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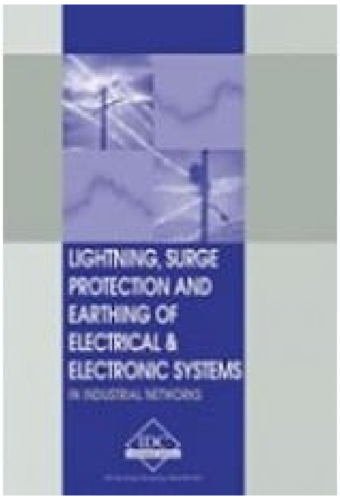
Phone: +61 8 9321 1702 - Email: books@idc-online.com,publishing@eit.edu.au

LZ-E - Lightning, Surge Protection and Earthing of Electrical & Electronic Systems in Industrial Networks



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Short Description

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Description

Poor practices in earthing and incorrect application and selection of lightning and surge protection devices can be the cause of continual and intermittent difficult-to-diagnose problems in a facility, often resulting in lost production and equipment failure.

This manual looks at these issues from a fresh yet practical perspective and enables you to reduce expensive down time on your plant and equipment to a minimum by correct application of these principles.

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Overview

In this chapter, we will introduce the phenomenon of lightning and the means of protecting buildings and structures from being damaged by lightning strikes and the importance of the role of grounding and bonding. We will also touch upon lightning detection and warning systems. We will also introduce the topic of surge protection of sensitive equipment. All these concepts will be explained in detail in the chapters that follow.

Learning objectives

This chapter dwells upon the following topics:

- Lightning and its effects on facilities and equipment
- Approach for protecting buildings and structures from lightning strikes
- Detection and warning systems
- Role of grounding and bonding in lightning protection
- Surge protection of electrical equipment (power, communication and control)
- Need for maintenance of lightning protection components

1.1 Lightning and its effects

Lightning is the sudden draining of electrical charge built up in low cloud systems. It may involve another cloud system (which is not of much interest to us in this course) or ground (which is). The flow of charge creates a steep fronted current waveform lasting for several tens of microseconds. A direct lightning strike on a human body or livestock can result in death or serious injury. Lightning can cause destruction of a living organism, such as a tree. It can damage building parts through which the lightning surge is conducted to the ground. It can even place personnel within a building at risk because of very high potential differences between different parts of a building that carry the lightning surge. Even the flow of lightning surges in the ground can cause electrocution due to high potential differences between different points in the soil carrying the surge currents. Lightning strikes on electrical installations (which include overhead conductors of power and communication lines) can cause current and voltage surges. A nearby strike to the ground can cause such problems by coupling into electrical circuits. A surge may consist of a single spike or multiple diminishing spikes and unless properly protected against, can cause failure of insulation in electrical wiring or devices due to excessive voltage. A surge traveling through electrical power supply network can damage sensitive electronic equipment. A proper understanding of the mechanism of lightning and its effects is, therefore, essential for planning protection against lightning strikes so that no damage is caused to personnel, buildings and electrical installations.

Lightning is one of the most widely studied and documented of all natural phenomena. Over the years a lot of research has been done worldwide and several publications as well as national and international standards have evolved. These give us a good insight into this phenomenon.

Some of these standards are:

- AS 1768:2007 Australian Standard on Lightning protection
- ANSI/NFPA 780 National Lightning protection code
- IEC 61024 Lightning Protection of structures
- IEC 61312 Protection against lightning electromagnetic impulse
- IEC 61662 Assessment of risk due to lightning
- IEC 61663 Lightning protection of telecommunication lines
- IEEE 142:2007 IEEE Green Book (Chapter-3)
- IEEE 487-2000 Protection of Wire-Line Communication Facilities Serving Electric Power Stations

While it is difficult to predict the behavior of lightning with exactitude, it is possible to provide a high level of safeguard against damages, injuries and loss of life due to lightning.

The following are some of the ways of protecting personnel and installations against lightning and related ill effects:

- Lightning warning systems to warn personnel who are engaged in

outdoor activities about impending lightning activity to enable them to take shelter
- Lightning protection systems for structures as per relevant codes
- Quality grounding and bonding
- Surge arrestors on power circuits
- Multi-level graded protection of signal paths using Surge Protective Devices (SPD)
- Periodic maintenance of lightning protection systems to ensure integrity of conducting paths.

We will discuss in this course the phenomenon of lightning, its effects and prevention of damages due to lightning strikes (also called lightning flashes).

1.2 Lightning protection system for a building or structure

A lightning protection system to be provided for a building or any other structure is based on the perceived risk of a lightning strike and the damage it may cause. The risk is, in turn, related to the extent of lightning (or thunderstorm) activity in the region where the facility is situated. Many countries have collected data on thunderstorms in their territories, which are published in the form of Isoceraunic maps for different world regions in different national and international standards. Figure 1.1 shows the distribution of lightning activity on a worldwide basis. The activity is expressed in terms of Flashes/Sq. km/Year. Note that the activity in arid regions is much lower than in regions with high rainfall. Areas with very little occurrence of thunderstorms are naturally at a much lower risk. Large continental regions close to the equator are observed to have a high level of lightning activity. Another observation is the lower incidence of lightning in oceans. The lightning activity increases as we approach the landmass.

Figure 1.1

Worldwide lightning activity distribution

Other factors such as the type of surroundings, height of the structure, type or value of contents in a building, degree of human presence, etc., are also of importance in deciding the extent of risk due to lightning and play a major role in deciding upon the necessity of providing lightning protection (or otherwise) for each specific case. Different national standards have evolved specific methods for risk assessment. We will discuss typical assessment methods in detail later in this course.

Once the need for providing lightning protection is assessed by these methods, the next step is to design a suitable protection system. It should be recognized that no system can guarantee 100% protection against all incidents of lightning. The severity of the lightning expressed in terms of the current flow varies and to ensure protection against all cases is simply not possible. The most probable values are considered in the design of lightning protection systems in order to make them cost effective and at the same time provide reasonable protection against most cases of lightning strikes.

Lightning protection systems have evolved over the years, from the simple Franklin Rod, followed by the Faraday cage method, to the modern, non-conventional lightning protection systems. A number of products are available in the market to ensure reliable protection of facilities against direct lightning strikes. Some of them have active lightning attraction components, which claim to focus the lightning discharges on themselves instead of other vulnerable portions of the facility that is being protected. Others attempt to suppress the formation of a lightning strike from happening. These claims are not validated properly and their scientific basis is open to debate. We will, however, review them briefly in the later chapters of this document.

Methods of computing the effectiveness of protection have also been under evolution, starting from the Cone of Protection type of analysis, to the Rolling Sphere Method, to the computations based on Collection Volumes. Many organizations such as the Electric Power Research Institute (EPRI), USA and the Lightning Safety Institute, as well as manufacturers of lightning protection hardware offer design services using computer applications which help in assessing the lightning risk and designing the most appropriate protection system. We will demonstrate a typical application as a part of the hands-on session in this course.

We will also discuss in detail the effects of lightning on electrical lines and outdoor installations and how these facilities can be protected against the damaging effects of strikes using the above-discussed principles.

1.3 Lightning detection and warning systems

While Isoceraunic maps are useful in obtaining a fair idea about the frequency of thunderstorms in a given area, they do not really help in understanding the actual number of cloud to ground lightning strokes or the severity of lightning discharges, both of which have a bearing on the design of lightning protection systems. The United States of America has addressed this issue with the installation of a network of lightning sensors throughout the geographical area of the country and by linking them on a real time basis to a central facility. This system communicates the presence of lightning activity in the area covered by each sensor, and the data of each discharge, to the central monitoring facility using satellite links. This facility immediately analyzes the data and issues appropriate warnings to local agencies for preventive measures. We will review the details of this network in a later chapter.

For areas where such a network does not exist, as well as for facilities handling highly hazardous materials (which may not want to rely on an external agency for warnings), individual localized lightning warning products can be deployed. Such products are also useful in outdoor facilities such as golf courses, wind farms etc., to indicate the approach of a thunderstorm so that people present in these sites can be warned to take shelter in safe locations. We will discuss a couple of typical systems later in this course.

1.4 Role of grounding in lightning protection systems

As noted in an earlier section, grounding plays a very important role in the protection of buildings and equipment against direct lightning strikes as well as surges from indirect strikes. In the case of direct strikes, a low impedance path from the lightning protection conductor to the ground is essential to keep the inevitable voltage-rise within safe limits, when currents of large magnitudes are conducted by the lightning protection system. Note the use of the term ***impedance*** in preference to ***resistance*** here. While the normal power system ground is designed primarily to provide a low resistance path to ground, in the case of grounding systems of lightning/surge protection systems, it is the impedance which is of importance. As we shall see later, a surge gives rise to voltage and current pulses having extremely fast rise times. Any inductance in the grounding circuit obstructs the flow of surge currents and produces a voltage drop. This drop is a function of the inductance and the rate of rise of the current. Remember that even a piece of wire has its own self-inductance, which is sufficient to cause an appreciable voltage drop while conducting a lightning surge if the length becomes excessive. Thus the grounding conductors of a lightning protection system (including the ground connections of surge protection devices) must be as short as possible and without any avoidable bends.

Conduction path to lightning can also be provided using the building’s structural members. In the case of concrete buildings, the steel reinforcement (re-bars) can provide a low impedance ground path.

The availability of a good, low-resistance (and low impedance) ground electrode system is also a matter of importance. The voltage rise of a facility is to be computed with reference to the true ground (the general earth mass) and electrode resistance thus becomes an important factor as the voltage drop across this resistance contributes to the potential rise. We will discuss in detail the principles of grounding electrodes, the effect of soil resistivity on ground electrode resistance and methods of obtaining lower ground resistance under difficult soil conditions (by the use of chemical electrodes and soil enhancement). Most vendors of integrated lightning protection systems include the required materials for ensuring low ground electrode resistance to facilitate proper operation of their protective systems.

We will briefly discuss electric shock and what causes it. The principles of electric shock and the related topics of ground potential rise, step potential and touch potential are applicable not only to electrical power systems but also to lightning protection installations.

1.5 Bonding of grounding systems and metallic services

Another important issue in protection of sensitive electrical equipment against damage by lightning-induced surges is the relative potential difference that can be caused during a lightning discharge through the protection system. To eliminate or at least minimize such potential difference, it is necessary to bond together the different grounding systems as well as other metallic service lines in a facility, so as to achieve an equipotential plane. Many a failure of sensitive electronic and communication equipment is due to the oversight of designers of these individual systems in recognizing the need for such bonding. A good designer will ensure integration of these systems properly so as to avoid destructive potentials from appearing between the internal parts of sensitive devices.

1.6 Surge protection

One of the major effects of lightning strike on electrical and electronic equipment is a high voltage surge. A surge is caused by the lightning discharge when the associated current tries to find a path to ground. A surge need not be due to a direct strike alone but can happen due to a strike on a nearby structure. In this event, a surge can be transmitted into an adjacent electrical system (which in this context includes communication or control systems) by various means.

These are:

- Galvanic (direct Electrical Contact)
- Electrostatic coupling
- Electromagnetic Induction
- Radio Frequency interference (RFI)

The type of protection to be provided at different points in the electrical system is based on the surge voltage/current values that the equipment is likely to be subjected to. For example, the highest exposure to surges happens in the equipment connected to an external power system. The surge current pulse reduces in magnitude with correspondingly lower energy levels as we move from the power inlet equipment to the main distribution circuits, then to the branch distribution and finally to power supplies of sensitive equipment. This is mainly because of the fact that the inductance of the conductors has an attenuating effect on the surge pulse. Even a short length of conductor may present substantial impedance because of the fact that the very steep wave front of a surge has the same effect as a current of very high frequency.

This means that equipment connected to the external power supply system needs to have a high impulse withstand rating while equipment further down the system can be rated progressively lower. Also, the devices used for surge protection must be suitably graded depending on the level of surge energy expected at the points of the electrical system where they are installed.

Several types of devices are available for protection of electrical equipment from the damaging effects of surges. These components are commonly known as Lightning arrestors (used to protect large electrical equipment such as transformers or switchgear from being damaged by surges) or Surge Protection Devices (SPD), a term used mainly in the context of sensitive equipment. Transient Voltage Surge Suppressor (TVSS) is another name for an SPD, an older term mostly used in earlier references. All these devices function by providing a low-impedance ground path and safely diverting the surge currents (and thereby the damaging energy of a surge) to ground – away from the sensitive equipment which they protect. The characteristic of these devices is such that they do not come into play during normal system conditions but act only when the voltage of the system exceeds certain threshold values. We will discuss these systems and devices in detail later.

1.7 Maintenance of lightning protection systems

Lightning protection systems operate under difficult conditions and are constantly exposed to weather. Also, the grounding components are usually buried in soil and are subject to corrosion due to galvanic action of stray currents as well as the action of chemical substances in the soil. Unless these components are periodically inspected and the defects attended to, the system may fail when subjected to lightning surges and may endanger life and property. We will discuss the measures to be instituted for periodic inspection and checks on various system components in the concluding chapter.

1.8 Additional information

We will discuss the above concepts in detail in the chapters that follow this overview. A few appendices have also been included for information on related topics. The first of these appendices illustrates the principles of lightning risk assessment as suggested by the Australian Standard AS 1768:2007. Others include lightning protection measures for special structures such as a Wind turbine generator and marine installations and the measures to be taken for mitigation of electrical noise (which can be caused by the Radio Frequency Interference from lightning activity).