IEC 62858

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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Lightning density based on lightning location systems – General principles

Densité de foudroiement basée sur des systèmes de localisation de la foudre (LLS) – Principes généraux

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Densité de foudroiement basée sur des systèmes de localisation de la foudre (LLS) – Principes généraux

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LIGHTNING DENSITY BASED ON LIGHTNING LOCATION SYSTEMS – GENERAL PRINCIPLES

FOREWORD

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International Standard IEC 62858 has been prepared by IEC technical committee 81: Lightning protection.

This second edition cancels and replaces the first edition published in 2015. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

Two informative annexes are introduced dealing with the determination of lightning density for risk calculation (Annex A) and ground strike point calculation methods (Annex B).

The text of this International Standard is based on the following documents:

FDIS	Report on voting
81/627A/FDIS	81/634/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

International standards for lightning protection (e.g. IEC 62305-2) provide methods for the evaluation of the lightning risk on buildings and structures.

The lightning ground flash density N_G, defined as the mean number of flashes per square kilometre per year, and the ground strike point density N_{SG}, defined as the mean number of ground strike points per square kilometre per year are the primary input parameters to perform such an evaluation (see Annex A).

In many areas of the world data for risk evaluation are provided by lightning location systems (LLSs), but no common rule exists defining requirements either for their performance or for the elaboration of the measured data.

LIGHTNING DENSITY BASED ON LIGHTNING LOCATION SYSTEMS – GENERAL PRINCIPLES

1 Scope

This document introduces and discusses all necessary measures to make reliable and homogeneous the values of ground flash density, N_G and ground strike point density, N_{SG}, obtained from lightning location systems (LLSs) in various countries. Only parameters that are relevant to risk assessment are considered.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62305-1, *Protection against lightning – Part 1: General principles*

IEC 62305-2, *Protection against lightning – Part 2: Risk management*

3 Terms, definitions, abbreviated terms and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62305-1 and IEC 62305-2 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
ground flash density
N_G
mean number of cloud-to-ground flashes per unit area per unit time (flashes x km^{-2} x year^{-1})

3.1.2
ground strike-point density
N_{SG}
mean of the number of strike-points to ground per unit area per unit time (strike-points x km^{-2} x year^{-1})

3.1.3
lightning sensor
device that measures electromagnetic signals produced by lightning discharges

3.1.4
lightning location system
LLS
network of lightning sensors that work together to detect and geolocate lightning events within the area of the system's coverage

Note 1 to entry: This note applies to the French language only.

3.1.5
confidence ellipse
ellipse centred on the estimated ground strike-point, describing the degree of confidence of the location estimation (e.g. 50 %, 90 %, 99 %) based on sensor measurement errors

Note 1 to entry: The confidence ellipse is described in terms of the lengths of the semi-major and semi-minor axes as well as the bearing of the semi-major axis.

3.1.6
uptime
duration of fully functional operation of a lightning location system sensor, expressed as a percentage of the total observation time

3.1.7
stroke detection efficiency
flash detection efficiency
percentage of strokes or flashes detected as a percentage of the total number of strokes or flashes occurring in reality

3.1.8
median location accuracy
value of the distances between real stroke locations and the stroke locations given by the lightning location system

3.2 Abbreviated terms and symbols

CG	cloud-to-ground
DE	detection efficiency
GSP	ground strike point
IC	intra-cloud and inter-cloud
LA	location accuracy
LLS	lightning location system
N_G	ground flash density
N_{SG}	ground strike-point density

4 General requirements

4.1 General

The performance characteristics of a lightning location system (LLS) determine the quality of the lightning data available for calculating N_G [1][1]. A value of N_G with an error of ±20 % or less is deemed to be adequate for lightning risk assessment. Data from any LLS that is able to detect CG lightning and accurately determine the point of strike of CG strokes can be used for the purpose of N_G computation. The following LLS performance characteristics are required for computation of N_G with adequate accuracy.

[1] Numbers in square brackets refer to the Bibliography.

- Flash detection efficiency (DE): The value of the annual average flash detection efficiency of an LLS for CG lightning shall be at least 80 % in the region over which N_G has to be computed. This DE is usually obtained within the interior of the network. The interior of the network is defined as the region within the boundary defined by the outermost adjacent sensors of the network.
- Location accuracy (LA): The value of the median location accuracy of an LLS for CG strokes shall be better than 500 m in the region over which N_G has to be computed. This LA is usually obtained within the interior of the network.
- Classification accuracy: In a network with a flash DE meeting the criteria set for N_G calculation, erroneously low or high values of N_G will be identified when too many CG strokes are misclassified as cloud pulses (or vice versa). This is especially true for single-stroke CG flashes. A classification accuracy (CG flashes not misclassified as IC) of at least 85% is required.

These performance characteristics of an LLS can be determined using a variety of methods including network self-referencing (using statistical analysis of parameters such as standard deviation of sensor timing error, semi-major axis length of the 50 % confidence ellipse, and the number of reporting sensors, which may be known from the LLS manufacturer or available from the LLS data) and comparison against ground-truth lightning data obtained using various techniques. These methods are discussed in Clause 5. A performance evaluation based on the methods described in Clause 5 and all the relevant basics of the network have to be provided on request.

The flash DE, LA, and classification accuracy of an LLS depend on a few fundamental characteristics of the network. LLS owners, operators, and data-providers should consider the following factors while designing and maintaining their networks to ensure that the lightning data are of adequate quality for N_G computation.

– Sensor baseline distance: The distance between adjacent sensors in an LLS so called sensor baseline distance is influenced by the area of desired coverage and the sensitivity of individual sensors. Sensor baseline distance is one of the factors that determine the DE and LA of an LLS. The maximum sensor baseline distance of an LLS shall be such that the DE and LA of the network meet the criteria for N_G calculation described above.

– Sensor sensitivity: The sensitivity of sensors in an LLS primarily determines the ability of the network to detect lightning events of different peak currents. The sensitivity of sensors in an LLS shall be such that lightning events with peak currents in the range of 5 kA to 300 kA are detected and reported by the LLS. Sensor sensitivity is determined by various factors such as trigger threshold, electronic gain, sensor bandwidth, and background electromagnetic noise.

– Sensor uptime: The uptime of different sensors in a network determines the DE and LA of the network. The spatial and temporal variations of DE and LA are determined by the location of sensors that are up and contributing to the network. Hence it is important to guarantee that LLS sensors are up and running with no interruption.

4.2 Stroke-to-flash grouping

Return strokes detected by lightning location systems shall be grouped into flashes for N_G calculation. Multiple ground strike-points are included in the same flash. This grouping is done based on a spatio-temporal window.

A subsequent stroke is grouped with the first return stroke to form a flash if the following criteria are met:

a) the stroke occurs less than or equal to 1 s after the first return stroke;

b) the location of the stroke is less than or equal to 10 km from the first return stroke;

c) the time interval for successive strokes is less than or equal to 500 ms.

The flash position is assumed to be the location of the first stroke.

Strokes can also be grouped into ground strike points to obtain N_{SG} based on different algorithms described in Annex B.

4.3 Minimum observation periods

A sufficiently long sampling period is required to ensure that short time scale variations in lightning parameters due to a variety of meteorological oscillations are accounted for. Additionally large scale climatological variations limit the validity of historic data. Some lightning detection networks have been recording lightning data for several decades and during this time there have been measurable changes to the climate.

A set of lightning data for at least 10 full calendar years is required, with the newest data used not being older than five years. The data should be as continuous as possible, unless the data does not fulfil the performance requirements in some particular years which have then to be removed.

4.4 Observation area

The observation area is an area over which lightning data of quality as described above are available.

Different networks and sensor technologies will have different sensitivities with which they detect lightning. Network coverage falls off outside the boundaries of a network. In general, lightning data within half the average sensor baseline distance (distance between adjacent sensors in the network) from the boundary of the network should be of sufficient quality for N_G calculation.

4.5 Grid cell size

Ground flash density (N_G) values vary annually and regionally. Lightning data have to be evaluated as a raster map, i.e. a gridded array of cells constrained by a geographic boundary: the area of interest is divided into a regular grid (tessellation of the geographic area) and the N_G calculation function is applied to all the flashes occurring within the grid. The resulting value is then assumed to be the meaningful value within that area.

Grid size has to be chosen in such a way that the dimensions of each cell and the number of years considered both comply with the minimum requirements obtained from Formula (1), following Poisson distribution and the law of rare events, thus obtaining an uncertainty of less than 20 % at 90 % confidence level [2].

$$N_G \times T_{obs} \times A_{cell} \geq 80 \tag{1}$$

where:

N_G is the ground flash density, in km^{-2} year^{-1};

T_{obs} is the observation period, in years;

A_{cell} is the area of each single cell, in km^2.

The data used in this analysis shall conform to the requirements of both 4.2 and 4.3. The minimum permissible cell dimension, irrespective of ground flash density and observation period, shall not be less than double the median location accuracy.

4.6 Edge effect correction

As defined in 4.5 the size of the smallest cell that can be considered should contain at least 80 flashes. In order to avoid edge effects for this cell the N_G value shall be obtained by integrating over a finer sub-grid of 1 km x 1 km resolution.

5 Validation of lightning location system performance characteristics

The performance characteristics of an LLS determine the quality of the lightning data available. These performance characteristics include:

– detection efficiency for IC and CG flashes and CG strokes;

– location accuracy;

– peak current estimation accuracy; and

– lightning classification accuracy.

As stated in Clause 4, for N_{G} and N_{SG}, the determination of DE, LA, and lightning classification accuracy is of primary importance. These performance characteristics can be evaluated using a variety of techniques which are summarized below.

a) Network self-reference: In this technique, statistical analysis of parameters such as standard deviation of sensor timing error, semi-major axis length of the 50 % confidence ellipse, and the number of reporting sensors, is used to infer the LA and DE of an LLS. Examples of such studies are found in [3], [4] and [5]. This method requires data collected by the network after it has been properly calibrated. It can provide a good estimate of the network's performance in a cost-effective, practical manner.

b) Rocket-triggered lightning and tall object studies: This method uses data from rocket-triggered lightning experiments or lightning strikes to tall objects (e.g. instrumented towers) as ground-truth to evaluate the performance characteristics of an LLS within whose coverage area the triggered lightning facility or the tall object is located. The LA, DE, peak current estimation accuracy, and lightning classification accuracy of an LLS can be measured using this method. Examples of studies using rocket-triggered lightning or lightning to tall structures for LLS performance evaluation include [6], [7], and [8]. These methods provide the best ground-truth data for performance characteristics validation for CG lightning. In addition, these methods are the only ways to directly validate peak current estimation accuracy of an LLS. However, they may be very expensive and may not be practical for all regions. There are only a few triggered lightning facilities and instrumented towers across the world. The results obtained from these methods are valid indicators of LLS performance only for the region where the rocket-triggered lightning facility or instrumented tower is located. Additionally, rocket-triggered lightning provides data for return strokes similar to only subsequent strokes in natural lightning. No data for first strokes in natural lightning can be obtained using this technique. This is also often the case for lightning strikes to tall objects depending upon the height of the object, local terrain, storm type, and other factors. Since first strokes in natural lightning are expected to have, on average, peak fields and currents that are a factor of two larger than those for subsequent strokes (e.g. [9]), CG flash and stroke DE estimated for an LLS using these methods may be somewhat of an underestimate.

c) Video camera studies: Lightning data obtained using video cameras can be used as ground-truth to evaluate the performance characteristics of an LLS within whose coverage area the lightning discharges occur. The LA, DE, and lightning classification accuracy of an LLS can generally be estimated using this method. Examples of studies using video cameras for LLS performance evaluation include [8] and [9]. In this method, data collection can be time consuming and challenging because the exact locations of lightning discharges to be captured on video cannot be predicted. Additional instrumentation such as antennas measuring the electric field from lightning discharges is often required for this technique.