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Technical Reference

Grounding and Lightning Protection in Vaisala Outdoor Installations

VAISALA

PUBLISHED BY

Vaisala Oyj

Street address:	Vanha Nurmijärventie 21, FI-01670 Vantaa, Finland
Mailing address:	P.O. Box 26, FI-00421 Helsinki, Finland
Phone:	+358 9 8949 1

Visit our Internet pages at www.vaisala.com.

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1. About This Document

This document provides information about lightning protection and grounding. The information helps you to tailor the basic protection and grounding methods to suit the infrastructure and soil type at the meteorological site.

This document is written for people who are bidding for, designing, and installing Vaisala outdoor instruments and systems, including but not limited to: wind masts, weather stations, hydrological stations, road weather stations, lightning detectors, and optical instruments for airports.

If the product manuals give specific grounding or lightning protection instructions, as well as surge protection instructions, follow those instructions. You can use the information of this manual to tailor those instructions to suit the actual installation site.

- For the related standards and theories behind the suggested solutions, see Reference Material (page 55).
- For the concepts of signal grounding and overvoltage protection inside the equipment, see Lightning Overvoltages (page 51). For details, see the product specific manuals.

The lightning protection system components presented in this manual follow the recommendations of the standards IEC 62305 edition 2 and UL 96A edition 12.

- For guidance on buildings and other inhabited constructions, see the IEC 62305 series (or UL 96A in the U.S.A).
- For guidance on weather radar towers, see FAA-STD-019 (revision E or later).

1.1 Version Information

Table 1 Document Versions

Document Code	Date	Description
M211786EN-B	February 2018	Document outlook updated.
M211786EN-A	September 2015	First version of this document.

1.2 Documentation Conventions

WARNING! **Warning** alerts you to a serious hazard. If you do not read and follow instructions carefully at this point, there is a risk of injury or even death.

CAUTION! Caution warns you of a potential hazard. If you do not read and follow instructions carefully at this point, the product could be damaged or important data could be lost.

Note highlights important information on using the product.

Tip gives information for using the product more efficiently.

Lists tools needed to perform the task.

Indicates that you need to take some notes during the task.

2. Overview of Grounding

2.1 Grounding

System level grounding serves two main purposes in Vaisala systems:

1. Electrical safety grounding (also known as earthing) in mains powered systems reduces touch voltages and ensures proper operation of the safety components inside a system in fault conditions.
2. Lightning protection grounding enables the lightning protection systems and transient protection devices to operate as intended to protect the system and reduce the risk of dangerous step voltages on ground near the system.

The same grounding system may serve both needs although the requirements for optimal performance can be quite different.

> The recommended practices in this manual do not cover all the requirements of every standard and specification available.

When designing a lightning protection system and the grounding of a site, take into account the structure to be protected and the needed protection level, as well as technical, geographic, and economic factors.

The general principle in grounding Vaisala weather station systems and masts is to install a lightning protection system, including an air terminal, down conductor, and a ground electrode, and ground the mast and the electronics enclosure with separate wires. See System and Equipment (page 19).

More Information

- Electrical Safety Grounding (Earthing) (page 8)
- Lightning Protection Grounding (page 8)
- Design Considerations (page 15)
- Lightning Overvoltages (page 51)

2.2 Bonding

Bonding means connecting system structures and enclosures together galvanically to maintain an equal electrical potential between the electrically conductive parts of a system. Bonding increases electrical safety and minimizes differential voltages.

Sometimes grounding is difficult or impossible to arrange so bonding is used instead. This applies, for example, to locations with extremely low soil conductivity (for example very dry locations) and Antarctica where the closest distance to soil is 2 km (1.24 mi) downwards, through the ice.

2.3 Electrical Safety Grounding (Earthing)

Protective grounding for mains distribution outlets is built mainly to protect people from electric shock and to protect property from fire.

In many countries, national standards, building codes, and installation instructions define the minimum requirements and recommended practices. Often protective grounding is designed and built by the local power utility companies. In some projects Vaisala is responsible for designing and building the grounding system.

2.3.1 Grounding Resistance

The key parameter in protective grounding is to maintain a low grounding resistance value all year round. Low grounding resistance ensures as low as possible touch voltages in fault conditions.

A preferable target value for low resistance safety grounding is below 10 Ω. In some soil types, this is challenging and expensive to achieve.

2.3.2 Grounding Systems

International standard IEC 60364 describes three families of grounding arrangements, using two-letter codes: TN, TT, and IT systems.

The first letter indicates the connection between the ground and the power-supply equipment (such as a generator or a transformer). The second letter indicates the connection between the ground and the electrical device being supplied.

- T: direct connection of a point with ground (from Latin ‘terra’)
- I: no point is connected with ground (isolation), except perhaps through a high impedance route
- N: direct connection to neutral at the origin of installation, which is connected to the ground

2.4 Lightning Protection Grounding

The purpose of lightning protection grounding is to:

1. Disperse the lightning current effectively into a large surface area of soil.
2. Handle current pulses with fast rise time without excessive rise of the potential near the ground electrode connection point.

To design a lighting protection system that disperses the lightning current into the ground and minimizes potentially dangerous overvoltages, the shape and dimensions of the grounding system are important. A low grounding resistance is recommended.

When planning and designing a lightning protection system, the shape and dimensions of the grounding system are critical in determining how it works in practice.

Low impedance grounding, which means small inductance and preferably high capacitance, is essential for the proper operation of transient suppressors and lightning protection systems. Vaisala recommends using several parallel routes that disperse the current to a large surface area of soil.

A lightning protection and grounding system requires three or more ground rods in the ground electrode. Using fewer rods does not provide sufficient protection and may cause dangerous step voltages.

2.4.1 Local Practices and Standards

There are local practices, traditions, and a variety of standards. For a list of related standards, see Reference Material (page 55).

Lightning density varies a lot based on geographic factors. The following figure illustrates the differences in lightning density in different areas. The figure shows the lighting strikes per square kilometer per year.

Lightning density is low to moderate around the poles and increases from moderate to high towards the equator.

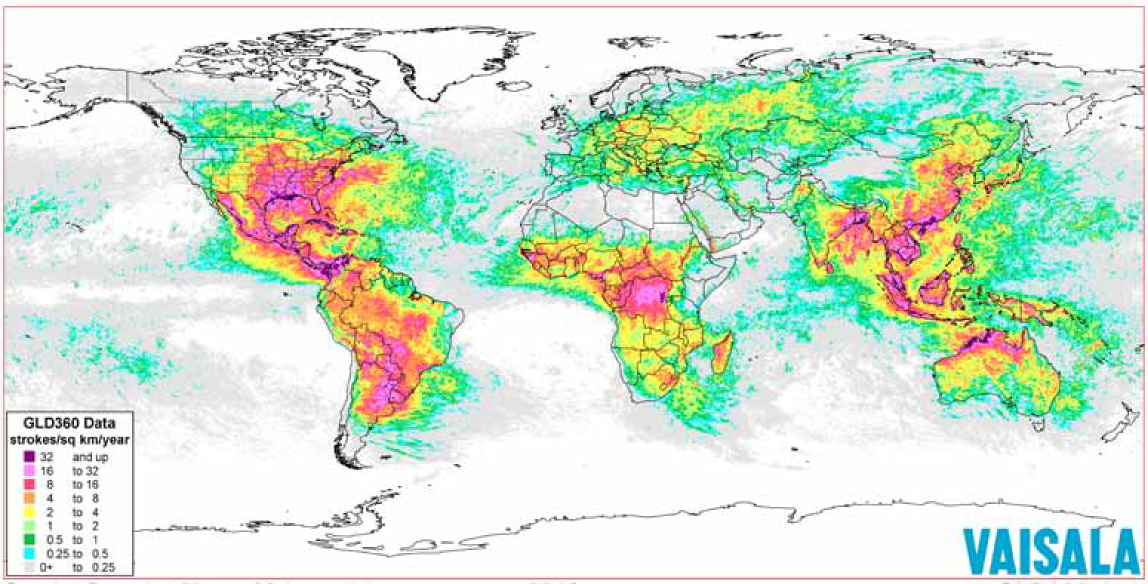

Figure 1 Geographical Variation in Lightning, GLD360 Data

Geographical variation can be substantial:

- In the northern countries, lightning strike density is low: annually ~1 strike/km^2 (10.8 ft^2), and the practices are less regulated.
- In tropical countries, lightning density is high. Local practices may contradict major international standards in some aspects. Follow the local code if that is a contractual requirement and it does not pose a safety hazard. An example of a safety hazard is, for example, substituting several standard air terminals with a single “special” device that is supposed to have an extraordinary large protection range.

3. Recommended Grounding for Vaisala Equipment

If there are no specific contractual requirements for the grounding system, you can use the following examples of field practices to ensure proper operation of Vaisala outdoor systems in a fairly cost-efficient way.

For basic knowledge about how to tailor the following examples to fit your specific system and local environmental needs, see Constructing a Lightning Protection System (page 13) and Installation (page 33).

3.1 Wind Masts and Towers (> 10 m / 33 ft)

Wind masts and towers that are taller than 10 meters (33 ft) tend to attract lightning strikes during their technical lifetime even in areas with low lightning density. In areas with high lightning density, dozens of strikes per year are possible.

A lightning protection system with a low impedance ground electrode is feasible even when local safety grounding is not mandatory, for example on a solar-powered site.

3.2 Weather Stations with Wind Mast (6 ... 10 m / 20 ... 33 ft)

Weather stations with wind masts that are 6 ... 10 m (20 ... 33 ft) tall are typically road weather station installations.

Road weather stations are typically installed far away from the equator, in cold regions where lightning density is from low to moderate. Exceptions may include high-terrain roads where winter maintenance is critical, but there can be severe thunderstorms during the warm season.

If safety grounding is not required, as is the case with TN systems and solar power, you can make the decision of a lightning protection system based on perceived risks versus associated costs.

If the wind mast is in tropical or sub-tropical regions, it needs a lightning protection system.

3.3 Stand-alone Outdoor Equipment (< 6 m / 20 ft)

Stand-alone outdoor equipment that are less than 6 m (20 ft) tall have a low to moderate probability of a lightning strike in most locations.

If a system (such as a visibility meter) is installed in an open airfield with no other taller structures nearby, the risk of a direct lightning strike increases.

The feasibility of a separate lightning protection system increases when approaching the equator.

The main reason for local grounding is electrical safety, especially in TT distribution systems where the ground is made with a local ground electrode. Observe local or contractual requirements for the needed maximum grounding resistance.

Local safety ground also enables the AC (mains) power line and signal line transient protectors (such as Termbox1200) to conduct the transient currents safely to ground. Systems with two or more structures (for example transmissometers) use a local bonding electrode to interconnect the units to the same potential for signal integrity. This bonding wire also acts as a moderate grounding electrode.

Even in cases of TN or IT systems, connecting the equipment chassis to the ground potential is beneficial to the transient protection.

4. Constructing a Lightning Protection System

The purpose of a lightning protection system is to advert direct lightning strikes from the equipment and conduct the current to the ground, dividing the current to multiple paths and dispersing the current to soil.

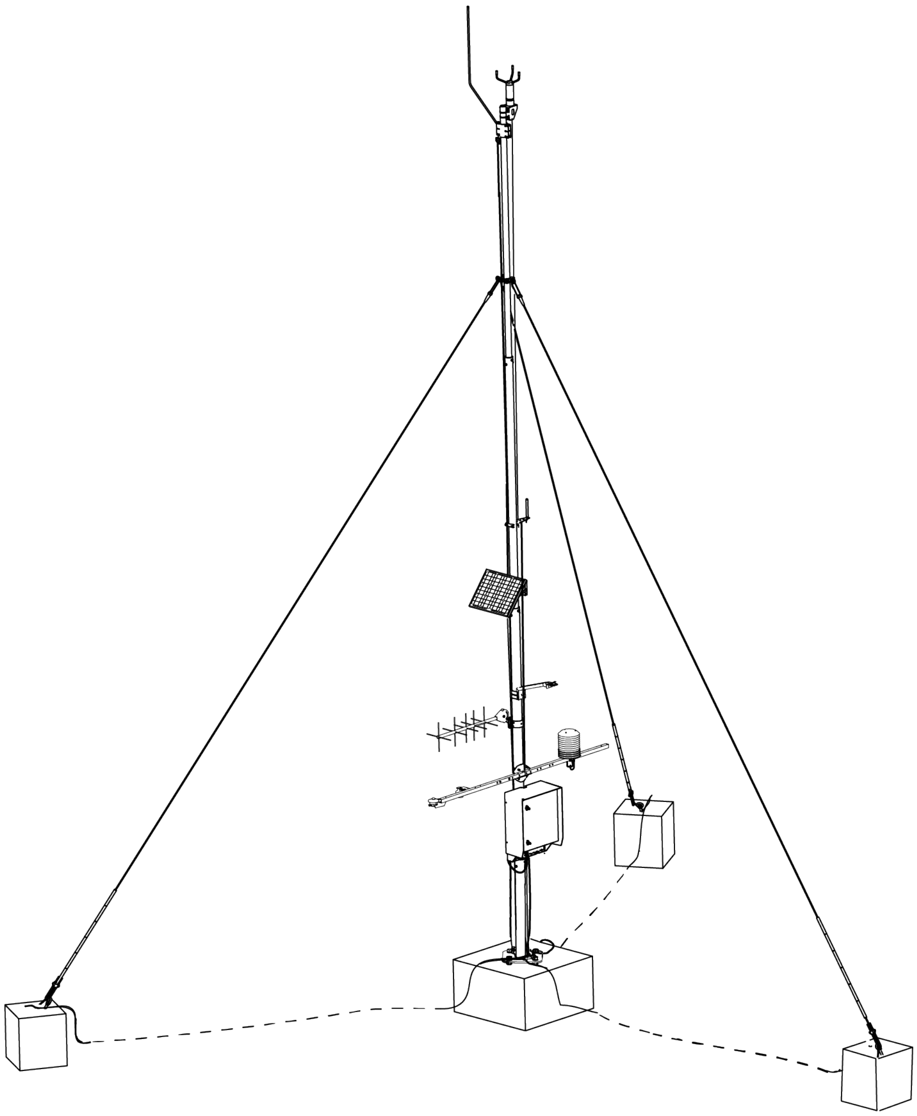

Figure 2 Example of Lightning Protection System

4.1 Dividing Current to Multiple Paths

A lightning protection system provides a low-impedance route or routes for the electric current to the ground. To lower the series inductance of the down conductor, you can split current to several parallel conductors, preferably located at opposite sides of the protected structure (for example a radar tower), or distribute it evenly around it, in case of more than two down conductors. Spacing affects the inductance: 1 m (3 ft) spacing of two parallel conductors reduces the net inductance to 60 % of a single similar conductor.

A mast is a special case where only one down conductor is used.

Adding extra conductors decreases the current in one conductor, causing less mechanical and thermal stress and reducing the risk of sparking and side flashes.

Several paths also make redundancy in the system in case one joint or connection becomes loose or corroded.

More Information

- System and Equipment (page 19)

4.2 Grounding Current

Disperse the charge from the ground electrode system to as large of an area as reasonable to keep the potential rise of the soil as low as possible.

The soil layer with the best conductivity is usually only a few meters thick. Typically 3 meters (10 ft) or less is sufficiently deep for the ground electrodes.

More Information

- Installation (page 33)

4.3 Connections

Galvanic corrosion is a threat to a grounding system. When you connect different metals together, use connection components or methods specially designed for that.

CAUTION! Do not interconnect metals that are not galvanically compatible. Corrosion increases in the presence of moisture.

More Information

- Material Combinations and Dimensions (page 24)

4.4 Design Considerations

When designing a lightning protection system and the grounding of a site, take into account the structure to be protected and the needed protection level, as well as technical, geographic, and economic factors.

Before you start constructing a lightning protection system, design the system and make preparations at the intended site or location.

To design a cost-efficient lightning protection system:

- Evaluate the probability and frequency of strikes during the intended service lifetime of the system.
- Consider the location and whether protection is needed for equipment only or for equipment and people.
- Take into account environmental factors, such as wind load, possible floods, heavy rain, earthquakes, and corrosive atmosphere, and the mechanical and chemical properties of the soil.

The presented field practices are intended to protect only the installed equipment with a low probability of failure. If the system installation resides in an area of high lightning density (more than 5 lightning strikes per 1 km^2/0.39 $mile^2$ per year) or a contract requires compliance to a certain standard , follow the material dimensions in the referenced standards. See Reference Material (page 55).

Remember that no system, whether standard or non-standard, can guarantee 100 % protection.

Most Vaisala systems and instruments are designed to be grounded to ensure specified operation. Good examples are meteorological stations with sensors that are in connection with the ground, such as road surface sensors, and soil temperature and moisture sensors. Missing or faulty grounding can make the system unstable, causing it to produce erroneous data.

CAUTION! External structures such as steel wiring that hold traffic signs or lights and similar may act as air terminals to lightning strikes. When using a pole that has a metal structure, ensure that the pole and all the equipment and external structures that are connected to it are properly grounded. If grounding is not possible, a separate pole mast for the sensors is recommended.

Situations where a lightning protection system may not be feasible are:

- The protected system is inexpensive and protection would cost more than replacing the system.
- The system is in place for a limited period of time, and in particular during season of low lightning intensity.
- The system or construction is not tall or is lower than its surroundings.
- The intensity of lightning strikes in the area is low throughout the year.

Although a lightning protection system may not be feasible in these cases, electrical safety grounding may be needed.

4.5 Soil Resistivity

Soil resistivity depends on the content of electrolytes in the soil. Geological differences and seasonal variations on a site can be big.

In particular frozen soil and dry soil are very poor conductors:

- In frozen soil, position the ground electrode deep enough to reach non-frozen moist soil even during the winter or dry season. Do this if you need a low resistance to ground for electrical safety reasons.
- In very dry soil, add soil enhancing chemicals, also known as backfill compounds, around the ground electrode to raise the moisture level, lowering the resistance to ground.

For installation examples in different soil types, see Installing Ground Electrode (page 37).

Table 2 Resistivity Values of Soil and Water Types

Type of Soil or Water	Resistivity (Ωm)	Usual Range (Ωm)
Sea Water	2	0.1 ... 10
Clay	40	8 ... 70
Ground well and spring water	50	10 ... 150
Clay and sand mixtures	100	4 ... 300
Shale, slates, sandstone, etc.	120	10 ... 1000
Peat, loam and mud	150	5 ... 250
Lake and brook water	250	100 ... 400
Sand	2000	200 ... 3000
Moraine gravel	3000	40 ... 10 000
Ridge gravel	15 000	3000 ... 30 000
Solid granite	25 000	10 000 ... 50 000
Ice	100 000	10 000 ... 100 000

Table 3 The Effect of Moisture Content

Moisture Content (% of weight)	Resistivity of Clay Mixed with Sand (Ωm)
0	over 10 000 000
2.5	1500

Moisture Content (% of weight)	Resistivity of Clay Mixed with Sand (Ωm)
5	430
10	185
15	105
20	63

4.6 Grounding Resistance Measurements

Grounding resistance is not the only qualification for good grounding, but a numerical value for electrical safety grounding is sometimes a contractual requirement. To verify whether a contractual requirement is met, for example a maximum of 10 Ω grounding resistance, you need to measure the grounding resistance.

The best time to make the measurement is right after the rainy season.

Soil resistivity measurements do not give correct results in frozen soil. Make the measurements when the soil in not frozen.

The measurement helps you to evaluate and design the required ground electrode for a certain resistance value.

There are several methods and pieces of measurement equipment for measuring grounding resistance:

- Use a widely preferred method, which is the four-electrode Wenner method (ASTM G57-06), to measure soil resistivity in the intended grounding location.
- Use soil type tables for rough estimates of the grounding resistance of different electrode sizes.
- Outsource grounding resistance measurements to a local power utility company.

Multi-meters and clamp-type loop resistance meters can be used to measure one ground electrode at a time in a large system with several interconnected ground electrodes located far from each other. This is very seldom the case on a Vaisala installation site.

For the operational details of measuring equipment, see the user manual of your specific grounding resistance instrument.

5. System and Equipment

This section lists the equipment and components used in a lightning protection system.

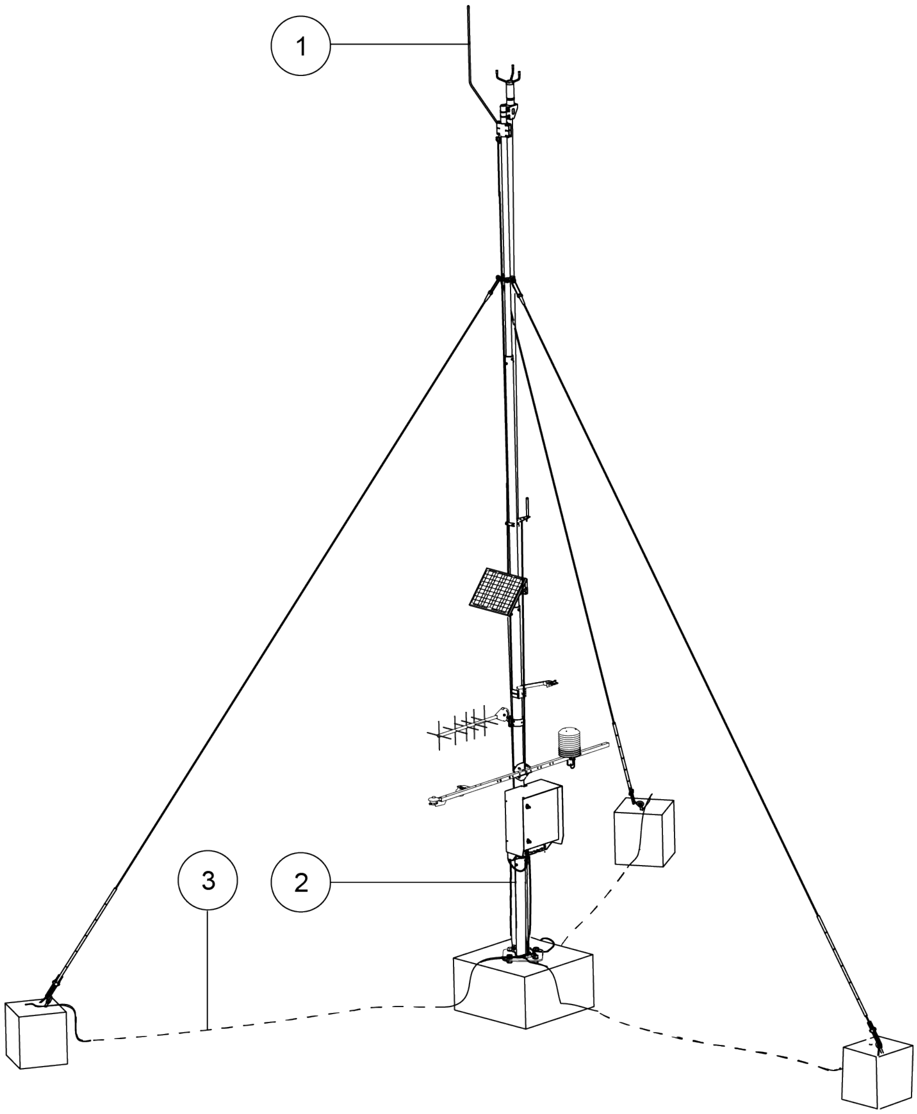

Figure 3 Lightning Protection System Equipment

1 Air terminal
2 Down conductor
3 Ground electrode

The ground electrode equipment are examples. Select the ground electrode equipment to suit your system, site, and soil properties.

Of the equipment presented here, Vaisala supplies the air terminal and the down conductor. You may want to purchase the ground electrode materials from local suppliers because the materials are typically needed when preparing the mast installation and when making the civil works at the installation site.

5.1 Air Terminal

The preferred air terminal materials are:

- Copper (Cu)
- Aluminum (Al)
- Stainless steel

Use only conductive coating materials, if any. Conducting mast structures are sometimes used as air terminals.

To ensure intended performance of the air terminal, do not paint the air terminal or use isolating coating, such as anodized aluminum.

- Typically Vaisala sites require only one air terminal. To protect larger areas, you can use two separate air terminals or two air terminals that are connected with a wire, but this is seldom applicable to a meteorological site.
- Prefer an air terminal that has a blunt tip because it attracts lightning strikes better than a pointed tip.
- Extend the air terminal tip so high that it keeps the protected equipment in the protected zone. A traditional protected zone estimate for a 10 meter (33 ft) wind mast is a 1 to 1 line (45º cone).

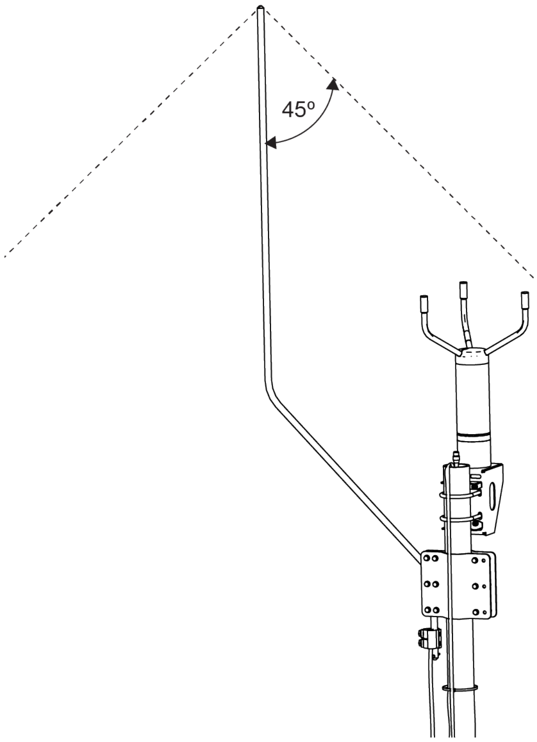

Figure 4 Protected Zone

Most standards model the protected area with an imaginary rolling sphere with a radius of 50 m (150 ft). However, it has been observed several times that lightning is more interested in the actual impedance to ground than physical dimensions of objects. Thus no 100% guarantee is given to any design rule for any lay-out. Just raise the air terminal tip as high as you safely can!

- To avoid air turbulence, minimize air terminal thickness versus horizontal distance ratio in a wind sensor mast. If you have a wind vane and an anemometer, place the air terminal further away from the wind vane because it is more easily affected by air terminal turbulence than the anemometer.
- Ensure structural safety under foreseeable wind and ice load.

Equipment with "special design" are sometimes used as air terminals, including early streamer emitters, repellers, and dissipators. If the customer requires a specific brand or type, and the design does not interfere with local legislation or safety and operational requirements, Vaisala follows the requirement, but does neither recommend nor specify such designs. In protected-zone or terminal-positioning calculations these "special designs" are treated as ordinary blunt-tip passive air terminals.

5.2 Down Conductor

You can use wires, strips, tubes, or stranded conductors as down conductors. All shapes work fine when interconnected with suitable connectors.

The preferred down conductor materials are:

- Aluminum is the preferred choice for meteorological sites due to its low weight, galvanic compatibility with steel and aluminum masts, and low cost.
- Copper is a good choice for very corrosive environments.

Make sure that stranded conductors have a minimum strand diameter to protect them from corrosion and ensure mechanical strength. For standard dimensions, see Table 5 (page 26).

5.2.1 Routing Rules

Before designing, routing, or installing a down conductor, note that:

- Use only smooth curves in the installation. The minimum bending radius is 2 cm (0.8 in). The magnetic forces of a lighting current straighten sharp corners — if the material is strong enough to remain in one piece.
- Never bend the conductor backwards! All routing must be in angles of less than 90º, preferably less than 45º.
- Make no loops of excess cable! The magnetic forces generated by the lightning current can shred a cable loop into pieces.

5.3 Ground Electrode

There is only one ground electrode system in one installation site.

If there are several ground electrodes on the site (for example old and new installations), bond the ground electrodes together to prevent dangerous potential differences during a lightning strike.

In general, ground electrode construction and shape depends on soil type.

To disperse the electric current to soil, two main electrode types are used:

- Ground rods
- Horizontal ground electrodes

Depending on the site, use either one type or both to complement each other. You may also use conductive plates and wire grids.

A typical ground electrode system consists of several horizontal and possibly also some vertical ground electrodes.

5.3.1 Ground Rods

Ground rods, also known as vertical rods, are solid metal rods or tubes. Tube rods can be filled with soil treatment chemicals. These rods require maintenance because you need to regularly add more chemicals.

To increase inductance in dry soil, you can use tube rods filled with soil treatment chemicals or enhance the soil with chemicals.

CAUTION! Use clamps to connect a cable to the ground rod or two cables together. In underground connections, use exothermic welding.

5.3.2 Horizontal Ground Electrodes

Horizontal ground electrodes, also known as trench electrodes, distribute the electric charge to a large area.

Use horizontal ground electrodes if the bedrock is close to the surface or the soil is rocky. To further minimize grounding resistance in dry soil, use vertical rods to terminate the horizontal sections.

You can arrange the ground electrodes in various ways to suit the installation site. Common shapes are loop and star (X and Y shape).

5.3.3 Conductive Plates

Conductive plates are also known as plate electrodes.

Metal plate and grid electrodes can be used in challenging sites, such as on a solid rock, if no better grounding area is nearby.

5.3.4 Metal Grids

A metal grid is often used for critical utilities, such as telecommunication, military, and flammable materials handling sites. The whole installation area is covered with a buried metal grid. Conductive objects are grounded to the nearest grid point or points.

This arrangement is seldom used in Vaisala installations, and when used, it already exists on the site.

5.4 Ground Electrode Materials

Use corrosion-resistant materials to ensure long, continuous operation:

- Copper and stainless steel are good.
- Stainless steel has better corrosion resistance than copper.
- Copper clad steel is cheaper than copper and commonly available in commercial rods.
- Hot-galvanized steel (with a minimum coating thickness of 60 µm) is cheap, and good especially in dry soil.
- Galvanized steel is cheap, but it is not practical in corrosive soil because the service life is short.
- Stainless or galvanized steel bars that are used in reinforced concrete foundations can be used as ground electrodes, providing they are galvanically connected to each other, preferably by welding.
- Round solid wires and sheet metal tapes that are 2 ... 3 cm (0.8 ... 1.2 in) wide are good in dry soil, but in corrosive acid, salty, or wet environment they need frequent maintenance and are short-lived.

Do not use bare steel or aluminum in ground electrodes because of their fast corrosion.

If you use stranded cables, use a strand with a big enough diameter to resist corrosion damage. For standard dimensions, see Table 6 (page 28).

5.5 Material Combinations and Dimensions

Make sure to use galvanically compatible metals in lightning protection system components and surface materials on which the components are mounted. For example, do not connect copper to aluminum. For more information, see Table 4 (page 25).

CAUTION! Do not use together metals that are not galvanically compatible. Bad matching accelerates their corrosion in the presence of moisture.

With aluminum conductors, use only connection devices designed for aluminum. Make sure to use the right fastening torque.

Examples of metals to use with copper

- Nickel
- Brass
- Tin
- Lead
- Stainless steel
- Monel (nickel–copper alloy)

Examples of metals to use with aluminum

- Magnesium
- Zinc
- Galvanized steel
- Stainless steel
- Lead
- Wrought iron
- Galvalume (an aluminum-coated sheet steel product)

Table 4 (page 25) lists generic guidance on materials and their use in different environments and conditions. Consider the conditions and requirements of individual sites when deciding on materials and their use.

Table 4 LPS Materials and Conditions of Use (IEC 62305-3 Ed 2)

Material	Use			Corrosion		
	In Open Air	**In Earth**	**In Concrete**	**Resistance**	**Increased by**	**May be destroyed by Galvanic Coupling with**
Copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	–
	Stranded	Stranded	Stranded	–	Organic materials	–
	–	As coating	As coating	–	–	–
Hot galvanized steel[1)2)3)]	Solid	Solid	Solid	Acceptable in air, in concrete, and in benign soil	High chlorides content	Copper
	Stranded [4)]	–	Stranded [4)]	–	–	–
Steel with electro-deposited copper	Solid	Solid	Solid	Good in many environments	Sulphur compounds	–
Stainless steel	Solid	Solid	Solid	Good in many environments	High chlorides content	
	Stranded	Stranded	Stranded	–	–	–
Aluminum	Solid	Unsuitable	Unsuitable	Good in atmospheres containing low concentration of sulphur and chloride	Alkaline solutions	Copper
	Stranded	–	–	–	–	–
Lead [5)]	Solid	Solid	Unsuitable	Good in atmospheres with high concentration of sulphates	Acid soils	Copper
	As coating	As coating	–	–	–	Stainless steel

1) *Galvanized steel may be corroded in clay soil or moist soil.*
2) *Galvanized steel in concrete should not extend into the soil due to possible corrosion of the steel just outside the concrete.*
3) *Galvanized steel in contact with reinforcement steel in concrete should not be used in coastal areas where there may be salt in the ground water.*
4) *Stranded conductors are more vulnerable to corrosion than solid conductors. Stranded conductors are also vulnerable where they enter or exit earth/concrete positions. This is the reason why stranded galvanized steel is not recommended in earth.*
5) *Use of lead in the earth is often banned or restricted due to environmental concerns.*

5.5.1 Material Dimensions

Several lightning protection system codes and standards define minimum dimensions for the components of a grounding system. These standards are designed to protect buildings and other inhabited or otherwise critical facilities.

Practical minimums are based on field experience and indicate what is needed to protect the installed equipment in a cost-effective way during the foreseeable technical lifetime, typically a few decades, taking into account local regulations. To ensure proper operation of the grounding system, periodic inspection and maintenance is needed.

More Information

- Minimum Material Dimensions According to IEC 623053 Ed 2 (page 26)
- Examples of Practical Minimum Dimensions (page 29)

5.5.2 Minimum Material Dimensions According to IEC 623053 Ed 2

Table 5 (page 26) and Table 6 (page 28) are based on standard IEC 62305-3 Ed 2. The tables list minimum dimensions for the lightning protection system equipment.

The following table lists the different materials and shapes that are used in air terminals, down conductors, and ground electrodes, including the cross-sectional area.

Table 5 Material, Configuration and Minimum Cross-sectional Area of Air-termination Conductors, Air-termination Rods, Earth Lead-in Rods and Down-conductors (IEC 62305-3 Ed 2)

Material	Configuration	Cross-sectional Area
Copper, tin-plated copper	Solid tape	50 mm^2 (AWG 0)
	Solid round 1)	50 mm^2 (AWG 0)
	Stranded 1)	50 mm^2 (AWG 0)
	Solid round 2)	176 mm^2 (AWG 350)
Aluminum	Solid tape	70 mm^2 (AWG 00)
	Solid round	50 mm^2 (AWG 0)
	Stranded	50 mm^2 (AWG 0)

Material	Configuration	Cross-sectional Area
Aluminum alloy	Solid tape	50 mm^2 (AWG 0)
	Solid round	50 mm^2 (AWG 0)
	Stranded	50 mm^2 (AWG 0)
	Solid round 2)	176 mm^2 (AWG 350)
Copper-coated aluminum alloy	Solid round	50 mm^2 (AWG 0)
Hot-dipped galvanized steel	Solid tape	50 mm^2 (AWG 0)
	Solid round	50 mm^2 (AWG 0)
	Stranded	50 mm^2 (AWG 0)
	Solid round 2)	176 mm^2 (AWG 350)
Copper-coated steel	Solid round	50 mm^2 (AWG 0)
	Solid tape	50 mm^2 (AWG 0)
Stainless steel	Solid tape 3)	50 mm^2 (AWG 0)
	Solid round 3)	50 mm^2 (AWG 0)
	Stranded	70 mm^2 (AWG 00)
	Solid round 2)	176 mm^2 (AWG 350)

1) *50 mm^2(AWG 0) with 8 mm (0.31 in) diameter may be reduced to 25 mm^2(AWG 3) in certain applications where mechanical strength is not an essential requirement. Consideration should in this case be given to reducing the spacing between the fasteners.*

2) *Applicable for air-termination rods and earth lead-in rods. For air terminals where mechanical stress such as wind load is not critical, a 9.5 mm (0.37 in) diameter, 1 m (3 ft 3 in) long terminal may be used.*

3) *If thermal and mechanical considerations are important then these values should be increased to 75 mm^2 (AWG 000).*

4) *If thermal and mechanical considerations are important then these values should be increased to 75 mm^2 (AWG 000).*

The following table lists the different materials, shapes, and sizes that are used in ground electrodes.

Table 6 Material, Configuration and Minimum Dimensions of Earth Electrodes (IEC 62305-3 Ed 2)

Material	Configuration	Dimensions		
		Earth Rod Diameter	**Earth Conductor**	**Earth Plate**
Copper, Tin-plated copper	Stranded	–	50 mm^2 (AWG 0)	–
	Solid round	15 mm (0.59 in)	50 mm^2 (AWG 0)	–
	Solid tape	–	50 mm^2 (AWG 0)	–
	Pipe	20 mm (0.79 in)	–	–
	Solid plate	–	–	500 × 500 mm (19.69 × 19.69 in)
	Lattice plate [1)]	–	–	600 × 600 mm (23.62 × 23.62 in)
Hot-dipped galvanized steel	Solid round	14 mm (0.55 in)	78 mm^2 (AWG 000)	–
	Pipe	25 mm (0.98 in)	–	–
	Solid tape	–	90 mm^2 (AWG 000)	–
	Solid plate	–	–	500 × 500 mm (19.69 × 19.69 in)
	Lattice plate [1)]	–	–	600 × 600 mm (23.62 × 23.62 in)
	Profile	[2)]	–	–
Bare steel[3)]	Stranded	–	70 mm^2 (AWG 00)	–
	Solid round	–	78 mm^2 (AWG 000)	–
	Solid tape	–	75 mm^2 (AWG 000)	–

Material	Configuration	Dimensions		
		Earth Rod Diameter	**Earth Conductor**	**Earth Plate**
Copper-coated steel	Solid round	14 mm (0.55 in) 4)	50 mm^2 (AWG 0)	–
	Solid tape	–	90 mm^2 (AWG 000)	–
Stainless steel	Solid round	15 mm (0.59 in) 4)	78 mm^2 (AWG 000)	–
	Solid tape	–	100 mm^2 (AWG 0000)	–

1) *Lattice plate constructed with a minimum total length of the conductor of 4.8 m (15 ft 9 in).*
2) *Different profiles are permitted with a cross-section of 290 mm^2(AWG 600) and a minimum thickness of 3 mm (0.12 in), e.g. cross profile.*
3) *Shall be embedded in concrete for a minimum depth of 50 mm (1.97 in).*
4) *In some countries the diameter may be reduced to 12.7 mm (0.50 in).*

5.5.3 Examples of Practical Minimum Dimensions

The following minimum material dimension values are widely used and field-proven to conduct lightning currents to ground without excessive heating or physical damage in majority of installations. These dimensions may not fulfill national or international standards.

Table 7 Air Terminal Minimum Dimensions

Material	Dimension
Copper, aluminum	Tube with a 16 mm (0.63 in) diameter, minimum wall thickness of 2 mm (0.08 in)
	8 mm (0.31 in) solid round
Steel	10 mm (0.39 in) steel

Table 8 Down Conductor Minimum Dimensions

Material	Dimension
Copper	25 mm^2 (AWG 4) solid or stranded wire or solid tape
Aluminum	35 mm^2 (AWG 2) in solid or stranded aluminum
Steel	35 mm^2 (AWG 2) solid steel or stranded wires

Table 9 Minimum Thickness of Tapes

Material	Thickness
Copper	1 mm (0.04 in)
Aluminum	2 mm (0.08 in)
Galvanized steel	2 mm (0.08 in)
Stainless steel	2 mm (0.08 in)

Table 10 Minimum Thickness of Strand Diameters in Stranded Cables

Material	Thickness
Copper	1 mm (0.04 in)
Aluminum	1.6 mm (0.06 in)
Steel	1.6 mm (0.06 in)

Table 11 (page 30) and Table 12 (page 30) show two examples of practical minimums for ground electrodes. The materials are preferred because they are fairly corrosion-resistant, not because they provide optimum conductivity.

The following table is applicable to an arrangement of three ground rods in a triangle layout at 6-m (20-ft) spacing.

Table 11 Ground Rod Minimum Dimensions

Material	Thickness
Copper	Solid round 15 mm (0.59 in)
	Pipe 20 mm (0.79 in) diameter with a minimum wall thickness of 2 mm (0.08 in)
Copper clad solid steel	14 mm (0.55 in)
Galvanized steel	16 mm (0.63 in)
Galvanized steel, pipe	25 mm (0.98 in) diameter with a minimum wall thickness of 2 mm (0.08 in)

The following table is applicable to an arrangement of three 10-m (33-ft) horizontal ground electrodes in Y-shape.

Table 12 Horizontal Ground Electrode Minimum Dimensions

Material	Thickness
Cu	25 mm^2 (AWG 4) solid/strand/tape with a minimum 2 mm (0.08 in) thickness
Galvanized steel, round wire	50 mm^2 (AWG 1) with a minimum 8 mm (0.31 in) diameter

Material	Thickness
Galvanized steel, stranded	50 mm^2 (AWG 1) with a minimum strand diameter of 1.7 mm (0.07 in)
Galvanized steel, tape	50 mm^2 (AWG 1) with a minimum thickness of 2 mm (0.08 in)

6. Installation

The general principle in grounding Vaisala weather station systems and masts is to install a lightning protection system, including an air terminal, down conductor, and a ground electrode, and ground the mast and the enclosure with separate wires.

- The wire for grounding the mast runs from the air terminal down to the grounding connector at the base of the mast. This wire is the (mast) down conductor.
- The wire for grounding the enclosure runs from the bottom of the enclosure down to the grounding connector at the base of the mast. This wire is the (enclosure) down conductor.
- From the grounding connector, cables run to the ground, terminating in ground electrodes such as ground rods or plates.

WARNING! Failure to provide proper grounding may result in personnel injury or death from electrical shock and may severely damage the equipment. Ground the system for safety and optimal performance.

WARNING! Lightning protection is generally required to prevent personnel injury and equipment damage due to direct lightning strikes.

WARNING! Consult the local electricity provider for local safety grounding requirements.

WARNING! Lightning and thunderstorms present a risk to personnel. Do not start working with or installing masts or their lightning protection systems when there is a risk of thunderstorm.If thunder is heard or lightning seen by personnel, cease any activity near the mast and move to shelter or to hardtop vehicles.

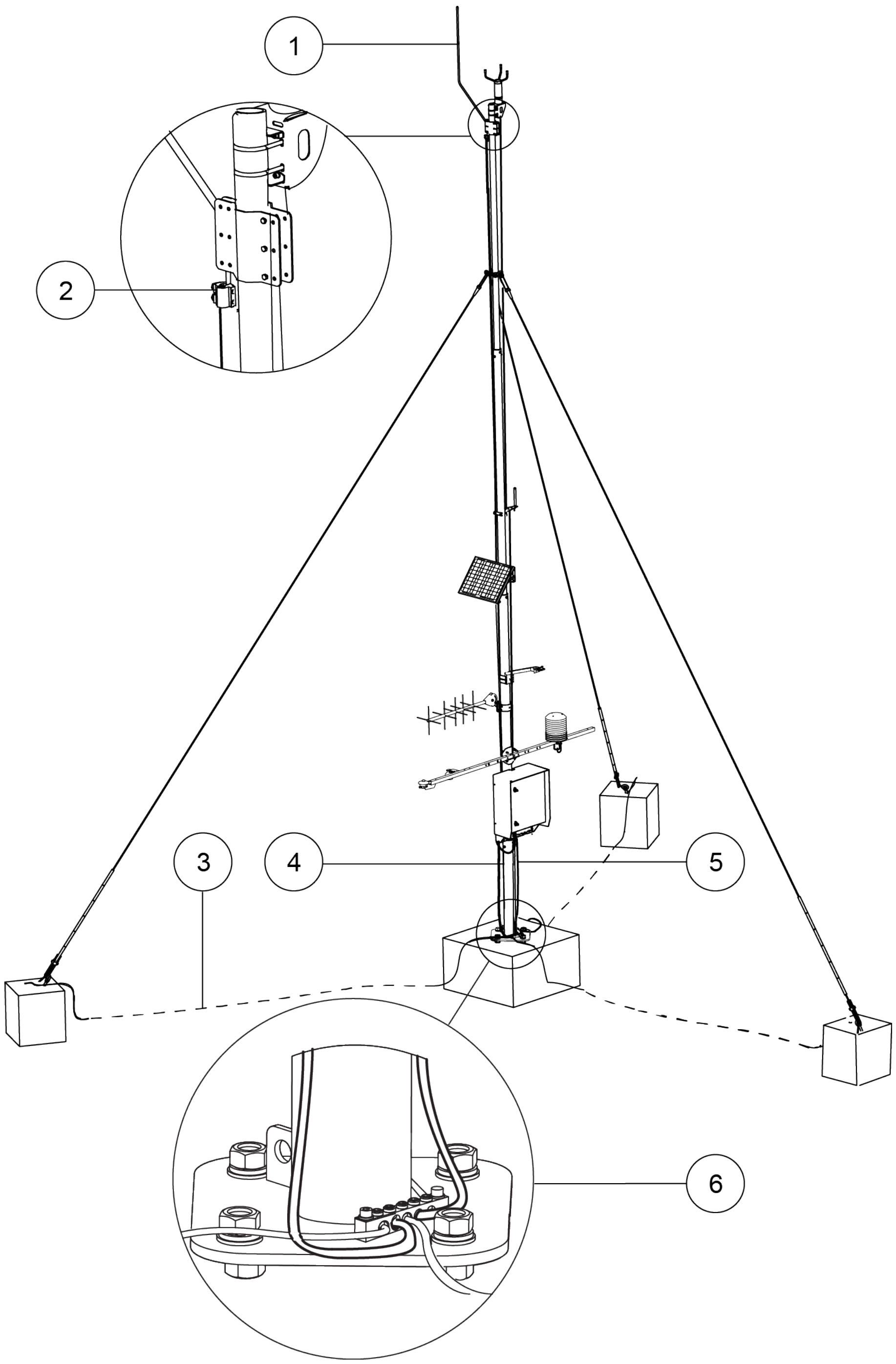

Figure 5 Example of Lightning Protection System on Pole Mast

1 Air terminal
2 Upper attachment of (mast) down conductor
3 Ground electrode
4 Mast down conductor
5 Signal cables
6 Grounding connector

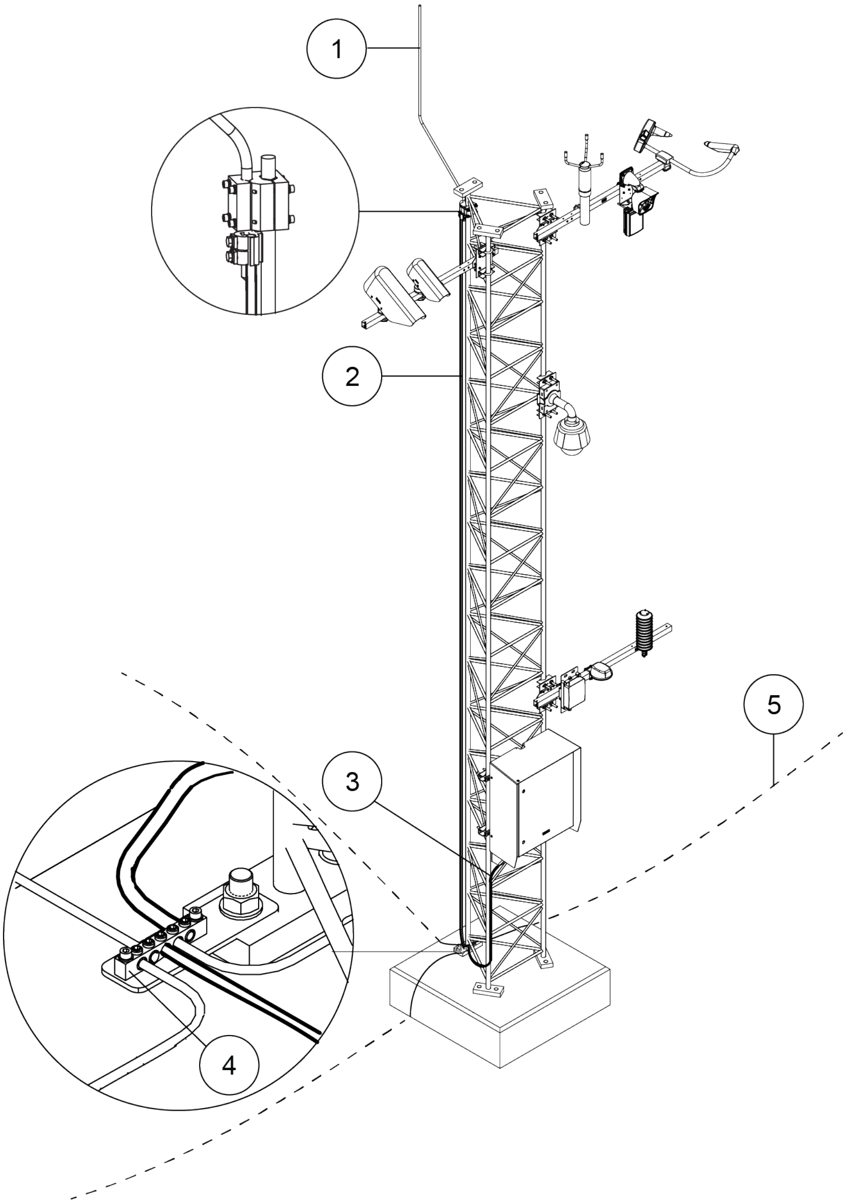

Figure 6 Example of Lightning Protection System on Lattice Mast

1 Air terminal
2 Mast down conductor
3 Enclosure down conductor
4 Grounding connector
5 Ground electrode

For instructions on installing an air terminal and grounding the enclosure, see the product-specific manuals.

Periodic inspection of the lightning protection system is recommended. When using lighter materials or materials that corrode fast, the role of inspection and maintenance is even more important.

6.1 Routing Down Conductor

Route the down conductor from the air terminal down to the grounding connector at the base of the mast using the shortest route possible.

You can route the mast down conductor and the enclosure down conductor on the same side of the mast.

CAUTION! To minimize the magnetic coupling between the down conductor and signal cables and the risk of electronic damage, install the down conductor on the opposite side of the mast than the signal cables.

Route the cables down and attach them to the grounding connector.

To prevent a lighting current causing damage to your wiring, make sure to install a down conductor as follows:

- Use only smooth curves to avoid damage to the conductor. The minimum radius is 20 cm (8 in).
- Never bend the conductor backwards. All angles must be less than 90 degrees, preferably less than 45 degrees.
- Do not make loops to the conductor.
- Remove all excess material from connections. Leave only a suitable slack near conductors to allow thermal and constructional movements.
- Bond separate down conductors (for example mast and enclosure down conductors) to a common connection point, such as a grounding connector.

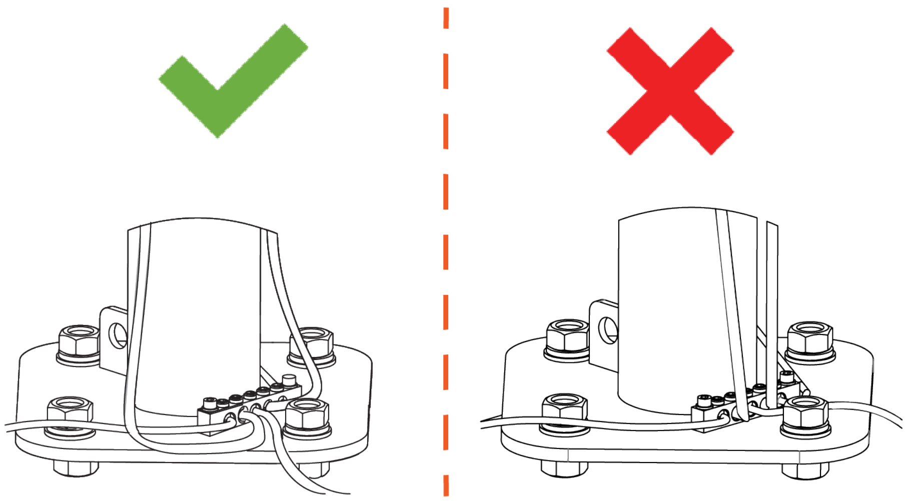

Figure 7 Correct Routing in Grounding Connector

6.2 Installing Ground Electrode

Ground electrode installation and arrangement is influenced by soil type and grounding resistance, as well as geographic factors and other site requirements.

Preferred shapes are Y and X (also known as star shape). Specific locations such as roadside or locations with limited space may require a loop or a T shape. In the T shape, two ground electrodes are along the road and the third electrode is perpendicular to them away from the road. The Y shape is the most cost-effective. To get an even lower impedance, you can use the X shape. The loop shape is an alternative when space is limited or you need to protect the sensors in soil.

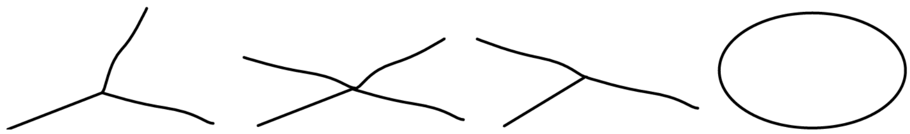

Figure 8 Ground Electrode Shapes: Y, X, T, and Loop

To decrease the rise of ground potential, you can add a loop around the connectors.

A practical solution is to form a star with 3 or 4 ground electrodes and connect them all to a center point, such as a grounding connector. Connect the down conductor and other ground wires (for example mains, signal, and transient suppressor) to the grounding connector too. Do not use daisy-chaining.

Distribute the conductors evenly around the protected structure to keep the impedance of the connection wires as low as possible.

More Information

- Installing Loop Electrode in Shallow Topsoil (page 42)
- Installing Loop Electrode to Protect Sensors (page 43)

6.2.1 Installation Depth

Install the ground electrode to a depth indicated in Table 13 (page 37). Depending on the moisture content of the soil, you can adjust the depth. For example, if the soil is very dry, install the ground electrode deeper.

Table 13 Installation Depth of Ground Electrode

Ground Electrode Type	Installation Depth
Ground rod	3 m (10 ft)
Horizontal ground electrode	0.6 m (2 ft)

CAUTION! Electrical safety grounding requires that the ground electrode is located below the frost level.

6.2.2 Ground Electrode Correspondence

In a homogenous soil, the grounding resistance of a single 3 m (10 ft) rod is roughly equivalent to 6 m (20 ft) of a horizontal ground electrode buried approximately 0.6 m (0.2 ft) underground.

A 6-m (20 ft) diameter loop and three 6-m (20-ft) electrodes in a horizontal star is equivalent to three 3 m (10 ft) rods driven in 7.5 m (25 ft) spacing. In practice, the connection wires of the rods are also buried forming a smaller star by themselves so that they lower the resistance and the impedance.

Buried wire lengths can be extended to several tens of meters (several dozens of feet) with almost linear relation to grounding resistance value. In a very poor soil, a maximum length of nearly 50 m (150 ft) per wire may be needed, but it is more cost-efficient to treat the soil chemically.

Table 14 Typical Ground Electrode Length and Spacing

Minimum values	Ground rod	Horizontal ground electrode
Length	Typically 3 m (10 ft)	10 ... 30 m (33 ... 100 ft), soil type dependent
Loop diameter	–	5 ... 6 m (16 ... 20 ft)
Spacing	Min. 2 × rod length	–

6.2.3 Length and Spacing of Ground Rod

The optimal ground rod length is 3 m (10 ft).

The minimum horizontal spacing of ground rods is two times the length of the rod: 6 m for a 3-m rod (20 ft for a 10-ft rod).

Closer spacing means wasted performance in grounding resistance because their effective soil volumes overlap, decreasing efficiency.

6.2.4 Length of Horizontal Ground Electrode

The length of a horizontal ground electrode is typically 10 ... 30 m (33 ... 100 ft).

In a shallow or rocky soil, three pieces of 10 m (33 ft) horizontal ground electrodes make good low impedance grounding. If the topsoil is moist and of low resistivity, you can use even shorter electrodes, but preferably not shorter than 6 m (20 ft) each.

A buried wire loop with a 5 ... 6 m (16 ... 20 ft) diameter is suitable for a single mast foundation or when arranged around a set of closely spaced equipment. Arrange at least two connection points on the loop, by making the loop out of two separate wires and leaving the wire ends above the surface.

6.2.5 Connections

Use bolted connections in places where they can be periodically checked. Use exothermic welding or pressure clamps in underground connections.

> The ground electrode installations that are presented here describe general principles and examples, and need to be modified in site installations according to individual site requirements and conditions.

6.3 Installing Horizontal Ground Electrodes in Shallow Topsoil

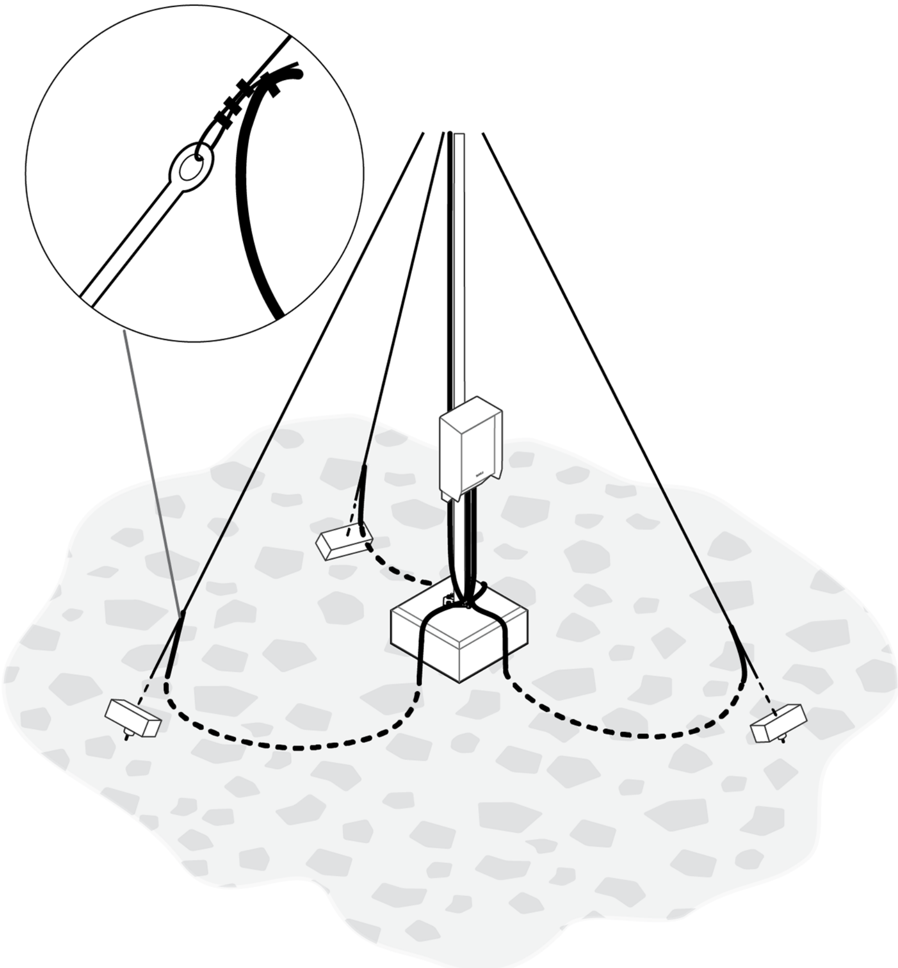

Figure 9 Horizontal Y-shaped Ground Electrode in Shallow Topsoil

Use horizontal ground electrodes when the topsoil is shallow. Horizontal ground electrodes distribute a lightning current to a large area of soil very efficiently with a small risk of dangerous step voltages.

- Route the ground electrodes from the grounding connector at the mast base to each guy wire foundation.
- Use two or three electrodes. Using more electrodes lowers the impedance.
- Bury the ground electrodes to a minimum of 0.6 m (2 ft) deep and connect them to the lower ends of the guy wires.
- If the soil is very dry, extend the electrodes further away and/or bury them deeper to where soil is moist.
- To lower resistance, terminate the ends with vertical ground rods if the soil allows it or use backfill compounds to increase soil conductivity.

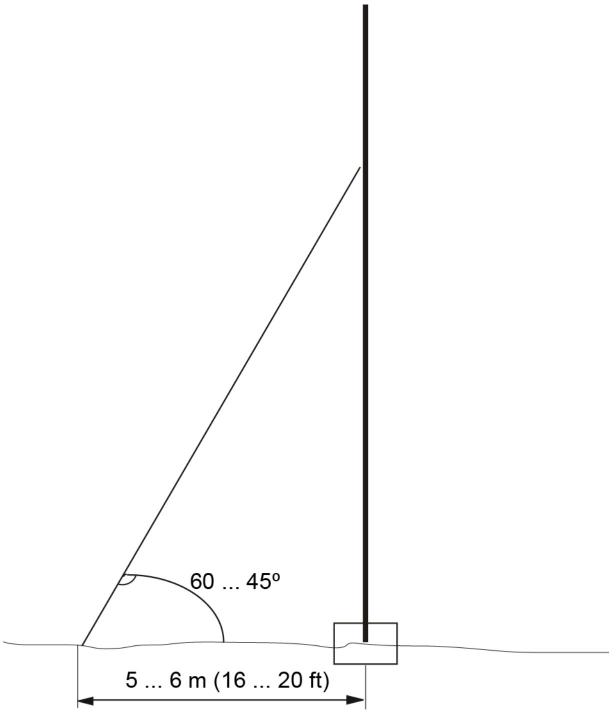

Figure 10 Example Guy Wire Distance and Angle

The electrodes do not need to be evenly spaced. You can guide the transient current to the most desirable direction, for example away from buildings or other equipment, or towards better conducting soil by arranging the wires to that direction.

Do not make the wires run parallel any longer than absolutely necessary.

Using ground electrodes where one electrode is longer than 50 m (164 ft) is not useful. Longer electrodes do not bring better results.

6.4 Installing Loop Electrode in Shallow Topsoil

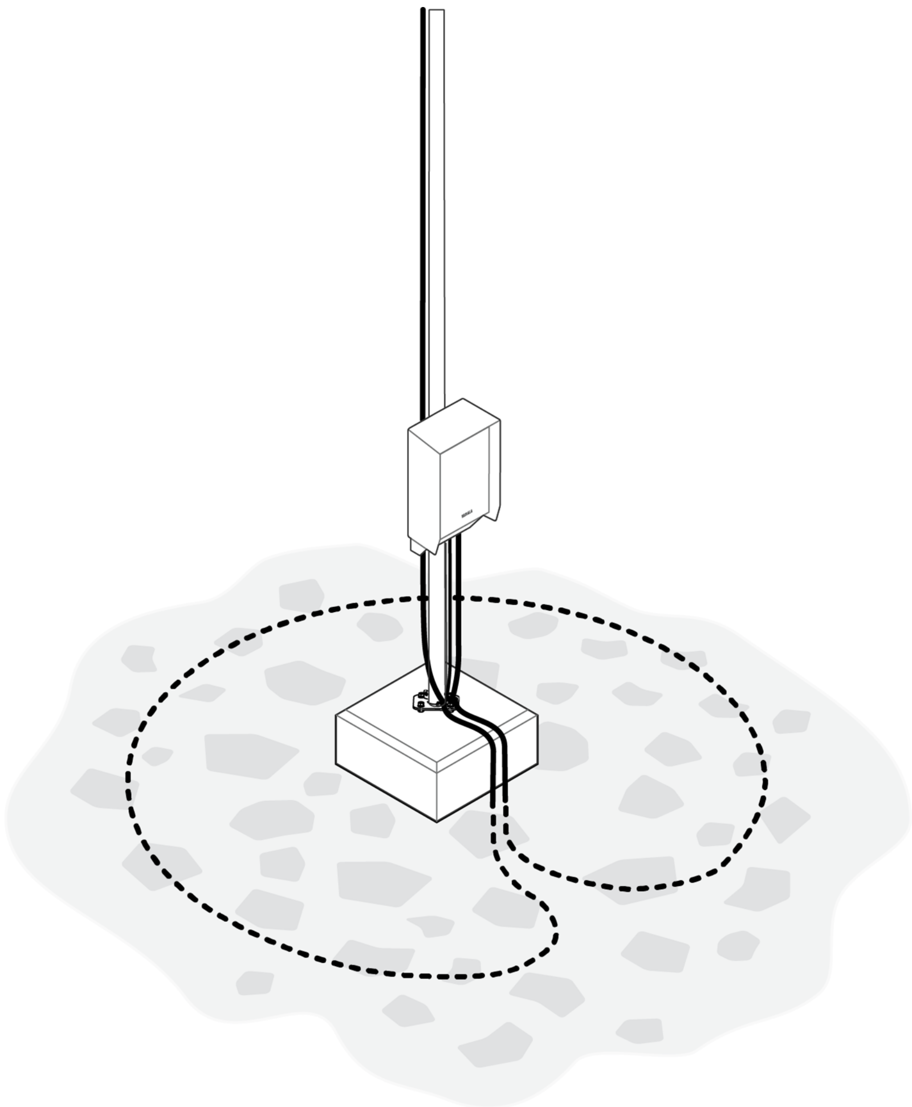

Figure 11 Loop Electrode in Shallow Topsoil

Use a horizontal ground electrode as a loop when the soil is shallow or rocky.

- Route the grounding cable from the grounding connector at the mast base to around the mast.
- Bury the ground electrode to a minimum of 60 cm (2 ft) deep or to moist soil, making a 5...6 m (16 ... 20 ft) diameter loop with the electrode. Guy wires are not needed.
- Connect the loop to the mast with two or more ground electrodes.
- To increase the current dissipation area and minimize ground impedance, enhance the loop with horizontal radials.

Do not make the wires run parallel any longer than absolutely necessary.

6.5 Installing Loop Electrode to Protect Sensors

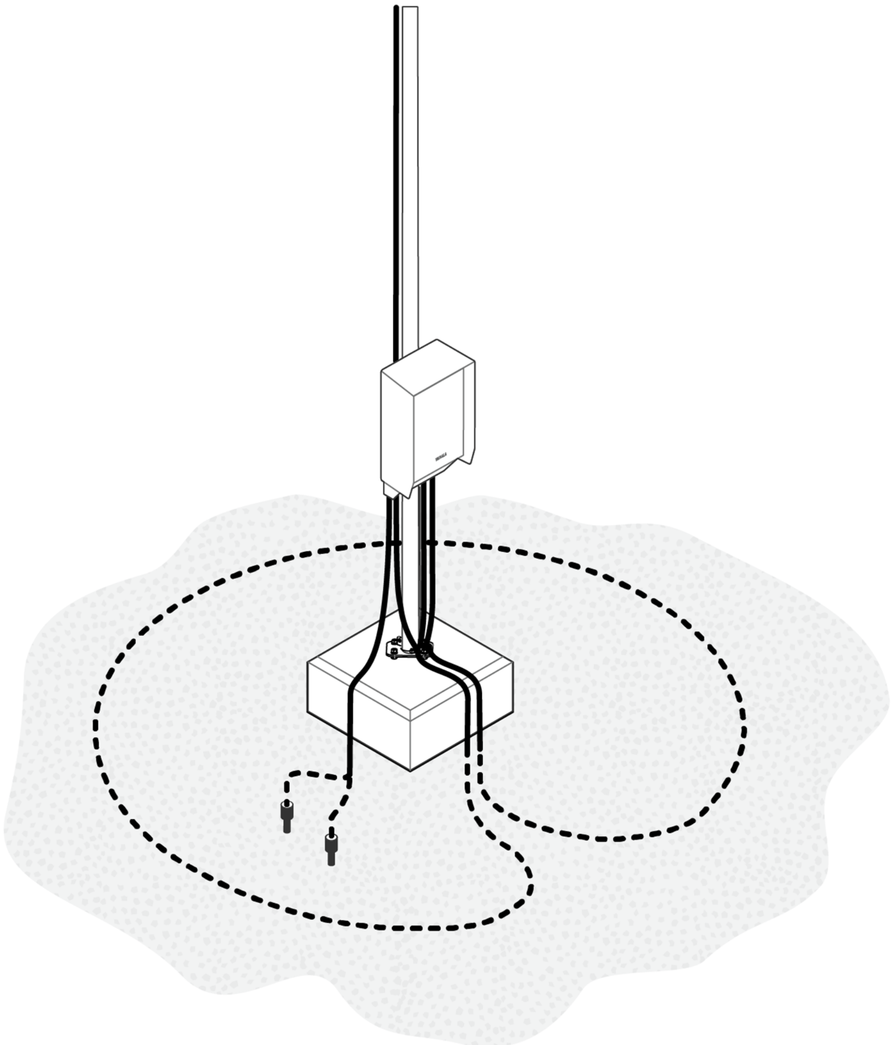

Figure 12 Loop Electrode to Protect Soil Sensors

Use a horizontal ground electrode as a loop to protect the soil sensors, for example soil moisture sensors. The loop prevents voltage differences from destroying the sensors and minimizes the effects of continuous ground currents (59/60 Hz hum) to the readings.

- Route the grounding cable from the grounding connector at the mast base to around the mast.
- Bury the electrode, making a 5 ... 6 m (16 ... 20 ft) diameter loop with the electrode. Guy wires are not needed.
- Make sure the buried loop electrode surrounds the sensors.
- Connect the loop to the mast with two or more connections.

Do not make the wires run parallel any longer than absolutely necessary.

More Information

- Installing Ground Electrode (page 37)

6.6 Installing Plate Electrode in Rocky Soil or Bare Rock

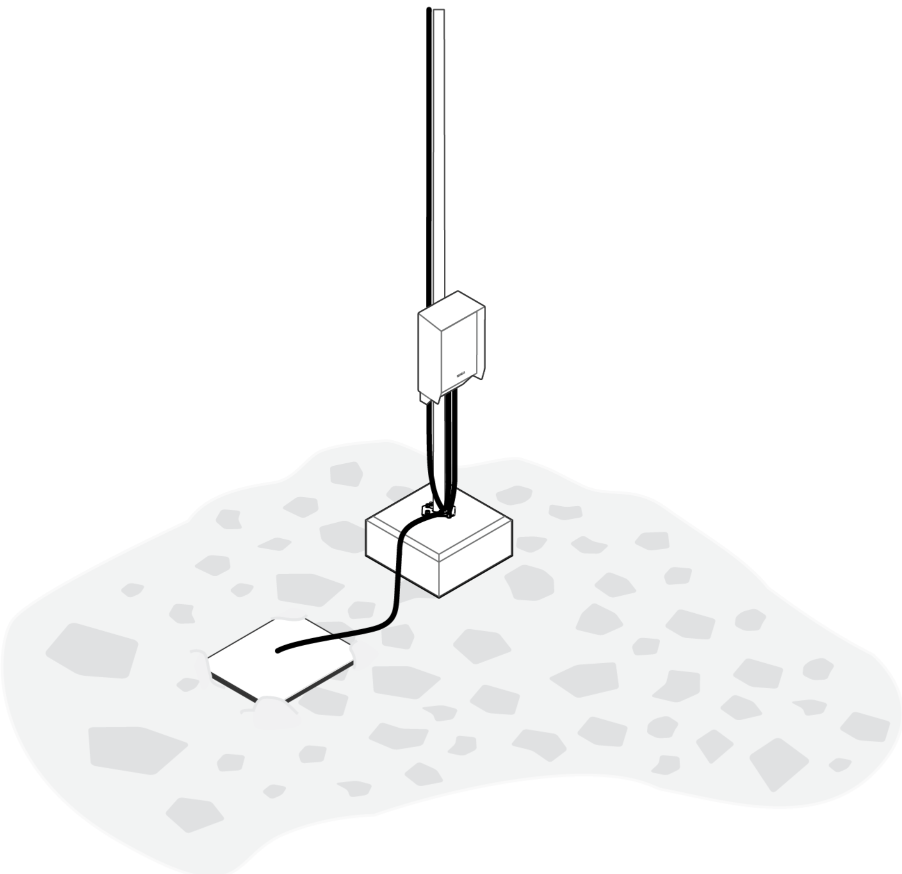

Figure 13 Plate Electrode in Rocky Soil or Bare Rock

Use a plate electrode on bare rock. The electrode distributes the lightning pulse, although the grounding resistance remains high.

> Rock is an insulator so do not drill holes in the rock to make a grounding.

- Route the grounding cable from the grounding connector at the mast base to the most desirable direction away from the mast.
- Place a plate electrode on the surface of the rock.
- To make sure the plate stays in place even during winter and high winds, fix the plate to the rock with bolts or by putting soil and rocks on the corners of the plate.
- Guide and solder the electrode to the plate. The distance of the plate from the mast can vary depending on the characteristics of the site. Keep the electrode as short as possible.

6.7 Installing Ground Electrode in Rocky Soil

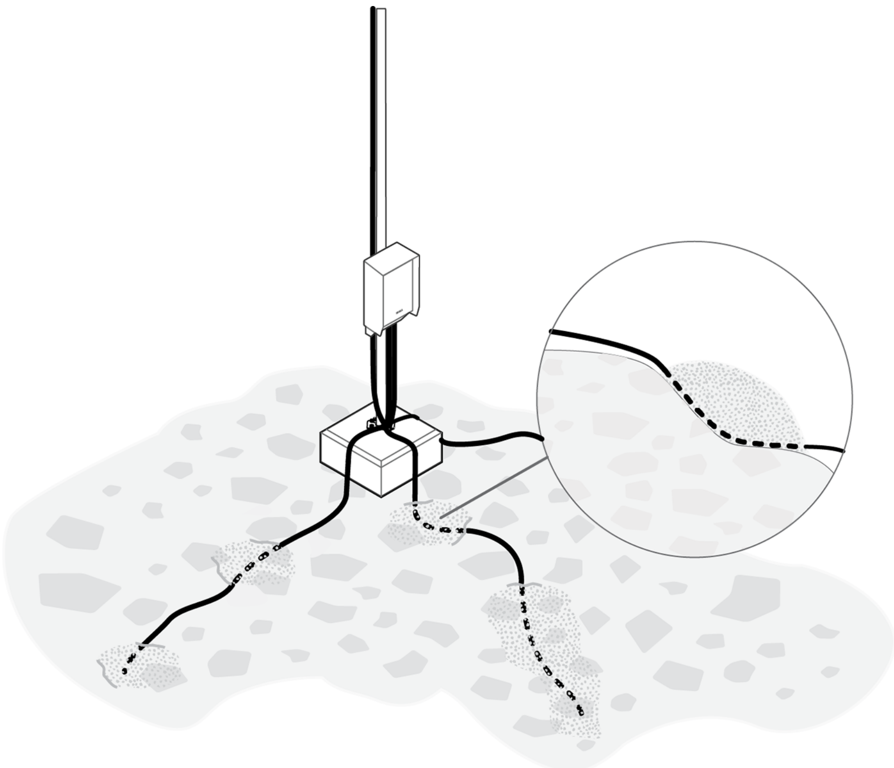

Figure 14 Grounding Cable in Rocky Soil

Use horizontal ground electrodes when there is some soil on rock surface. Spread the electrodes around the mast.

- Route the electrodes from the grounding connector at the mast base to the most desirable direction away from the mast.
- Use two or three electrodes. Using more electrodes lowers the impedance.
- Spread the ground electrodes on the rock surface and bury in patches of soil or fix with clamps to the rock.
- Cover a wide area of the surface to make a low-impedance capacitive ground electrode.

6.8 Installing Ground Electrode in Soft and Moist Soil

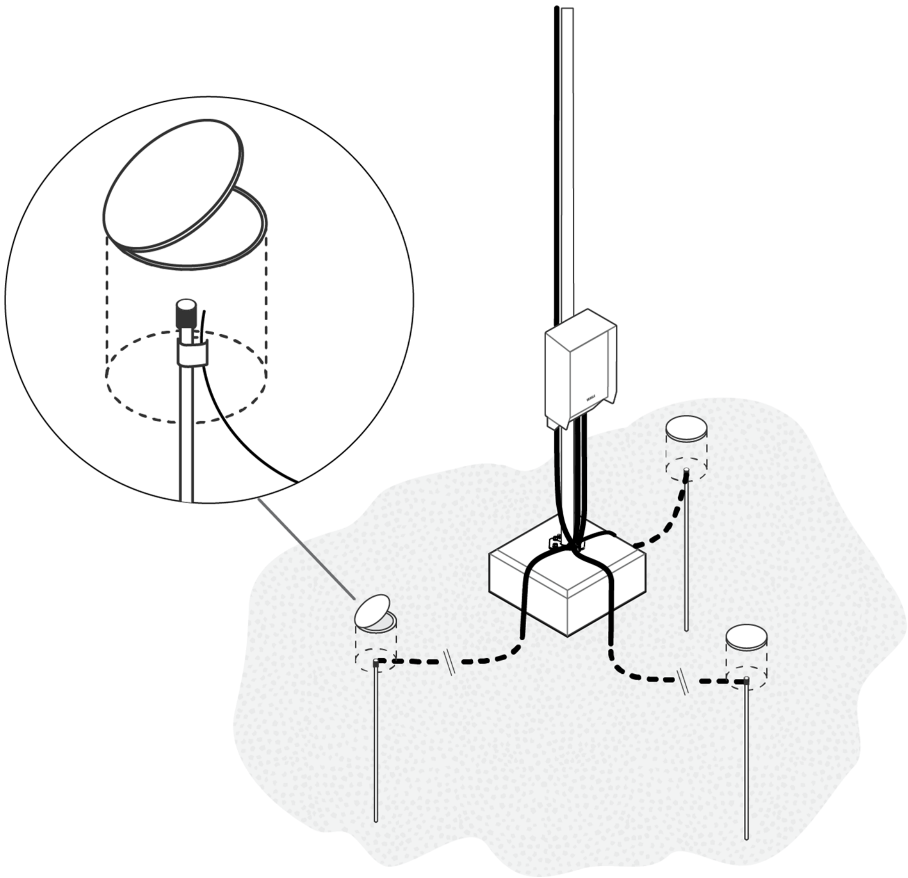

Figure 15 Ground Electrode in Soft and Moist Soil

Use horizontal ground electrodes, ground rods, and access wells when the soil is soft and moist. This system is fast to build, but the impedance is quite high although grounding resistance is within specifications. That is because two to three rods distribute the current to a fairly small area, causing high step voltages.

- Route the horizontal ground electrodes from the grounding connector at the mast base to the ground and towards the access wells. Bury the ground electrodes to a minimum of 60 cm (2 ft) deep or to moist soil.
- Use two or three ground electrodes.
- The minimum spacing of rods is at least two times the rod length, preferably more. If rod length is 2.5 ... 3 m (8 ... 10 ft), spacing must be 6 ... 8 m (20 ...26 ft).
- To lower impedance, use more electrodes, extend the electrodes further away, and/or bury them deeper to where soil is moist.
- Bury the ground rods into soil to a minimum of 3 m (10 ft) deep close to where you routed the horizontal ground electrodes.
- Connect the horizontal ground electrodes to the ground rods above the ground using exothermic welding or bolts.
- If you use bolted connections, install access wells around the connection points to protect the connections from moisture.
- If you use exothermic welding in the connections, access wells are not needed.

Check the access wells and bolted connections regularly.

The electrodes do not need to be evenly spaced. You can guide the transient current to the most desirable direction, for example away from buildings or other equipment, or towards better conducting soil by arranging the wires to that direction.

The minimum spacing of ground rods is two times the rod length. Otherwise their effective soil volumes overlap, decreasing efficiency.

Use access wells to protect the connections and help in maintenance. The access well must have room for hands and tools so that it is possible to check and tighten the connections if necessary.

The material of access wells can be metal, concrete, or plastic, for example. You can buy access wells or build them yourself, using a plastic tube with a water-proof lid.

The following figure shows ground rod installation in an access well.

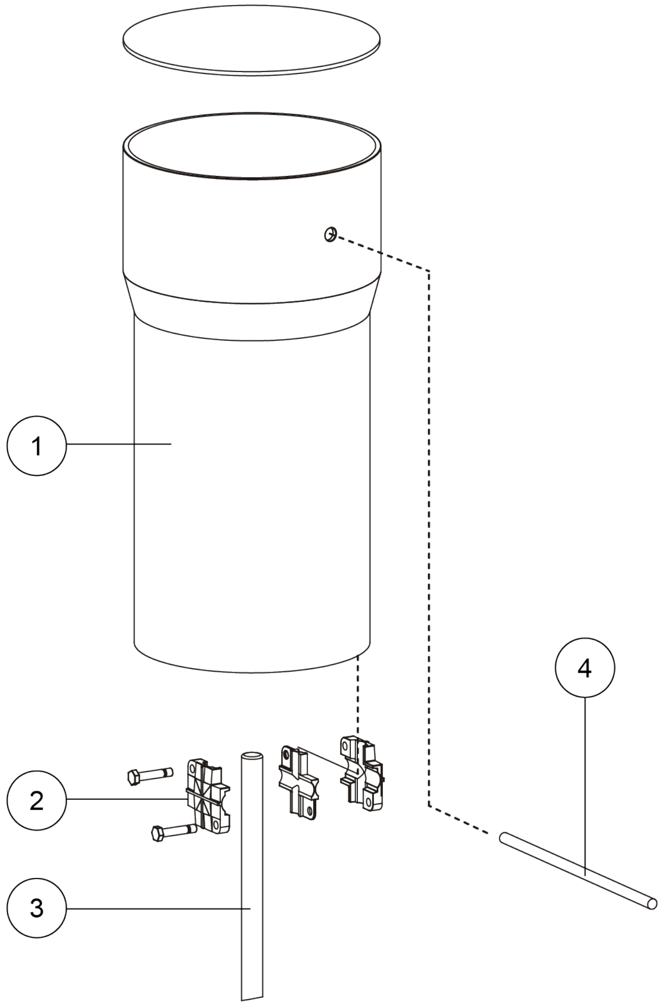

Figure 16 Installing Ground Rod in Access Well

1 Access well
2 Compression lug
3 Ground rod
4 Grounding cable

6.9 Installing Ground Electrode in Marsh or Salty Marsh

Use horizontal ground electrodes, ground rods, and access wells when the soil is soft and moist. Due to the very low soil resistance, one or two ground rods are sufficient. In populated areas, use two to four ground rods to avoid high step voltages.

- Route the horizontal ground electrodes from the grounding connector at the mast base to the access wells. You can guide the transient current to the most desirable direction.
- Use one or two ground electrodes.

> Do not make the wires run parallel any longer than absolutely necessary.

- If you use two ground rods, place them so that the minimum spacing is two times the rod length.
- Bury the ground rods into soil to a minimum of 3 m (10 ft) deep close to where you routed the horizontal ground electrodes.
- Connect the horizontal ground electrodes to the ground rods above the ground using exothermic welding or bolts.
- If you use bolted connections, install access wells around the connection points to protect the connections from moisture.
- If you use exothermic welding in the connections, access wells are not needed.

6.10 Installing Ground Electrode on Coastline or Island

Use horizontal electrodes for installations near coastline or on an island. Salty seawater provides for low impedance grounding.

- Use bronze, copper, and stainless steel.
- To lower impedance, use two ground electrodes if possible.
- Use electrodes that are at least 2 ... 3 m (6.6 ... 10 ft) long.
- Route the ground electrodes from the grounding connector at the mast base to the most desirable direction towards the sea.
- Attach the electrodes to a fixed point if seas are rough or there is a risk of ice formation.
- Make sure the electrode remains submerged all the time, even during low tide and other sea level variations.
- Check the equipment regularly for corrosion. Even the slightest amount of leakage current flowing from the equipment to the ground causes the electrode to corrode very fast.

In freshwater, use a somewhat longer submerged electrode, 5 ... 10 m (16 ... 33 ft).

Appendix A. Lightning Overvoltages

This section explains in brief how to protect equipment from lightning and from resulting transients.

A.1 Anatomy of Lightning Strike

The potential difference between a thundercloud charge center and ground is estimated to be of the order of 10 million to 100 million volts.

Lightning strikes:

- Only ~35 % of all lightning strikes are cloud-to-ground strikes in the northern hemisphere. Even less (~15 %) in the tropic.
- Majority (80 ... 85 % in Scandinavia) of cloud-to-ground strikes are negative. Positive strikes tend to double the current.
- The average thickness of a bolt is 2.5 ... 5.1 cm (1 ... 2 in) and the temperature in the strike channel exceeds 30 000 °C (50 000 °F).
- Single-strike discharges (which amount to about half of the negative strikes) or multi-strike discharges are possible.
- Up to 42 separate strikes have been recorded with 10 ... 90 ms intervals. A more common number of repetitive strikes is two. Positive strikes are usually single shots.
- The current pulse rise time is about 1 ... 20 µs (10 ... 90 %) and the duration (to half-value) is 50 ... 700 µs. Ground potential rise caused by the strike can last even longer.

Lightning strike current distribution (according to IEC 62305-1) is:

- 0.1 % > 600 kA
- 1 % > 200 kA
- 10 % > 80 kA
- 50 % > 35 kA
- 90 % > 10 kA
- 99 % > 3 kA

Standards recommend the following maximum values to be used when designing a lightning conductor (99 % confidence):

- Current 200 kA
- Maximum di/dt 200 kA/µs

Typical down conductors have inductance of the range of 1.5 uH/m. The voltage difference over a 10 m (33 ft) down conductor can be several megavolts.

A.2 Protection from Conducted Transients

Every Vaisala outdoor system has a capable two-stage transient protection in all external signal cables (leaving the site) and power connection cables. Local sensors with short cables may rely on the built-in protection on the signal interfaces.

Surge protection devices (SPD) cannot protect equipment against direct lightning strikes. They protect cables by neutralizing voltage surges that are caused by inductive or resistive (ground potential variations) coupling from nearby lightning strikes.

A.2.1 Lightning Transient Coupling to Signal Lines

Lightning transients have three main coupling paths:

1. Radio-frequency interference (RFI) with limited impact on anything. It can cause data packet loss or similar.
2. Induced voltages through magnetic or capacitive coupling. Use shielded signal cables and twisted pairs that are fairly immune against differential coupling. Still, common mode voltages can cause component damage.
3. Surge currents caused by localized shifts in ground potential. They cause relatively low-voltage, long-lasting common mode pulses, which can burn series impedance components in multi-phase surge protection circuits.

Ground potential shifts are a common cause of modem failures in systems connected to both the AC (mains) power and telecommunication networks.

A.2.2 Induced Surges in AC Lines and Telecommunication Lines

The voltage of a direct lightning strike is virtually unlimited. In a lightning strike to medium voltage AC distribution lines (over 30 kV), the voltage is air-gap limited to around 100 kV at transformers.

Recommended protection capacities in 230 VAC line are (according to IEEE C62.41):

- Category C: open distribution lines: 0 kV/10 ... 20 kA
- Category B: building entry point: 6 kV/3 kA
- Category A: distribution outlets: 6 kV/1 kA

An indirect strike within 100 m (330 ft) of cables or buildings can induce surges up to 5 kV and 1.25 kA in AC cables.

Telephone and instrumentation cables have higher series impedance, which typically limits the current to over 200 A.

- Category C: (high) 10 kA (design value, acceptable for many small surges)
- Category C: (low) 2.5 kA

A.2.3 Surge Protection Component Properties

Components and their properties:

- Air gaps are used especially in medium voltage distribution lines. They can handle very high surge currents, without very precise voltage limitation.
- Gas discharge tubes (GDT) can tame fairly high surge currents, but are relatively slow to trigger.
- Metal oxide varistors (MOV) are suitable for medium to high surges and quite fast, but do not limit the voltage very precisely.
- Transient-voltage-suppressor (TVS) diodes can take only small surge currents, but have an accurate clamp voltage and are very fast.

A.2.4 Protection Principle of Low-voltage AC Line

1. Install a first-stage arrestor (usually a metal oxide varistor) with over 20 kA current capability between the phase and neutral lines and from both lines to a low impedance ground.
2. Install a series inductor with adequate current rating on the line and on neutral conductors. Several meters of wire can also act as an inductor.
3. Install second-stage metal oxide varistors (over 3 kA rated) with lower voltage rating at the equipment mains input.
   Check that there are fuses or other overcurrent protectors in front of the first-stage arrestors.

A.2.5 Protecting Signal Lines

Protect signal lines using two-stage protection with a resistor in-between.

1. At the line end, install a 10 kA capable gas discharge tube (GDT) to system ground.
2. Install a series impedance.
3. Install a 600 W or 1.5 kW transient voltage suppression (TVS) diodes from line to line and from all lines to signal ground.
4. For best protection, select the TVS diode voltage to be as low as the used signal permits.

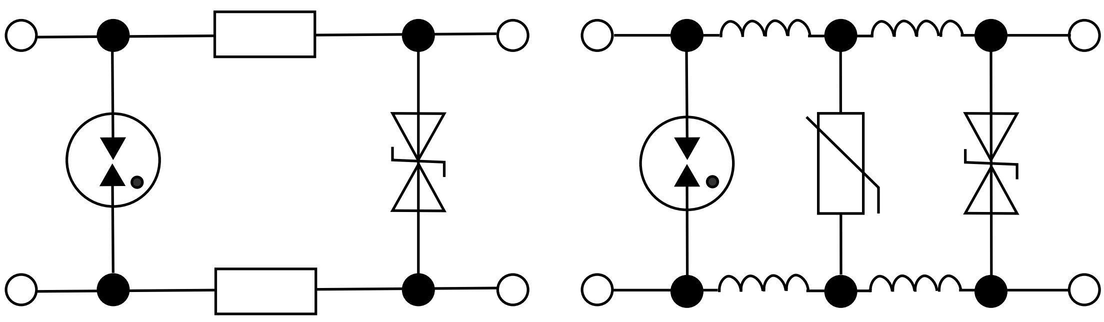

Figure 17 Signal Line Protection

A.2.6 Protecting Protectors

Transient current can destroy metal oxide varistors, gas discharge tubes, and transient voltage suppression diodes, or they deteriorate over time. They can fail-safe by shorting the connection and protecting the electronics. Include overcurrent protection in the series with the surge protection component.

There are two philosophies in overcurrent protection in case of a shorted protective component:

1. Install a series overcurrent protector (usually a fuse) and after it an overvoltage protector component. When the protector shorts and blows the fuse, a visit to the site is needed to repair the protector. The equipment is protected from further transients before the maintenance visit, but this method reduces system availability.
2. Overvoltage protectors (with fuses) are connected in parallel with the power/data line. When the fuse blows the overvoltage protector is disconnected from the line and system seems to operate normally. The situation can remain unnoticed until the next transient arrives and possibly destroys the protection of the system. Several commercial surge protection devices (SPD) are connected this way to maximize the short-term system availability.

The threshold voltage of gas discharge tubes (GDT) tends to creep lower after numerous trigger cycles. In certain applications, you need to test them periodically if the threshold voltage is critical for the system.

It is best to design overvoltage protecting devices that you can easily and safely replace several times during the technical lifetime of the system.

Appendix B. Reference Material

1. IEC 62305 Series international standards: Lightning Protection
    - IEC 62305-1: Part 1: General Principles
    - IEC 62305-2: Part 2: Risk Management
    - IEC 62305-3: Part 3: Physical damage to structures and life hazard
    - IEC 62305-4: Part 4: Elect. & Electronic systems within structures
    - IEC 62305-5: Part 5: Services
2. Cenelec international standards for lightning protection components:
    - EN 50164-1: Part 1: Requirements for connection components
    - EN 50164-2: Part 2: Requirements for conductors and earth electrodes
3. Underwriters Laboratories, Inc., (UL); Installation Requirements for Lightning Protection Systems, UL 96A
4. National Fire Protection Association, (NFPA); Standard for the Installation of Lightning Protection Systems, NFPA 780
5. Lightning Protection Institute, (LPI); LPI Standard of Practice, LPI-175
6. Suomen Sähkö- ja teleurakoitsijaliitto, Maadoituskirja ISBN 952-9756-72-0 (in Finnish)
7. Suomen Sähkö- ja teleurakoitsijaliitto, Rakennusten ylijännite- ja ukkossuojaus (ISBN 952-5382-70-2) (in Finnish)
8. U.S. Department of Transportation, Federal Aviation Administration Standard FAA-STD-019, Lightning Protection, Grounding, Bonding and Shielding Requirements for Facilities
9. Department of Defense Grounding Bonding and Shielding for Electronic Equipment and Facilities, MIL-HDBK-419A (1987)
10. Institute of Electrical and Electronic Engineers, Recommended Practice for Grounding of Industrial and Commercial Power Systems, IEEE Std 142-1991
11. IEEE Emerald Book; IEEE STANDARD 1100-1999, Recommended Practice for Powering and Grounding for Sensitive Electronic Equipment

Glossary

air terminal
An air terminal is part of a lightening protection system that attracts lightening strikes.

air-termination rod, air-termination conductor
See air terminal.

bonding
Bonding is a connection where you connect the electrically conductive parts of systems together galvanically to maintain an as equal as possible electrical potential between the parts. Bonding increases electrical safety and minimizes differential voltages.

conductive plate
A conductive plate is a copper sheet plate used as a special ground electrode on mountain tops or on bare rock when the ground electrode cannot be buried.

conductivity
Conductivity measures the material's ability to conduct electric current. When conductivity is low, resistance is high, and vice versa.

down conductor
A down conductor is part of a lightning protection system that conducts the lightning current from the air terminal to the ground electrode.

earth conductor
Earth conductor is a British English term. See ground electrode.

earth electrode
Earth electrode is a British English term. See ground electrode.

earth plate
Earth plate is a British English term. See conductive plate.

earth rod, earth lead-in rod
Earth (lead-in) rod is a British English term. See ground rod.

earthing
Earthing is a British English term. The American English term is grounding. See electrical safety grounding and grounding.

electrical safety grounding
Electrical safety grounding is grounding that reduces touch voltages in mains powered systems and enables the safety components inside the system to operate properly in fault conditions.

ground electrode
A ground electrode is part of a lightning protection system and has direct electrical contact with the ground, conducting and dispersing the lightning current into the ground. Ground electrode can be implemented by means of ground rods and conductive plates, for example.

ground potential rise
Ground potential rise is the phenomena of a large current flowing to ground through a ground electrode. The potential rise is highest at the point where current enters the ground, and declines with distance from the source. The change of voltage over distance can injure a person due to the voltage developed between two feet, or between the ground on which the person is standing and a metal object. Ground potential rise is a hazard to people and equipment.

grounding
Grounding is the physical connection of an electric circuit to the ground.

grounding resistance
Grounding resistance is the property of the grounding system to ground to conduct current to ground. The goal is to achieve the lowest feasible grounding resistance value for a certain site or application.

impedance
Impedance is the measure of the opposition that is presented to a (lightning) current when voltage is applied. In the context of lightning and grounding, the lower the impedance, the better.

inductance
Inductance is the property of a conductor by which a change in the current flowing through it creates a voltage in the conductor and in nearby conductors.

IT system
An IT system is a power distribution system where there is no connection between the ground and the equipment, except possibly through a high impedance route, and there is a direct connection between the ground and the electrical device being supplied. The letter ‘I’ stands for 'isolation' and ‘T’ stands for ‘terra’ (Latin for ‘earth’). IT system is defined in International standard IEC 60364. In an IT system, the line and neutral are isolated from ground.

lightning protection grounding
The purpose of lightning protection grounding is to attract lightning, disperse the lightning current to different paths, and ground the current.

lightning protection system, LPS
A lightning protection system is a system that reduces or prevents physical damage to a structure due to lightning. An external lightning protection system intercepts direct lightning strikes to the structure, and conducts the lightning current from the point of strike to ground. Equipment of an external lightning protection system include an air-termination system, a down-conductor system, and an earth-termination system (ground electrode system).

LPS
See lightning protection system.

safety grounding
See electrical safety grounding.

soil resistivity
Soil resistivity is the property of soil to conduct electricity. Soil resistivity is dependent on the mineral and moisture content of the soil. Soil resistivity is not homogenous.

step voltage

Step voltage is the voltage between the feet of a person standing near an energized grounded object. Step voltage poses a risk of electric shock. See also touch voltage.

TN system

A TN system is a power distribution system where the connection between the ground and the power-supply equipment is direct and the connection between the ground and the electrical device being supplied is such that there is a direct connection to neutral at the origin of installation.

touch voltage

Touch voltage is the voltage between an energized object and the feet of a person in contact with the object. Touch voltage poses a risk of electric shock. See also step voltage.

TT system

TT system is a power distribution system where there is a direct connection between the ground and the power-supply equipment (such as a generator or a transformer) and between the ground and the electrical device being supplied. The letter ‘T’ stands for ‘terra’ (Latin for ‘earth’). TT system is defined in International standard IEC 60364. In a TT system, the neutral wire is connected to the ground at the supply end (transformer or generator) or on the site.

Technical Support

Contact Vaisala technical support at helpdesk@vaisala.com. Provide at least the following supporting information:

- Product name, model, and serial number
- Name and location of the installation site
- Name and contact information of a technical person who can provide further information on the problem

For more information, see www.vaisala.com/support.

Recycling

Recycle all applicable material.