses and circuit-breakers, or
- Falling power lines...

These phenomena generate transients of several kV with rise times in the order of a few microseconds, disturbing equipment in networks to which the source of disturbance is connected.

2.2.3 Electrostatic overvoltage (ESD)

Electrically, a human being has a capacitance ranging from 100 to 300 picofarad (pF), can pick up a charge of as much as 15kV by walking on a carpet, then touch some conducting object and be discharged in a few nanoseconds, with a current of about ten Amperes. All integrated circuits (CMOS, etc.) are quite vulnerable to this kind of disturbance, which is generally eliminated by shielding and grounding.

2.2.4 NEMP phenomena (Nuclear Electro Magnetic Pulses)

A high-altitude nuclear explosion, above the atmosphere, creates an intense electromagnetic field (up to 50 kV/m in 10ns), radiated to a ground area up to 1,200 kilometers in radius. In the ground, the field induces very large transient overvoltage in power and transmission lines, antennas, etc., destroying the telecommunication equipment. The field rise may reach several kV/ns. While it is difficult to eliminate all overvoltage induced by an electromagnetic pulse, there are ways to reduce them and strengthen the systems to be protected. Despite the amplitude of the phenomenon, protection can be provided by shielding and filtering/surge protection adapted to NEMP.

2.3 Keraunic levels

Few areas in the world are free from thunderstorms and the hazard of a lightning strike, but some areas have more storms than others. The higher the lightning flash density (or earth flash density), the higher the probability of a lightning strike at your facility which will require a higher level of lightning protection.

Determining the lightning flash density at a given facility location is of vital importance. IEEE 998, which is the **Institute of Electrical and Electronics Engineers** (IEEE) guide for direct lightning stroke shielding of substations, estimates lightning flash density based on average number of thunderstorm days, also known as “keraunic” level.

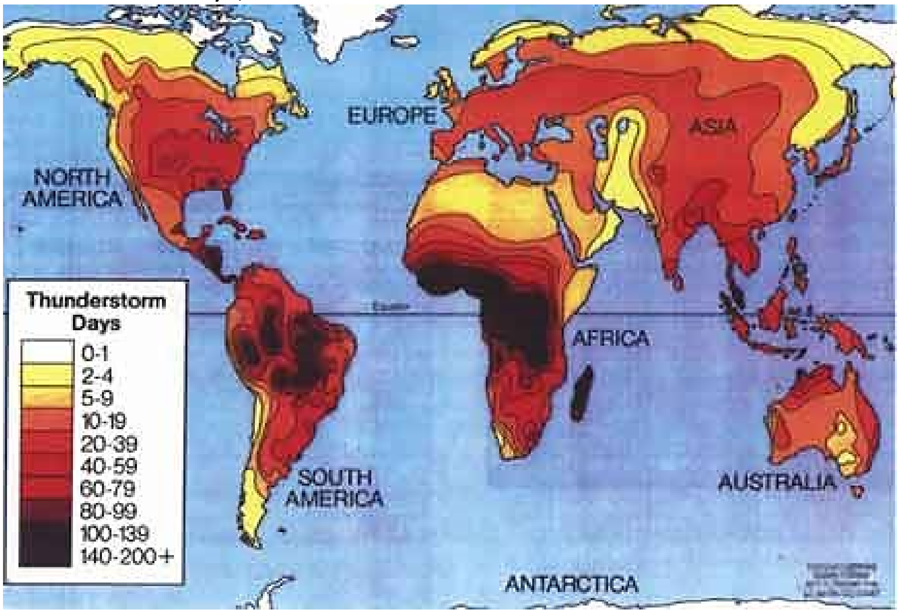

Figure 6 : World map of average number of thunderstorm days per year – Source : E&S Grounding Solutions

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Depending on the countries, surge protectors could be recommended or mandatory in relation with the external conditions (type of network and lightning threat). Risk assessment methods are also available to determine more accurately the need of surge protection. To assess the risk accurate keraunic maps for the dedicated country or location shall be used (see example below for USA).

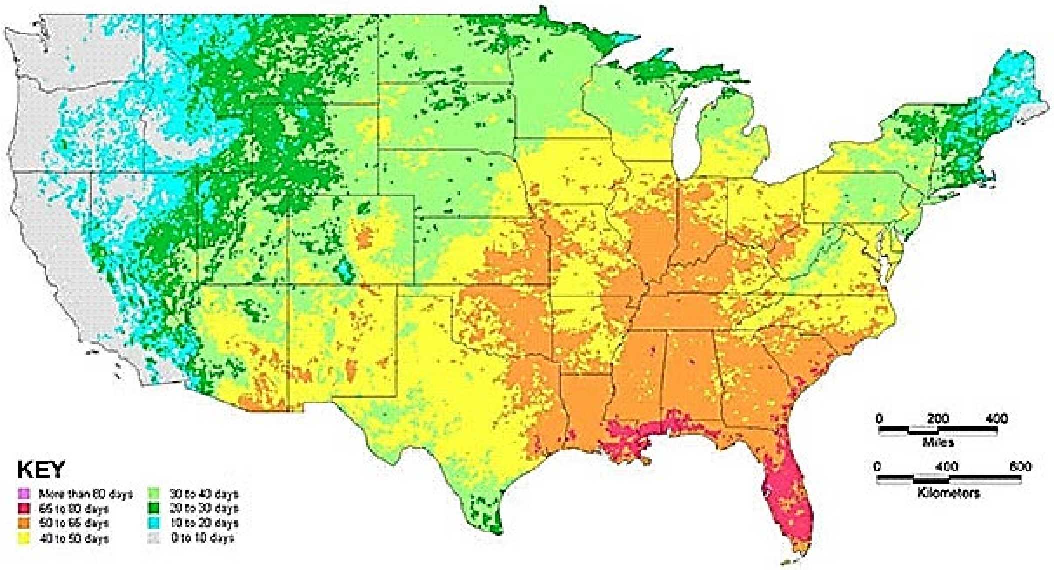

Figure 7 : Average number of thunderstorm days per year in USA - SOURCE: https://www.ecoclimax.com

2.4 Effect of lightning

Accident created by lightning is quite common. Statistically, the percentage of damages caused by lightning on computing equipment is far from being unimportant. Consequences from a disturbance are not always visible or immediate. The weakening of a component by a surge can entail a **reduction of the life cycle of the equipment**, or a **"deferred" breakdown**. The user cannot make the link between the breakdown and the real cause. He will hurry to establish a bad diagnosis, thus a wrong treatment to solve the problem.

Consequences of lightning on the installations are very real since the standardization of the electric installations makes henceforth compulsory, in some cases, the installation of surge protectors. Overvoltage have many types of effects on electronic equipment, in order of decreasing importance:

- **Destruction**
    - Voltage breakdown of semiconductor junctions,
    - Destruction of bonding of components, and
    - Destruction of tracks of PCBs or contacts.
- **Interference with operation**
    - Erasure of memory,
    - Program errors or crashes, and
    - Data and transmission errors.
- **Premature ageing**
    - Components exposed to overvoltage have a shorter life.

2.5 Lightning rod and LPS

A lightning rod is a metal rod mounted on a structure and intended to protect the structure from a lightning strike. If lightning hits the structure, it will preferentially strike the rod and be conducted to ground through a wire, instead of passing through the structure, where it could start a fire or cause electrocution.

Figure 8 : Examples of lightning rods

A lightning rod is very simple: it is a pointed metal rod attached to the roof of a building. The rod might be an inch (2 cm) in diameter. It connects to a huge piece of copper or aluminum wire that's also an inch or so in diameter. The wire is connected to a conductive grid buried in the ground nearby.

Lightning rods are also called finials, air terminals or strike termination devices. This technology goes back about 250 years when this technology was developed by Benjamin Franklin.

An earthing system or grounding system connects specific parts of an electrical installation with the Earth's conductive surface for safety and functional purposes. The point of reference is the Earth's conductive surface.

Regulations for earthing systems vary considerably among countries, though many follow the recommendations of the **International Electrotechnical Commission** (IEC).

Regulations may identify special cases for earthing in mines, in patient care areas, or in hazardous areas of industrial plants.

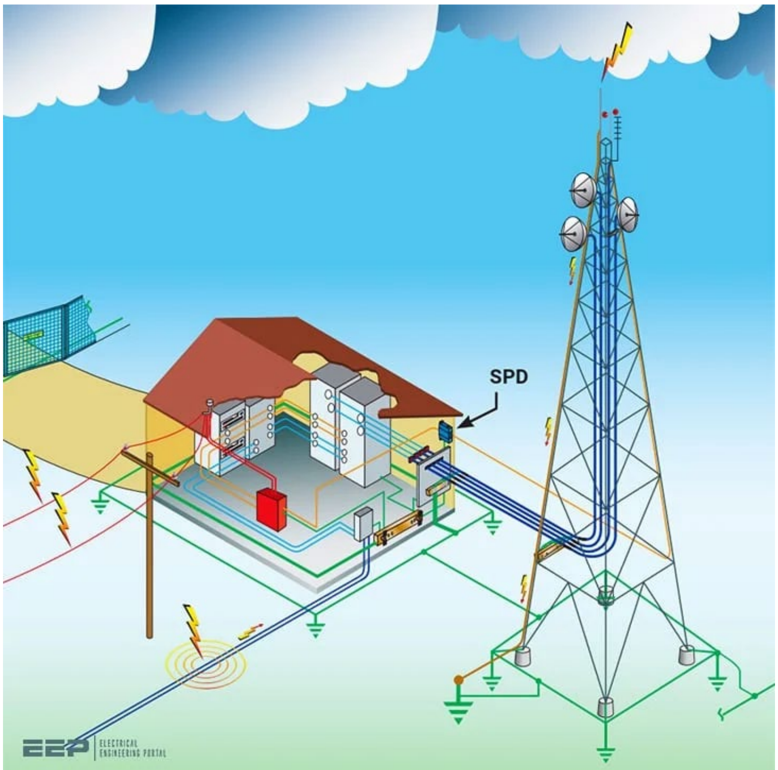

Figure 9 : Lightning rod + bonding + earthing – Source: Electrical Engineering Portal

The purpose of lightning rods is often misunderstood. Many people believe that lightning rods "attract" lightning. It is better stated to say that lightning rods provide a low-resistance path to ground that can be used to conduct the enormous electrical currents when lightning strikes occur. If lightning strikes, the system attempts to carry the harmful electrical current away from the structure and safely to ground. The system can handle the enormous electrical current associated with the strike. If the strike contacts a material that is not a good conductor, the material will suffer massive heat damage. The lightning-rod system is an excellent conductor and thus allows the current to flow to ground without causing any heat damage.

The simple rod lightning does not allow for extensive protection area. **This solution is only appropriate in cases of small-sized ground structures (towers, masts ...).**
On structures less than 30 meters (about 100 feet) in height, a lightning rod provides a cone of protection whose ground radius approximately equals its height above the ground (45° cone from the rod's tip).
On taller structures, the area of protection extends only about 30 meters from the base of the structure.

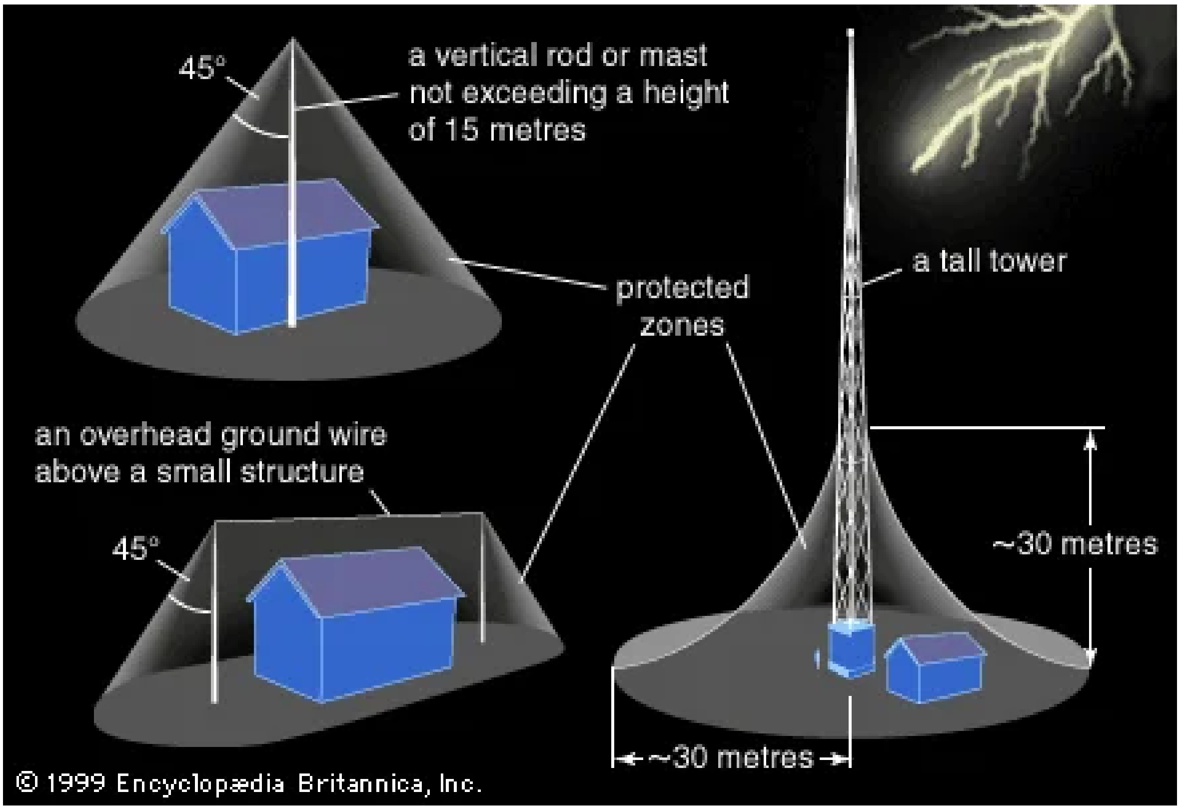

Figure 10 : Lightning rod protection area

2.6 The different surge protector solutions

To limit surges generated by lightning to an acceptable level for equipment and installations, the most efficient solution is setting up a protection device against these surges, called Surge Protective Devices (SPD) on AC power or communication networks of the installation to protect.

Examples, from CITEL Company, of surge protectors adapted to all the different types of networks and all configurations of telecommunications installations, are detailed hereafter.

CITEL is a worldwide leader in the surge protection market and preferred KERLINK partner for lightning surge protections.

2.6.1 AC Surge Protectors

CITEL DAC50 AC power surge protection devices are designed to meet all surge protection needs for any low voltage installation. These DIN rail mounted surge protectors are easy to install in any standardized distribution panel or control cabinets. They are equipped with a thermal disconnection device and provide real-time fault indicators thus allowing complete operational safety. These surge protectors are available with several protection circuits to comply with even the most demanding installations and standards compliance requirements. CITEL offers a line of surge protectors for the single and three phase AC networks connected to sensitive equipment. These products are available in various formats: hard-wired units single-phase or hard-wired units and combiner box for US market.

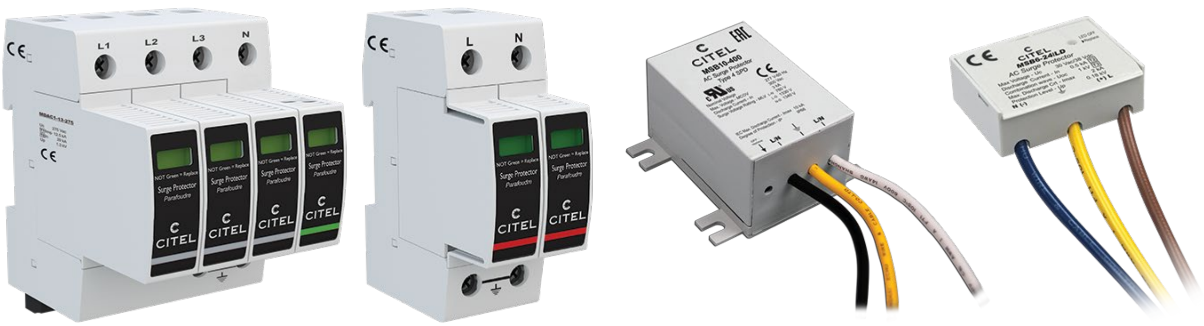

Figure 11 : Example of CITEL AC surge protectors

2.6.2 Photovoltaic Surge Protectors

The photovoltaic grid-connected low voltage power lines may be subject to overvoltage on different networks: AC, DC or communication network. Depending on the type of networks, the presence of lightning rod or primary surge protectors existing, CITEL offers a complete range of solutions to protect the AC part of the photovoltaic system.

Figure 12 : Example of CITEL photovoltaic surge protectors

2.6.3 Telecom and Data Line Surge Protectors

These subassemblies can be easily used by the installer. They are designed to protect PBX's and all the information and electronic equipment either connected to the phone system or to the Local Area Network (LAN). The demand, linked to the implementation of digital telecom centrals and terminals more and more fragile, is growing fast. This evolution requires the design of very effective protection systems adapted to all networks, actual and future.

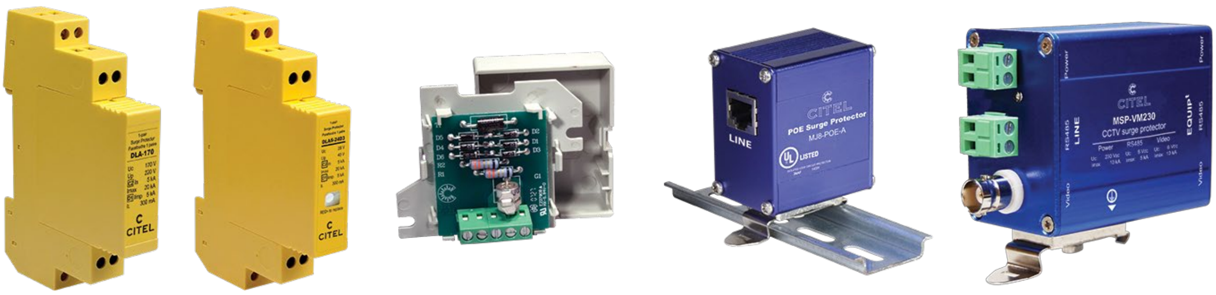

Figure 13 : Example of CITEL data line surge protectors

2.6.4 Coaxial Surge Protectors

To complete the range of surge protection, CITEL offers a diversified line of coaxial surge protection to protect coaxial feeds and antennas. With the wide range of mobile equipment available (GSM, PCN, UMTS, BLR, LPWAN...), coaxial protectors are becoming more and more important and continue to evolve towards new technology such as Quarter Waves.

Figure 14 : Examples of CITEL coaxial surge protectors

2.7 Earthing / grounding

Electrical grounding is a commonly misunderstood and improperly implemented component of environmental monitoring systems. Systems that do not use electrical grounding components can experience either complete system failures or intermittent problems that are hard to diagnose. However, just using grounding devices is not enough. Improper installation of electrical grounding components can ultimately make the components ineffective. **Installing a system with the proper grounding equipment and following proper installation guidelines can reduce potential down time as well as costly repairs to system electronics**.

Low impedance paths to ground are preferred by lightning. Dedicated wire down conductors or building steel, or both, shall be installed in accordance with NFPA 780. High impedance paths shall be avoided since they can create unwanted heat and/or mechanical damage. Adjacent metal bodies, for example, shall be bonded to the low impedance path "so as to prevent side flash or spark-over".
Where down conductors are near metal bodies without bonding the two, lightning tends to jump from one to the other tending to create sparks.

There are several types of lightning grounding, used separately or in combination, as selected by the installation contractor. Ground rods, perimeter (ring) bare wire, radials, plates, and concrete (rebar) encased designs all constitute acceptable earth electrodes. The lightning grounding electrode is a dedicated part of the lightning protection system. No other ground shall be used as a lightning ground. Other (non-lightning) systems requiring grounding shall be integrated (bonded or connected) to the lightning ground to form a common ground potential. This is to protect electrical equipment from voltage rise mismatches where separate grounds are employed. Under lightning attachment conditions, the lightning ground will function independently of any other grounds. Should electrical system grounds not be connected to the lightning ground, the overall lightning protection system will still function as designed.

It is important to ensure that ground potential differences are not derived across equipment within a facility during ground potential rises (GPR). One way to ensure this is to adopt a single point approach to grounding of the equipment and services in the facility. This usually entails referencing all equipment grounds in the facility like the generator chassis ground, inverter chassis ground, solar panel chassis ground and the battery negative ground to a single ground bar (or a number of ground bars that are solidly electrically bonded together) and ensuring that this internal bonded system is connected to the external ground system. **"Single point grounding" refers to the single connection between the internal facility ground system and the external ground network.** The external ground network can utilize multiple grounding elements such as ground rods and / or counterpoises. This ensures that there is no voltage potential between chassis grounds of all the devices in the system. No voltage means no current flow through the system and hence, damage will be prevented.
All equipment involved in a system should physically be located as close as possible to one another. This reduces the potential that is developed between the ground site and the individual components of the system during a lightning strike. This single point grounding greatly reduces the potential for lightning damage to electrical equipment.

2.8 Risk Assessment

Risk management with foresight includes calculating the risks for the company. It provides the basis on which decisions can be made to limit these risks, and it makes clear which risks should be covered by insurance. When considering the management of insurances, it should be borne in mind, however, that insurance is not always a suitable means of achieving certain aims (e.g., maintaining the ability to deliver). The probabilities that certain risks will occur cannot be changed by insurance.

Companies which manufacture or provide services using extensive electronic installations shall also give special consideration to the risk presented by lightning strikes. It shall be borne in mind that the damage caused by the non-availability of electronic installations, production and services, and the potential loss of data, is often far greater than the damage to the hardware of the affected installation itself.

In the case of lightning protection, innovative thinking about damage risks is slowly gaining in importance. The aim of risk analysis is to objectify and quantify the risk to buildings and structures, and their contents, as a result of direct and indirect lightning strikes. **This new way of thinking has been embodied in the international standard IEC 62305-2: 2006 or the European standard EN 62305-2: 2006**.

According to IEC 62305-2 (EN 62305-2), risk R of lightning damage can generally be found using the relationship: **R = N x P x L**

- **N** : Number of hazardous events (frequency of lightning strikes in the considered area)
- **P** : Probability of damage
- **L** : Loss (What are the effects, amount of loss and consequences).

The task of the risk assessment therefore involves the determination of the three parameters N, P and L for all relevant risk components.

The **National Fire Protection Association** (NFPA) also offer guidelines on risk assessment.

2.9 Standards and guidelines in surge protection

A non-exhaustive list of standards and guidelines is provided below. The list may need to be completed by other standards depending on the applications and the country.

- IEC / EN 61643: **Low-voltage surge protective devices**
  - Part 11 and 12: Surge Protectors for Low-Voltage installations
  - Part 21 and 22: Surge Protectors for Telecom Equipment

- **IEC / EN 62305: Lightning protection**
  - Part 1: General principles
  - Part 2: Risk management
  - Part 3: Physical damage to structures and life hazard
  - Part 4: Electrical and electronic systems within structures

- **IEC / EN 60728-11: Cable networks for television signals, sound signals and interactive services**
  - Part 11: Safety

- **EN 61663: Lightning protection – Telecommunication lines**
  - Part 1: Fiber optic installations
  - Part 2: Lines using metallic conductors

- **IEC 60364: Electrical Installations for buildings**
  - Part 4: Protection for safety; Section 41: Protection against electric shock
  - Part 4: Protection for safety; Section 443: Protection against overvoltage of atmospheric origin or due to switching.
  - Part 5: Selection and erection of electrical equipment; Section 534: Devices for protection against overvoltage.
  - Part 5: Selection and erection of electrical equipment; Section 548: Earthing arrangements and equipotential bonding for information technology installations.

In North America, the international standard IEC does not apply. Other national standards and guidelines exist, such as UL, NEC and ANSI/IEEE, which are used to determine the risk to transients in low voltage power networks as well as the use of appropriate protector for each application.

- **NFPA 780**
  Standard for the installation of lightning protection systems.

- **NEC (National Electrical Code)**
  The article 285 of NEC defines the use of standalone surge protectors and imposes their compliance with the product standard UL1449.
  The article 285 defines the selection and installation conditions of SPDs.

- **Product Standard UL1449**
  This document, devoted to surge protection manufacturers, defines the parameters as well as the test procedure to qualify an SPD: it is important to note that the UL Type designations of surge protective devices, while similar, is not exactly the same as SPD types in IEC 61643-11.

- **ANSI/IEEE Guide:**
  ANSI/IEEE publishes different informative guides regarding the risk of transient overvoltage to low voltage networks (IEEE C62.41.1), the surge environment and types of transients (IEEE C62.41.2) as well as the method for testing equipment against transients that are connected to the low voltage network (IEEE C62.45).
  Another important guideline detailing the installation of SPDs in a power distribution system is called IEEE C62.72.

3 Lightning protections for LoRaWAN® outdoor gateways

3.1 Industrial surges and ESD protection

In Europe, LoRaWAN® outdoor gateways shall be compliant to the EMC directive 2014/30/UE and therefore to following EMC requirements:

- ETSI EN 301 489-1 (Common technical requirements)
- ETSI EN 301 489-3 (SRD operating between 9KHz and 246GHz)
- ETSI EN 301 489-19 (ROMES operating in the 1.5 GHz band)
- ETSI EN 301 489-52 (Cellular Communication Mobile and portable radio)

These requirements imply several tests to be completed:

- **Electrical fast transient/burst immunity**: the tests are conducted according to EN 61000-4-4 and the equipment shall support +/-0.5KV on Power over Ethernet (PoE) and RF ports and +/-1KV on AC mains power input.
- **Surge immunity**: the tests are conducted according to EN 61000-4-5 and the equipment shall support +/-1KV (applied lines to ground) and +/-0.5KV (applied line to line) on PoE and RF ports. For mains power input, the equipment shall support +/-2KV (applied lines to ground) and +/-1KV (applied line to line).
- **ESD Immunity**: the tests are conducted according to EN 61000-4-2, and the equipment shall support +/-8KV air discharges and +/-4KV contact discharges.

3.2 Lightning protections for outdoor gateways

LoRaWAN® outdoor gateways shall be provided with optimal internal surge protections according to §3.1. In harsh environment, additional protections shall be used to improve lightning immunity. **Kerlink recommends adding surge protections in high keraunic levels areas and on high points**.

A lightning rod, or LPS system, with a down conductor to earth is strongly recommended for this kind of applications. The lightning rod avoids direct impacts on the aerials (antennas and gateway) as detailed in §2.5.

The lightning surge protections shall be completed on three interfaces to be efficient:

- Mains supply (or DC supply),
- Ethernet (PoE) cable, and
- RF coaxial cable (antenna interfaces).

Another key parameter for an efficient lightning surge protection is "earthing". The earthing connection ensure that the lightning surge is driven to the ground properly as detailed in §2.7. Earthing of the installation is mandatory for:

- indoor installation (mains supply, PoE injector), and
- outdoor installation (tower, pole, …)

The following paragraphs and figures describe the lightning protections that are required in a high keraunic area configuration. Two use cases are considered, depending on if some parts of the installation (PoE for instance) are indoor or outdoor.

3.2.1 Lightning rod

To avoid direct impacts on the aerials (antennas and gateway) a lightning rod shall be installed on the top of the tower or mast.
The aerials (antennas and gateway) shall be installed inside the 45° cone from the rod's tip, as detailed in §2.5, to ensure proper protection.

Figure 15 : Installation on top of a tower, with lightning rod - @Lorin, 2021

3.2.2 Outdoor installation with indoor PoE

In this configuration, **the global installation is composed of two separated areas that complete each other: indoor installation and outdoor installation**.

On the one hand, **the indoor installation** is composed of:

- A main electrical board including:
  - a circuit breaker,
  - a surge protection type 1, and
  - a connection to "earth".

- A secondary electrical board including:
  - a circuit breaker,
  - a surge protection type 2, and
  - a connection to "earth".
- The PoE injector to power the gateway,
- An Ethernet surge protection, connected to "earth", to protect the indoor materials.

On the other hand, **the outdoor installation** is composed of:

- A tower, mast or pole, with LPS, that shall be connected to "earth",
- The LoRaWAN® gateway and its mounting kit,
  The mounting kit shall be connected to earth,
- The antennas (LoRa, LTE, GNSS) with their RF coaxial surge protections connected to "earth", and
- An outdoor Ethernet surge protection to protect the gateway.

The LoRaWAN® gateways and the antenna are installed inside the 45° cone from the rod's tip to avoid direct impacts.

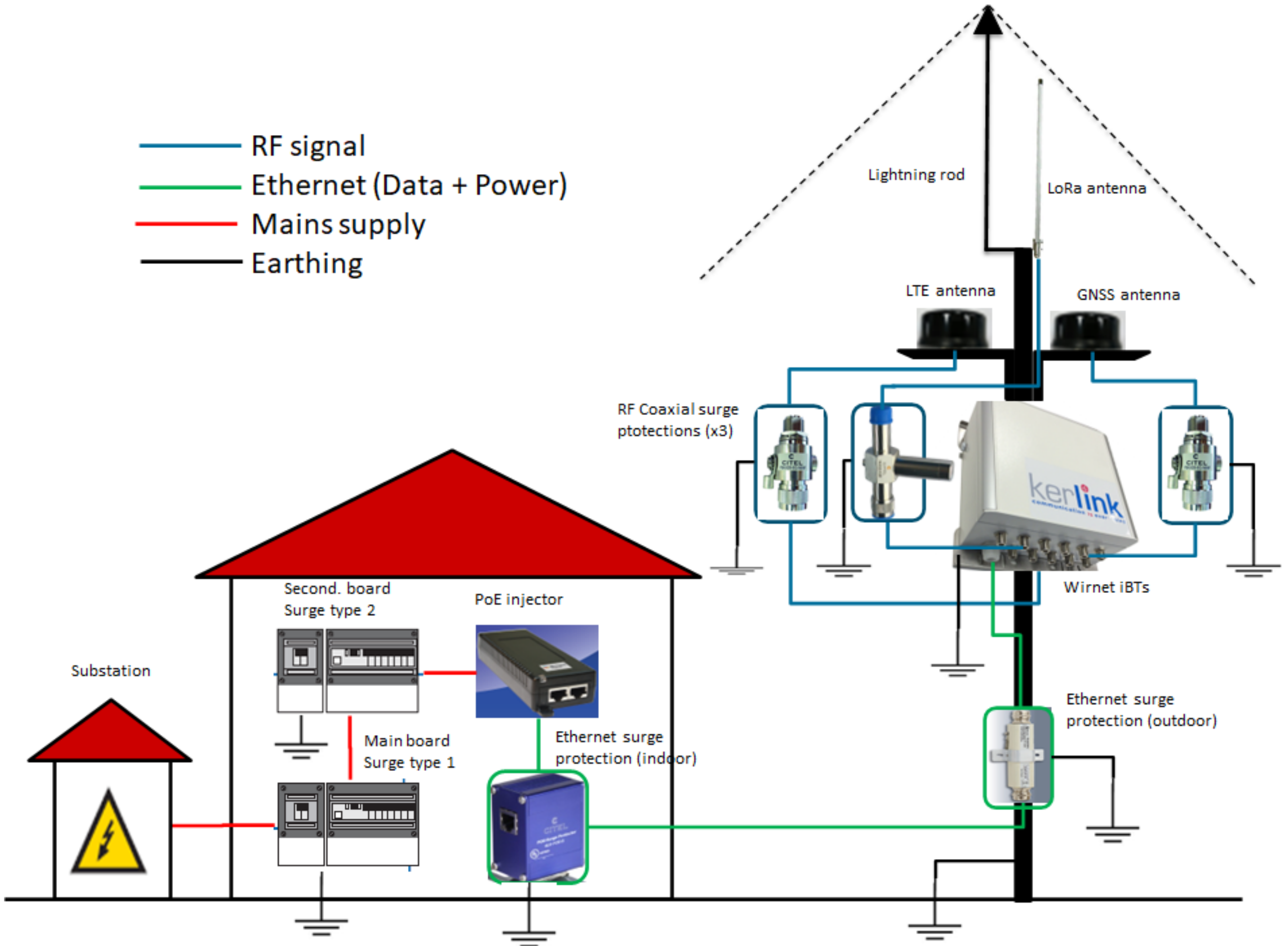

Figure 16 : Installation with recommended lightning protections – Source: ©Kerlink®

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3.2.3 Outdoor installation with outdoor PoE

In some use cases the electrical installation does not have the required surge protections type 1 and type 2. Also, the PoE injector and Ethernet surge protection could not be installed indoor. Therefore, an alternate PoE injector and an Ethernet surge protection dedicated to outdoor applications are required.

In this use case, **the installation is still composed of two separated areas that complete each other: indoor installation and outdoor installation**.

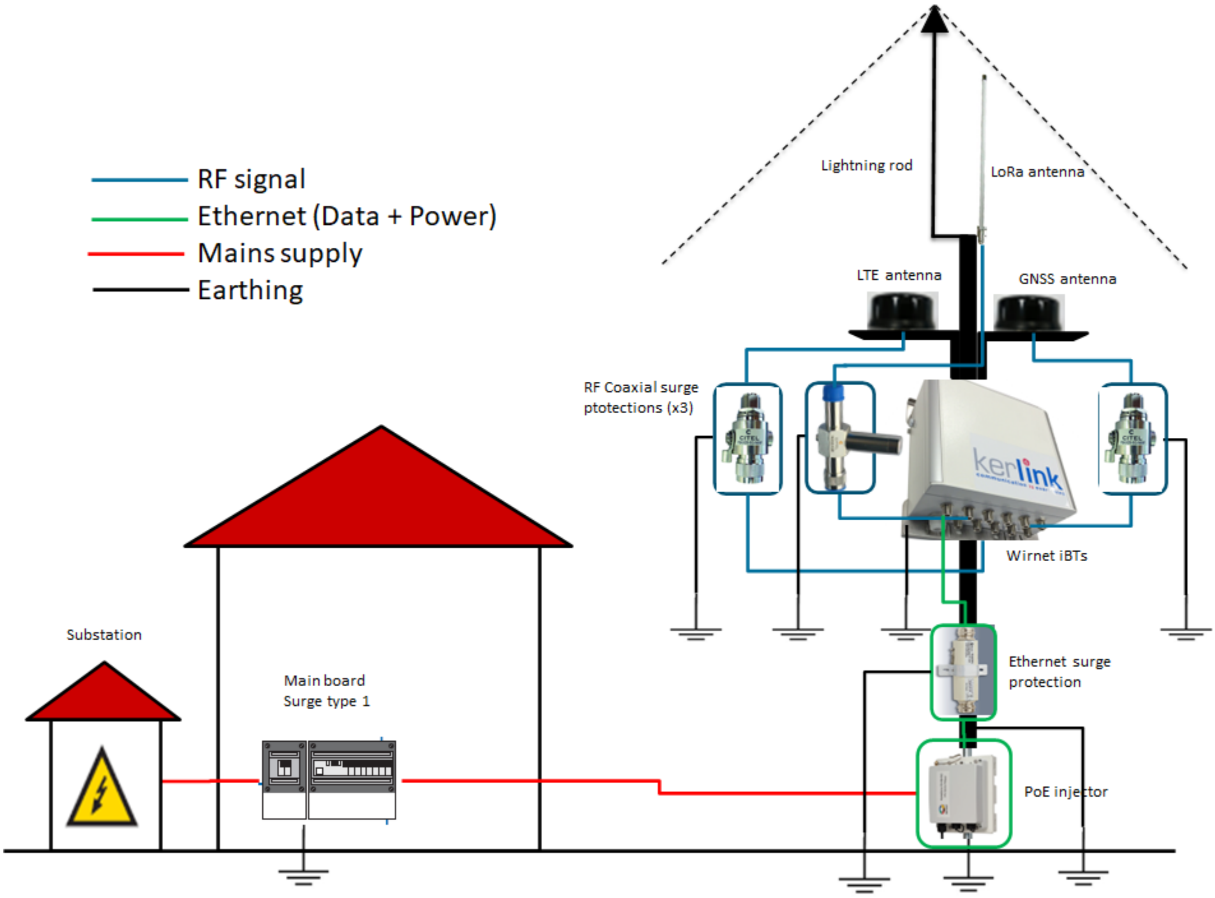

Figure 17 : Installation with recommended lightning protections / Outdoor PoE injecto r- Source : ©Kerlink®

On the one hand, **the indoor installation** is composed of:

- A main electrical board including:
  - a circuit breaker,
  - a surge protection type 1, and
  - a connection to "earth"

On the other hand, **the outdoor installation** is composed of:

- A tower, mast or pole, with LPS, that shall be connected to "earth",
- The LoRaWAN® gateway and its mounting kit,
  The mounting kit shall be connected to earth,
- The antennas (LoRa, LTE, GNSS) with their RF coaxial surge protections connected to "earth",

- The outdoor PoE injector to power the gateway, and
- An outdoor Ethernet surge protection, connected to "earth", to protect the gateway

The LoRaWAN® gateways and the antenna are installed inside the 45° cone from the rod's tip to avoid direct impacts.

3.2.4 RF coaxial surge protections

3.2.4.1 LoRa link

For the LoRa antenna link, **Kerlink recommends usage of quarter wave coaxial protection** - PRC series from CITEL, like PRC822S-N/MF:

- Very fast response time,
- Greater endurance,
- No maintenance, and
- Lower residual voltage (Up) ensuring better protection.

Figure 18 : PRC822S-N/MF Citel

The RF coaxial surge protector shall be connected to the earth (see §3.3.3). The RF coaxial surge protector shall be directly mounted onto the RF connector of the gateway.

3.2.4.2 GNSS and LTE links

For the antenna links (GNSS, LTE), **KERLINK recommends the following gas tube coaxial protection** - P8AX series from CITEL, like P8AX09-6G-N/MF

- Wider frequency range,
- DC pass,

Compared to quarter wave coaxial protection, the gas tube coaxial protection has however some disadvantages:

- Longer response time,
- Higher residual voltage (Up),
- Lower endurance, and
- Required maintenance.

Figure 19 : P8AX09-6G-N/MF Citel

The RF coaxial surge protector shall be connected to the earth (see §3.3.3).
The RF coaxial surge protector shall be directly mounted onto the RF connector of the gateway.

3.2.5 DC surge protections

DC surge protections are recommended when the gateways are supplied via an External DC supply port (11V to 55V DC). The protection can be completed on one pole (+) or two poles (+ and -). The 2 poles solution offers better protection, but the choice is sometimes driven by implementation considerations such as:

- Can the DC surge protection be installed outside the gateway enclosure? Make sure in this case that the DC surge protection are installed in a waterproof cabinet or enclosure, as close as possible to the gateway, to reduce length of the wires.
- Is there enough room available in the gateway enclosure to install the DC surge protection? The 2 poles surge protection requires more room than the 1 pole protection.

3.2.5.1 DC surge protection, 1 pole

Kerlink recommends using the following protection:

- DS71R-48DC reference from CITEL.

Figure 20 : DS71R-48DC DC surge protections (1 pole)

3.2.5.2 DC surge protection, 2 poles

Kerlink recommends using the following bipolar DC surge protection:

- DS72R-48DC from CITEL.
- Kerlink PN = KLK02880

Figure 21 : DS72R-48DC DC surge protections (2 poles)

Kerlink recommends realizing a good direct connection between the unipolar DC surge protection and the earthing system of the installation. The used earthing cable shall be as short as possible (< 50 cm). See also §3.3.4 and §3.3.10.

3.2.6 Indoor Ethernet surge protection

For the Ethernet / PoE link, **KERLINK recommends the following protection**:

- MJ8-POE Series reference from CITEL.
- Kerlink PN = KLK02818

The indoor Ethernet surge protector shall be placed at the entrance of the shelter or building as the purpose is to protect the building but not the gateway.

The PoE surge protector shall be connected to the earth.

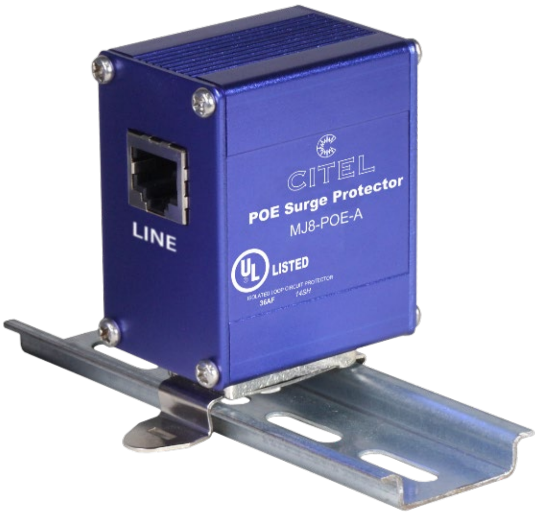

Figure 22 : MJ8-POE-A Citel

3.2.7 Outdoor PoE surge protection

In case the PoE surge protection cannot be installed indoor, and to protect the gateway, KERLINK recommends the following protection:

- PD-OUT/SP11 reference from Microsemi.
- Kerlink PN = KLK02817

Figure 23 : PD-OUT/SP11 Microsemi

<u>Notes</u>

- The PoE surge protector shall be connected to the earth.
- The outdoor PoE surge protector shall be placed close to the gateway to ensure adequate protection. A distance of 0.50m max is recommended.
- An alternate outdoor PoE surge protection can CxMJ8-POE Series be also purchased at CITEL. The preferred reference is CWMJ8-POE-C6A8.
- Kerlink PN = KLK03639

Figure 24 : CWMJ8-POE-C6A Citel

3.2.8 AC surge protections

AC surge protections are under responsibility of the facility manager.
Selecting the adequate AC protection depends on many factors:

- type of building (commercial, industrial, …),
- location (urban area, mountains area, open flat area, …),
- lightning risk (lightning rod or LPS on top of the building),
- type of switchboard,
- short circuit level,
- number of phases,
- earthing type (TT, TN-S, TN-C),
- etc.

Our partner CITEL can help to dimension AC surge protection.

3.3 Earthing

Several earthing cables, wires, clamps, tapes or ring tongue terminals are required to connect the installation and the materials to earth for lightning immunity and electrical security:

- Earthing of the gateway,
- Earthing of the gateway mounting kit,
- Earthing of the RF coaxial surge protection,
- Earthing of the PoE surge protection,
- Earthing of the PoE injector,
- Earthing of the antenna brackets, and
- Earthing of the cables (RF coaxial, Ethernet).

The earthing cables characteristics are detailed in §3.3.10.

3.3.1 Earthing of the gateway

Earthing of the gateway can be completed in two different ways:

- A specific drilled hole and screw is available on the metal enclosure of the gateway. The earthing symbol ⏚ is placed close to dedicated holes and screws.
- Earthing is completed through the gateway mounting kit (see §3.3.2). Ground connection between the gateway enclosure and the mounting kits are completed via screws or specific metal parts.

iStation, for instance, has its own ground hole and screw and the required earthing symbol ⏚. The gateway is provided with a green/yellow cable as detailed below:

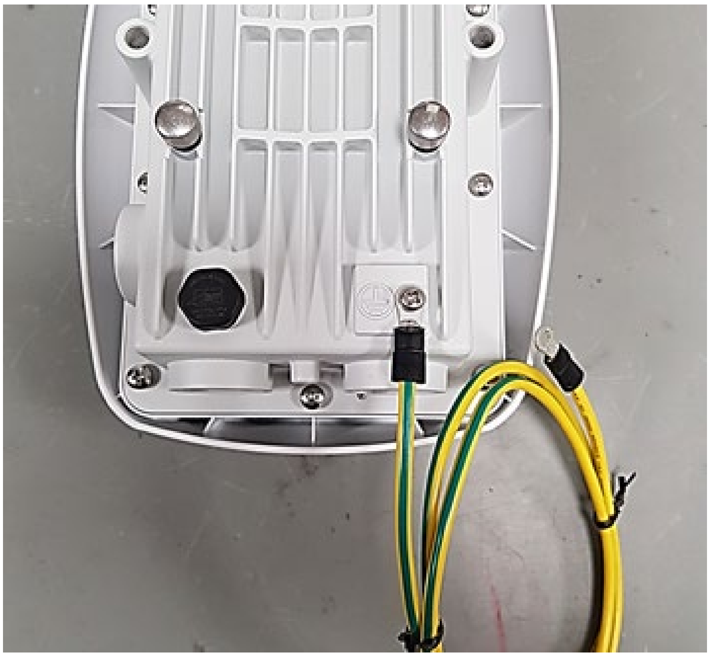

Figure 25 : Ground connection of the Wirnet iStation, ©Kerlink® 2021

The earthing cables characteristics are detailed in §3.3.10.

3.3.2 Earthing of the gateway mounting kit

For most of the gateways, the earthing is completed through the mounting kit. Anyway, the gateways are delivered with mounting kit already installed. Ground connection between the gateway enclosure and the mounting kit is completed via screws or specific metal parts.

Considering Kerlink Wirnet™ iBTS for example, a M8 ring tongue terminal is provided for earthing of mounting kit.
Earthing of the mounting kit is completed through the 2 holes dedicated to the M8 U Bolt used for pole mount. The earthing symbol ⏚ is placed close to dedicated holes:

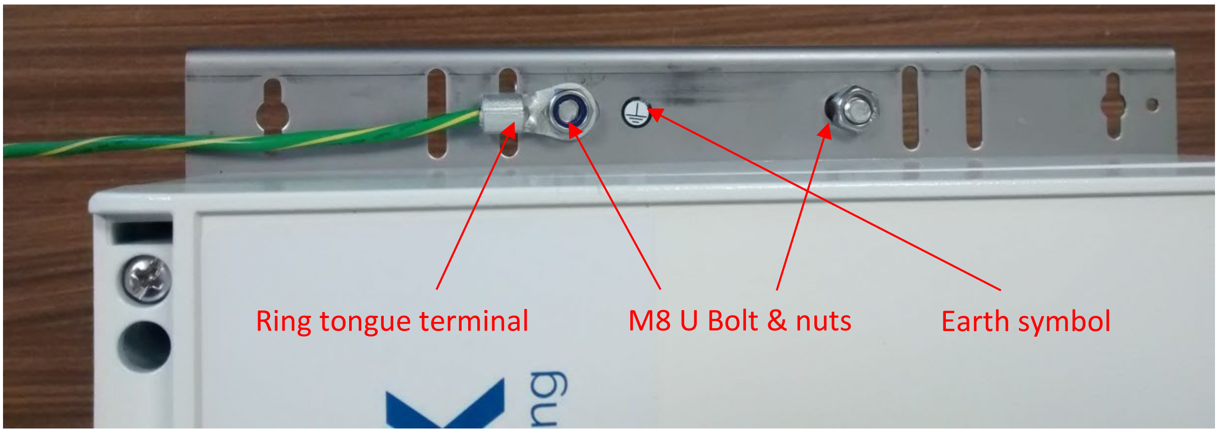

Figure 26 : Wirnet iBTS – earthing with U bolt configuration - ©Kerlink® 2021

3.3.3 Earthing of the RF coaxial surge protection

On the RF coaxial surge protection side, the earthing connection is completed through a ring tongue terminal. The earthing cable shall be crimped inside this ring tongue terminal.
A specific crimping tool is required to perform the operation.

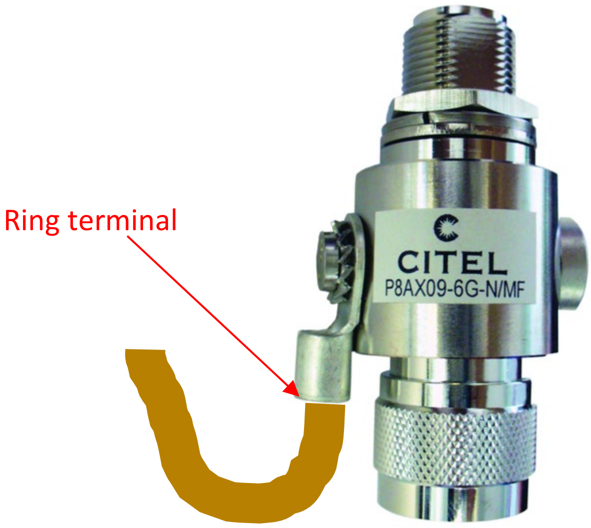

Figure 27 : Earthing of the RF coaxial surge protection

3.3.4 Earthing of the DC surge protection

On the DC surge protection side (DS71R-48DC or DS72R-48DC), the earthing connection is completed through a stripped wire. The other side of the cable could be connected through a ring tongue terminal.

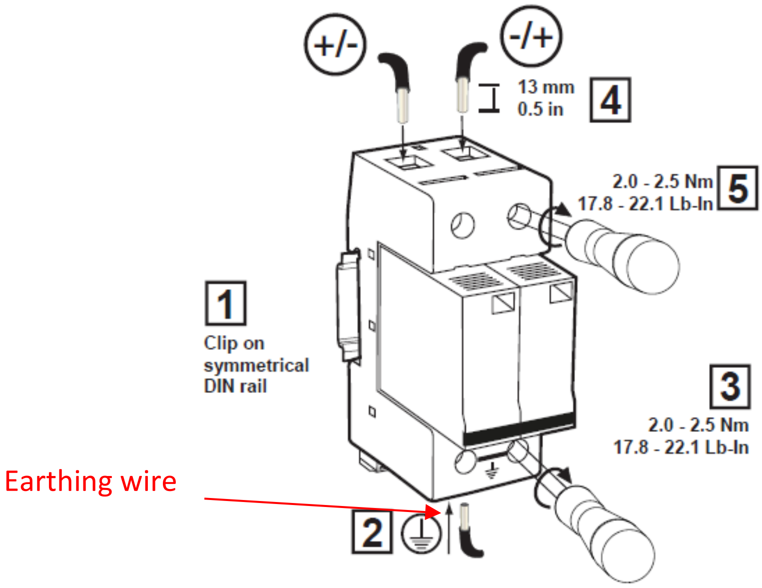

Figure 28 : Earthing of the RF coaxial surge protection – Source: CITEL

3.3.5 Earthing of the PoE surge protection

On the indoor PoE surge protection side, the earthing connection is completed through the DIN rail clip. Therefore, the earthing cable can be connected to the DIN rail itself or using the nut of the DIN rail clip.

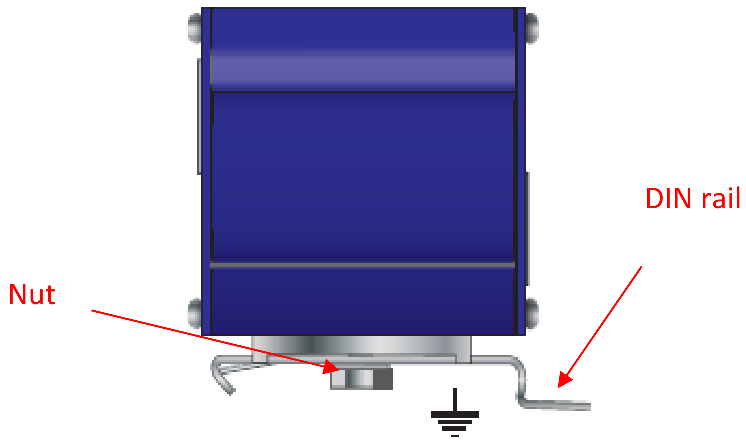

Figure 29 : Earthing of the indoor Ethernet surge protection – Source: CITEL

On the outdoor PoE surge protection side, the earthing connection is completed through a dedicated earthing screw. The earthing connection is completed through a ring terminal. The earthing cable shall be crimped inside this ring terminal.
A specific crimping tool is required to perform the operation.

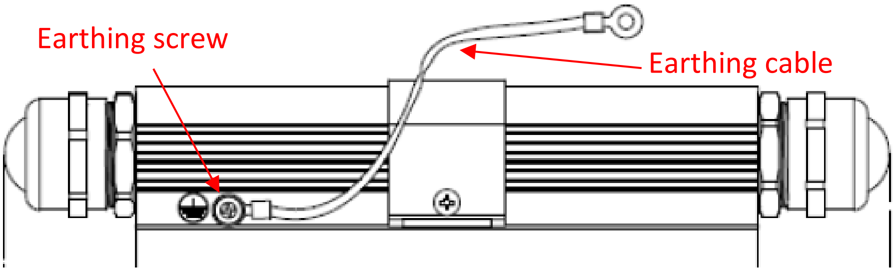

Figure 30 : Earthing of the outdoor Ethernet surge protection – Source: Microchip

3.3.6 Earthing of the outdoor PoE injector

On the outdoor PoE injector, the earthing connection is completed through a dedicated earthing bolt and two nuts. The earthing connection on the cable is completed through a ring terminal. A specific crimping tool is required to perform the operation. The earthing cable shall be crimped inside this ring terminal.
The ring terminal is inserted between the two nuts as follows:

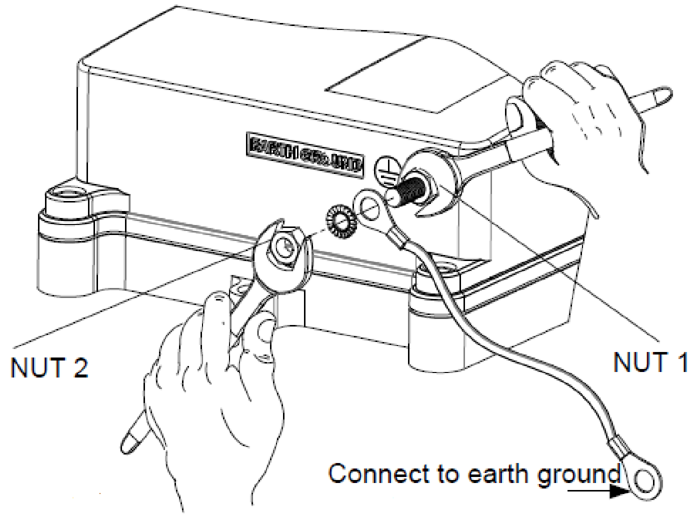

Figure 31 : Earthing of the outdoor PoE injector - Source: Microchip

3.3.7 Earthing Ethernet cable

In may use cases, the Ethernet cable has a significant length (up to 100m) from the Ethernet switch to the gateway. The long Ethernet cable shall be properly guided, and grounding of the cable is recommended to offer better surge protection. Cable grounding clamp can be used for this purpose as shown below:

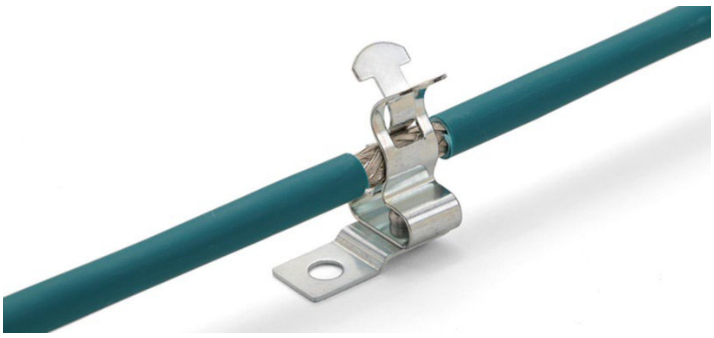

Figure 32 : Earthing of the Ethernet cable - Source: Hebotec

The sheath of the cable shall be obviously removed to ensure good connection to the clamp and therefore good ground connection. Removing the sheath may compromise sealing of the Ethernet cable so a waterproof tape is recommended in this case.

3.3.8 Earthing RF coaxial cables

In some use cases, antennas may be deported using long RF coaxial cables (>5m). The long coaxial cable shall be properly guided, and grounding of the coaxial cable is recommended to offer better surge protection. Cable grounding clamp can be used for this purpose (see also §3.3.7).
The sheath of the cable shall be obviously removed to ensure good connection to the clamp and therefore good ground connection. Removing the sheath may compromise sealing of the Ethernet cable so a waterproof tape is recommended in this case.
In most of the use case, short RF coaxial cables are used (1m), so earthing is not required.

3.3.9 Earthing antenna brackets

Antenna brackets can be provided with the gateways as accessories. This could be LoRa, GNSS or LTE antenna brackets. The brackets are metal parts, and they shall be also connected to earth to prevent surges to be driven to the gateway RF ports.
Earthing of the antenna brackets can be completed by:

- Pole mounting: by using the metallic strapping.
- Wall mounting: by using M4 screws provided with the bracket

3.3.10 Earthing cables

Several earthing cables, wires or tapes are required to connect the installation and the materials to earth for lighting immunity and electrical security.
The earthing cables are detailed hereafter with recommended wires and sections:

Cable description	Technical characteristics
Earthing of the gateway	25mm^2, copper
Earthing of the gateway mounting kit	25mm^2, copper
Earthing of the antenna brackets (LoRa antenna, GNSS antenna, LTE antenna)	25mm^2, copper
Earthing of the RF coaxial surge protection	16mm^2, copper
Earthing of the Ethernet surge protection	16mm^2, copper
Earthing of the DC surge protection	16mm^2, copper
Earthing of the outdoor PoE injector	16mm^2, copper

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4 Conclusion

Due to the height of the towers and masts, the LoRaWAN® gateways are highly vulnerable to the effects of direct and indirect lightning strikes.
The consequences may vary from a simple interruption of service to damaged materials with potential huge associated costs. In the worst case, human life safety is in danger.
Investing in lightning protection and appropriate set-up, following clear guidelines, can extend LoRaWAN® gateway and installation lifetime, improve customer services and greatly reduce overall operating and infrastructure costs.
KERLINK, through the partnership with CITEL and its proven track-record of carrier-grade and industrial-grade outdoor installation in various harsh and demanding environment, has a complete portfolio of SPD, associated installation recommendations, to protect the LoRaWAN® gateways and the whole installation.

5 References

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[6] World map of average number of thunderstorm days per year
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[7] Average number of thunderstorm days per year in USA
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About Kerlink® Group

Founded in 2004, Kerlink® is a fast-growing, global and publicly traded provider of Internet of Things (IOT) connectivity solutions helping telecom operators, public authorities and private businesses to design, launch and operate public and private IOT networks. Kerlink® is a founding and Board member of the LoRa Alliance® and of the uCiFi Alliance™.

Based in France, with subsidiaries in the US, Singapore, India and Japan, Kerlink®offers a comprehensive portfolio of industrial-grade premium network equipment, best-of-breed network operations and management software, value-added applications and expert professional services to design, orchestrate and monetize tailored IoT networks.

In just over 10 years, more than 200,000 Kerlink® installations have been rolled out for more than 350 clients in 70 countries, with major deployments in Europe, South Asia, South America and Oceania, for tier-one telecom operators, major transportation companies and large utility players.

Kerlink® crystalizes a strong ecosystem of partners leveraging its connectivity solutions best in-class building blocks not only to design innovative connected device and conceive smart applications but also to unlock the real potential of IoT to improve the lives of people around the world.

Kerlink® is also constantly improving its efficiency, operations control and processes through its Quality Program and has been certified ISO 9001-2015 by AFNOR for its IoT network solutions overall design, development, and sales processes.