CASE STUDY
LIGHTNING PROTECTION
OF AN INDUSTRIAL PLANT

Robert Kane
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CASE STUDY SITE

- Diamantina Power Station (DPS) – Mt Isa
- DPS is a new Combined Cycle Gas Turbine (CCGT) power station, comprising of two 120MW units, large 132kV switchyard and various buildings and plant facilities.
- It supplies the power requirements for Mt Isa and the surrounding mines.
Control Room and Warehouse Buildings
The Cooling Tower
The Water Treatment Plant/Building and Raw Water Tanks
A single 120MW Unit, showing the GT & HRSG, Power Building (Substation) and Cooling Tower
The 132/11kV Switchyard
LIGHTNING PROTECTION DESIGN

• The project objective was to design a direct strike Lightning Protection System (LPS) for the plant.

• The key design criteria were:
  – Fully compliant with AS1768:2007
  – Confirm the need for direct strike protection; and that the level of protection manages to an acceptable level of risk.
  – Where practical, make use of adjacent buildings & structures.
  – Protection Level I (PLI) to be used for gas hazardous zones.
  – Protection Level II (PLII) to be used for other structures/systems.
  – Check structures are appropriately bonded to earth.
RISK CALCULATIONS

• AS1768 provides a spreadsheet with in-built formulae for calculating the risks and comparing to predetermined acceptable levels of risk for:
  – Loss of Human Life
  – Loss of Cultural Heritage
  – Loss of Essential Services
  – Economic Loss

• Relevant parameters for the installation are entered for:
  – Structure Dimensions
  – Environment
  – Protection Measures
  – Structure Attributes
  – Service Lines
  – Loss Categories

• Under Protection Measures, can set the efficiency of LPS:

<table>
<thead>
<tr>
<th>Protection Level PL</th>
<th>LPS Efficiency $\eta$</th>
<th>Sphere Radius $a$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>0.98</td>
<td>20</td>
</tr>
<tr>
<td>II</td>
<td>0.95</td>
<td>30</td>
</tr>
<tr>
<td>III</td>
<td>0.90</td>
<td>45</td>
</tr>
<tr>
<td>IV</td>
<td>0.80</td>
<td>60</td>
</tr>
</tbody>
</table>
Risk Assessment Calculation from AS1768

Risk Assessment for Lightning Protection

Structure Identification

Structure Dimensions
- Length (m): 45.5
- Width (m): 20.9
- Height (m): 7.1

Structure Attributes
- Risk of Fire or Physical Damage: Low
- Risk of Dangerous Discharge: Medium
- Internal Wiring Type: Unscreened

Other Overhead Services
- Number: 0
- Cable Type: Unscreened

Other Underground Services
- Number: 1
- Cable Type: Screened

Environment
- Ground Flash Density: 2
- Environmental Factor: Similar Height
- Service Line Density: Suburban

Protection Measures
- Efficiency of Building Protection: 0.93
- Surge Protection at Point of Entry: Yes
- Surge Protection on All Equipment: No

Loss Categories
- Category 1 - Loss of Human Life
  - Special Hazard: 1
  - Fire Damage Factor: 0.96
  - Overvoltage Damage Factor: 0.0605
- Category 2 - Loss of Essential Services
  - Fire Damage Factor: 0.64
  - Overvoltage Damage Factor: 0.001
- Category 3 - Loss of Cultural Heritage
  - Fire Damage Factor: 0
- Category 4 - Economic Loss
  - Fire Damage Factor: 0.5
  - Acceptable Risk of Economic Losses: 1.0E-01

Overall Risk

<table>
<thead>
<tr>
<th>Loss Category</th>
<th>Calculated Risk (R)</th>
<th>Acceptable Risk (R_A)</th>
<th>Direct Strike Risk (R_d)</th>
<th>Indirect Strike Risk (R_i)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss of Human Life</td>
<td>9.7E-06</td>
<td>1.0E-05</td>
<td>2.7E-06</td>
<td>9.7E-06</td>
</tr>
<tr>
<td>Loss of Essential Services</td>
<td>1.96E-05</td>
<td>1.0E-03</td>
<td>6.74E-08</td>
<td>1.96E-05</td>
</tr>
<tr>
<td>Loss of Cultural Heritage</td>
<td>0.0E+00</td>
<td>1.0E-03</td>
<td>0.0E+00</td>
<td>0.0E+00</td>
</tr>
<tr>
<td>Economic Loss</td>
<td>9.79E-05</td>
<td>1.0E-03</td>
<td>2.47E-07</td>
<td>9.7E-05</td>
</tr>
</tbody>
</table>
ROLLING SPHERE METHOD

- AS1768 specifies the Rolling Sphere Method (RSM) for the design of a LPS with the air terminals positioned to establish a zone of protection over the whole structure.

- The protection efficiency used in the risk assessment corresponds to the radius of the sphere to be used.

- The sphere is brought up to and rolled over the air terminals to determine the zone of protection.
• The Benefits of 3D Modelling
  – Allows Rolling Sphere Method to be easily applied to complex structures.
  – Clearly Identifies elements protruding from the zone of protection.
• Central Control Room (CCR) and Warehouse:
  – The CCR included a communication antenna and solar hot water mounted on roof.
  – Risk assessment using PLII showed that surge protection also required at cable entry to CCR to achieve acceptable levels of risk for Loss of Essential Services and Economic Loss.
  – The LPS was designed using a 30m rolling sphere and air terminals mounted on 7 free-standing masts.
LPS coverage over the Central Control Room and Workshop Buildings
• Power Buildings (Substations):
  – Comprising a block building with air-conditioner units on western end, emergency generator on eastern end and supply transformers on southern side. HV cables supplying the transformers were underground (and included surge arrestors).

  – Risk assessment using PLII showed that surge protection also required at the point of cable entry to the building to achieve acceptable levels of risk for Loss of Human Life; Loss of Essential Services and Economic Loss.

  – The LPS was designed using a 30m rolling sphere, making use of the pipe rack structure and air terminals mounted on 5 free-standing masts.
LPS coverage over the Power Building (Substation)
• Cooling Tower:
  – Cooling tower structures are made from fibreglass and not designed to carry the additional loads of metal lightning masts. Also have to ensure protection over cooling water pumps.
  – Risk assessment using PLII showed acceptable risk levels.
  – The LPS was designed using a 30m rolling sphere and air terminals mounted on 6 free-standing masts.
LPS coverage over the Cooling Tower
• Chiller:

– The chiller structure was mostly metal, but we wanted to also protect the exposed pipe work (not protected by installation within pipe racks).

– Risk assessment using PLII showed acceptable risk levels.

– The LPS was designed using a 30m rolling sphere and making use of the pipe rack structure and air terminals mounted on 2 free-standing masts.
LPS coverage over the Chiller
• GT & HRSG:

– The GT comprises several large steel structures and metal-clad enclosures, which:

  o Are bonded to the buried site earth grid at regular intervals.
  o Act as air terminals and a down conductor network.
  o Provide appropriate protection and comply with AS1768.

However specific equipment and areas need to be protected from a direct strike, eg:

  o Instruments, silencers and exposed steam lines.
  o Hazardous areas (above the gas vents at the GT and HRSG structures).
– The risk calculation used PLI over the hazardous areas. With surge protection at the cable point of entry, acceptable loss levels were achieved for all risks, except Loss of Human Life.

The risk associated with Loss of Human Life at the hazardous areas is most significantly influenced by the explosion risk. Given that the PLI (Efficiency of Building Protection) is already set at the highest level (0.98), it was recommended that personnel do not work on or near the hazardous areas when there is an approaching storm.

The risk calculation used PLII over the remainder of the structure. It found with protection at the cable point of entry, all acceptable loss levels were achieved for all risks.
– The LPS was designed making use of air terminals fitted to the top of the stacks and steel structure, and using a 20m rolling sphere above the hazardous areas and a 30m rolling sphere for the remainder of the structure.

– For the gas vents on top of the GT Air Intake Filters, direct strike protection was provided over the top of the vents, but it was not practical and cost effective to provide protection over the full 6m high hazardous area above these vents.

DPS manages this risk, given that:

• Gas (a very small amount) only vents during a start-up sequence.
• Gas quickly disperses in air above the filter house.
• There are no walkways or people access in the vicinity.
• Plant Operators have a lightning tracking system in place.
GT and HRSG Unit, showing hazardous zone protruding through the LPS coverage
• HV Switchyard Control Building:

– The LPS for the HV Switchyard had been designed and installed with the initial construction. However the control building hadn’t been included in the LPS. It consisted of a demountable building on posts and a communication antenna on the roof.

– The existing LPS design using a 20m rolling sphere for the switchyard, was extended to include the control building by adding air terminals mounted on 2 free-standing masts.
LPS coverage over HV Switchyard Control Building
• External Gas Gate Station:
  – The LPS for the External Gas Gate Station had been designed (using a 20m rolling sphere) and installed with the initial construction.
  – Only required 3D modelling of the LPS to provide consistent graphical presentation of the plant’s direct strike lightning protection.
LPS coverage over the External Gas Gate Station
• Water Treatment Plant/Building:
  – This is a metal-clad, steel framed building.
  – Recommended that the steel framework on all four corners of the building frame be bonded to the buried site earth grid.

• Water Tanks:
  – This applied to the Raw Water Tanks, Demin Water Tank and Potable Water Tank.
  – All tanks were of a solid steel construction and bonded to the buried site earth grid at 2 opposite locations. This is appropriate and compliant with the standard.
• Pipe Racks and Cable Ladder:
  – Cables installed on aluminium cable ladders with covers fitted, and positioned within the pipe racks.
  – Recommended that the cable ladders be bonded directly to the buried earth grid at the point of entry into the Power Buildings. Also, a few additional bonds required on the pipe rack where bonding spacing exceeded 20m.

• Floodlighting:
  – The Floodlight Poles around the plant had not been bonded to the buried earth grid – instead connected to the earth conductor in the power cable to the light.
  – Recommended that all poles not within the zone of protection, be bonded to the buried earth grid, and that surge protection be fitted to the outgoing light cable at the DB.
Overall plant LPS coverage showing floodlight poles penetrating the LPS coverage
QUESTIONS

Acknowledgement for 3D Modelling in SolidWorks
Tony Gibson, Gibson Design & Drafting Pty Ltd, Gladstone.

For more information...
Robert.Kane@welcon.com.au
Average annual lightning ground flash density

Analysis generated from NASA Optical Transient Detector and Lightning Imaging Sensor data (0.5 degrees grid resolution) averaged over the 8-year period 1995-2002. The satellite data were calibrated against the ground-based Lightning Flash Counter data and adjusted accordingly.