Isolated Down-Conductors
Improved Lightning Protection for Rooftop or Outdoor Electrical Equipment

Abstract

Traditional lightning protection practices were standardized many years prior to the recent proliferation of modern electrical and electronic equipment installations on building rooftops. This paper presents an isolated down-conductor solution that combines the advantages of the IEC 62305[1] series or various other national standards regarding isolated and non-isolated lightning protection methodologies. Isolated down-conductor design and testing methods are reviewed and proposed as part of an overall solution for protection of technology located on the modern rooftop.

Keywords: Isolated down-conductor, separation distance, isolated lightning protection.

1. Introduction

Lightning protection in accordance with the IEC 62305 series of standards typically follows two concepts: isolated or non-isolated systems.

The most common is the non-isolated system, where the lightning protection system (LPS) and metallic items of the structure to be protected are bonded together (equipotential bonding), eliminating potentially devastating potential differences. Generally, a network of air terminals, down-conductors and grounding electrodes are installed and electrically bonded to the structure.

The limitation of a non-isolated system is most apparent when considering the protection of technology present on the roof of buildings today. A very rigorous bonding procedure must be followed, with no exceptions. The result is that the rooftop equipment, metallic items and the structure itself may also carry a proportion of the discharge current. This is potentially devastating in today's building environment where the "items" may be rooftop telecommunication masts or air conditioning units containing sensitive electronic equipment. These may be subjected to partial lightning discharge currents.

Isolated systems, which are less common, also use a network of air terminals, down-conductors and grounding electrodes. However, in this system, the air terminals and down-conductors are mounted on insulators to stand-off the structure. By using an appropriate "separation distance" between the LPS and the structure, the lightning energy can be contained on the LPS without risk of uncontrolled side-flashing to the structure – thus the structure does not carry partial lightning currents, nor require frequent bonding. The disadvantages of this approach include the added cost and labor required for stand-off insulators, the visual impact of such hardware, and the complication in design to ensure separation distance is met and maintained.

Non-isolated systems are well suited to metallic-clad or concrete-reinforced structures where these structural elements can actually be used in place of the down-conductors, resulting in substantial cost savings. However, they offer no benefit to the protection of modern rooftop electrical and electronic equipment where it is undesirable for the equipment chassis to be a possible lightning discharge path, or a second separate mast system is installed to protect the equipment on a telecommunication mast.

For over 20 years, non-IEC standards systems using a hybrid technology with isolated down-conductors[2,3] have provided the benefits of the isolated system, but without the need for stand-off insulators and brackets. The following introduces the most recent application of this technology, which is in full compliance with the IEC standards on lightning protection.

2. Isolated Lightning Protection Systems & Separation Distance

The required distance between the objects to be protected and the air terminals and down-conductor of the isolated system is determined by IEC 62305-3, Section 6.3. This distance is referred to as the "separation distance" ***S***, where

$$S = k_i \frac{k_c}{k_m} l$$

Where k_i is a factor that depends upon the chosen lightning protection level (0.08, 0.06 and 0.04 for Levels I, II and III/IV respectively), k_c is a factor that depends upon the number of down-conductors (1 for single down-conductor), k_m is a factor that depends upon the electrical insulation material (1.0 for air, 0.5 for concrete) and l is the length of the down-conductor from the point being considered to the closest equipotential bonding point.

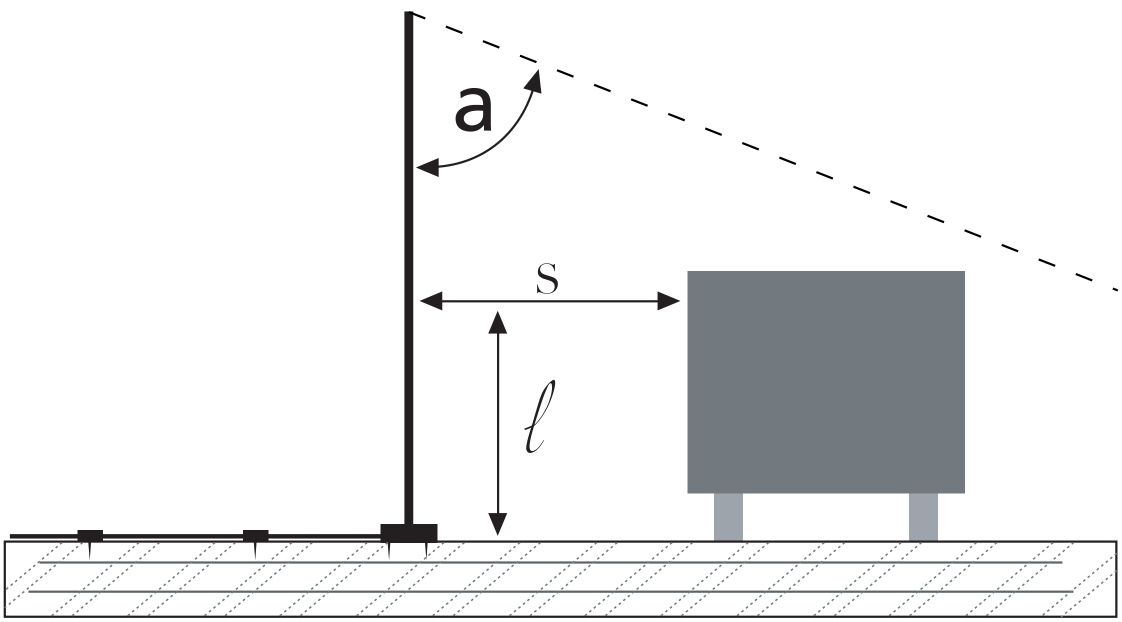

Figure 1. Separation distance concept for an isolated lightning protection solution.

The separation distance calculation is also used within the IEC 62305 series standards to determine the need for equipotential bonding for non-isolated systems. That is, should a metallic item such as wall vents or window frames be located more than the separation distance from the closest down-conductor, then the item does not need bonding to the down-conductor (LPS). If the items are within this distance, then they need to be bonded to the LPS. The calculation also applies to the presence of internal metallic items such as electrical circuits, plumbing, etc., which must be bonded or located at a greater distance than the separation distance.

This requirement creates a common cause for LPSs failing to comply with the design standards. While occasionally the designer and installer of the LPS may not be aware of the presence of such items within the wall cavity, more commonly the design violation occurs after the LPS is installed and then low-voltage circuits are added to the structure. The corners of structures are the preferred location for down-conductors, which are also the common location for low-voltage security camera systems. Modern commercial buildings with large glass window frontage provide limited opportunities to run down-conductors, increasing the likelihood that such services are within the separation distance of the LPS. Unfortunately, the installers of such services are not aware of the separation requirements of the LPS, and LPS inspection may not occur, or they may only identify this issue several years later.

Security system cables

Bare down-conductor

Figure 2. Conventional down-conductor separation distance problem.

3. Isolated Down-conductor System

The isolated down-conductor provides the material and cross-sectional area equal to a traditional bare 50 mm^2 IEC standards compliant down-conductor, but with a highly insulated covering. The insulation is sufficient to provide a separation distance equivalent to that provided by an air gap of 1,000 mm. Therefore, circuits and services can be located in the immediate down-conductor proximity, without risk of side-flash. It should be noted that the isolated down-conductor provides protection against side flashing and reduces the risk of partial lightning currents being carried by unintentional circuits (galvanic coupling). No down-conductors can provide protection against induced currents (magnetic coupling), therefore, running low-voltage circuits close and parallel to the isolated down-conductor for extended distances is not recommended.

The practical implementation of this system is a tall, isolated support mast through which the isolated down-conductor is run as shown in figure 3. At the top of the mast, a conventional air terminal is mounted. The mast is installed such that the tip of the air terminal provides the required protection using the IEC 62305 Protection Angle Method (PAM) design (the Rolling Sphere design method could also be used for this purpose). The isolated support mast is generally mounted upon the object to be protected, and the down-conductor is run to the grounding system or is interconnected with a traditional isolated or non-isolated LPS.

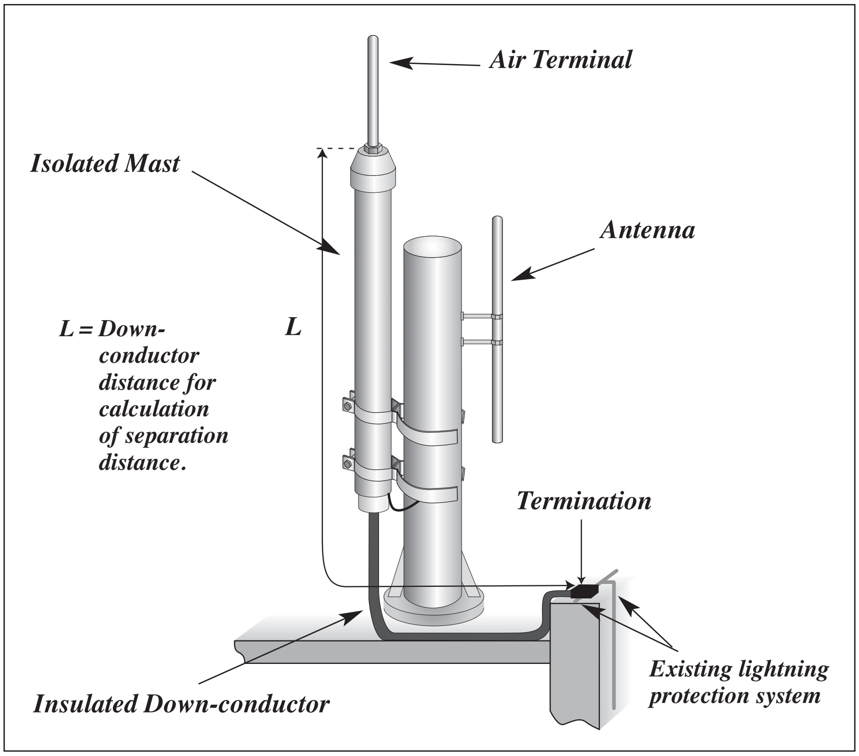

Figure 3. Isolated mast and isolated down-conductor protecting a rooftop antenna.

.

4. System Testing & Equivalent Separation Distance

A test regime developed to test the insulators used to stand-off the non-isolated down-conductor of a traditional isolated system is used to test the performance of the isolated down-conductor. Here, the breakdown voltage of the insulator (S_v) is compared to that of air by placing the insulator in parallel with an air gap in a high-voltage environment. The air gap is constructed with a pair of conductors, placed at right angles and arranged so the distance between the conductors can be adjusted. High-voltage impulses are applied and the air gap distance is increased to find the distance at which the air gap and insulators fail with a probability of 50%. At this distance, the insulator is deemed to have the equivalent separation distance as the air gap distance.

In application, the voltage build-up on the LPS will be due to its total inductance and the rate-of-current-rise (di/dt) of the lightning impulse. While the first stroke of the lightning impulse has the largest current magnitude, it is the subsequent strokes that have the highest rate-of-current-rise. The applied voltage for the test is therefore not the traditional 1.2/50 µs waveform, but a faster waveform in the region of 0.5/40 µs.

Hence, a similar testing regime is also used for testing of the isolated down-conductor, where the insulator is replaced by approximately 4 m of isolated down-conductor. The grounded connections applied near either end of the down-conductor are placed at a distance in accordance with the down-conductor manufacturer's requirements, representing the proximity of closest grounded items when installed. The arrangement tests against down-conductor insulation breakdown (through the down-conductor) to the grounded points, as well as testing for tracking flash-over (or "creepage discharges") along the insulation surface (C_1). The latter is the more likely failure scenario.

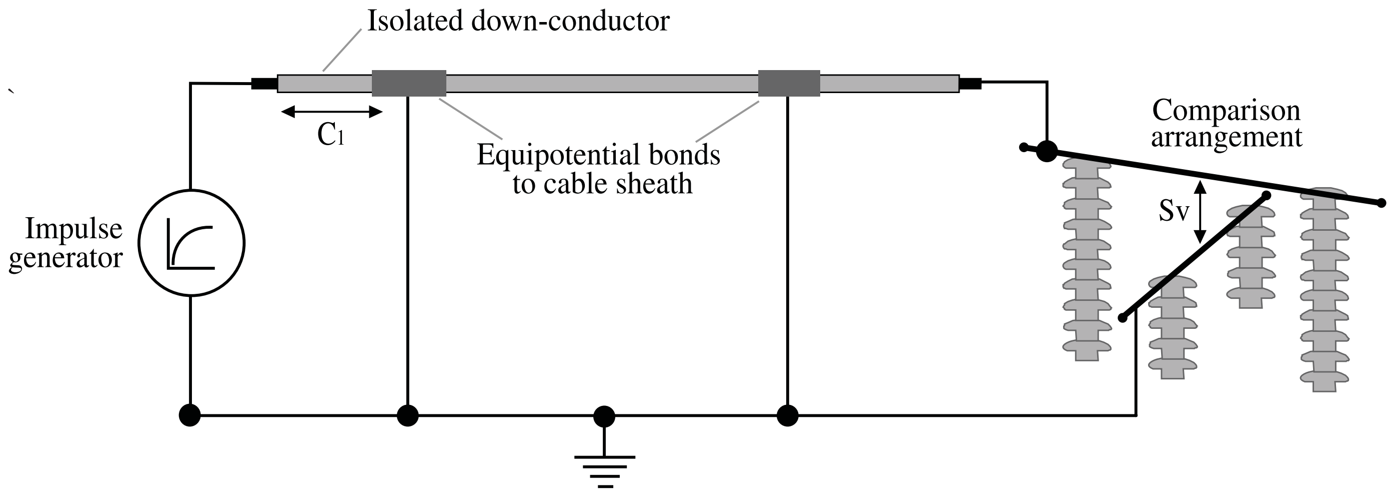

Figure 4. Isolated down-conductor test arrangement.

As the breakdown voltage of an object is highly dependent upon its shape (related to e-field intensification), testing of the down-conductor alone would not be sufficient to guarantee reliable field performance. For example, the presence of a connection piece to connect the down-conductor upper termination to the air terminal may have bolts or other protrusions that could generate significant electrical field distortions. This intensification may increase the local electric field to a level sufficient to cause down-conductor tracking at the upper termination. Therefore, for this system, the testing has also been carried out on a final installed configuration of cable with upper termination fittings, masts and connections in order to confirm the validity of the overall design.

The above voltage-based testing only assesses the insulation properties of the system components. Within the European Community (EU), compliance is also required to CENELEC EN 50164-2[4] "Lightning Protection Components (LPC) – Part 2: Requirements for conductors and earth electrodes." This includes environmental and dimensional compliance tests of the conductor. Aluminium conductors require a minimum cross-sectional area of 50 mm^2. Copper conductors also require a minimum of 50 mm^2. Note that while IEC 62305-3 relaxes the requirement for solid round copper conductors to 28 mm^2 (6 mm diameter) where mechanical strength is not an issue, these smaller sizes are not permitted by the EN 50164-2 standards.

Compliance with CENELEC EN 50164-1[5] "Lightning Protection Components (LPC) – Part 1: Requirements for connection components" is also required within the EU. This requires that all connection items within an LPS be tested. Given that proprietary couplings are used at the ends of the isolated down-conductor to connect air terminal and grounding system, these couplings require testing to the standard. For the mentioned design, the entire conduction path with all connectors has been tested. Therefore, the entire system components have been tested to withstand heating and mechanical forces by conducting a lightning strike impulse of 100 kA for a 10/350 µs waveform.

5. Isolated Down-conductor Design

To pass the test requirements, the cable design requires more than a conventional down-conductor with high-voltage insulation applied. The problem with such a concept is that, at intermediate voltages, a partial discharge may form on the cable surface, leading to thermalization and cable breakdown. Laboratory tests[3] have shown that for standard polyethyelene-based cables, this type of flash-over can occur even over cable distances of 5 m.

To control the risk of flash-over, a semi-conductive outer sheath is used. The use of the semi-conductive sheath provides a known (high) resistance longitudinally from the upper termination to the first grounded bonding point, thereby eliminating partial discharges. This arrangement requires a special layered upper termination fitting involving metallic, semiconductive, stress relief and anti-tracking components. The primary bond is made to the cable sheath at approximately 2.25 m below the termination. A connection is made to the metallic part of the structure to provide an equipotential bond and controlled voltage gradient to the upper termination.

Figure 5. Isolated down-conductor and multilayered insulation and semi-conductive sheath.

6. Environmental Evaluations

In addition to electrical performance and compliance with standards, the design needs to consider the environmental conditions. Component and system performance is evaluated against temperature extremes, such as the effects of ice loading. For example, the support mast system material is UV stable and impervious to moisture and humidity, to help ensure a long service life. Flash-over of the mast has been evaluated during separation distance testing. Due to the resistive semi-conductive control of the isolated down-conductor, the effects of moisture on the down-conductor surface are negligible.

The major environmental consideration is wind. The mast material and diameter provides tensile and flexural strengths that are sufficient for wind speeds up to 195 km/h. The upper terminations and fittings use locking devices to reduce the risk of loosening due to wind-induced vibration that occurs at the top of the mast.

7. Conclusion

Lightning protection standards provide isolated and non-isolated design concepts for the protection of structures. The advantages and disadvantages of each concept make them best suited to specific applications. However, for the protection of modern rooftop equipment, a hybrid approach has been introduced combining the advantages of each. The isolated down-conductor with semi-conductive coating allows design engineers and installers to maintain the separation requirements almost independently of the routing requirements. The performance of the system has been proven by established test procedures that allow the determination of an equivalent separation distance, the result of which can be used in the IEC 62305 design process.

8. References

1 International Electrotechnical Commission, IEC 62305-1, IEC 62305-2, IEC 62305-3 & IEC 62305-4, Geneva, Switzerland.

2 D'Alessandro, F., "On the applicability of insulated downconductors", Proc. of 8th International Symposium on Lightning Protection (VII SIPDA), São Paulo, Brazil, pp. 301-307 (2005).

3 D'Alessandro, F. & Alghusain, F., "PSpice modelling of a special insulated down-conductor", Proc. 28th ICLP, Kanazawa, Japan, pp. 698-703 (2006).

4 European Committee for Electrotechnical Standardization, CENELEC, EN 50164-2 "Lightning protection components (LPC) Part 2: Required for conductors and earth electrodes" (2002).

5 European Committee for Electrotechnical Standardization, CENELEC, EN 50164-1 "Lightning protection components (LPC) Part 1: Required for connection components" (1999).

WARNING
ERICO products shall be installed and used only as indicated in ERICO's product instruction sheets and training materials. Instruction sheets are available at www.erico.com and from your ERICO customer service representative. Improper installation, misuse, misapplication or other failure to completely follow ERICO's instructions and warnings may cause product malfunction, property damage, serious bodily injury and death.

www.erico.com

ERICO®

E678WWEN E1259LT06ENWW 007WB8