BS EN 62858:2015

BSI Standards Publication

Lightning density based on lightning location systems (LLS) — General principles

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National foreword

This British Standard is the UK implementation of EN 62858:2015. It is identical to IEC 62858:2015.

The UK participation in its preparation was entrusted to Technical Committee GEL/81, Protection against lightning.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

Lightning density based on lightning location systems (LLS) - General principles (IEC 62858:2015)

Densité de foudroiement basée sur des systèmes de localisation de la foudre (LLS) - Principes généraux (IEC 62858:2015)

Blitzhäufigkeit basierend auf Blitzortungssystemen - Allgemeine Grundsätze (IEC 62858:2015)

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European foreword

The text of document 81/470/FDIS, future edition 1 of IEC 62858, prepared by IEC/TC 81, "Lightning protection", was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62858:2015.

The following dates are fixed:

– latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-06-09
– latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2018-09-09

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 62305-1	-	Protection against lightning -- Part 1: General principles	EN 62305-1	-
IEC 62305-2	-	Protection against lightning -- Part 2: Risk management	EN 62305-2	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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LIGHTNING DENSITY BASED ON LIGHTNING LOCATION SYSTEMS (LLS) – GENERAL PRINCIPLES

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

The text of this standard is based on the following documents:

FDIS	Report on voting
81/470/FDIS	81/494/RVD

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

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

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

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

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 lightning flashes to ground per square kilometer per year is the primary input parameter to perform such an evaluation.

In many areas of the world N_G is derived from data provided by lightning location systems (LLS), 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 (LLS) – GENERAL PRINCIPLES

1 Scope

This International Standard introduces and discusses all necessary measures to make reliable and homogeneous the values of N_G obtained from LLS in various countries. Only parameters that are relevant to risk assessment are considered.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 and abbreviations

3.1 Terms and definitions

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

3.1.1
cloud-to-ground lightning
CG
discharge that is comprised of one or more cloud-to-ground lightning strokes that propagate from cloud to ground or vice versa and lead to a net transfer of charge between cloud and ground

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

3.1.2
cloud lightning
IC
discharge occurring within or among thunderclouds (intracloud), or between thunderclouds (intercloud), or between cloud and air, without a ground termination

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

3.1.3
first return stroke
first stroke to ground of a cloud-to-ground lightning discharge

Note 1 to entry: The stepped leader and attachment process precede the first return stroke.

3.1.4
subsequent stroke
subsequent stroke to ground that follows a previous (return) stroke in the same flash

Note 1 to entry: A subsequent stroke is preceded by a dart leader and may or may not have the same ground strike-point as any previous (return) stroke in the same flash.

3.1.5
multiplicity
number of first and subsequent strokes in a cloud-to-ground lightning flash

3.1.6
ground flash density
N_G
mean number of cloud-to-ground flashes per unit area per unit time (flashes × km^{-2}× year^{-1})

3.1.7
ground strike-point density
N_{SG}
mean number of strike-points to ground or to ground based objects per unit area per unit time (strike-points × km^{-2} × year^{-1})

3.1.8
lightning sensor
device that measures electromagnetic signals produced by lightning discharges

3.1.9
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.

3.1.10
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.

3.1.11
uptime
duration of fully functional operation of a lightning location system sensor, expressed as a percentage of the total observation time

3.1.12
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

3.1.13
median location accuracy
median value of the distances between real stroke locations and the stroke locations given by the lightning location system

3.2 Abbreviations

CG cloud-to-ground lightning

DE flash detection efficiency

IC cloud lightning

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) [3, 15][1] determine the quality of the lightning data available for calculating N_G. A value of N_G with an error of ± 20 % or less is deemed to be acceptable 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.

- **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 all regions 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 that meets the criteria set for N_G calculation, if too many CG strokes are misclassified as cloud pulses, or vice versa, this may lead to erroneously low or high values of N_G. This is especially true for single-stroke CG flashes. A classification accuracy (CG flashes not misclassified as IC) of at least 85 % is required.

  It is not recommended to use N_G values having more than 2 decimals.

These performance characteristics of 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.

The flash DE, LA, and classification accuracy of 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 or 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.

———————

1 Numbers in square brackets refer to the Bibliography

- **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. 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.

Multiple ground strike-points shall be included in the same flash using the above criteria.

Currently a multiplication factor of 2, relating N_G to N_{SG} shall be used [2].

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 global meteorology.

Lightning data for at least ten years is required, with the newest data used not being older than five years.

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 [11].

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.

The grid size shall 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 [8].

$$N_G \times T_{obs} \times A_{cell} \geq 80 \quad (1)$$

where

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

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 both the requirements of 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 be such that it contains 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 × 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} determination of CG flash 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 (e.g. [11]) 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 [4] and [7]. 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 for LLS performance evaluation include [6], [8], and [12], [13]. While these methods provide the best ground-truth data for performance characteristics validation for CG lightning (and are the only ways to directly validate peak current estimation accuracy of an LLS), they may be very expensive, may not be practical for all regions (as there are only a few triggered lightning facilities and instrumented towers across the world), and are a valid indicator of LLS performance only for the region where the rocket-triggered lightning facility or tall object is located (especially in cases where the performance of the LLS is expected to vary significantly from region to region). 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 camera for LLS performance evaluation include [1] and [14]. 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 electric field from lightning discharges is often required for this technique.

d) **Inter-comparison among networks:** The performance of one LLS that is being tested can be compared against another LLS that may be used as reference, as long as the reference LLS is extremely well calibrated and its performance has been characterized independently. This method allows inferences to be made about the detection efficiency and location accuracy of the test LLS relative to the reference LLS. If the reference network provides VHF lightning mapping, inference about the test network's IC detection efficiency can be made. Examples of such studies include [10]. One limitation of this technique is that the test and reference networks have to overlap substantially. Further, if the performance of the reference network is unknown or if the reference network is not well calibrated, any inferences about the test network's performance are invalid.

While one or a combination of the above techniques can be used to evaluate the performance characteristics of an LLS, it is important to understand the strengths and weaknesses of the methods used in order to obtain reliable estimates of LLS performance characteristics.

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