Lightning Protection for Buildings

Introduction

A lightning strike can cause significant structural damage to a building. It can lead to damage to machinery and equipment, both inside and outside the building and may also result in harm to people. An effective external structural “lightning protection system” is therefore an important precaution. The system should, if correctly designed, installed and maintained, provide an effective path of low resistance to earth, along which the electrical energy can travel and safely dissipate, leaving the building and associated assets largely undamaged.

This Risktopic has the objective of providing some background information about the principles of lightning as a potentially destructive natural force and various considerations for structural lightning protection.
For high buildings, buildings containing flammable liquids and explosion risks and other special plant and tall structures, it is advisable to contact UK Risk Engineering at an early stage to discuss proposals.

Zurich recommends that lightning protection systems are installed by contractors who are members of a recognised trade body, such as ATLAS (Association of Technical Lightning and Access Specialists).

NB: protection against electrical disturbances including lightning likely to cause damage to electrical and electronic equipment is not covered in detail in this Risk Topic – see the more specific titles.

**What is Lightning?**

Lightning is the result of the discharge of electricity from a thunderstorm cloud. As is the case in most electrical systems, the movement of electricity is due to a potential difference – in this case the potential or voltage difference is between the cloud and its surrounding weather system environment and this includes the earth surface below and whatever is built upon it.

**Lightning Strike Formation**

An initial discharge or path of charged air starts from a negatively charged region in the cloud. Discharge channels are known as "leaders" and positively- and negatively-charged leaders are generally of a stepped formation, so called “stepped leaders”, which proceed in opposite directions (leaders travel up to 36,000 km / hr. and can attain 30,000 degrees Celsius). Negatively-stepped leaders can reach the ground below a cloud in quick jumps or steps using approximately 10-100m length steps and these may branch into a number of paths. These leaders are almost invisible.

When a stepped leader approaches the ground, the presence of opposite positive charges on the ground enhances the electrical field. The electrical field is strongest on high points with earth connectivity, i.e. features such as trees and tall buildings. If the field is strong enough, a “positive streamer” is sent up from these positive points to meet the descending stepped leader. This is often shown in photographs of lightning.

Once this type of path is established involving a channel of charged air, it becomes a more direct path of least resistance and allows for a much greater current to propagate from the earth back to the cloud. This is the main stroke or “return stroke” and this is the most luminous and visible part of the lightning discharge. When the electric discharge follows, successive portions of air become a conductive discharge channel but are at the same time superheated. They expand the air rapidly and this produces shock waves heard as thunder.

**The Destructive Power of Lightning**

The power of natural lightning tends to be very great but of very limited duration. A large bolt of lightning will reach negative electrical currents of 30kA and positive currents of 300kA. Significant damage can occur to property and lightning will cause structural damage, even to masonry if it passes through that type of material. Lightning can also cause damage by a terminated strike near a building or its services. Lightning can create sub millisecond transient over-voltages of up to 6,000 volts on power, data, signal and telephone lines.
Risk Assessment

There is no law which requires that a building must be protected with a lightning protection system but the first consideration is life safety in buildings and therefore the risk of having no (or inadequate) protection needs to be assessed. Relevant Duty Holders are required to maintain electrical safety in buildings and this remains relevant in the case of the maintenance of a lightning protection system. Designers of buildings, such as architects, have to consider lightning protection systems as part of their designs and they have done this on a routine basis since Victorian times. To assess if lightning protection is required, a risk assessment should be undertaken. Risk assessments are likely to consider the following aspects:-

- area and height of the building
- likely number of flashes to ground per square kilometre per year
- use of the building or structure
- type of construction
- nature of building contents
- degree of building isolation

As property insurers, Zurich also considers the possibility of significant property or business continuity losses as a risk factor.

Lightning protection risk assessments are complex and are often now the subject of computer analysis, which is why Zurich recommends using a competent Lightning Protection Engineer to undertake any risk assessment. The basic principles can be summarised as “a building needs a lightning protection system when it reaches into air which is subject to high flash density” or even as far as an insurer is concerned “if in any doubt – protect”. One of the reasons for doubt is that flash density data is historic and with some change being observed in climatic patterns in global weather systems, the historic data may not be a reliable enough source to suggest that any building does not need protection.

The Systems used for Protection

Lightning protection systems need to provide a path of low electrical resistance by which a lightning strike can enter or leave the earth without causing damage. This section details the various different ways in which lightning protection can be provided.

Faraday Cage - Electromagnetic Shield

A Faraday Cage is an enclosure fixed to the outside of the building made of conductors laid out on a grid pattern to produce an external mesh. If the building is steel framed, the job can be made considerably easier as the steel frame itself can be used as part of the cage, but air termination devices are needed if the upper external surface of the roof is not metal and continuous with the steel frame. The Faraday Cage, if designed correctly, will form an electromagnetic shield. This means that there will be no electric fields inside the cage resulting from currents flowing to earth on the surface of the cage.

One great advantage of this form of protection is that each one of numerous down conductors will be earthed to ground. The air termination network can easily be made suitably extensive.

This is the type of protection which is likely to be most reliable in terms of lightning protection and is the type which is most acceptable to Zurich.
**Single Mast Systems - Franklin Cone / Protective Angle Cones**

Some older systems simply used a single mast conductor system but some poor experience is associated with this type of protection.

The principle of protective angle is still used however, based on the use of a 45 degree angle forming the sides of a cone-shaped zone of protection – forming a circular base on the ground around a building or part of a building. This approach is generally limited to buildings less than 20m high.

There are several inherent weaknesses in the older type single mast approach, including potentially inadequate air and grounding termination. In some countries, lightning protection standards do not allow for single mast types of protection of any type.

**Improved Single Mast Systems - Early Streamer Emissions Systems**

Various versions of a system which uses electrically produced “positive emitting streamer terminals” as a type of protection system have become available. These use the principle that if positive charges produced at high level in the air terminals are present; these space charges will produce streamer propagation effects and streamers which are likely to meet with the negatively charged “leaders” earlier and more predictably in the protection against lightning strikes.

The advantage over the Faraday Cage principle is the fact that less material goes into the system and this will give a significantly lower installation cost - but Zurich are concerned that any such system, with predictably reduced air and ground termination networks and less down conductors compared to a fully specified Faraday Cage, may not provide the same level of overall property protection that a Faraday Cage system would provide.

**CTS and DAS Charge Transfer Systems and Dissipation Array Systems**

These systems are intended to prevent the formation of positive streamers and are normally used for specialist applications such as chimneys, masts and electrical transformers.

**Inspection, Testing and Maintenance**

Once installed, it is very important that the lightning protection system is kept in efficient working order and this can only be correctly achieved by making sure that regular and documented 12-monthly inspections and testing is done by competent contractors. Mechanical condition and lack of corrosion are key inspection criteria. The equi-potential bonding of recently added services should be checked.

Suitably low levels of electrical resistance need to be confirmed for each earthing electrode and the complete earth termination system. Also, the electrical continuity of conductors should be measured.

Ideally, electrical resistance testing at earthing points should be done at different times of year over a period of several tests as the ground moisture and therefore electrical resistance may change significantly with the seasons.
Summary

A well designed, installed and maintained structural lightning protection system can prevent lightning strikes from damaging buildings, as well as secondary damage such as fires. If considering the installation of a lightning protection system, Zurich recommends that an initial risk assessment is undertaken by a competent Lightning Protection Engineer. In the United Kingdom, Zurich are prepared to consider all proposals for lightning protection systems which comply with both BS EN 62305 for systems and the associated BS EN 50164 for lightning protection components. However, in particular cases of property and business continuity risk, Zurich may require protection levels over and above those suggested by the British Standards and customers are advised to seek advice from Zurich at an early stage.

Glossary

Air Termination Network: This is the total extent of air terminals in the system. These are designed to be located at the highest point of a protection system. Air terminals provide a preferential positive to connect to downward leaders of lightning strikes.

Down Conductors: These are the single or numerous conductor routes which are designed to safely transmit the lightning strike to earth.

Earth Termination Network: This is the total extent of earthing points at ground level in the system.

Side Flashing: These are strikes which move laterally. Lateral strikes are of particular concern with buildings over 20m high. The Rolling Sphere zoning protection model is normally used. Side wall air terminals on tall buildings are needed.

Bonding and Earthing: These are essential precautionary extensions to the main protection when plant and machinery for example might be the subject of strikes. Equi-potential earthing cables are used to join the items of concern together and to eliminate the risk.

Zone of Protection: Volume within which a lightning conductor gives protection against a lightning strike.

Useful References

BS EN 62305-2:2006 - Protection against lightning. Risk management.
BS EN 62305-3:2006 - Protection against lightning. Physical damage to structures and life hazard.
BS EN 62305-4:2006 - Protection against lightning. Electrical and electronic systems within structures.
Electricity at Work Regulations 1989.
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CONTACT

Risk Engineering
Risk Support Services
126 Hagley Road
Edgbaston
Birmingham
B16 9PF

Phone +44 (0) 121 697 9131
www.zurich.com

For more information please visit:
www.zurich.com/riskengineering

Zurich Management Services Limited, Registered in England and Wales no. 2741053, Registered Office:
The Zurich Centre, 3000 Parkway, Whiteley, Fareham, Hampshire PO15 7JZ