SANS Code 10313:2010 – Protection against Lightning Physical Damage and Life Hazard

The South African code of practice as amended in 2010 gives a brief description of the requirements for the protection of structures and persons against lightning. The document itself does not cover all aspects of the protection of structures and persons against lightning. The cover page of the code of practice therefore clearly states that it can only be used in conjunction with the IEC 62305 series.

The session therefore will concentrate on the requirements as per IEC 62035 part 2 (Risk Assessments) and part 3 (Physical Damage and Life Hazard). Each part of the IEC code is a substantial document and the objective of the session is to give attendees a clear and practical insight of these requirements.

Introduction

The session will briefly cover the process of assessing the risk of damage caused by lightning and give an in-depth description of the requirements of protecting structures and living beings against the hazards of lightning.

IEC 62305 Part 2

Risk Assessments

Risk assessments shall be conducted for all structures under consideration.

The Risk is defined as the probable average annual loss in a structure and its services due to Lightning Flashes, depends on:

- The annual number of Flashes to the Structure and its services (N)
- The probability of damage by one of the Lightning Flashes (P)
- The mean amount of consequential loss (L)

\[ R = N \times P \times L \]

The risk must be determined for all sources of damage and the consequential risk of loss:

- **S1** = Direct Lightning strike to the structure
- **RA** = Human Life
- **RB** = Fire / Explosion
RC = Overvoltage (LEMP)

S2 = Lightning Strike near the structure
RM = Overvoltage (LEMP)
S3 = Lightning Strike to a service connected to the structure
RU = Human
RV = Fire / Explosion
RW = Overvoltage
S4 = Lightning Strike near to a service connected to the structure
RZ = Overvoltage

The risk of damage must be calculated for all of the ‘R’ values listed above. It is therefore preferable to perform risk assessments with assistance of computer software.

Protection against lightning is needed if the Calculated Risk is higher than the Tolerable Risk RT.

\[ R > RT \]

<table>
<thead>
<tr>
<th>Type of Loss</th>
<th>RT ( (y^{-1}) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of Human Life</td>
<td>( 10^{-5} )</td>
</tr>
<tr>
<td>Loss of services to the public</td>
<td>( 10^{-3} )</td>
</tr>
<tr>
<td>Loss of cultural heritage</td>
<td>( 10^{-3} )</td>
</tr>
</tbody>
</table>

\( 10^{-5} = 1 \text{ in } 100000 \text{ chance of a fatal injury over the course of } 1 \text{ year} \)
(Maximum tolerable risk – Loss of human life)

IEC 62305 Part 3
Protection Against Physical Damage and Life Hazard

The main and most effective measure for protection of structures against physical damage is considered to be the Lightning Protection System.

A Lightning Protection System usually consists of an external and an internal lightning protection system
An External LPS is intended to:
- Intercept a lightning flash to the structure – AIR TERMINATION SYSTEM
- Conduct lightning current safely towards earth – DOWN-CONDUCTOR SYSTEM
- Disperse the lightning current into the earth - EARTH TERMINATION SYSTEM

An internal LPS prevents dangerous sparking within the structure using either equipotential bonding or a separation distance between the external LPS and other electrically conducting elements internal to the structure.

**Class of Lightning Protection System**

The class of required LPS **SHALL** be selected on the basis of a risk assessment (IEC 62305-2).

Four classes of LPS (I to IV) are defined and correspond to the lightning protection level as shown below:

<table>
<thead>
<tr>
<th>Class of LPS</th>
<th>Lightning Protection Level (LPL)</th>
<th>LPS Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>I</td>
<td>0.98</td>
</tr>
<tr>
<td>II</td>
<td>II</td>
<td>0.95</td>
</tr>
<tr>
<td>III</td>
<td>III</td>
<td>0.90</td>
</tr>
<tr>
<td>IV</td>
<td>IV</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Protection measures are effective provided that they comply with the requirements of IEC 62305 Part 3 and are able to withstand the stress expected in the place of its installation.

**Air Termination Systems**

The probability of structure penetration by lightning is considerably decreased by the presence of a properly designed air termination system.

Air Termination Systems can be composed of any combination of the following elements:
- Rods & Finials (incl. free-standing masts)
- Centenary Wires
- Meshed Conductors
Individual Air Termination Rods should be connected together at roof level to ensure current division.

**Positioning**

Air terminals installed to a structure shall be located at corners, exposed points and edges in accordance with one or all of the following methods:

- Protection Angle Method
- Rolling Sphere Method
- Mesh Method

<table>
<thead>
<tr>
<th>Class of LPS</th>
<th>Rolling Sphere Radius r (m)</th>
<th>Mesh Size w (m)</th>
<th>Protection Angle ( \theta )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>20</td>
<td>5 X 5</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>30</td>
<td>10 X 10</td>
<td>See graph on next Pg.</td>
</tr>
<tr>
<td>III</td>
<td>45</td>
<td>15 X 15</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>60</td>
<td>20 X 20</td>
<td></td>
</tr>
</tbody>
</table>

**Construction**

Air terminals should be installed as follows:

- If the roof is made of non-combustible material, air terminals may be installed on the surface of the roof.
- If the roof is made of readily-combustible material, due care needs to be taken with regard to the distance between the air termination conductors and the material. Typically for thatch roofs a distance of 1.0m is adequate.
Natural Air Terminals

Metal components of a roof structure may be considered as natural air terminals and therefore part of the LPS provided they are in accordance with the table below:

<table>
<thead>
<tr>
<th>Class of LPS</th>
<th>Material</th>
<th>Thickness $^a$ t $^a$ mm</th>
<th>Thickness $^b$ t $^b$ mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>I to IV</td>
<td>Lead</td>
<td>-</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Steel (Stainless,</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Galvanised etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Titanium</td>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>Aluminium</td>
<td>7</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
<td>-</td>
<td>0.7</td>
</tr>
</tbody>
</table>

$^a$ t = Prevents puncture, hot spot or ignition
$^b$ t = only for metal sheets if it is not important to prevent puncture, hot spot or ignition problems
Down Conductor Systems

In the event of a direct lightning strike to the LPS, the down conductor system is designed to safely guide the lightning current towards the earth termination system.

In order to reduce the probability of damage due to lightning current flowing in the LPS, the down conductors shall be arranged in such a way from the point of strike to earth:
- So that several parallel current paths to earth exist
- So that the length of current path is kept to a minimum
- So that equipotential bonding to conducting parts of the structure is performed

The Separation Distance between the down conductors and other electrically conductive elements within the structure shall be taken into account and calculated.

Down Conductor Materials

- The number and spacing of the down conductors should be as described above.
- Copper, aluminium and galvanized steel are generally used as down conductor materials, the minimum dimension as shown below
- When the distance from a down conductor to a combustible material cannot be assured, the cross section of the conductor shall not be less than 100mm².

**MINIMUM DIMENSIONS FOR DOWN CONDUCTOR MATERIALS**

<table>
<thead>
<tr>
<th>Protection Level</th>
<th>Material</th>
<th>Down Conductor mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Copper</td>
<td>16</td>
</tr>
<tr>
<td>1 to 4</td>
<td>Aluminium</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Steel</td>
<td>50</td>
</tr>
</tbody>
</table>

Natural Down Conductors

The following parts of a structure can be considered as a natural down conductor:
- Structural Steelwork
- Concrete Steel Reinforcing (Care must be taken to ensure electrical continuity across the interconnected concrete steel reinforcing).
• Rainwater Down Pipes (Provided that the cross section exceeds 50mm², the thickness exceeds 0.5mm and that the sections are welded together).
• Steel Facades (Provided that the thickness exceeds 0.5mm and that there is electrical continuity in a vertical direction)

Down Conductors - Test Joints
At the connection to the earth termination system, a test joint should be fitted on each down conductor.
An exception can be made when using natural down conductors with foundation earth electrodes.
The joint shall be capable of being opened with the aid of a tool. In normal use the joint shall remain closed.

Earth Termination Systems
The shape and dimension of the lightning protection earthing system are important when dealing with safe dispersion of the lightning current into the ground.
In order to minimize any dangerous overvoltages a low resistance earthing system is recommended – if possible lower than 10 Ohms.
A single integrated earthing system is preferable, which is suitable for all purposes (i.e. lightning protection, power systems, telecommunications systems and data systems).
Alternatively all earthing system shall be equipotentially bonded together.

Types of Earthing Arrangements
1) Type ‘A’ Arrangements
   This type of arrangement comprises of horizontal or vertical earth electrodes installed outside the structure; each connected to a down conductor.
   In type ‘A’ arrangements, the total number of earth electrodes shall not be less than two.
- The minimum length of vertical electrodes = 0.5 minimum length shown on graph.
- Protection level III and IV are independent of soil resistivity.
- The minimum lengths can be disregarded if the overall resistance of the earth termination system is less than 10 Ohms.

**Type ‘B’ Arrangements**

- Type ‘B’ arrangements consist of a ring conductor external to the structure being protected. The conductor shall be in contact with the soil for at least 80% of its length.
- A foundation earthing system can also be regarded as type ‘B’, type ‘B’ earthing systems can also be meshed.
- The minimum resistance of a type ‘B’ earthing system can be disregarded provided that the minimum length requirements according to the protection level are met.
- Additional vertical earth electrodes should be installed when a single integrated earthing system is utilised and the overall resistance of the earthing system does not meet the minimum requirements of the safety earthing system (i.e. 1 Ohm or less).
Earthing Materials

1) **Natural Earth Electrodes**
   Interconnected reinforcing steel in concrete foundations or concrete piles and other underground metal structures, should be used as a natural earth electrode.

2) **Earthing Materials**

   **MINIMUM DIMENSIONS FOR EARTHING MATERIALS**

<table>
<thead>
<tr>
<th>Protection Level</th>
<th>Material</th>
<th>Earthing Conductor mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Copper</td>
<td>50</td>
</tr>
<tr>
<td>1 to 4</td>
<td>Aluminium</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Steel</td>
<td>80</td>
</tr>
</tbody>
</table>
Equipotential Bonding

Equipotentialization is performed to prevent dangerous sparking within a structure due to lightning current flowing in the external LPS or any conductive parts of a structure.

The equipotential bonding of the following elements to the external LPS is essential:

- Metal Installations
- Internal Systems
- External conductive parts and lines connected to the structure.

The interconnection of the LPS to these systems can be done by means of the following:

- Bonding conductors, where electrical continuity is not provided by natural bonding
- Surge Protection Devices, where direct connections with bonding conductors is not feasible.

The value of carrying out of the correct equipotential bonding cannot be understated in value of protecting electronic equipment.
Separation Distances

An adequate separation distance should be maintained between the external LPS and all conductive parts of the structure.

The separation distance can be calculated as follows:

\[ s = k_i \frac{k_c}{k_m} l \]

Where

- \( k_i \) depends on the LPS Level
- \( k_c \) depends on the lightning current flowing on the down conductors
- \( k_m \) depends on the electrical insulation level
- \( l \) is the length, in metres along the air termination or the down conductor, from the point where the separation distance is to be considered, to the nearest equipotential bonding point.

VALUES OF COEFFICIENT \( k_i \)

<table>
<thead>
<tr>
<th>Class of LPS</th>
<th>( k_i )</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.08</td>
</tr>
<tr>
<td>II</td>
<td>0.06</td>
</tr>
<tr>
<td>III and IV</td>
<td>0.04</td>
</tr>
</tbody>
</table>

VALUES OF COEFFICIENT \( k_c \)

<table>
<thead>
<tr>
<th>No. of Down Conductors</th>
<th>( k_c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1...0.5</td>
</tr>
<tr>
<td>4 and more</td>
<td>1...1/n</td>
</tr>
</tbody>
</table>

VALUES OF COEFFICIENT \( k_m \)

<table>
<thead>
<tr>
<th>Material</th>
<th>( k_m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>0.08</td>
</tr>
<tr>
<td>Concrete, Bricks</td>
<td>0.06</td>
</tr>
</tbody>
</table>
Discussion Subjects

- Industry sectors
- Timing of LPS Installations
- Use of concrete reinforced steel as part of LPS
- Value of Integrated Earthing Systems
- Value of correct Equipotential Bonding
- Maintenance of Lightning Protection Systems

References
SANS Code 10313:2010
IEC 62305 Part 2 & 3