LIGHTNING PROTECTION, EARTHING AND HAZARDOUS LOCATIONS

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INTRODUCTION

• Lightning is an ionised channel that propagates from one charge region to another oppositely charged region.

• Two types
  – Cloud discharges (no channel to ground)
  – Cloud-to-ground discharges (at least one channel connecting cloud to ground)

• Cloud-to-ground lightning
  – Negative downward
  – Positive downward
  – Negative upward
  – Negative upward
THE FINAL RELEASE OF THE CSIR MAP (1994) FOR Ng
GLOBAL COMPARISON

- Planetary average
  \( N_g = 6.5 \) ground flashes/km\(^2\)/year

- Soil resistivity: 150\( \Omega \).m (cf 10 000\( \Omega \).m!)

- High lightning activity + poor soil conditions + clustered population + areas of high economic activity
  - A high proportion of the South African population live in areas with relatively high lightning ground flash densities.
  - A significant proportion of our industry is located in areas characterised by \( N_g \) value of greater than 6.

Implication:
- A significant problem is that South Africa has relatively dry conditions (leading to high values of soil resistivity).
- Establishing a ‘good earth’ is therefore relatively difficult.
- And we must understand that the surges (voltages) associated with lightning activity tend to be higher than predicted elsewhere (lightning is a current source).
- The risk of lightning damage is therefore relatively high.
ILLUSTRATIVE RISK EXAMPLE

- Factory/office unit
  - Length = 60m
  - Width = 30m
  - Height = 10m
  - Area = 1800m²

- $N_g = 8$ flashes/km²/year

- Adjacent strikes can potentially affect equipment and cause injury

- Typical indicative values
  - Number of direct strikes
    - $N_d = 0.08$ direct strikes per annum
    - $N_d = $ direct strike every 12.4 years
  - Number of indirect strikes:
    - $N_i = 3.79$ indirect strikes per annum \((cf\ 0.08)\)
    - $N_i = $ an indirect strike influencing the structure and contents every 3.17 months \((cf\ 12.4\ years)\)
LIGHTNING RISK MANAGEMENT

- Risk assessment and management is required to understand the potential risk and minimise potentially damaging effects of lightning.

- Clear that effective risk management must take account of both direct and adjacent (indirect) lightning.

- The role of the lightning protection system (LPS) in conjunction with other measures such as safety and maintenance plans, is to manage the risks associated with direct and indirect lightning strikes in a holistic manner.
INDUSTRY & MINES

• Two distinct but interrelated objectives:
  − Human safety
  − Protection of electric and electronic systems, and infrastructure

• Objectives common to all applications – BUT
  − Can include hazardous environment
  − Often over extended area
  − Exposed equipment & personnel
  − Challenges with legacy installations and approaches
  − Challenges to maintain integrity of installation

• Combination of LPS and safety plan (plus maintenance and training) is required
POTENTIAL CONSEQUENCES

- Structural damage
- Equipment damage
- Personal injury
- **Fire**
- Economic loss (direct and indirect)

*Discuss in particular the fire risk*
LIGHTNING AND FIRE

• Ignition mechanism – fire can be caused by:
  – Direct heating/ignition
  – Arc/flashign

• Fire risk associated with
  – Vegetation (e.g., veld and forest fires)
  – Industrial (including mining) installations
  – Commercial and domestic structures

• *Particular risk in hazardous locations*
FIRE CAUSES - DIRECT HEATING

- Typical of veld & forest fires
  - So-called *dry ignition*
  - Dependent inter alia on:–
    - Nature of material (fuel) – eg moisture level
    - Atmospheric moisture conditions
    - Concurrent rainfall
    - Fire suppression efforts

- Can also be related to structures depending on materials, intensity of strike, but relatively low probability in urban areas for standard brick and tile structures

- Potential hot spots and melting of materials at strike location is a particular issue in the case of hazardous locations
FIRE CAUSES – FLASHING/ARCING

- Flashing or arcing can be ignition source (eg side flash, spark due to poor bonding etc)

- What can be ignited? Examples are:-
  - Flammable gases (eg gas line related)
  - Other flammable vapours (eg fuel, methane)
  - Dust (eg organic dust such as maize, sawdust, sugar dust)

- Dependant on circumstances such as concentration of materials and gases (also related to temperatures, flash points etc) – in turn related to hazardous location classifications
INDUSTRIAL & MINING INSTALLATIONS

- Typically more hazardous than commercial and domestic installations

- Requires presence of flammable materials
  - Dust (e.g., grain dust, sugar dust, fine saw dust)
  - Flammable gases and vapours

- Significant fire and/or explosion risk due to flashing/arcing, typically associated with
  - Poor bonding / earthing
  - Lack of proper lightning protection strategy and systems

- Can also be a risk associated with direct heating

- Hazardous areas represent a particular risk
SOME CHARACTERISTICS OF THE MINING ENVIRONMENT

- Surface to underground interfaces (material handling access points; ventilation shafts etc)

- Multiple metallic penetrations through the surface/underground interface (incl cabling & services)

- Flammable/explosive environment (dust and gas) – flame proof

- Difficult earthing conditions (layered soils; exposed environment; mobile components)

- Mines covers large geographic areas
HAZARDOUS AREAS – SOME ISSUES

• LPS must not allow sparking, melting, sputtering of hot metals (except at point of strike – *but this must also not impact on the hazardous location*)

• Equipotentialisation, bonding, site-wide earthing (“type B” - ring/surround) all critical

• Consider effectiveness of natural components – thickness of metal, avoidance of hot spots/melting, etc

• Control of voltages on “floating” components is critical (eg special isolating spark gaps on pipelines, etc)

• Type and location of SPDs

• Use of appropriate standards
LIGHTNING PROTECTION = RISK MANAGEMENT

• Not just about how often direct or indirect strikes can affect installation

• Risk management =
  – What happens when lightning affects installation?
  – What risk management measures must be put in place? *(lightning risk management and engineering, operational & maintenance risk management)*

• Lightning risk management process:
  – Establish strike risk (direct and indirect)
  – Establish effect of risk and identify level of protection required
  – Design and implement protection measures to required risk level

• Lightning protection is a risk *management* process – there are no absolute guarantees
### SANS 62305-1 SOURCE/DAMAGE/LOSS MATRIX

<table>
<thead>
<tr>
<th>Source/Damage Type</th>
<th>Loss Type</th>
<th>Damage Type</th>
<th>Loss Type</th>
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</thead>
<tbody>
<tr>
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<td>Damage Type</td>
<td>Loss Type</td>
</tr>
<tr>
<td>Structure - Direct</td>
<td>S1</td>
<td>D1, D2, D3</td>
<td>L1, L4</td>
</tr>
<tr>
<td>Structure - Adjacent</td>
<td>S2</td>
<td>D3</td>
<td>L1</td>
</tr>
<tr>
<td>Service - Direct</td>
<td>S3</td>
<td>D1, D2, D3</td>
<td>L1, L4</td>
</tr>
<tr>
<td>Service - Adjacent</td>
<td>S4</td>
<td>D3</td>
<td>L1</td>
</tr>
</tbody>
</table>

(1) Only for structures with risk of explosion, and for hospitals or other structures where failures of internal systems immediately endanger human lives

(2) Only for properties where animals may be lost

### Damage Source/Point of Strike/Service Structure - Service

<table>
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<tr>
<th>Damage Source</th>
<th>Point of Strike</th>
<th>Service Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>L'2, L'4</td>
<td>L1, L4</td>
<td>L2, L4</td>
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### Table Legend

- **D1**: Injury to living beings
- **D2**: Physical damage
- **D3**: Failure of electrical and electronic systems

- **L1**: Loss of human life
- **L2**: Loss of service to the public
- **L3**: Loss of cultural heritage
- **L4**: Loss of economic value (structure & content, service, activity)
SOME CURRENT STANDARDS

- Lightning protection and earthing:
  - SANS 10313:2010
  - SANS 10199: 2004
  - SANS (IEC) 61643-1
  - SANS (IEC) 62305 suite
    - Part 1: General Principles
    - Part 2: Risk Management
    - Part 3: Physical Damage to Structures and Life Hazard
    - Part 4: Electrical and Electronic Systems within Structures
    - Part 5: Services

- Other referenced/relevant standards include:
  - SANS 10347:2002 *(Avoidance of hazards underground in Collieries due to lightning)*
  - SANS 1063 *(Earth Electrodes)*
  - SANS 10108 *(Classification of hazardous locations and selection of apparatus for use in such locations)*
  - SANS 60079 suite *(Explosive atmospheres)*
  - SANS 10142-1 *(The wiring of premises – part 1: Low voltage installations)*
  - SANS 10142-2 *(The wiring of premises – part 2: Medium voltage installations)*
  - SANS 10225 *(The design and construction of lighting masts)*
The LPS
- complete/holistic strategy

- Lightning Protection System (LPS)
  - External LPS
    - Air Termination
    - Earth Electrode
  - Internal LPS
    - Down Conductor
    - Site-wide Earthing
    - Bonding
    - SPDs
    - Cabling
    - LP Zones
KEY PROTECTION TECHNIQUES

- Impedance minimisation
- Direct strike protection
- Earthing and equipotentialisation
- Lightning protection zones
- Cabling strategies, shielding and bonding
- Surge protection
- Isolation transformers and UPSs

Touch briefly on these techniques
Lightning behaves like a current source. Therefore the voltage at the point of strike is determined by the effect of the current flowing through the impedance presented by the structure to the lightning current.

This concept also applies to partial lightning currents in bonding, screening, equipotentialisation and earthing conductors.

\[ V = IR + L \frac{dI}{dt} \]

When we consider the high values of peak lightning current and high rates of rise of lightning current we expect high peak voltages (megavolts) across typical impedances presented by typical structures and conductors.
DIRECT STRIKE PROTECTION

- Clearly must avoid direct strikes to sensitive components and to points in or via hazardous locations
  - Install external LPS
  - Shield overhead cable runs
  - Bury cables
  - Appropriate location of equipment and cables

- Objective of external LPS therefore to intercept lightning and safely discharge it to earth without generating excessive voltages

- Also plays a role in reducing the magnitude of the electric field in the vicinity of the structure or system to be protected

- Examples of particular hazardous location implications to be considered include:
  - Air termination and down conductor design location and materials
  - Positioning of hazardous locations relative to air termination, down conductor and earthing/bonding elements
  - Bonding methods (particularly inside hazardous locations)
EQUIPOTENTIALISATION AND GALVANIC COUPLING

Diagram showing an electrical setup with labels for signal line, impedance ($L_e$), and resistance ($R_e$).
• Difficult to minimise $L_e$ and $R_e$

• Bond equipment together

• Multiple bonds for lower impedance (wide-band performance)

• Use “natural” components (building steelwork, cable trays, conduit, armouring)
EQUIPOTENTIALISATION AND GALVANIC COUPLING

Principles applicable to linked plants and plant areas, and associated equipment.
BUT!

It’s not just about the planning, design and original installation

The risk must be managed on an ongoing basis

Which implies……..
MAINTENANCE IS CRITICAL
SOME KEY ENGINEERING CONSIDERATIONS

- A holistic and structured “systems engineering” approach is critical.
  - “Systems engineering is a process by which the orderly evolution of man-made systems can be achieved”
  - “Systems engineering is a process employed in the evolution of systems from the point where a need is identified, through production/construction and ultimate deployment of that system.”
  - “The process involves a series of steps accomplished in a logical manner and directed towards the development of an effective and efficient product or system.”
    [Blanchard BS, Fabrycky WJ. Systems Engineering and Analysis. Prentice Hall.]

- A warning and safety plan, including awareness training, is essential to complement the LPS. Lightning protection must be incorporated into the overall OHS strategy & plans for the facility.

- Engineering co-ordination across the facility is critical.

- The qualifications, expertise and experience (competence) of the lightning protection engineer are important, particularly for complex applications and those involving special risks (e.g., hazardous locations).
MANAGEMENT = A CONTINUOUS PROCESS

ASSESSMENT

iLPS

IMPLEMENT & MAINTAIN

DESIGN & DOCUMENT

iLPS: Integrated Lightning Protection Solution
DYNAMIC, INTEGRATED ENVIRONMENT => ILEP

Integrated Lightning Engineering Plan (ILEP)

- Risk Assessment
- External & Internal Lightning Protection Systems
- Personnel & Site Safety Plan
- Engineering Site-wide Co-ordination Plan
- Training and Awareness Plan & Programme
- Maintenance Plan (& Actions)

Insight. Innovation. Integrity
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