2018

SANKŌSHA

Eliminating Losses Caused by Lightning

Contents

It is both unwise and expensive to underestimate lightning. A single bolt of lightning can pack up to 100 million volts of electricity, which is why lightning protection systems (LPSs) are so important in reducing or eliminating loss caused by lightning in the United States.

Thunderstorms come into existence when warm air masses containing sufficient moisture are transported to high altitudes. Thunderclouds form when these warm updrafts, caused by the sun heating the Earth's surface, meet cold air entering the upper atmosphere. When the temperature inside these clouds is between -10° C and -20° C, ice particles are formed and collide with each other in the updrafts. These collisions cause charge separation, with small ice droplets becoming positively charged and the larger droplets becoming negatively charged and accumulating at the lower base of the cloud due to gravity. When the negative charge reaches a certain value, electrical discharge occurs both within the cloud and between the cloud and the surface of the Earth.

This separation of charge within the cloud produces enormous electrical potential. It can amount to millions of volts, and, eventually, the electrical resistance in the air breaks down and a flash begins. Lightning, in its simplest form, is an electrical discharge between positive and negative regions of a thunderstorm (Figure 2).

Figure 1: Over 40 million lightning strikes take place in the U.S. each year.

Lightning discharges can be divided into two types: cloud-to-ground discharges, which have at least one channel connecting the cloud to the ground, and cloud-to-cloud discharges, which have no channel to ground.

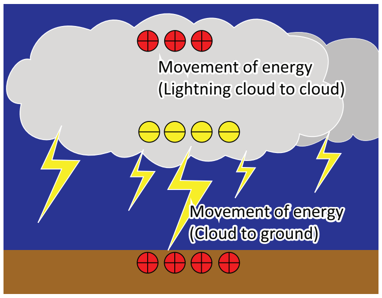


Figure 2: Lightning is an electrical discharge between positive and negative regions of a thunderstorm.

Cloud-to-ground lightning is the most damaging and dangerous form of lightning. A bolt of lightning has the power to rip through a roof, explode brick walls and cause fires. Lightning accounts for more than one billion dollars annually in structural damage to buildings in the United States, according to Underwriters Laboratories. Factory Mutual Insurance Company notes that between three and five percent of all commercial insurance claims are lightning related. Also, the National Weather Service puts the number of lightning strikes that occur in the US each year at over 40 million. On Earth, the lightning frequency is approximately 40-50 times a second or nearly 1.4 billion flashes per year.

During a thunderstorm, electric arcs strike through the air at half the speed of light and heat it up to as much as 20,000° C, or approximately four times the surface temperature of the sun.

About half of all lightning strikes reach 20,000 volts with — according to various studies — current ranging from 5 to 200 kA. Strikes can, however, occasionally exceed 100,000 volts and can travel up to three miles through the ground. Each flash of lightning typically has 3 to 4 strokes, but may contain as many as 30 individual strokes. The average region in the United States can expect between two to 30 strikes per year within a square mile.

Studies have also found that lightning's typical impulse has both high- and low-frequency content. The high-frequency component is associated with an extremely fast rising "front" on the order of 10 microseconds (μs) to peak current. The lower frequency component resides in the long, high-energy "tail" or follow-on current in the impulse.

Most lightning current is negatively charged, with wave peak lengths often between 2 and 4 μs, and mostly within a 1 to 20 μs range. Wave tail lengths fall within a 10 to 100 μs range.

Lightning damage can be caused by a direct strike or by induced lightning from a nearby strike. The amount of energy induced from lightning is dependent on the ability of the object to absorb the energy and the level of energy exposure. Experimentation has shown that a lightning strike nearly a mile away from telephone lines can induce more than 35 volts per meter of exposed wire. The lightning doesn't have to actually strike the wire since the energy is transferred into the wire by induction.

Countermeasures

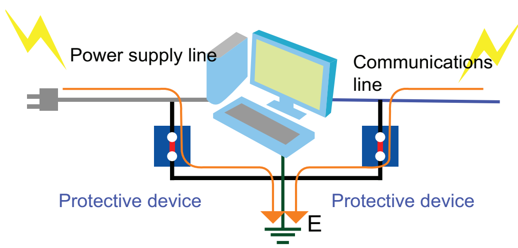
Damage from lightning strikes can be avoided with the installation of an LPS designed to control or provide a designated path for the lightning current to travel to ground. The purpose of an LPS is to protect building structures and people from lightning strikes and possible fire or explosion, as well as from the consequences of lightning currents.

Most LPSs are made up of several components, including the combined technology of lightning rods, conductors, surge arresters and suppressors, to protect electrical and electronic equipment. Regardless of the type of system, all must link to some type of ground terminals, usually in the form of metal rods driven into the earth. Vertically-driven earthing or grounding rods made of copper or, commonly, copper-clad steel, are generally one or two meters long and are provided with screwed ends in order to reach a considerable depth. Multiple earthing electrodes in a triangular or 'crow's foot' geometric design buried at least a half meter deep can be used if they are all interconnected.

Protection systems also require surge protection because electronic equipment and components are very vulnerable to voltage surges. Damaging surges may be produced by lightning, but also by such things as pumps

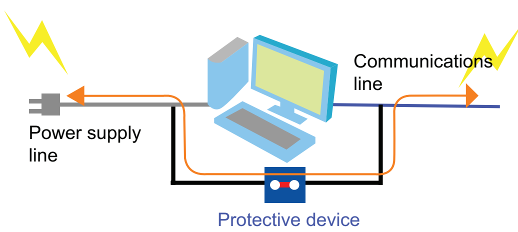
Table 1: Basic Concepts of Lightning Protection

SHARED GROUNDING



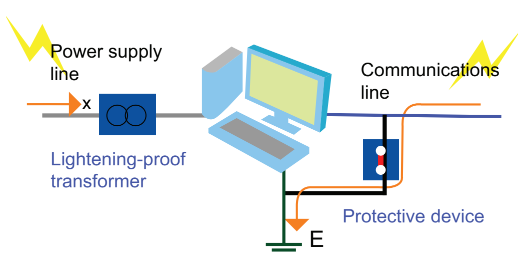
A proper protective device is attached to each equipment interface and the ground is shared. If there is a lightning arrester for each interface, or the arrester elements have separate grounds, there is a danger that a voltage potential difference will be generated between the grounds and that the equipment may be damaged.

BYPASS (EARTH-FREE) METHOD



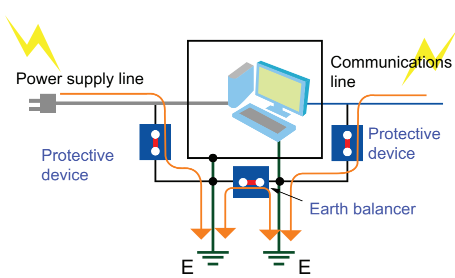
A proper protective device (operating at a lower withstand voltage than that between the interfaces) is attached to each equipment interface so that lightning is diverted by the protective devices and does not pass through the internal circuitry of the equipment. Since no grounds are needed, this method is effective for use in ordinary houses, where it would be difficult to lay grounds.

INSULATION METHOD



A lightning-proof transformer is used to electrically isolate the power supply system. Lightning is prevented from passing through to the internal circuitry of the equipment. In the protection of communication lines, standard protective devices tied to earth ground should be used or isolation transformers can be used if an earth ground is not easily accessible.

ISOLATION RESISTANCE



A lightning-proof transformer is used to electrically isolate the power supply system. Lightning is prevented from passing through the internal circuitry of the equipment. For the protection of power and communication lines, protective devices are installed. An earth balancer is used to prevent any excessive voltage potential differences between the two earth grounds.

being turned on or off, by starting up a transformer, or by a short in a power source. It is not unusual for a 120-volt power line to have as many as 2,500 surges each year.

Surge protection works by providing a path of lower resistance for electrical surges so they dissipate in the ground. No matter how elaborate the LPS, it's only as good as the grounding system that it is connected to. Good grounding breaks up the electrical energy of lightning and then directs it to a path to the ground that has low resistance. The resistance of the ground electrode and its connection is generally very low as ground rods are typically made of highly conductive materials such as copper or steel. The idea is to keep the ground resistance of the external LPS also as low as possible to minimize the effects of lightning strikes.

If the current has no path to ground through a properly designed and maintained grounding system, it will find an unintended path that could include people. A direct strike will release a massive amount of energy and this surge needs to be diverted quickly to the earth using equipotential bonding and the correct SPD (surge protective device), which suppresses excess voltage and current on electrical circuits.

Proper installation of grounding systems requires knowledge of national standards, conductor materials, connections and terminations. U.S. standards for complete LPSs include NFPA 780, UL96 and 96A and LPI 175. These are based on providing a reasonably direct, low-resistance, low-impedance metallic path for lightning current to follow.

Lightning can initiate a domino effect path of transient overvoltage that can disrupt and damage electronic systems and connected equipment. For example, in a factory production line, stoppages due to lightning damage can result in huge financial losses. Factories contain many types of equipment. Each type of equipment requires its own countermeasure (Figure 3), and as this e-zine will demonstrate, Sankosha addresses this need with a broad lineup of lightning protection products.

As one of the world's only comprehensive lightning protection companies, Sankosha's mission is to protect infrastructure (e.g. telecommunications, electric power, railways) from lightning and other natural disasters via detection, observation and countermeasures. Sankosha's direct lightning protection products deliver protection level 1 (direct lightning surge of 200 kA) performance and can be easily installed in areas that are prone to lightning strikes.

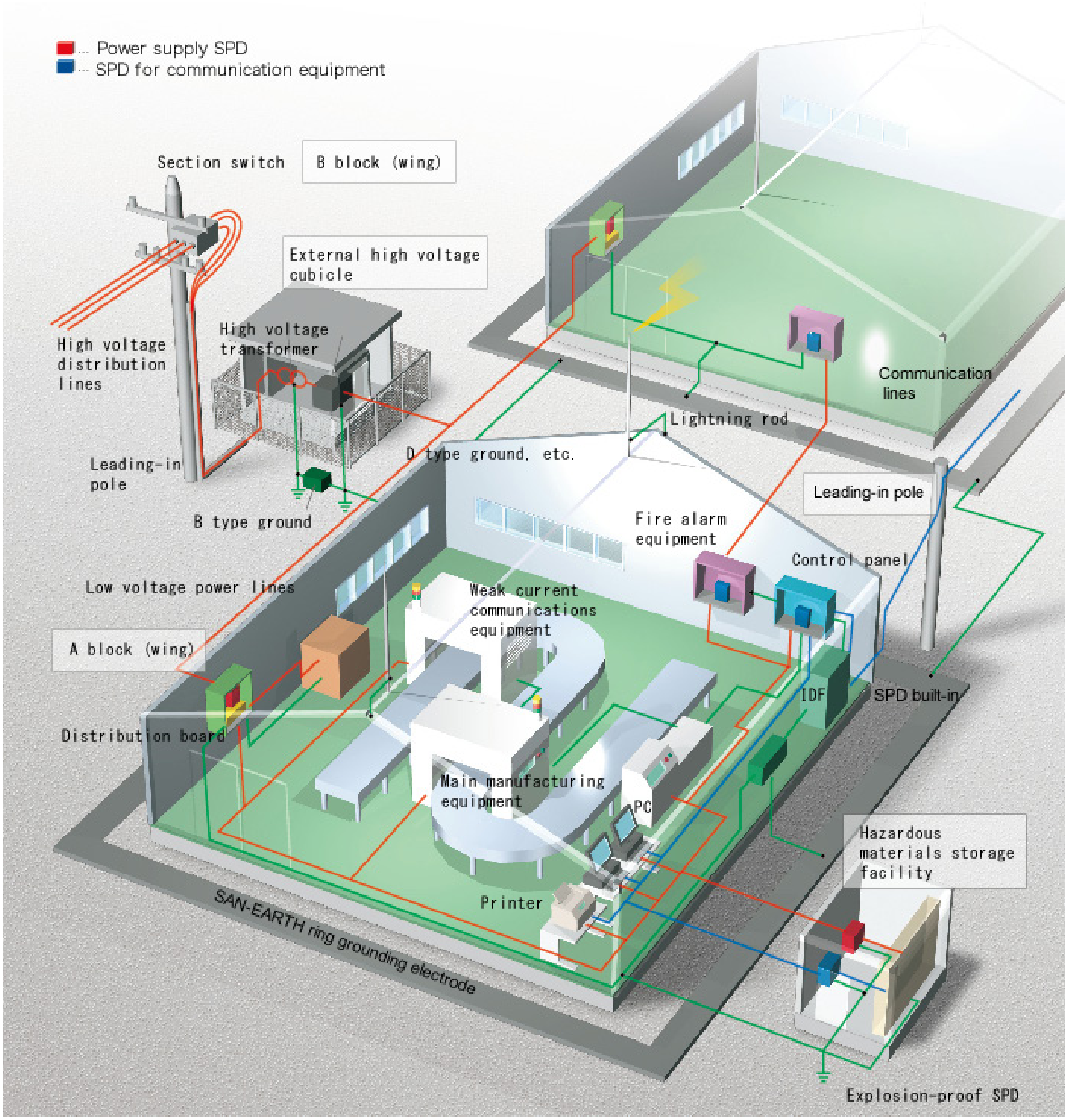


Figure 3: Lightning protection for factories.

Grounding

A good LPS has to start with proper grounding. All good grounding systems should provide low-impedance paths for lightning-induced currents to enter the earth, ensuring maximum safety. In a typical grounding strategy, an electrode is inserted into a deep hole that has been mechanically bored into the ground. The resistivity of the earth significantly impacts the overall impedance of the buried conductor. Resistivity can have a wide variance from place to place and over time. Soils with high organic content are usually good conductors because they retain higher moisture levels and have a higher electrolyte level, leading to low soil resistivity. Sandy soils and soils that drain quickly have much lower moisture content and electrolyte levels and consequently higher impedance. Solid rock and volcanic ash, such as that found in Hawaii, contain virtually no moisture or electrolytes. These soils have high levels of resistivity, meaning effective grounding can be difficult to achieve.

Soil characteristics such as moisture content, soil temperature and type determine the overall resistivity at any particular location. The soil's moisture enables chemicals in the soil that surround ground conductors to carry the electrical current. In general, the higher the moisture content, the lower the soil's resistivity. Soil resistivity greatly increases when the percentage of moisture in the soil drops below 20%. Temperatures below freezing also greatly increase soil resistivity. As soon as moisture turns to ice, resistivity increases sharply.

Soil should be tested to determine its characteristics. Soil resistivity is expressed in ohm-meters (Ω·m) or ohm-centimeters (Ω·cm). Soil models are the basis of all grounding designs and they are developed from accurate soil resistivity testing.

As just noted, one option available to lower soil resistivity is to increase the moisture content of the soil. Another is to use bentonite clay. Bentonite was discovered by Wilber C. Knight in the 19th century near Fort Benton (hence the name) in Montana. At around the same time, it was also discovered near Montmorillon, France. Bentonite is now a generic name for water-absorbing clay that usually contains montmorillonite, a 2:1 clay, meaning that it has two tetrahedral sheets of silica sandwiching a central octahedral sheet of alumina.

The largest source of bentonite in the United States is in Wyoming. In all, the nation produces 70% of the world's sodium bentonite. Bentonite from Wyoming can absorb up to 10 times its weight in water and expand up to 16 times its original size. But bentonite clay must be moist to provide the required resistance levels; its performance is completely dependent on its water content. So bentonite is typically mixed with a large amount of water before installing. When bentonite clay loses moisture, its resistivity increases and its volume decreases—it shrinks and thus pulls away from both the conductor and the surrounding soil—and it becomes ineffective.

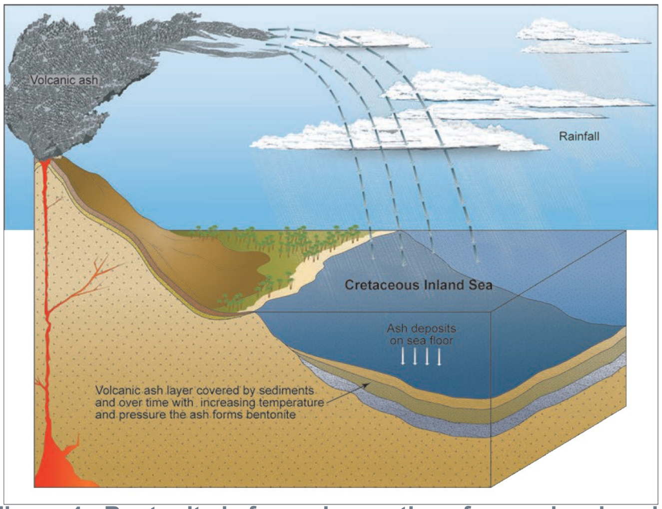


Figure 4: Bentonite is formed, over time, from volcanic ash.

Still another way to lower earth resistivity is to treat the soil with a salt, such as copper sulfate, magnesium sulfate or sodium chloride. Combined with moisture, the salts leach into the soil to reduce earth resistivity. However this process has a couple of downsides. First, as the salts wash away, the soil reverts to its untreated condition so the system must be recharged periodically. But more importantly, some salts may corrode the grounding conductors.

Artificial treatment of soil with gel electrolytes in the immediate vicinity of an electrode also may lead to a decrease in local resistivity. Care must be taken to avoid damaging surrounding landscaping or polluting the water table. Again, treating the soil surrounding an electrode does not necessarily reduce electrode resistance on a permanent basis, since rainfall and natural drainage may gradually wash the chemicals out of the soil and these materials will need to be replenished approximately every two to three years. If the soil is very sandy or is composed of gravel, clay with the property of absorbing water and swelling up to form a colloidal-type material can be used to fill the spaces between particles of sand or stone.

Conductive Cement

A better alternative, because it works under almost all soil conditions, is to use a ground enhancement material such as conductive cement, which has low resistivity in all forms (including powder and hardened forms) so it can be installed in different ways to improve grounding effectiveness. Conductive cement is typically a fine powder that makes excellent surface contact with its surroundings. Its resistivity, pH level and hardness when it dries are dependent on the ratio of carbon to cement. Ninety-nine percent of conductive cement used is for grounding systems.

In the mid-1970s, Chubu Electric Power Co. in Japan needed a grounding material that could be used in mountainous areas where access and construction were difficult and soil resistivity was typically high.

The material needed to not only have low resistivity but it also had to conform to rocky, uneven terrain, be usable above ground as well as below, provide protection to the copper electrode, not wash away or move, be environmentally safe and, because of the remote location, it had to be maintenance-free. In conjunction with the power company, Sankosha developed a conductive concrete named SAN-EARTH M5C, a mixture of fine carbon powder and Portland cement. It was patented in Japan and has been sold commercially since 1979. It will not leach into the soil and it meets EPA requirements for landfill. Unlike bentonite clay, the material does not depend on the continuous presence of water; nor does it require periodic charging treatments or replacement.

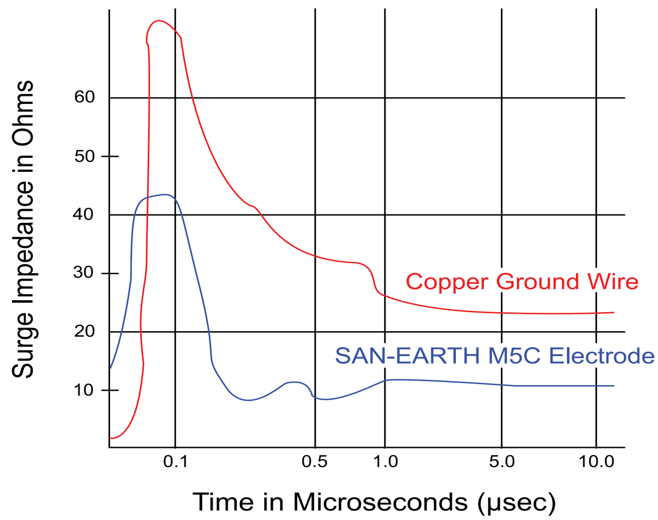


Figure 5: The fast response of SAN-EARTH M5C provides enhanced protection for sensitive equipment.

How efficiently grounding electrodes discharge electrons into the earth is called its 'sphere of influence.' Or, put another way, it is the volume of soil throughout which the electrical potential rises to more than a small percentage of the potential rise of the ground electrode when that electrode discharges current into the soil. Ground rods can be quite efficient. The greater the surface area, the greater the contact with the soil and the more electrical energy that can be discharged per unit of time.

Sankosha's SAN-EARTH is used to build conductive concrete grounding electrodes. Tests show that using an electrode surrounded by SAN-EARTH reduces surge impedance by more than 50% (particularly during the first critical 0-0.1 μs of the surge). The fast response (Figure 5) provides enhanced protection for sensitive equipment and represents a significant advantage over other grounding methods.

Next we'll take a closer look at SAN-EARTH M5C.

Conductive Concrete: A Key Element in any Lightning Protection Solution

The concept of a low-resistance path to the Earth is fundamental to electrical theory and practice. When designing and installing electrical systems, proper grounding is a necessity. If lightning or power fault-induced currents have no easy path to Earth, they will find unintended paths that may cause damage to equipment or, worse yet, injury to personnel. Good grounding is essential to prevent damage in industrial facilities where millions of dollars of equipment and products can be ruined in a flash. A large thunderstorm can produce over 100 lightning strokes a minute and even a modest storm cloud can generate hundreds of kiloamps.

Fortunately, lightning is one of the only forms of natural disaster where the impact can be controlled. Well-designed surge protection devices coupled with a low resistance path to Earth are the most important factors in providing protection for both personnel and equipment.

All LPSs must terminate in a connection to Earth, where the lightning strike current will finally travel into the soil and dissipate. Grounding systems must provide low Earth impedance as well as low resistance. The most important factor affecting grounding resistance is the soil resistivity where the electrode is installed. In areas where resistivity is high, special steps must be taken to ensure a low resistance path to Earth.

Grounding resistance and soil resistivity are, by definition, always proportional. When the dimensions of the electrode are known, resistance can be expressed as follows:

$$R = \rho \times f$$

Where:
R = grounding resistance
ρ = soil resistivity
f = a function determined by the shape and size of the electrode

Soil resistivity is a measure of how much the soil resists the flow of electricity. An understanding of soil resistivity and how it varies is necessary in order to design an effective grounding system. The resistivity of soil is, in fact, influenced by many factors and fluctuates constantly—it is typically lower in summer and higher in winter.

There are two ways to determine the resistivity of the soil at a certain site. The first is to actually measure the resistivity itself with specialized equipment. The second is to drive a ground rod of known length and diameter into the ground and to measure its grounding resistance. That reading can then be used to calculate the resistivity of the surrounding soil.

Soil characteristics, including moisture content, temperature and composition (Figure 1) determine the overall resistivity at any particular location. Soil with high organic content tends to be a better conductor because it retains a higher moisture level. Some varieties of soil and earth are highly resistive and can act like insulators. Typical soil does not permit electric current to flow when it is completely dry (although soil is almost never found completely dry in its natural state). Sandy soils have much lower moisture content and tend to have higher resistivity.

CLASS OF SOIL	RESISTIVITY (Ω - m)
Paddy of clay and swamps	10 ~ 150
Farmland of clay	10 ~ 200
Seaside sandy soil	50 ~ 100
Paddy or farmland with gravel stratum	100 ~ 1,000
Mountains	200 ~ 2,000
Gravel, pebble seashore or parched river bed	1,000 ~ 5,000
Rocky Mountains	2,000 ~ 5,000
Sandstone or rocky zone	10^4 ~ 10^7

Figure 1: Soil type and resistivity (Source: SAN EARTH Technical Review)

The soil's moisture content is important because it helps chemicals in the soil that surround ground conductors to carry electrical current. In general, the higher the moisture content, the lower the soil's resistivity. When moisture content falls below 20%, resistivity increases significantly (Figure 2).

After moisture, the factor that has the biggest effect on the resistivity of soil is temperature. Figure 3 below shows how the resistivity of soil varies with changes in temperature and the rate of its increase as temperature declines.

Temperatures below freezing increase soil resistivity dramatically so grounding systems should be installed below the frost line to maintain a low-resistance ground. When the moisture turns to ice, its resistivity increases sharply.

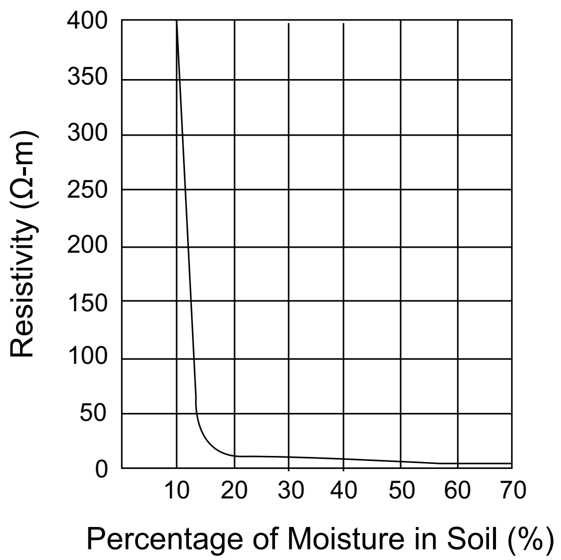


Figure 2: Percentage of moisture in soil versus resistivity.

Temperature	Ground Resistivity (Ω - m)	Rate
20° C	72	1.0
10° C	99	1.4
0° C	130	1.8
0° C (ice)	300	4.2
-5° C	790	11.0
-15° C	3,300	45.9

Figure 3: Soil temperature versus resistivity (Source: SAN EARTH Technical Review)

SAN-EARTH M5C

Ground enhancement materials are used in areas with high soil resistivity to reduce grounding resistance. SAN-EARTH M5C is a fine powder packaged in 25 kg (55 lb.) bags that provides an environmentally safe, long-term solution to many grounding problems. It was originally developed to aid in the grounding of electric power transmission lines in mountainous areas where construction is difficult and soil resistance values tend to be high. SAN-EARTH M5C reduces resistance to ground by up to 50%, lowers surge impedance significantly, is environmentally safe and reduces corrosion in grounding conductors.

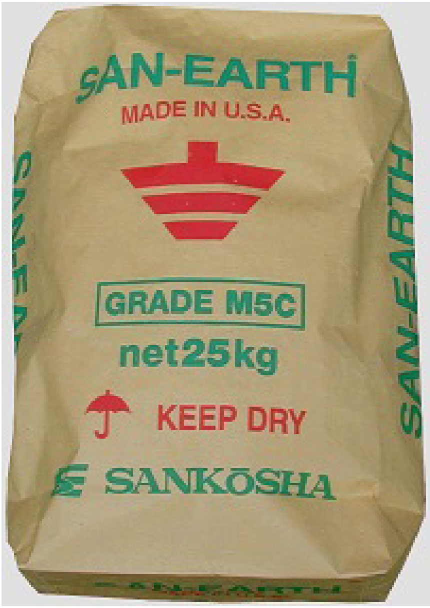


Figure 4: SAN-EARTH M5C electrodes provide the low resistance grounding essential to any LPS.

SAN-EARTH M5C is frequently used as a grounding material because of its convenience and effectiveness. It can be deployed in two forms, as a powder that can be spread over the ground or as a grout or slurry that can be poured. In general, no water is required when grounding with SAN-EARTH M5C. It is designed to solidify by absorbing the moisture from the surrounding soil. This makes it perfect for use in grounding at sites where a supply of water is not readily available.

SAN-EARTH M5C grounding electrodes are easily installed by spreading the dry powder in a strip over and around a conductor in a horizontal trench. One bag (Figure 4) is enough to build a two-foot-wide, ten-foot-long electrode. When the trench is refilled, SAN-EARTH M5C absorbs moisture from the surrounding soil and hardens to become part of the grounding electrode. The surface area of the electrode is dramatically increased, resistance is substantially reduced and surge impedance is lowered significantly. The hardened SAN-EARTH M5C also acts as a theft-deterrent for the conductor.

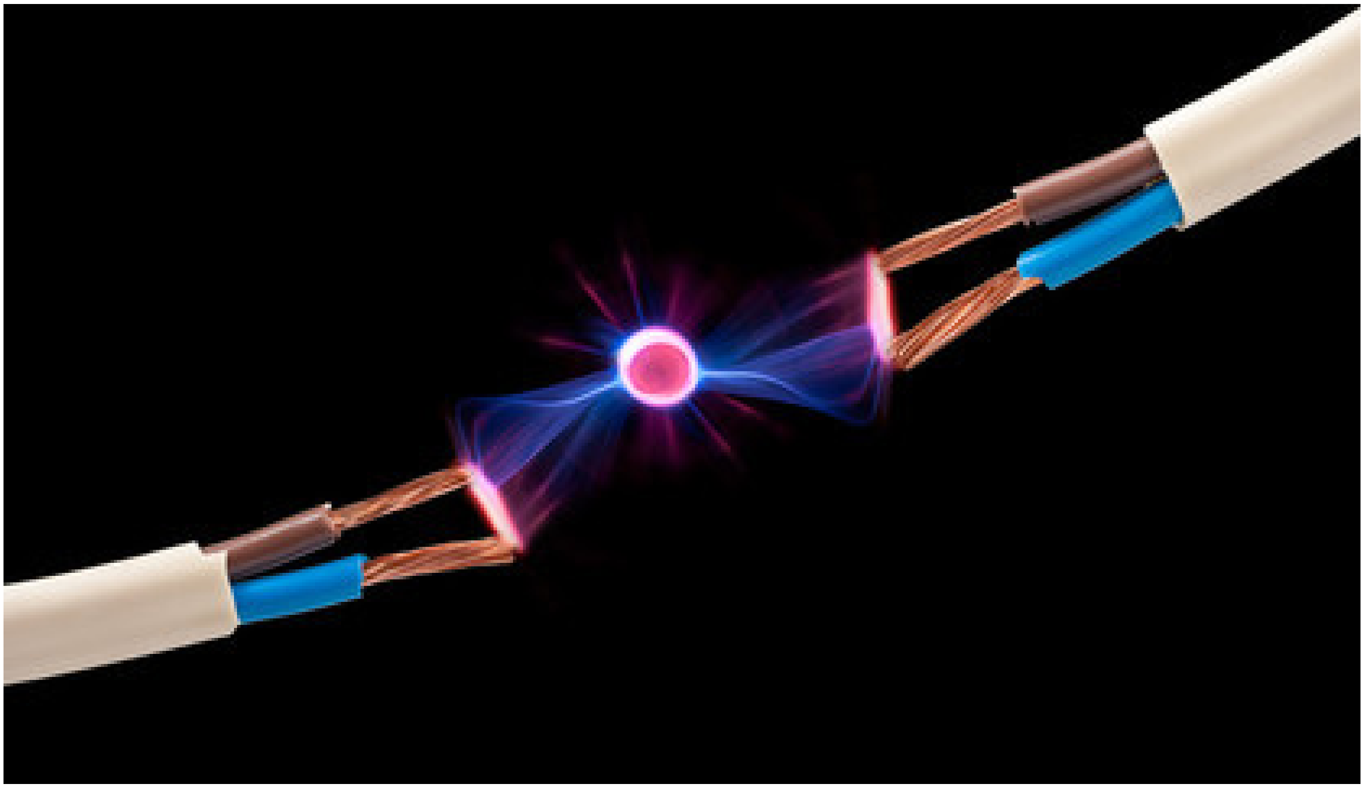
In normal conditions, an electrolytic reaction occurs when any metal buried in the ground is exposed to a positive electric current. That reaction caused by ionic conductivity can result in serious corrosion of the metal. This condition can be avoided through the use of SAN-EARTH M5C. Covering the metal with SAN-EARTH M5C creates conduction between the metal and the ground enhancement material, reducing the electrolytic reaction and preventing the metal from corroding. Studies show that corrosion is reduced by a factor of ten in electrodes that are encased in SAN-EARTH M5C.

SAN-EARTH M5C offers many advantages over bentonite, a material discovered by Wilbur C. Knight in the 19th century near Fort Benton, Montana. Bentonite is a term now used as a general description of water absorbing clay and is known by such names as Wyo-Ben or Lynconite II. In its powder or dry form, bentonite is a very poor grounding backfill material due to its high resistivity. Consequently, it is typically mixed with large amounts of water before installation. Then it is poured as a liquid or gel into the grounding system. Bentonite cracks and shrinks dramatically and returns to its non-conductive state as it dries. Unlike bentonite, SAN-EARTH M5C has a low resistivity in its powder form, slightly wet form, very wet form or hardened form—it remains conductive and can be installed in many different ways.

SAN-EARTH M5C is manufactured in accordance with Sankosha's ISO 9001 Quality Standards and conforms to IEC Standard 62561-7, which specifies the requirements and tests for earthing enhancment compounds producing low resistance in an earth termination system. The tests required by this standard include leaching, sulfur content, resistivity and corrosion. IEC 625561 also details the requirements of the structure and content of the test report (see sidebar).

The consistent performance of SAN-EARTH M5C grounding systems has been monitored for more than 30 years. Independent testing has proven SAN-EARTH is environmentally safe and has shown that SAN-EARTH-covered copper electrodes last ten times longer than bare copper ground wires.

For more information about SAN-EARTH M5C conductive grounding cement click here.



IEC 63561-7 Specifications

Lightning protection system (LPS) components, Part 7 (or IEC 62561-7): "Requirements for Earthing Enhancing Compounds," was published in November 2011 by the International Electrotechnical Commission (IEC), a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees).

IEC 62561-7 specifies product requirements including general performance, documentation, material and marking. The tests required by this standard include leaching, sulfur content, resistivity and corrosion. One requirement for earthing enhancement materials is that they must be chemically and physically stable. They must be chemically inert to the surrounding soil and must not leach over time. Conformance is verified by testing in accordance to EN 12457-2 "Characterization of Waste - Leaching -Compliance Test for Leaching of Granular Waste Materials and Sludges - Part 2" and EN 12506 "Characterization of Waste - Analysis of Eluates."

If an earthing enhancement material contains a significant amount of sulfur, it can corrode the ground rod electrode. IEC 62561-7 requires that any earthing enhancement material contains less than two percent sulfur. Conformance to this requirement is verified by testing to ISO 14869-1 "Soil quality – Dissolution for the Determination of Total Element Content -- Part 1: Dissolution with Hydrofluoric and Perchloric Acids."

Although the IEC does not require a minimum resistivity value for earthing enhancement materials, it does prescribe that all manufacturers of materials used for earthing enhancement test the resistivity in accordance to ASTM G57 "Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method."

The test for corrosion covers the procedure for determining the corrosiveness of materials used as earth enhancement compounds. The corrosion rate is determined by using potentiodynamic polarization resistance methods as outlined in ASTM G59-97 and ASTM G102-89. The resulting open circuit potential polarization curves will be used to determine the Tafel curves and polarization resistance. The significance of the test is important because earth enhancement materials have to be physically and chemically inert with the earth electrodes in order to avoid corrosion damage to the earthing electrode.

SAN-EARTH M5C
Conductive Concrete FAQs

Question **What is SAN-EARTH M5C conductive concrete?**

Answer SAN-EARTH M5C is a fine cement-based powder that provides environmentally safe, long-term solutions to many grounding/earthing problems.

Question **When was SAN-EARTH M5C first developed?**

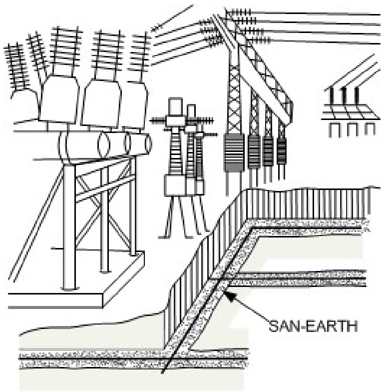
Answer SAN-EARTH M5C was first developed in the 1970s to aid in the earthing of electric power transmission towers in mountainous areas where construction is difficult and soil resistivity tends to be high.

Question **How does it work?**

Answer One of the basic principles in using SAN-EARTH M5C is to create the largest surface area possible that is in full contact with the surrounding soil. By doing this, any fault current event will be dissipated into the surrounding earth with the least resistance possible. SAN-EARTH M5C has been shown to reduce resistance to ground by up to 50%. The effective surface area of the SAN-EARTH M5C grounding electrode is more than 50 times larger than the counterpoise wire.

Question **Are there various applications for SAN-EARTH M5C?**

Answer Yes. SAN-EARTH M5C can be applied in many different areas of industry. These are just some of them: electric transmission and distribution towers, substations, surge protection, telecom networks, motorway and rail communication networks, fiber optics, computer systems and wind farms. SAN-EARTH M5C is typically used as a safe, long-term replacement for earthing rods.



Question **Do you need to mix SAN-EARTH M5C with water before installing?**

Answer SAN-EARTH M5C is typically installed as a dry powder to create a horizontal electrode. However, it may also be mixed with water and applied as a mortar if space is limited and a vertical electrode is required.

Question **What size are the bags of SAN-EARTH M5C?**

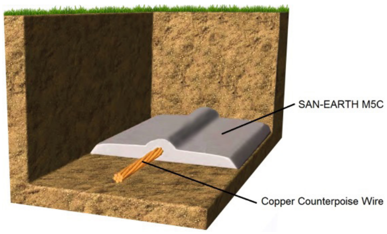
Answer The SAN-EARTH M5C is packaged in 55 lb. (25 kg) bags. There are 36 bags on a pallet.

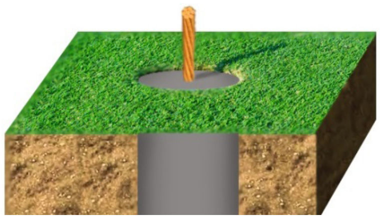
Question **Does SAN-EARTH M5C remain a powder?**

Answer No. SAN-EARTH M5C is generally applied as a dry powder. Once covered and compacted, the powder draws in moisture from the surrounding earth and sets solid, achieving an ultimate strength in 28 days of about 3000 psi. SAN-EARTH M5C absorbs moisture from the surrounding soil and hardens to become a conductive solid. The surface area of the electrode is dramatically increased, resulting in significant reductions in both resistance to ground and surge impedance. In this way, SAN-EARTH M5C offers important advantages over chemically charged electrodes and other ground enhancement materials.

Question **How is SAN-EARTH M5C typically installed in grounding applications?**

Answer SAN-EARTH M5C is typically installed in one of two ways. Installing as a lateral electrode plate is the recommended method as this gives the best results. This is typically achieved by digging a trench and placing a copper counterpoise wire in the center and pouring a layer of SAN-EARTH M5C with the wire completely encased. The second typical installation is in a vertical hole around a grounding rod. It is recommended to mix the SAN-EARTH M5C with enough water so that it can easily be poured into the hole. Both methods will greatly improve the performance and life of the grounding system when compared to using bare copper wire or grounding rods.





Question **How many bags of SAN-EARTH M5C do I need to use for my application?**

Answer Each 55 lb. bag contains 0.83ft^3 (0.02342m^3) of dry material. When mixed with water, the volume only slightly increases. You should know that placing 18 bags of SAN-EARTH M5C results in a resistance four times lower than would be achieved with four chemically charged ground rods and costs 65% less. Also, SAN-EARTH M5C sets up much better than other similar products, so less material is required. One bag is enough to install a two-foot-wide, ten-foot-long electrode. Other manufacturer's specifications require three times as much material. For the two most common uses, refer to the following charts. For other methods, please contact Sankosha with your design requirements.

Lateral / Trench Installation - Estimated Length One 55lb Bag of SAN-EARTH M5C Covers						
TRENCH WIDTH	AVERAGE THICKNESS OF SAN-EARTH M5C LAYER					
	0.25in (0.6cm)	0.5in (1.3cm)	1in (2.5cm)	3in (7.6cm)	6in (15.2cm)	12in (30.5cm)
0.25ft (7.62cm)	158.8ft (48.4m)	79.4ft (24.2m)	39.7ft (12.1m)	13.2ft (4.0m)	6.6ft (2.02m)	3.31ft (1.01m)
0.50ft (15.24cm)	79.4ft (24.2m)	39.7ft (12.1m)	19.8ft (6.0m)	6.6ft (2.02m)	3.31ft (1.01m)	1.65ft (0.503m)
1ft (30.48cm)	39.7ft (12.1m)	19.8ft (6.0m)	9.9ft (3.0m)	3.31ft (1.01m)	1.65ft (0.503m)	0.83ft (0.253m)
2ft (60.96cm)	19.8ft (6.0m)	9.9ft (3.0m)	4.96ft (1.51m)	1.65ft (0.503m)	0.83ft (0.253m)	0.41ft (0.125m)
3ft (91.44cm)	13.2ft (4.0m)	6.6ft (2.02m)	3.31ft (1.01m)	1.10ft (0.335m)	0.55ft (0.168m)	0.28ft (0.085m)

Vertical / Grounding Rod Installation - Estimated Number of 55lb Bags of SAN-EARTH M5C Needed							
HOLE DIAMETER	LENGTH OF ROD / DEPTH OF HOLE						
	3ft (0.9m)	5ft (1.5m)	6ft (1.8m)	8ft (2.4m)	10ft (3.0m)	15ft (4.6m)	20ft (6.1m)
4in (10.16cm)	0.32 bags	0.53 bags	0.63 bags	0.84 bags	1.06 bags	1.58 bags	2.11 bags
6in (15.24cm)	0.71 bags	1.19 bags	1.42 bags	1.90 bags	2.37 bags	3.56 bags	4.75 bags
8in (20.31cm)	1.27 bags	2.11 bags	2.53 bags	3.38 bags	4.22 bags	6.33 bags	8.44 bags
10in (25.40cm)	1.98 bags	3.30 bags	3.96 bags	5.28 bags	6.60 bags	9.98 bags	13.19 bags
12in (30.48cm)	2.85 bags	4.75 bags	5.70 bags	7.60 bags	9.50 bags	14.25 bags	18.99 bags

Question **How long can SAN-EARTH M5C electrodes be expected to last?**

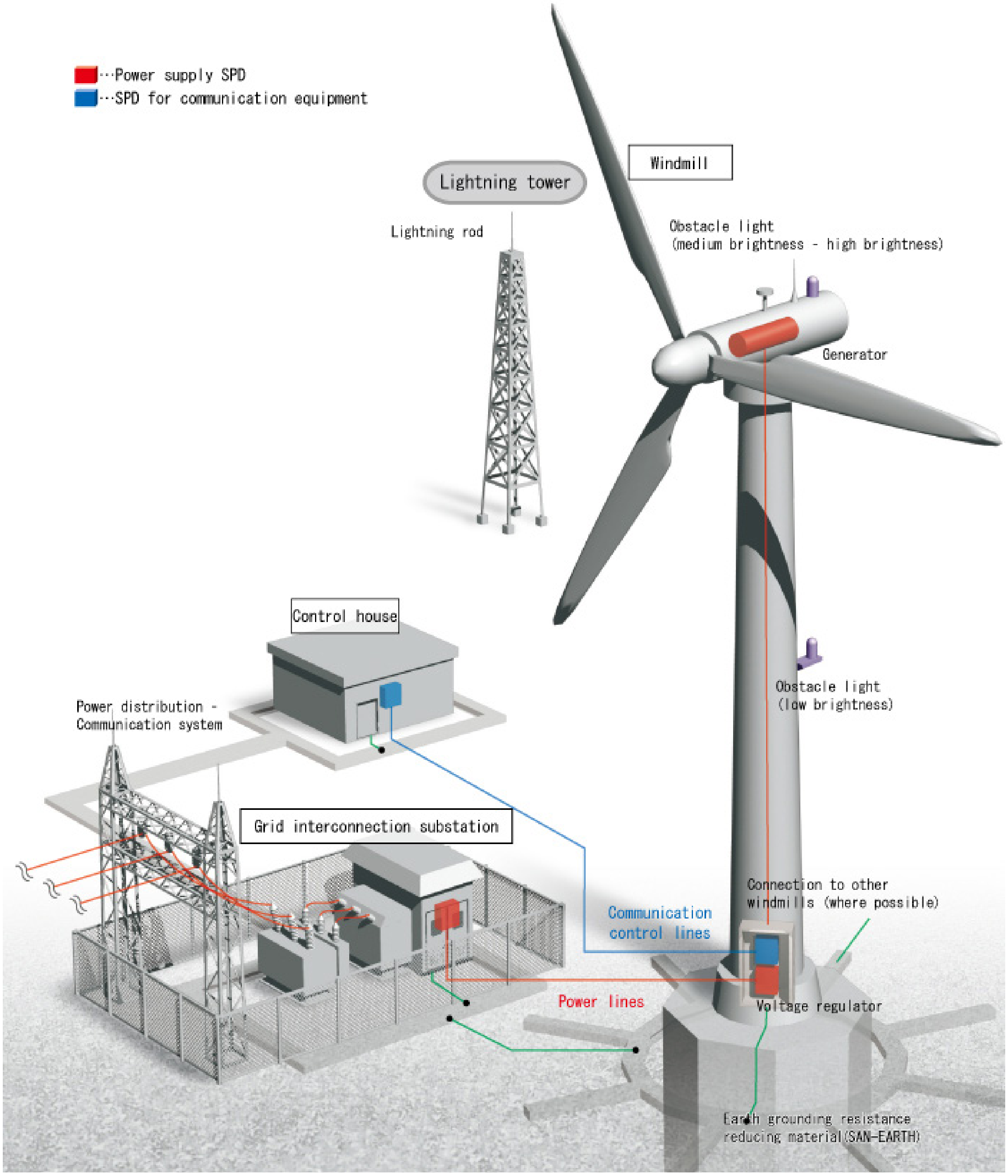
Answer Monthly measurements of SAN-EARTH M5C electrodes created in 1978 have shown consistent performance for over 40 years and are expected to continue performing well beyond 50 years. Corrosion is reduced by a factor of 10 in electrodes that are encased in SAN-EARTH M5C, allowing them to last a very long time.

Question **How is the copper conductor affected by SAN-EARTH M5C?**

Answer SAN-EARTH M5C reduces corrosion in the copper electrodes it covers so they will last up to 10 times longer than bare conductors would. It also acts as a theft deterrent for the copper conductor.

Question	**How does SAN-EARTH M5C compare to bentonite-based products?**
Answer	Bentonite-based products rely on water to be the conductor and greatly change size based on their water content. There is a huge risk involved when using bentonite products as they do not give consistent results, especially in dry locations where a ground enhancing material is typically desired due to high soil resistivity. SAN-EARTH M5C gives excellent and consistent performance in all environments.
Question	**How does SAN-EARTH M5C compare to other similar conductive cement products?**
Answer	SAN-EARTH M5C is the original conductive cement. Other similar products often induce galvanic corrosion and shorten the life of the copper electrode. They often do not harden well and easily crack or break, exposing the copper electrode to harmful elements and reducing performance. SAN-EARTH M5C is produced with strict quality control and longtime experience to ensure the optimum performance while extending the life of the grounding system.
Question	**Does the application of SAN-EARTH M5C have an environmental impact on the surrounding soil?**
Answer	No. SAN-EARTH M5C is environmentally neutral and pH neutral, having no negative impact on the environment even in highly environmentally sensitive areas. SAN-EARTH M5C will not leach, dissolve or migrate into the soil or water. SAN-EARTH M5C provides completely pollution-free grounding because it is composed of very safe inert chemical matter.
Question	**Are there any other benefits from using SAN-EARTH M5C?**
Answer	Yes. New applications for SAN-EARTH M5C are being discovered frequently. By introducing SAN-EARTH M5C into any earthing design, the benefits are realized immediately. Onsite costs, productivity and safety being the biggest, with ongoing theft risks and maintenance virtually eliminated
Question	**Where can SAN-EARTH M5C be purchased?**
Answer	In the United States, the order desk can be reached at orderdesk@sankosha-usa.com or via toll-free call at 888.711.2436. Outside of the Unites States, go to Sankosha's webpage for a complete list of Sankosha's international offices.

Protecting a Wind Turbine: A San-Earth Conductive Cement Electrode System Combined with Surge Protection Devices



Lightning is the leading cause of unplanned wind turbine downtime. It is estimated that up to 38% of all damage to wind turbine facilities from natural causes is due to lightning strikes (Source: NEDO—New Energy and Industrial Technology Development). The average length of time that windmills are put out of action by lightning strikes is 64 days. Wind-turbine grounding systems must be designed so that excessive overvoltages are prevented and potential gradients that could cause damage to equipment or threaten human life are eliminated. The turbine blades, nacelle, structural components, the drive train, low-voltage control systems and high-voltage power systems all must be protected. As is true for all LPSs, a low resistance path to Earth must be provided.

Figure 1 below shows the recommended design for a conductive cement electrode system for a single wind turbine. It consists of a perimeter ground, totaling 60 m (197 ft.) in length, combined with four radial electrodes 30 m (98 ft.) each in length and yields a resistance value of 2.5 ohms in 300 ohm-meter soil. The conductive cement electrodes are 0.25 m (10 in.) wide and installed at a depth of 1 m (39 in.).

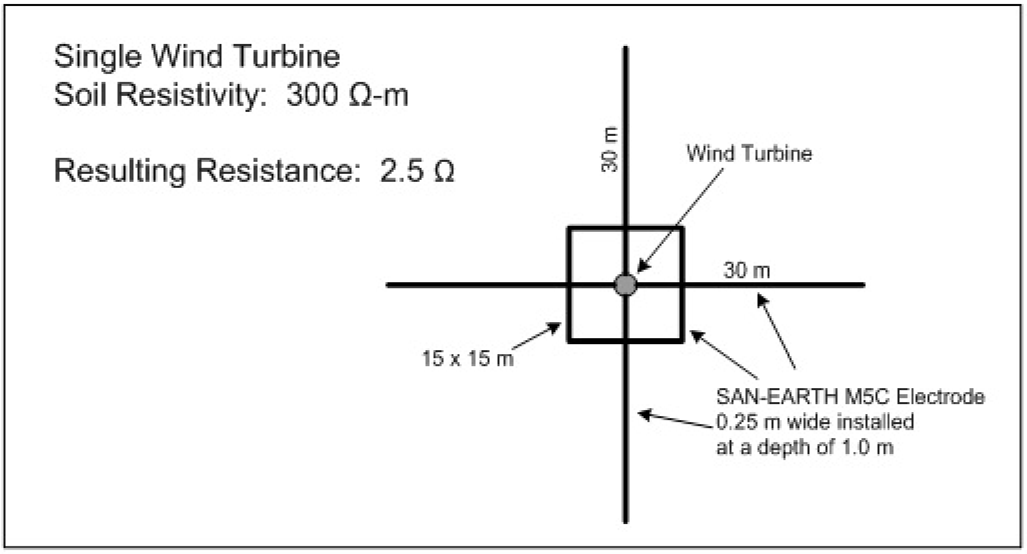


Figure 1: Conductive cement electrode system for a single wind turbine.

In the higher resistivity environments often associated with wind-farm installations, similar low-resistance values can be achieved by simply increasing the length of the radials. Four 75 m (246 ft.) radials yield a resistance of 2.4 ohms in a 500 ohm-meter resistivity environment.

SAN-EARTH M5C conductive cement is designed to solidify by absorbing the moisture in the surrounding soil. This makes it perfect for use in grounding at sites where a supply of water is not readily available.

Installation is easy. In a typical lateral installation (which will give you best performance at lowest cost by providing maximum electrode surface area at minimal installation expense) a trench is dug about 2 ft. deep, 1.5-2 ft. across and several yards long, and then the electrode is laid in the center of the trench (#2 AWG tinned solid wire is recommended). Next, SAN-EARTH M5C is spread across the bottom of the trench in a thin layer, slightly thicker at the center to make sure the electrode is completely embedded. The material is spread across the width of the trench by slowly dragging the bag along its length; one 55 lb. bag of SAN-EARTH will cover about 10 ft. laterally within the trench. The electrode is lifted slightly so that it is surrounded by SAN-EARTH M5C which will protect it from corrosion. Over time, the cement hardens to become a conductive solid. Thus, the surface area of the grounding electrode is greatly increased, and lower resistance values are achieved. The electrode should be insulated at any point where it exits the SAN-EARTH M5C cement (electrical tape works well for this). It is covered with 4-5 in. of soil and tamped until firmly packed. The trench is then filled with backfill to complete the ground electrode installation.

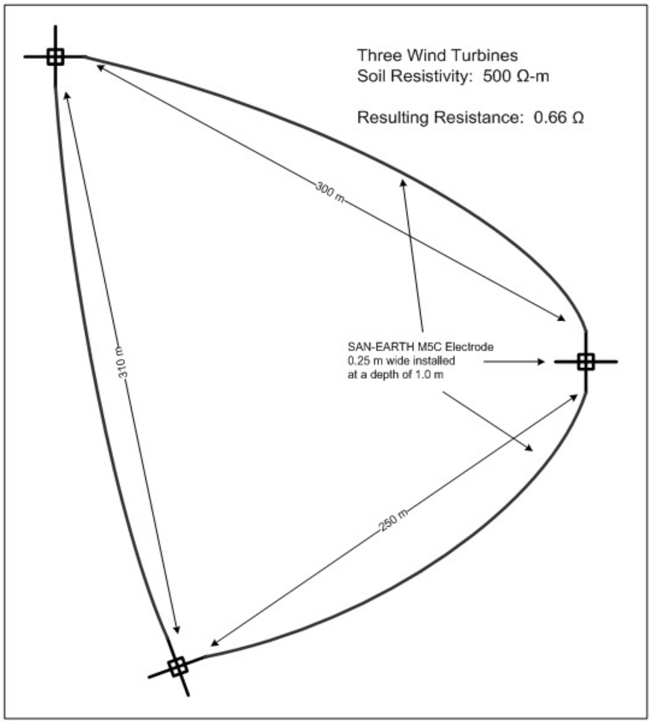


Figure 2. Grounding electrode system for three wind turbines.

Wind turbines grounded in this way can be connected together to achieve even more dramatic results. In Figure 2, the grounding electrode systems for three turbines are connected together using the San-Earth design. Vertical ground rods, often difficult to install at wind-farm locations, are not needed to achieve a consistent low-resistance connection to earth.

The system in Figure 2 would yield a resistance value of 1.32 ohms in a 1,000 ohm-meter resistivity environment. Even if the resistivity went as high as 3,000 ohm-meters, this design would produce a resistance value below 4 ohms.

Sankosha Surge Arresters

No matter how well the ground system performs, some lightning energy will reach down into sensitive electronics, potentially doing damage. That is where surge arresters play a role. While LPSs protect buildings, structures and people, lightning surge arresters protect electrical and electronic equipment in buildings.

Surge arresters work by diverting excess voltage from a signal or power carrying conductor to ground. There are, generally speaking, three types of surge arresters. The first type is a gas discharge tube (GDT), which is a sealed glass-enclosed device containing a special gas mixture trapped between two electrodes that conducts electric current after becoming ionized by a high voltage spike. GDTs can conduct more current for their size than other components and since a GTD can handle very large currents, such as from a direct lightning strike, they are an excellent device for this purpose.

The second type of arrester uses a metal oxide that becomes conductive in the presence of a strong electrical field. Metal oxide varistors (MOVs) protect sensitive circuits from a variety of overvoltage conditions. They act as a resistor with improving conductivity as the current through it increases. The current handling capacity of an MOV is much lower than that of a GTD. Varistors tend to be highly durable, which is essential for withstanding repeated high-peak pulse currents and high-energy surge transients. Transients induced by lightning are not the result of a direct strike, but are caused by the associated magnetic field that induces large magnitude transients in nearby electrical cables. MOVs offer a wide voltage range, high energy absorption and fast response to voltage transients. They do tend to fail after a number of high-current conduction cycles and they fail as a short circuit.

The third type is semiconductors such as Zener diodes. While a primary lightning protection element, closer to the source, is intended to carry the majority of the current, secondary protection elements provide protection near sensitive circuits. Semiconductor arresters have operating characteristics that make them ideal for use in the protection of electronic equipment that is vulnerable to voltage surges. In some cases, they can respond to the very fast occurrence of irregular voltage in less than a nanosecond. They have the best controlled clamping behavior of the various arrester types, but unfortunately their current handling capabilities are the smallest of all three arrester types.

Surge arresters are rated using such characteristics as rated voltage, nominal discharge current (the normal current they can handle repeatedly when clamping a surge) and the maximum voltage remaining when it is clamping, usually at their nominal discharge current. A good surge arrester is one that is fast enough to react to a surge, so the surge gets shorted to ground before it gets to the point of doing damage.

Three Electrode 3Y06 Series GDT

Sankosha's ceramic (GDT) surge arresters provide fast protection for personnel, equipment and circuitry from abnormally high voltages caused by lightning or other electrical transients and limit resulting dangerous currents. They feature high surge ratings with very low capacitance and provide excellent response to fast rising transients.

These hermetically-sealed GDTs have precise sparkover (breakdown) characteristics when the abnormal voltage on a line reaches a specific level. When sparkover occurs in the GDT, the surge is redirected to earth. Sankosha's gas discharge tubes (GDTs) are extremely durable and provide the industry's best impulse life specifications. Different applications require different surge suppressors and it is important that arresters be selected in accordance with the requirements of the particular application.

Sankosha provides gas tubes to meet every need: consumer electronics, modems, satellites, computers, CATV/ Broadband, industrial and telecom circuit protection are just a few areas that utilize Sankosha GDTs. They are available in axial leaded, radial leaded, surface mount and special packages. High-voltage gas tube models like the Y08SV-312B are designed for power supply applications where high potential (hipot) testing is required, and they meet the rigorous requirements of both UL 1449 and UL 1414, making it ideal for power supply protection applications. Sankosha also manufactures very small gas tube arrester models for surface mount applications where real estate is at a premium.

F-JP-1W coaxial SPD

Sankosha's GDTs come in both two- and three-electrode configurations. Discharge voltages from 75 to 6,000 V are available. Arresters for special applications are also available and inquiries are welcome.

Sankosha's coaxial surge protection devices (SPDs) provide heavy-duty protection from surges caused by lightning or other transients. Radio and wireless telephone communication equipment is particularly vulnerable because antennas are typically located in areas where the probability of exposure to lightning-related surges is high. Damage caused by direct strikes to the antenna itself, or by induced surges through the grounding system, are prevented when coaxial protectors are in place.

These SPDs are well suited for broadband, CATV, GPS and cellular applications.
GDT-equipped coaxial surge protectors are ideal in high frequency transmission applications due to their low capacitance. When confronted by a fast rising transient voltage, the protector sparks over temporarily and diverts energy away from sensitive equipment. Damage to transceivers in remote locations is avoided. Coaxial SPDs are easily installed in series with the antenna line.

LAN-CAT5e-P+ II Gigabit Ethernet/LAN Protector

Sankosha's SPDs for local area networks (LANs) protect equipment used on GigE (1000Base-T), 100Base-TX, 10Base-T and Power Over Ethernet (PoE) equipment. All of its compact LAN modules are equipped with RJ45 connectors and can be used as stand-alone SPDs.

Sankosha's LAN protectors come in two different technology types–earth grounding type and isolation transformer type. Grounding types, like the LAN-CAT5e-P+ II, use GDT technology to divert the surge or overvoltage to the grounding terminal of the LAN protector and away from all equipment. If an earth ground is not available, isolation types, like the LAN-CAT6-IS, use transformer technology to prevent the surge or overvoltage from traveling through the LAN protector and damaging equipment on the other side.

The LAN SPDs are also designed with integrated clips for easy installation on a standard 35 mm DIN rail. The LAN-CAT5e-P+ II complies with IEEE Standard 802.3af, combining 1000Base-T data transmission speed with reliable PoE transient protection. It also complies with the direct lightning impulse (10/350μs) 2.5 kA waveform requirements of the Category D1 Test under IEC 61643-21. The LAN-1000IS-2 insulates equipment from lightning-induced or other power surges without the need for a ground.

For more information on these and other Sankosha products, visit the official
Sankosha lightning protection solutions page.