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THE INTEGRATED LIGHTNING ENGINEERING PLAN AS AN OVERARCHING AND COORDINATING FRAMEWORK FOR AN EFFECTIVE AND HOLISTIC LIGHTNING PROTECTION SOLUTION

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ABSTRACT

The objective of a lightning protection system (LPS) is to comprehensively protect humans, animals, structures, systems and equipment against the damaging and dangerous effects of lightning. Human behaviour during a lightning storm is an important consideration and emphasises the need for a holistic safety strategy over an extended period of time. Lightning protection solutions must be holistically engineered and relevant risks (due to lightning and in a wider context) must be assessed and managed. Furthermore, the ongoing integrity of the LPS must be properly coordinated with all relevant parties (for example at a plant) and maintained. Awareness and training of all stakeholders and potentially affected parties in respect of the objectives, measures and plans in place is key to the effectiveness and sustainability of the strategy and solution. This paper discusses the requirements and key elements of an Integrated Lightning Engineering Plan (ILEP) and argues that such a comprehensive and integrated plan should be the overarching and coordinating engineering management framework to enable an effective and holistic lightning protection strategy and solution.

1 INTRODUCTION

The key objectives of lightning protection are to ensure safety of living beings, and to protect infrastructure and systems against direct losses (eg actual damage to structures and equipment) and indirect or consequential effects (eg downtime and loss of production, loss of services etc). Furthermore, these objectives are interrelated. For example, infrastructure and systems protection contributes to safety (directly and indirectly), in addition to specific safety measures and precautions [1, 2].

Whilst a technical standards based approach to lightning protection has been shown to be effective [3], the authors' experience in South Africa and further afield suggests that it is a common perception that the mere installation of a lightning protection system (and often even just external protection) is the solution to all potential lightning problems at a facility and that once the installation has been completed the responsibility is over. The fact that a "specialist contractor" has done the installation often strengthens this perception.

Limited understanding of the interrelated objectives mentioned above also leads to a non-holistic and uncoordinated approach that is ultimately ineffective. Indeed, the comprehensive nature and technical content of current standards such as the IEC 62305 suite (Parts 1–4) [2] may be encouraging a "cookbook" type approach with such superficial and narrowly directed engineering effort. The ongoing integrity of any installed provisions is also at risk, from uncoordinated activities at the facility that may compromise the installation, poor maintenance and ineffective awareness of what actions to take and when to take them.

Similar experiences of a limited engineering approach have also been reported in various countries and locations by other practitioners [4], indicating that this is a widely experienced situation that requires further attention from an engineering management perspective.

2 FURTHER BACKGROUND AND MOTIVATION

Injury or death due to lightning can be caused by direct effects as well as by indirect effects (such as plant damage/malfunction due to lightning leading to injury or death). The safety problem is exacerbated at sites where personnel are more exposed than general – eg slimes dams, general mining operations, agricultural facilities, sporting venues and the like – and/or where measures such as warning systems and safety plans are inadequately implemented and integrated into the holistic solution.

In the authors' experience, lightning protection solutions are often implemented with inadequate technical co-ordination across the facility and inadequate

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and ineffective maintenance management, leading to a degradation of the status and effectiveness of the installation systems (often not realised until problems are experienced). A holistic approach is often not adopted to incorporate all relevant elements and systems into the lightning protection solution.

Furthermore, risk assessment often tends to be viewed from the narrow perspective of assessing the direct impacts of lightning and consequential losses, whilst not addressing the broader risk issues that will affect the initial and ongoing integrity and effectiveness of the lightning protection solution. These broader risk issues, in common with other engineering projects, include financial risk (eg present and future budgets/constraints), other technical and engineering constraints and issues at the plant/facility including the impact of environment changes, other systems and their co-ordination, maintenance as well as "softer issues" such as training and awareness for personnel, and skills and education/understanding levels of technical and non-technical personnel.

Effective lightning safety and protection therefore clearly entails more than just the technical design and installation of the lightning protection system. The potentially deleterious impact on persons, plant and operations and the resultant economic impact mean that it is necessary to view lightning protection as an integral part of occupational health and safety as well as of overall facility or plant operation, maintenance and integrity, and not just as an isolated component or subsystem, through a structured and systematic engineering approach.

3 CURRENT STANDARDS AND APPROACH AND PRACTICAL APPLICATION

Effective lightning safety and protection (of people, animals and plant) is not adequately addressed by simply following or complying with the technical lightning protection standards such as the IEC62305 suite [2, 5]. Whilst these may adequately and comprehensively address the technical issues and requirements, they do not provide an adequate engineering management framework within which to formulate, engineer and manage holistic and comprehensive lightning protection solutions.

Whilst the IEC62305 suite indeed addresses technical and engineering process issues (for example in Part 3 Appendix E and Part 4 Section 8), it does so in what is considered and interpreted as a piecemeal and non-integrated manner. This is exemplified for instance by splitting the process description and recommendations across different parts of the standard with inadequate cross-referencing and coordination between the sections relating to the external and internal LPS parts of the standard. This is reflected in the authors' experience in industry where a holistic technical approach (ie in terms of an integrated and comprehensive solution including the external and internal LPS) is often not well understood or implemented, if indeed at all.

As a technical tool and guideline for engineering professionals trained in the process of engineering analysis and design, the present standards therefore provide a comprehensive and useful technical reference guide. As already noted however, the comprehensive technical content of the IEC62305 suite also facilitates, as an "unintended consequence", the use of the standards in a "cookbook" approach by persons with inadequate engineering and/or technical grounding, experience, training and qualifications, simplistically following the standards with a "recipe-based" technique, believing that this is adequate. It is not, because it removes from the equation the essential need for engineering analysis and judgement and engineering management (including coordination) aspects.

The use of such a simplistic cookbook approach is particularly problematic and potentially hazardous in the case of complex applications, such as, for example, those involving industrial, communications, energy, IT and other infrastructural plants and facilities.

As a result the present standards and process recommendations do not adequately encourage and facilitate a holistic and structured engineering approach, where all engineering issues are considered and incorporated. These include, for example:

- All interfaces:
  - Technical interfaces.
  - Management & coordination.
- All risks including project and broader engineering and application environment risks (not just the narrow risk assessment as per IEC62305-2).
- All facility plans and operations (eg engineering, health and safety, training, facility coordination, maintenance).

Some other issues relating to the engineering process described as per the current IEC62305 standard suite that can be highlighted include the following:

- In Part 3 procedures, the obtaining of the basic information noted is not just recommended where reasonably practical – it is essential to a comprehensive engineering process.
- The procedures in Part 3 (and indeed in Part 4) are more oriented to commercial (and residential) structures and buildings rather than to more complex applications such as industrial plants, communications and power infrastructure etc, where a more diverse and complex range of systems, technologies and interfaces are involved, and where the engineering teams may be more diverse and/or separated. Such applications exacerbate the engineering

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management and co-ordination challenges.

- The flowchart in Appendix E of IEC62305-3 is too narrowly defined from an engineering perspective and only particularly addresses the design phase. It also does not directly cross-reference or tie into the management plan in IEC62305-4 (Section 8). It also does not adequately and comprehensively tie in with Section 7 (Maintenance).

Whilst it is rightly pointed out in Appendix E of IEC62305-3 that planning, implementation and testing of an LPS encompasses a number of technical fields and makes coordination demands, the present framework is inadequate and piecemeal from an engineering management perspective. Furthermore, whilst the correct observation is made - that if changes are made at the facility or structure the adequacy of the LPS must be rechecked - this is not considered to be adequately incorporated into the engineering management process.

In practice, and particularly at large industrial plants and other complex infrastructure and facilities, there are often different departments and engineering teams involved in design, maintenance and future extensions and modifications. Furthermore, the responsibility for lightning protection can be fragmented across the plant, or isolated within a particular department or team. This can often lead to a “silo-based” approach and associated engineering management challenges in respect of an integrated approach to lightning protection.

Whilst it must be emphasised, as already stated, that it is clear that where the current technical standards are appropriately applied, the techniques and technical methodologies described are effective, it is also clear that a comprehensive engineering management guideline or framework is required as an integrated plan. This needs to incorporate, but not be limited to, the technical management recommendations in the current standards (as previously referred to)

The need for such an engineering management framework is further emphasised where often a specialist engineering professional is not involved in the design and indeed the general engineering process, and/or the engineering process responsibility lies with an essentially unqualified or inadequately trained person (an unfortunate and undesirable, but often encountered situation). Making such an engineering management framework part of the standard (but as an integrated and single-point reference, even if only as an informative part of the standard) will provide appropriate visibility (including to facility management) of the complex and integrated approach (and also hence the engineering skills) required, for effective and lasting solutions.

This is exemplified by the authors’ experiences in South Africa and elsewhere, where the inadequacies in the engineering approach adopted are often not evident to management and those responsible at the time.

4 A SYSTEMS ENGINEERING APPROACH AND KEY ISSUES

A holistic and structured “systems engineering” approach is considered by the authors to be the basis of the key engineering management approach and framework required.

Blanchard and Fabrycky [6] make the following observations regarding the systems engineering approach that are instructive in understanding the ethos of the approach:

- *“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”.*

Key issues that must be comprehensively considered to provide and ensure effective lightning safety and protection include a number of interrelated aspects:

- Lightning risk assessment and risk exposure, as well as the overall engineering and operational risk assessment and management.
- Design and installation of a lightning protection system (direct and indirect strike protection)
- Detection and warning systems and their integration into the safety and protection strategy.
- Maintenance of the system including technical coordination across the facility, across the system life cycle.
- Integration of the LPS with existing plant /facility infrastructure.
- Engineering coordination across the plant/facility and between operational units at all phases (design, implementation, ongoing maintenance of integrity), across the system lifecycle.
- Appropriate understanding and awareness of the key hazards and of the appropriate behaviour and actions to be taken during lightning activity (including appropriate lighting safety plans).
- Appropriate training and awareness of site personnel, across the application environment, of plans and procedures and of protection measures and systems.

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- Formal and structured integration of the lightning protection plans and strategies into the facility's occupational health and safety procedures, as well as other operational and engineering procedures and protocols.

It is vital that these interrelated aspects be properly co-ordinated and managed within a formal engineering management framework. This needs to be effectively applied across the entire life-cycle of the lightning protection solution, and involve all stakeholders who need to collectively understand and take "ownership" of the solutions and strategies in order for their integrity to be retained and for their proper and effective execution.

The proposed engineering management framework is described as the Integrated Lightning Engineering Plan (ILEP).

5 THE INTEGRATED LIGHTNING ENGINEERING PLAN (ILEP)

The Integrated Lightning Engineering Plan (ILEP) provides a core mechanism and engineering management framework to ensure a holistic and systematic approach to achieve effective lightning safety and protection at a facility. This paper argues that ownership of this plan must be at the highest level as a key component of both occupational health and safety, and of plant/facility management, engineering, operations and ongoing integrity.

Key aspects that the Integrated Lightning Engineering Plan (ILEP) must address include *inter alia*:

- The motivation for, and objectives of, lightning protection and safety at the facility (ie the "core values").
- The particular lightning related risks for that specific facility, including specific issues, constraints and other factors that affect the lightning technical risk and associated assessment.
- The particular engineering and other pertinent risks at the facility that will impact on the implementation and ongoing integrity and effectiveness of the lightning safety and protection solution.
- The engineering design of the lightning safety and protection measures for that facility.
- The maintenance plan and measures to ensure the ongoing integrity of the lightning safety and protection systems over their life cycle. This includes the constant reassessment of the appropriateness and effectiveness of the solutions and changing circumstances that may impact on these.
- The coordination, communication, awareness and training needs relevant and integral to the effective initial and ongoing integrity of the safety and protection measures and associated procedures.

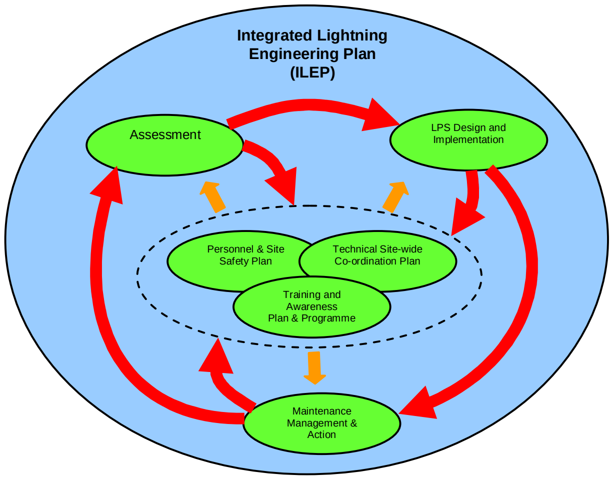

Figure 1: Diagrammatic representation of the Integrated Lightning Engineering Plan (ILEP)

The ILEP is therefore not a static framework, but a dynamic engineering management tool, as conceptually illustrated in Figure 1, that must reflect the dynamic and constantly changing environment within which it must be, and remain, effective.

In this diagram, the "outer ring" represents the key "top level" elements of the engineering process that must be addressed in an ongoing cyclical manner. These are:

- Assessment and analysis in a broad engineering context (ie overall technical and engineering risk and issues, in addition to just the lightning risk).
- Design and implementation of the holistic technical solution (ie including the external and internal LPS).
- Maintenance management and actions.

The "inner-core" in the diagram represents a summary overview of core facility activities and elements that both influence and are influenced by, the assessment, analysis, design and maintenance, and therefore effectiveness of, the lightning protection system, and therefore form a core part of the overall engineering process.

The cyclical nature of the ILEP process must be considered and understood in both a proactive (planned) and reactive (event driven) nature. Events would include both facility-driven events (eg changes, expansions etc) as well as environment driven events (including lightning strikes).

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6 CONCLUSIONS

Effective lightning safety and protection solutions are achieved through a comprehensive and systematic engineering process rather than through a "piece-meal" approach, which in turn requires an appropriate engineering management framework.

An overarching and coordinating engineering management framework, viz the Integrated Lightning Engineering Plan (ILEP), must exist as a "living framework" that will encapsulate the key issues and ensure the achievement of the interrelated key objectives of safety and protection of infrastructure and systems over time and on an ongoing basis. Furthermore, this core framework must be engineered to provide a holistic solution by design. As such it becomes the core repository and management centre of the integrated lightning protection and safety solution at a facility.

It is strongly recommended that such an engineering framework recommendation be incorporated into relevant standards as an engineering guideline (for example in an *integrated* manner as an Appendix in Part 1of the existing IEC 62035 suite [4], and into national and other front-end standards). This will be a strong driver to achieve enhanced effectiveness of lightning safety and protection measures through the use of a structured, holistic and systematic engineering approach, rather than the "piece-meal" approach that is often encountered. Protection and safety does not happen by accident – it happens by comprehensive and holistic engineering and design.

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8 REFERENCES

[1] I.S. McKechnie, I.R. Jandrell, "Best practices in lightning protection and earthing of structures and systems". Seminar notes, Innopro (Pty) Ltd (in association with the School of Electrical & Information Engineering, University of the Witwatersrand), PO Box 9288, Centurion South Africa 0046, November 2009

[2] SANS (IEC) 62305 suite: "Protection against lightning". South African Bureau of Standards, Private Bag X191, Pretoria, 2001

[3] I.S. McKechnie, I.R. Jandrell, "Further Southern African experiences with the application of the IEC lightning protection standards based on their application at four major installations". Proceedings of the 27th International Conference on Lightning Protection (ICLP 2004), Avignon, France, September 2004.

[4] R. Kithil Jr, "Lightning safety in the mining industry". National Lightning Safety Institute (NLSI), www.lightningsafety.com, 2010

[5] SANS 10313:2010: "South African National Standard: Protection against lightning – Physical damage to structures and life hazard". South African Bureau of Standards, Private Bag X191, Pretoria, 2001.

[6] B.S. Blanchard, W.J. Fabrycky, "Systems Engineering and Analysis". Prentice-Hall International Series in Industrial and Systems Engineering, 1981. ISBN 0-13-881631-X.

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