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International Telecommunication Union
Standardization Sector

Recommendation

ITU-T K.154 (01/2024)

SERIES K: Protection against interference

Operating telecommunication facilities using lightning strikes data obtained from lightning location systems

Recommendation ITU-T K.154

Operating telecommunication facilities using lightning strikes data obtained from lightning location systems

Summary

Recommendation ITU-T K.154 is principally concerned with the use of lightning location systems (LLS) data which is commonly used to determine the cause of malfunctions or damage in telecommunication facilities, and is intended to promote the research and formulation of guidance for operating telecommunication facilities using data related to lightning strikes.

Lightning strikes data obtained by other systems such as lightning monitoring systems (LMS) are also introduced in Appendix IV. Those concerned with data usage strategy can also refer to this Recommendation.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T K.154	2024-01-13	5	11.1002/1000/15766

Keywords

Lightning location system (LLS), lightning strikes, using data.

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Operating telecommunication facilities using lightning strikes data obtained from lightning location systems

1 Scope

This Recommendation provides guidance for using lightning strikes data obtained from lightning location systems (LLS), to protect telecommunication facilities from lightning strikes or to prevent lightning strikes from occurring. The purpose of this Recommendation is to provide information on the utilization of LLS data to prevent damage from lightning strikes and/or to protect telecommunication facilities. This means that the data in this Recommendation is not limited only to the case of maintenance, but also concerns the case of design or installation. This Recommendation also introduces best practices for using LLS data.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T K.27] Recommendation ITU-T K.27 (2015), *Bonding configurations and earthing inside a telecommunication building*.

[ITU-T K.39] Recommendation ITU-T K.39 (2019), *Risk assessment of damages to telecommunication sites due to lightning discharges*.

[ITU-T K.44] Recommendation ITU-T K.44 (2019), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents – Basic Recommendation*.

[ITU-T K.66] Recommendation ITU-T K.66 (2019), *Protection of customer premises from overvoltages*.

[ITU-T K.85] Recommendation ITU-T K.85 (2011), *Requirements for the mitigation of lightning effects on home networks installed in customer premises*.

[ITU-T K.97] Recommendation ITU-T K.97 (2014), *Lightning protection of distributed base stations*.

[IEC 62305-1] IEC 62305-1:2011, *Protection against lightning – Part 1: General principles*.

[IEC 62305-2] IEC 62305-2:2011, *Protection against lightning – Part 2: Risk management*.

[IEC 62305-3] IEC 62305-3, *Protection against lightning – Part 3: Physical damage to structures and life hazard*.

[IEC 62305-4] IEC 62305-4, *Protection against lightning – Part 4: Electrical and electronic systems within structures*.

[IEC 62858] IEC 62858:2019, *Lightning density based on lightning location systems – General principles*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 surge due to lightning [b-ITU-T K.72]: A surge which is caused by lightning through any type of electromagnetic (conductive, inductive and capacitive) coupling.

NOTE – It is characterized by the following five parameters: peak value; front time, T1, and time to half value, T2 (or time parameters T1/T2); steepness; and specific energy.

3.1.2 loss [b-ITU-T K.72]: Annual mean amount of loss (humans and goods) consequent on a specified type of damage due to a dangerous event, relative to the value (humans and goods) of the object to be protected.

3.1.3 risk [b-ITU-T K.72]: Value of probable average annual loss (humans and goods) due to lightning, relative to the total value (humans and goods) of the object to be protected.

3.1.4 lightning location system (LLS) [IEC 62858]: Network of lightning sensors that work together to detect and geolocate lightning events within the area of the system's coverage.

NOTE – The system for measuring the atmospheric electromagnetic field and determine a location where lightning strike occurs (including ground stroke and flash inside a cloud). Direction finding method by magnetic fields, Time of Arrival method by electric field, or mixed method is commonly used to determine the location.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

DBS Distribution Base Station

DF Direction Finding

DoA Direction of Arrival

GDT Gas Discharge Tube

GPRS General Packet Radio Service

GPS Global Positioning System

GSP Ground Strike point

LA Location Accuracy

LLS Lightning Location System

LMS Lightning Monitoring System

LPL Lightning Protection Level

MEB Main Earthing Bar

PE Protective Conductor

SIMD SPD Intelligent Monitoring Device

ToA Time of Arrival

5 Conventions

None.

6 Data acquired by lightning location system

6.1 Overview of lightning location system

In late 1970s the lightning location system (LLS) which can determine the position where a lightning strike has occurred, was developed by detecting electromagnetic waves produced by the lightning. Until now, many kinds of LLS have been operating in the world. Moreover, by connecting these systems into networks, observation networks have been building up in domestic/international regions. Data from LLS is now available in academia, on the market, or over the Internet.

6.2 Methods to determine location where lightning strikes

There are two major techniques to determine the location where a lightning strike occurs. One method is the call direction finding (DF) method that detects the magnetic field produced by the return current of lightning strikes. The other method is called the time of arrival (ToA) method that measures the time difference among measurement stations when electromagnetic waves arrive.

6.2.1 Direction finding system

In the DF system, electromagnetic waves produced by lightning are detected by perpendicular loop antennas, which consists of two loop antennas.

Figure 1 shows the system configuration. Perpendicular loop antennas can detect electromagnetic waves produced by lightning strikes. Using measurement data, the direction angle of the wave is analysed, and the direction of arrival (DoA) is obtained. To locate the antenna system in more than two places, the location where a lighting strike occurs can be specified by connecting the DoA at each measured point.

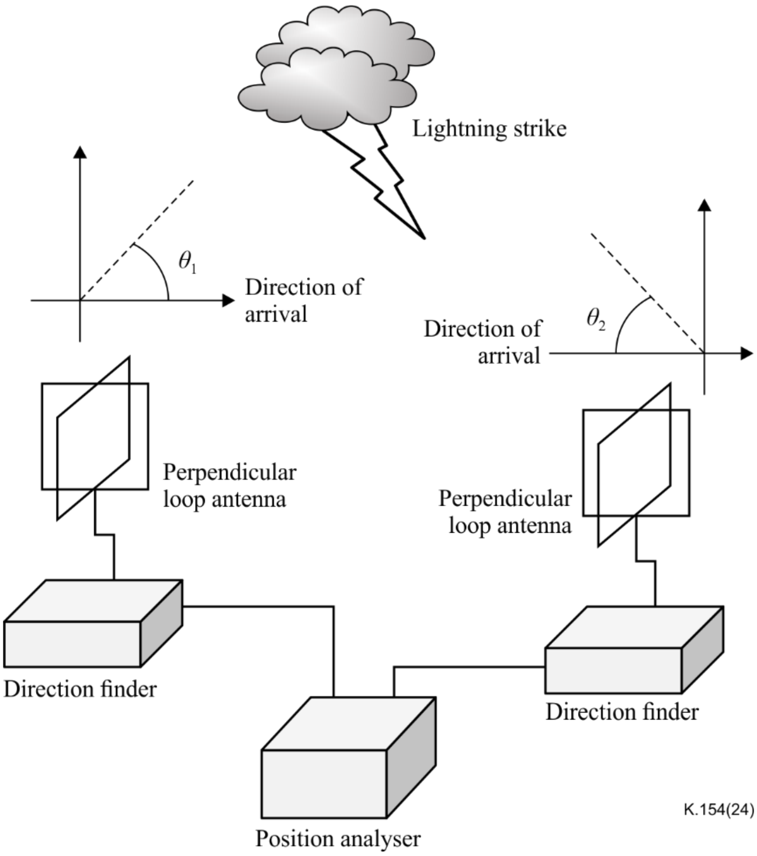


Figure 1 – Overview of DF system

6.2.2 Time of arrival system

Figure 2 shows the ToA system configuration. Vertical electric antennas are used to detect the vertical component of the electromagnetic wave and are located at multiple points. When an electromagnetic wave is radiated from a lightning strike, the antennas detect it at different arrival times. Each measurement point has a GPS system to precisely measure this time difference. The time difference is determined by comparing the peak values of the measurement data, e.g., first peak values after triggered points of measurement data are compared between different measurement sites. Thus, the location of lightning strikes can be specified by obtaining time differences among more than three different measurement points.

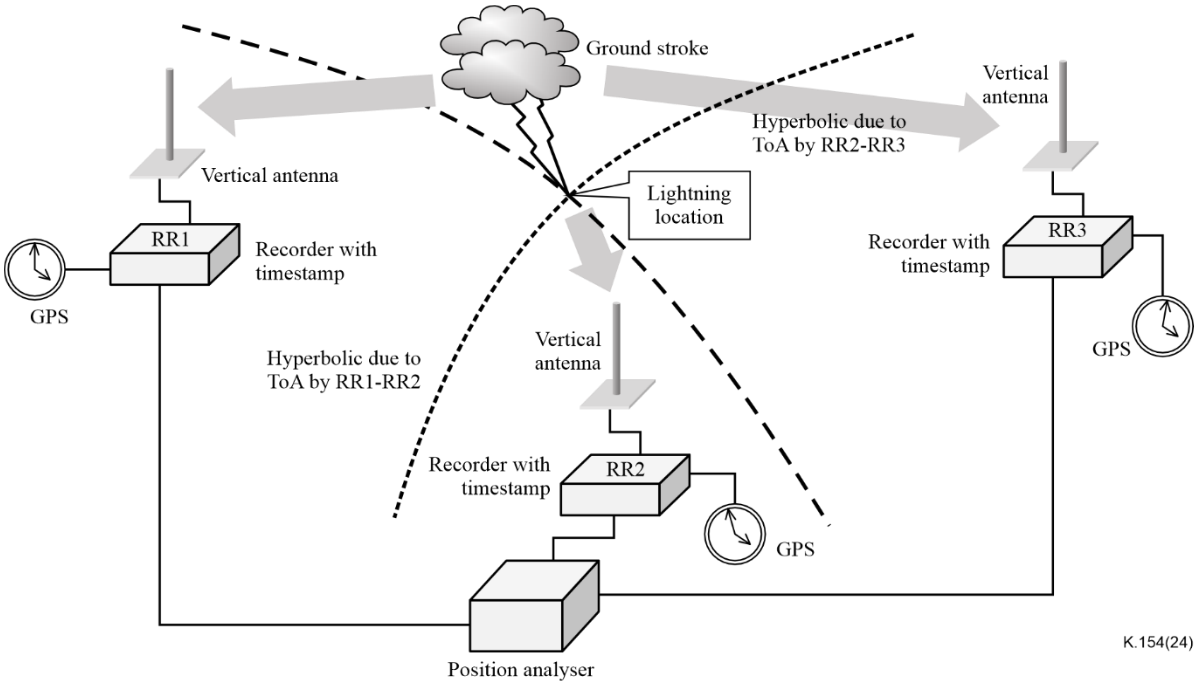


Figure 2 – Overview of ToA system

6.2.3 Mixed system

In current LLS systems, both methods described in clause 6.2.1 (DF system) and clause 6.2.2 (ToA system) are combined to improve the lightning strike location accuracy.

6.3 Error factor of LLS

Typical error factors of LLS include:

1) Geometric configuration from lightning strike point to observation point.
2) Artificial construction (e.g., buildings, towers, etc.) in surroundings.
3) Propagation conditions.

For the DF method, the main error factor is geometric configuration. For the ToA method, the main error factor is artificial construction.

There are many approaches to improve these error factors and today, artificial intelligence (AI) techniques are being introduced.

7 Guidance for data utilization

7.1 Overview of the lightning data usage

There are two main stages at which lightning data is applied to telecommunication network operations. The first stage, the maintenance stage, is related to network maintenance when damages that are caused by lightning strikes occur. Lightning related data, such as the magnitude of surge voltages/currents in the telecommunication facilities, etc., provides the location where the lightning strike occurred. By comparing the location where trouble occurred and the location where the lightning strike occurred, the relation between the lightning and network trouble can be identified. Moreover, suitable protection measures can be selected for the damaged facilities by evaluating the amplitude data of lightning strikes. Furthermore, as is described in Appendix I, it is possible to estimate invading routes of lightning surges in connection and comparison with both data recorded by the LLS and the lightning monitoring system (LMS).

The second stage, the design stage, relates to damage prevention when the telecommunication network is being designed or installed by the network operator. Lightning related data is used as a fundamental data to estimate the risks of lightning in the area/location where telecommunication facilities are to be installed. Risk assessment methods are provided by [ITU-T K.39] and [IEC 62305-2]. If the estimated risk is high, necessary protection measures will be added to the facilities to prevent lightning strikes.

7.1.1 Maintenance stage

In maintenance stage, typical use cases of lightning data are as follows:

1) To identify a cause of trouble, whether it is lightning strike, or not.
2) To evaluate protection measures already implemented in an area. If these protection methods are considered insufficient to protect the facilities, then appropriate protection measures can be selected by analysing both the damage to facilities and the strength of lightning strikes.
3) To manage the number of service personnel at an operation area in accordance with the annual frequency distribution of lightning strikes in the area. If real-time data can be used for resource management, then re-location of service personnel can be implemented in accordance with the movements of lightning occurrences.

7.1.2 Design stage

In the design stage, typical use cases of the lightning data are as follows:

1) Selection of suitable protection devices for telecommunication facilities to prevent lightning damage. Protection devices will be selected by taking into consideration LLS data such as the annual frequency distribution of lightning occurrences, maximum, minimum, or average levels, area distribution of lightning damage, etc., when equipment/devices are being designed.
2) To select appropriate standards for checking over-voltage levels for equipment/devices selected at the network design stage. In accordance with the level of lightning strikes from lightning related data acquisition systems, such as LLS and LMS, the conformity of standards can be checked.
3) To determine in an area, whether lightning protection measures are necessary or not.

By using lightning data in design stage, operators can prevent damage from lightning strikes. Operators may be influenced to not only decrease counter-measure costs, but also to optimize human resources. Thus, total maintenance costs could be reduced.

7.1.3 Other stages

Lightning related data comprises a lot of information regarding lightning strikes and usage of the data is not limited to design or maintenance stages. Currently, there are no case studies for using the data in different stages. However, if new approaches for using lightning related data are implemented, then any information about it, such as case studies, applications, etc. should be added to this Recommendation.

7.2 Procedure of how to use LLS data

7.2.1 Flow chart for utilizing LLS data

Figure 3 shows an example flow chart that indicates how to use LLS data for ensuring normal operation of telecommunication services against lightning. The first step is to determine the purpose of the data usage, then each step thereafter will be carried out in accordance with the flow chart.

7.2.2 Collecting data

To utilize lightning data for telecommunication operations, several kinds of data need to be collected. The following clauses present examples of data used to analyse the influence of lightning on telecommunications.

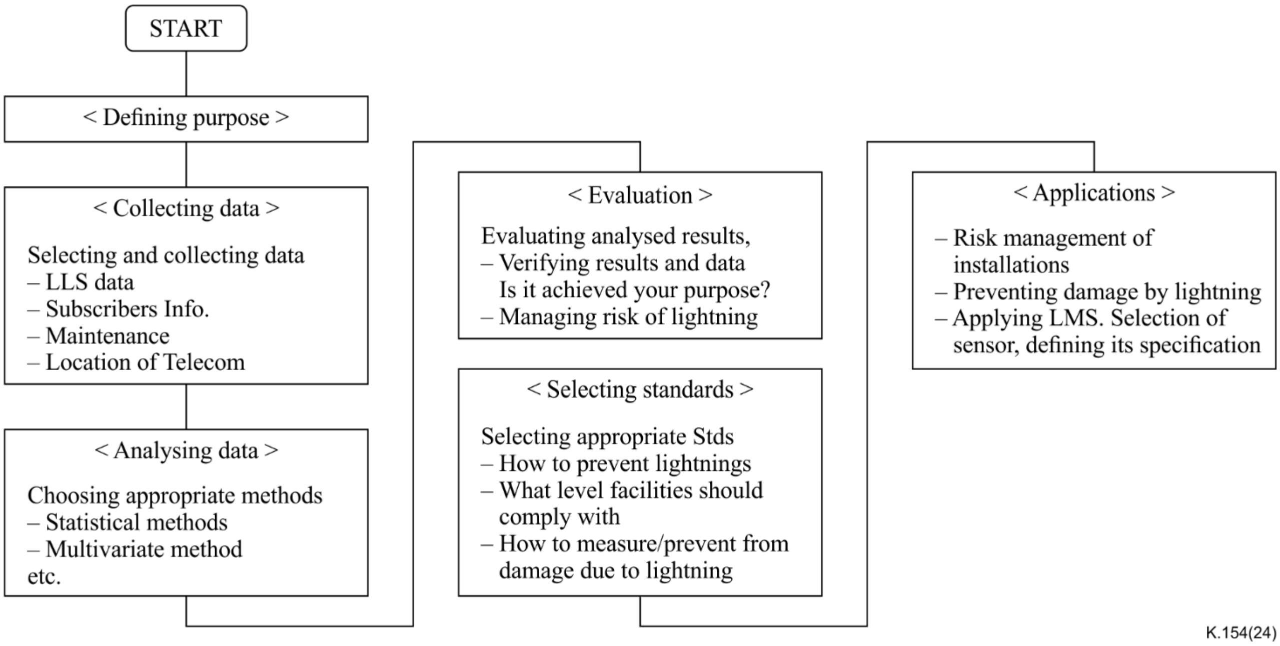


Figure 3 – Example of flow chart that shows how to utilize data

7.2.2.1 LLS data

LLS data is the fundamental data for information about lightning strikes. It normally gives several items of information regarding lightning strikes such as for example, lightning polarization which may be positive or negative, direction of strike, such as, to ground, to cloud, or inside a cloud, a longitude and latitude position at the lightning strike, and lightning current strength and direction.

7.2.2.2 Subscriber or population density

The number of troublesome incidents, or the influence caused by lightning depends on the area where the lightning strikes occur. Subscriber density is one of the key data items used to evaluate the influence of lightning strikes. However, in some cases, it is difficult to know exactly where customer is located. In this case, population density figures, that are usually made available to the public by governments, can be used to estimate how many subscribers are in an area subjected to lightning strikes. Comparisons between subscriber density and lightning strike density at a specific area, allow the risk of damage/malfunction to customer equipment to be evaluated.

7.2.2.3 Locations of telecommunication facilities

Locations of telecommunication facilities are also important data used to evaluate the influence of lightning strikes. Operators have the data of where the facilities are located. By comparing the location of a telecom facility and lightning strike per unit surface, the risk of damage to the telecom facility at the location can be evaluated.

7.2.2.4 Maintenance data

When lightning occurs, there are a lot of devices, facilities, and services that may be affected by lightning strikes. Telecom operators normally record maintenance activities when damage, malfunctions or disconnections occur due to lightning strikes. This maintenance data includes subscribers' information, date/time when a problem occurs, counter-measures employed, and so on. This data therefore provides information about the influence of lightning strikes. For example, by calculating the cumulative occurrence of damages in a unit area, the risk of damage could be evaluated.

7.2.3 Analysing data

Collected data should be analysed by applying mathematical methods. There are many mathematical methods that can be employed, including for example:

1) Basic statistical methods for analysing collected data

By analysing collected data using basic statistical methods, such as average, variance, frequency, and so on, information such as frequency of occurrence, area density, etc., can be obtained.

Examples include: Occurrence density in unit area, frequency of occurrence, cumulative frequency in a year, etc.

2) Multivariable methods

By collecting many types of data, it becomes possible to analyse relationships and trends between data using multivariate analysis techniques. Obtaining relationships between data can lead to effective prevention and countermeasures according to environmental conditions, elucidation of failure mechanisms, etc.

Examples include: Correlation, cross-correlation, multiple regression analysis, etc.

3) Machine learning

Because the amount of data collected is enormous, it is difficult to ascertain trends manually. Therefore, using machine learning techniques such as deep learning, it is possible to analyse the relevance of data. However, it is necessary to adapt appropriate analysis methods and rules.

The analysing methods should be selected to achieve the purposes of data utilization. Moreover, original data and analysed data could be combined, compared, or calculated to obtain data that indicates new information.

7.3 Evaluating and using analysed results

Analysed data should be evaluated and applied to the design and/or maintenance of telecom facilities. Risk assessment of lightning strike damage, selection of relevant standards for telecommunication facilities, and use in other systems, such as LMS, are key issues to be considered to evaluate damage from lightning.

7.3.1 Management risk of lightning strike

The risk levels of lightning strikes are considered in ITU-T and IEC standards. Risk management of lightning strikes to telecommunication installations is considered in [ITU-T K.39]. Risk assessment methods for lightning strikes are also considered in the IEC 62305 series. For example [IEC 62305-2] provides a method for lightning risk assessment of buildings where ground lightning density is the primary input parameter for lightning risk assessment. LLS data can be utilized to calculate ground lightning density. An example of risk assessment is presented in Appendix I.

7.3.2 Selection of appropriate standards

After evaluation, relevant standards to prevent damage from lightning strikes should be selected.

[ITU-T K.44] provides advice on selecting the required level of resistibility, e.g., "basic" and "enhanced". Guidance on how to choose the required level of resistibility is presented in clause 6.2 of [ITU-T K.85].

Earthing and bonding are key issues in the protection of telecommunication facilities from lightning strikes. Consideration of earthing methods is presented in clause 6.4 of [ITU-T K.85]. Earthing and bonding for telecommunication facilities is presented in [ITU-T K.27]. Consideration of earthing and bonding in customer premises is addressed in [ITU-T K.66]. Counter-measures and the other lightning related information is presented in [b-ITU-T Handbook 1] and [b-ITU-T Handbook 2].

7.4 Applications

The results of data analysis and evaluation can be used for several application purposes, as described in clauses 7.4.1 to 7.4.3.

7.4.1 Risk management of installations

Consideration of risk assessment methods is provided in the IEC 62305 series. This series is divided into 4 parts: [IEC 62305-1] presents the general principle of lightning protection, [IEC 62305-2] presents risk management, [IEC 62305-3], and [IEC 62305-4] describe internal and external protection systems against lightning.

The IEC 62305 series takes into consideration the annual density of lightning strikes, surrounding environmental conditions, past lightning strike records, possibility of secondary damage in the event of lightning strikes, importance of internal equipment, etc., and uses the necessary information to manage risk. Risk management is carried out by setting protection levels that are considered to be effective. An example of risk management is presented in Appendix I.

7.4.2 Preventing damage by lightning

By analysing LLS data together with subscriber data, failure data, etc., it is possible to obtain the data necessary for the designing, installing, operating, and maintaining telecommunications network infrastructures. For example, by combining the frequency of lightning strikes and subscriber densities on a map, it is possible to estimate the failure rate due to lightning damage, which can be used to implement effective preventive measures and for allocating workers. Additionally, by combining the frequency of lightning occurrences with equipment data, this information can be used to determine the overvoltage resistibility required for equipment and the measures to be implemented. Examples of LLS data usage for telecommunication operations in some telecom operators are presented in Appendices II and III.

7.4.3 Use of data for measurement or monitoring system

The information obtained from analysed LLS data can help to develop measurement/monitoring systems for phenomena caused by lightning in telecommunication facilities. For example, this information needs to be taken into account when LMS are being designed. For example, the selection of current sensors/probes is one of the key issues for the measurement of surge current in telecommunication cables in a telecommunication centre building. The analysed LLS data could guide selection of suitable probe characteristics. An example of usage for LMS in China is given in Appendix IV.

8 Best practices

Best practices for utilizing LLS data are presented in the appendices. These include examples of data analysis and usage of LLS data, applications for monitoring overvoltage and overcurrent in telecommunication buildings, and an example of risk assessment based on IEC 62035-x and [ITU-T K.39]. These are some of the applications for utilizing LLS data. Best practices in accordance with this Recommendation will be added in future.

Appendix I

Example of risk assessment for telecommunication facilities based on the IEC 62305 series and ITU-T K.39

(This appendix does not form an integral part of this Recommendation.)

I.1 Calculation method and processing of the data provided by LLS (N_g)

[IEC 62305-2] provides a method for lightning risk assessment of buildings. The ground lightning density N_g is the primary input parameter for lightning risk assessment. Currently, N_g is mainly obtained from the data provided by LLS, however, there are no general guidelines for describing the main performance and measurement data from LLS.

[IEC 62858] defines general principles of lightning density based on lightning location systems and specifies the method for obtaining N_g from LLS. When obtaining the annual lightning flashes in the statistical area from the LLS system, N_g can be calculated according to the following formula:

$$N_g = \frac{\sum_{i=1}^{N} F_i}{A*N} \quad \text{(I.1)}$$

In the equation,

N_g – cloud to ground lightning density, unit: flashes to ground per km^2 and year

F_i – annual number of cloud to ground lightning in the statistical area, unit: times

A – square measure of statistical area, unit: km^2

N – number of years, unit: a

The calculation process of N_g based on LLS data, is shown in Figure I.1.

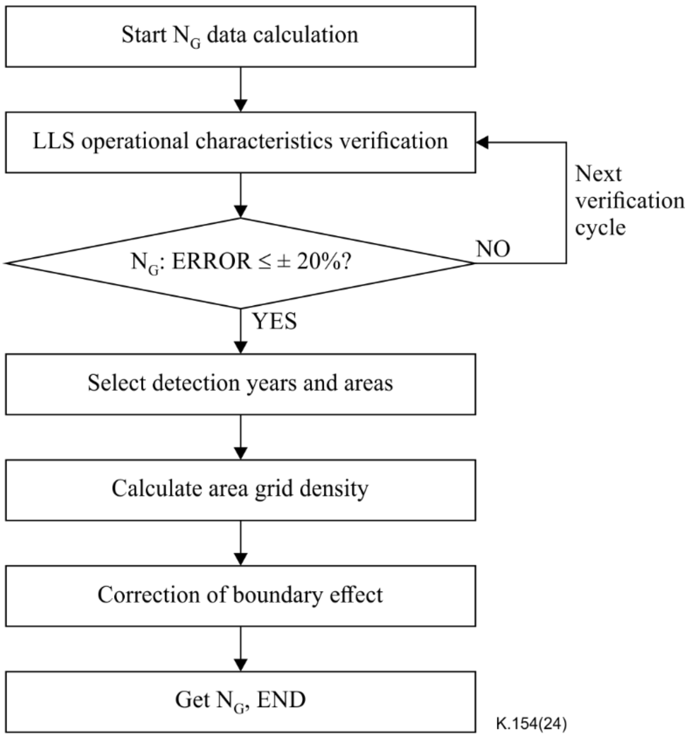


Figure I.1 – The calculation process of N_g based on LLS data

The operational characteristics of LLS determine the quality of lightning strike data used to calculate N_G. As the lightning risk assessment allows for an error of no more than 20% in the N_G value, the operational characteristics of LLS should meet the requirements of cloud to ground lightning (CG) detection efficiency (DE), location accuracy (LA), and classification accuracy of lightning strikes. The performance requirements of LLS can be determined through the methods presented in chapter 5 of [IEC 62858]. When obtaining the annual lightning flashes (F_i) in the statistical area from the LLS system, N_g can be calculated according to formula I.1.

The calculation process of N_g is presented below:

1) Cloud to ground lightning (CG) imputation: For the convenience of calculating N_G, the return strikes detected by LLS should be collected as cloud to ground lightning data, and the lightning strike point of the first return strike should be recognized as the lightning strike point of that cloud to ground lightning stroke.
2) Observation period: Considering the short-term changes in lightning parameters caused by various meteorological conditions, a sufficiently long sample period should be used. In addition, large-scale climate change limits the representativeness of lightning historical data. Some LLS have experienced significant climate changes during the accumulation of several decades of lightning data. Therefore, the observation period of lightning data used for calculating N_G should not be less than 10 years, and the latest one-year data should be within the past 5 years. The data within the sample cycle should be as continuous as possible.
3) Observation area: The area that meets the quality requirements for lightning data mentioned above is the observation area. The LLS coverage range extends a certain distance outward from the boundary composed of sensors, usually half of the average baseline distance of lightning sensors. The quality of lightning data within this range should meet the requirements for calculating N_G.
4) Grid size: Lightning data shall be calculated in the grid map, that is, the grid array composed of all of the grid within a specific geographical boundary: divide the target area into multiple regular grids, and the formula for calculating N_G is applicable to all lightning strikes occurring within the grid.
5) Boundary effect correction: The smallest grid unit should contain at least 80 ground flashes. To avoid boundary effects of grid elements, it is advisable to subdivide the observation area into 1 km × 1 km subunit areas. By accumulating a large number of subunits in the boundary region, N_G is obtained.

I.2 Using data N_g to calculate frequency of damage, F

I.2.1 General rules

Information about the lightning flash density (N_g) can often be obtained from detailed keraunic maps. Otherwise, the following approximate formula may be used:

$$N_g = 0.04\ T_d^{1.25} \text{ per km}^2 \text{ and year,}$$

where T_d is the average number of thunderstorm days registered per year.

According to [ITU-T K.39], the sum of the areas gives the total risk area for the site and corresponds to the average number of damages every year, F, at a normalized lightning intensity N_g of 1 flash to ground per km^2 and year.

Regarding the local lightning flash density, the number of yearly prospective number of damages, F, is expressed by the formula:

$$F \approx N_g\,(A_d p_d + A_n p_n + A_s p_s + A_a p_a) \quad \text{(I.2)}$$

where the different values of p depend on the existing or planned protective measures, which all decrease the probability of damages.

$$F \approx F_d + F_n + F_s + F_a \quad \text{(I.3)}$$

The four terms represent damages caused by direct strikes to the site, (d), nearby strikes to ground, (n), lightning discharges to or in the vicinity of incoming cables, (s), and direct discharges to adjacent objects, e.g., antenna towers, with metallic connection to the telecommunication site (a). In most cases the third term will dominate, but for large buildings or buildings with high antenna towers, the influence from other terms may be substantial.

It is advantageous to keep the terms separated during the calculations in order to be able to identify the main reason of failures and to implement the most efficient protective methods.

I.3 Using N_g data to assess damages to a telecommunication site

The flash density N_g is calculated by the formula:

$$N_g = 0.04 \times T_d^{1.25} = 2.1 \text{ per km}^2 \text{ and year for } T_d = 24.$$

Table I.1 presents basic data for a telecommunication site with an adjacent antenna mast.

Table I.1 – Basic data for a telecommunication site

Building, size and material:	5×3×3 m, reinforced concrete.
Antenna tower, height h and distance from building:	80 m placed 4 m from the telecom building.
Total cable length and shielding:	Power cable 600 m, unshielded, underground. Telecom cables 1000 m, unshielded, overhead.
Soil resistivity:	High, estimated to at least 500 m within the area considered.
Lightning flash density:	No measurements available. 24 thunderstorm days/year according to a keraunic map.

Figure I.2 shows an example of a well-shielded telecommunication building with incoming cables, this figure is adapted from Figure I.1 of [ITU-T K.39].

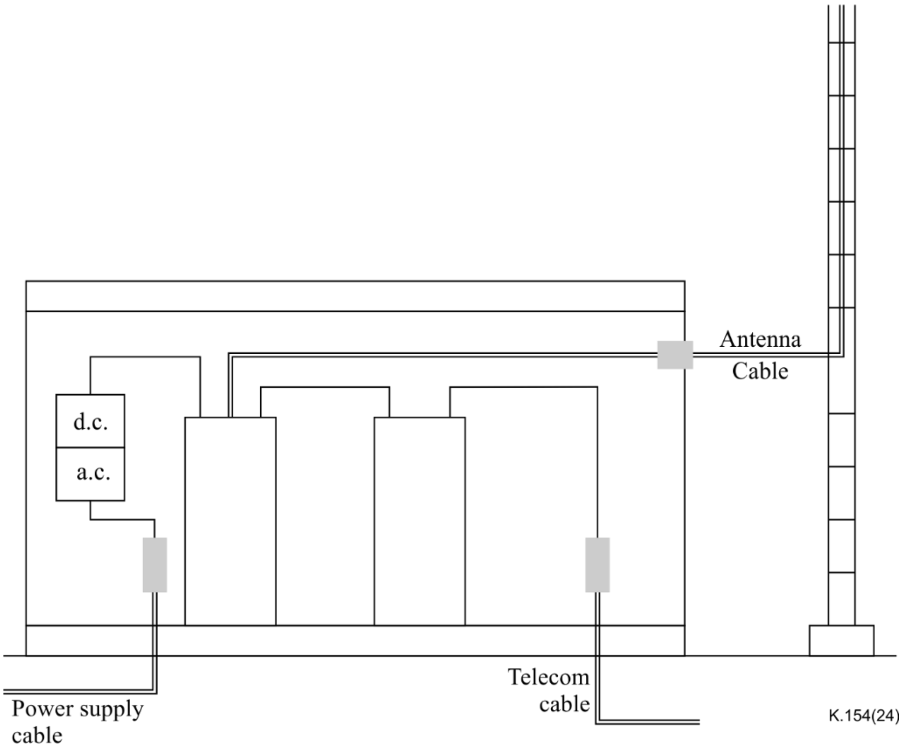


Figure I.2 – Example of a well-shielded telecommunication building with incoming cables

Calculation of expected number of damages, F

$$F = N_g((A_n(\text{tele}) + A_n(\text{power}))p_n + (A_s(\text{tele}) + A_s(\text{power}))p_s + A_a p_a) = 4.6 \text{ per year}$$

The above calculation suggests one damage event on average more than four times every year, for operators this damage rate will undoubtedly not be tolerable.

I.4 Using N_g data to calculate lightning protection level of an AC surge protective device (SPD)

Considering that the protective measures presented in [ITU-T K.97] are applied in the services entering the distribution base station (DBS), the frequency of damage (F) is as described in:

$$F = N_D \times P_{SPD} \tag{I.4}$$

where:

N_D number of direct flashes to the tower per year;

P_{SPD} protection factor of the protection module.

When the frequency of damage is greater than the tolerable value ($F > F_T$), then protection measures are necessary. The tolerable frequency of damage value should be defined by the network operator. For example, $F_T = 0.05$ means that, in average, 1 damage in 20 years (1/20) is acceptable.

The number of direct flashes to the tower can be calculated by:

$$N_D = 9\times\pi\times\text{c}\times h_t^2\times N_g \tag{I.5}$$

Where:

c exposition factor (equal to 1 for flat ground and 2 for mountain top)

h_t tower height (m)

N_g ground flash density (flashes $\times$ km^{-2} $\times$ year^{-1})

The ratio between the tolerable (F_T) and expected number of direct flashes to the tower (N_D) gives the probability associated with the lightning peak current to be considered (P_{SPD}):

$$P_{SPD} = F_T/N_D \tag{I.6}$$

The value of P_{SPD} shall be used as in Table I.2 in order to determine the LPL to be considered in the protection design. In doing so, the P_{SPD} value calculated by Eq. 3 shall be converted to the next lower value in Table I.2, e.g., a value $P_{SPD} = 0.03$ shall be converted to $P_{SPD} = 0.02$.

Table I.2 – Lightning protection level (LPL) as a function of P_{SPD}

LPL	I [kA]	P_{SPD}
III-IV	100	0.05
II	150	0.02
I	200	0.01
SPDs having better characteristics (see [IEC 62305-2] Table B.3 for more information)		0.005 – 0.001

The protection need shall be evaluated by the risk assessment of loss of services (R_2) according to [IEC 62305-2]. When the risk is greater than the tolerable risk R_T, defined by network operator, protection measures are necessary. The comparison between the risk and the tolerable risk allows determining of the lightning protection level (LPL) that the protection measure at each equipment interface has to withstand to reduce risk below the tolerable risk.

According to the P_{SPD} factors in listed Table I.2, the lightning protection level (LPL) OF AC SPD should be used for lightning protection of distribution base stations.

Appendix II

LLS data use case – Orange Labs

(This appendix does not form an integral part of this Recommendation.)

NOTE – This appendix is adapted from [b-ITU-T COM5-C101]

II.1 Introduction

This document presents some applications of a lightning positioning system developed by France Telecom to carry out network maintenance and to anticipate collective faults on transportation/distribution cables (recovery services). Data from this lightning positioning system could also be used by hotline services for improving their diagnosis.

II.2 *Meteorage* lightning positioning system

French company *Meteorage* supplies real-time data services using its national detection network.

As can be seen in Figure II.1, this network consists in 35 homogeneously distributed sensors each having a 200 km detection radius:

– 18 in France
– 1 in Switzerland
– 16 shared sensors (Italy, Spain, Benelux, Austria, UK)

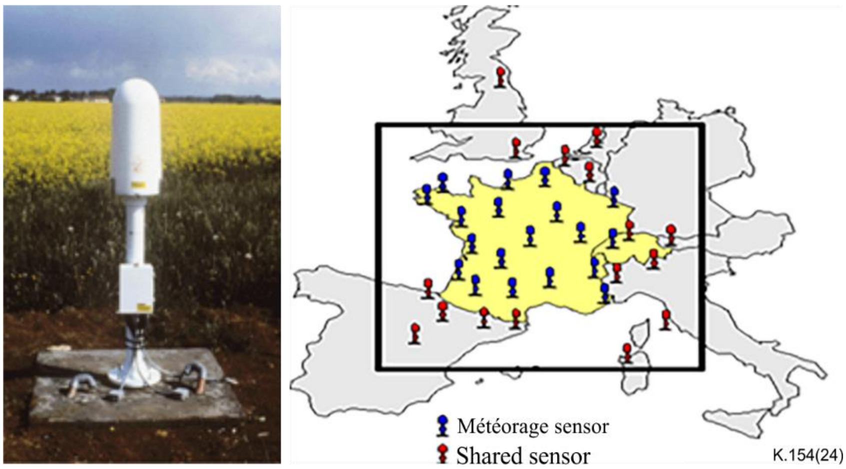


Figure II.1 – Meteorage sensor and network

Each sensor is composed of two crossing magnetic antennas and one electric antenna.

Based on global positioning system (GPS) and triangulation, sensors interconnected to a calculator give information about lightning strikes localization, and characteristics (date, time, coordinates, polarity, level, accuracy, etc.).

Figure II.2 presents the customer interface of the *Java Observation (Jobs)* software which allows users to display / download information provided by the *Meteorage* system.

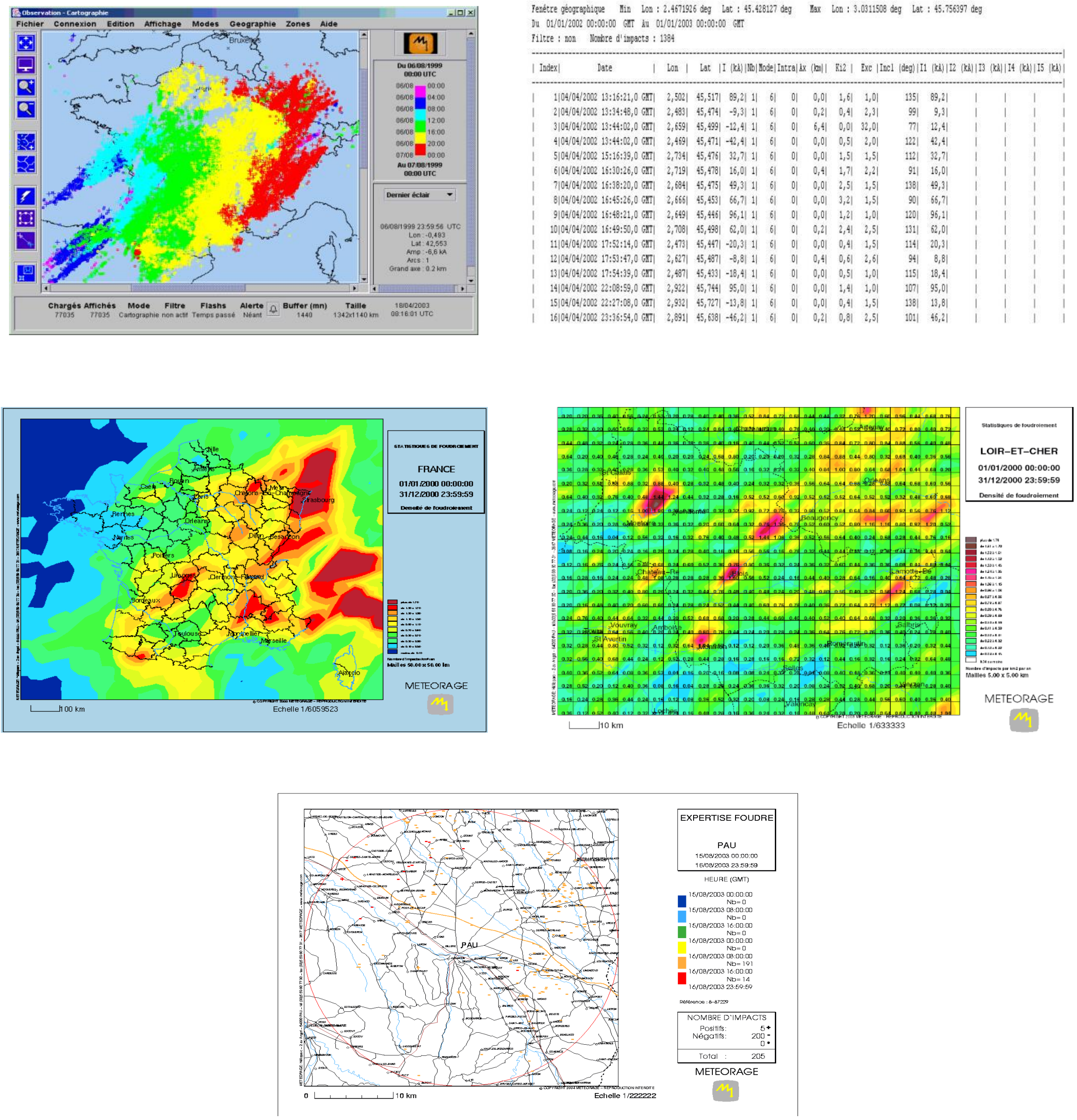


Figure II.2 – *Jobs* software

II.3 France Telecom application

Using data from the *Meteorage* and *France Telecom* information systems, *Orange Labs* R&D is developing software applications to:

– perform network maintenance versus lightning activities (*Flash Care*)

– identify cables or customers, directly below thunder clouds, thus potentially affected by lightning strikes (*Meteor42*)

Flash Care

The objective of the *Flash Care* application is to establish a classification of territorial divisions (municipalities), in a decreasing order according to their lightning sensitivity. Figure II.3 shows an example of an area concerned by lightning.

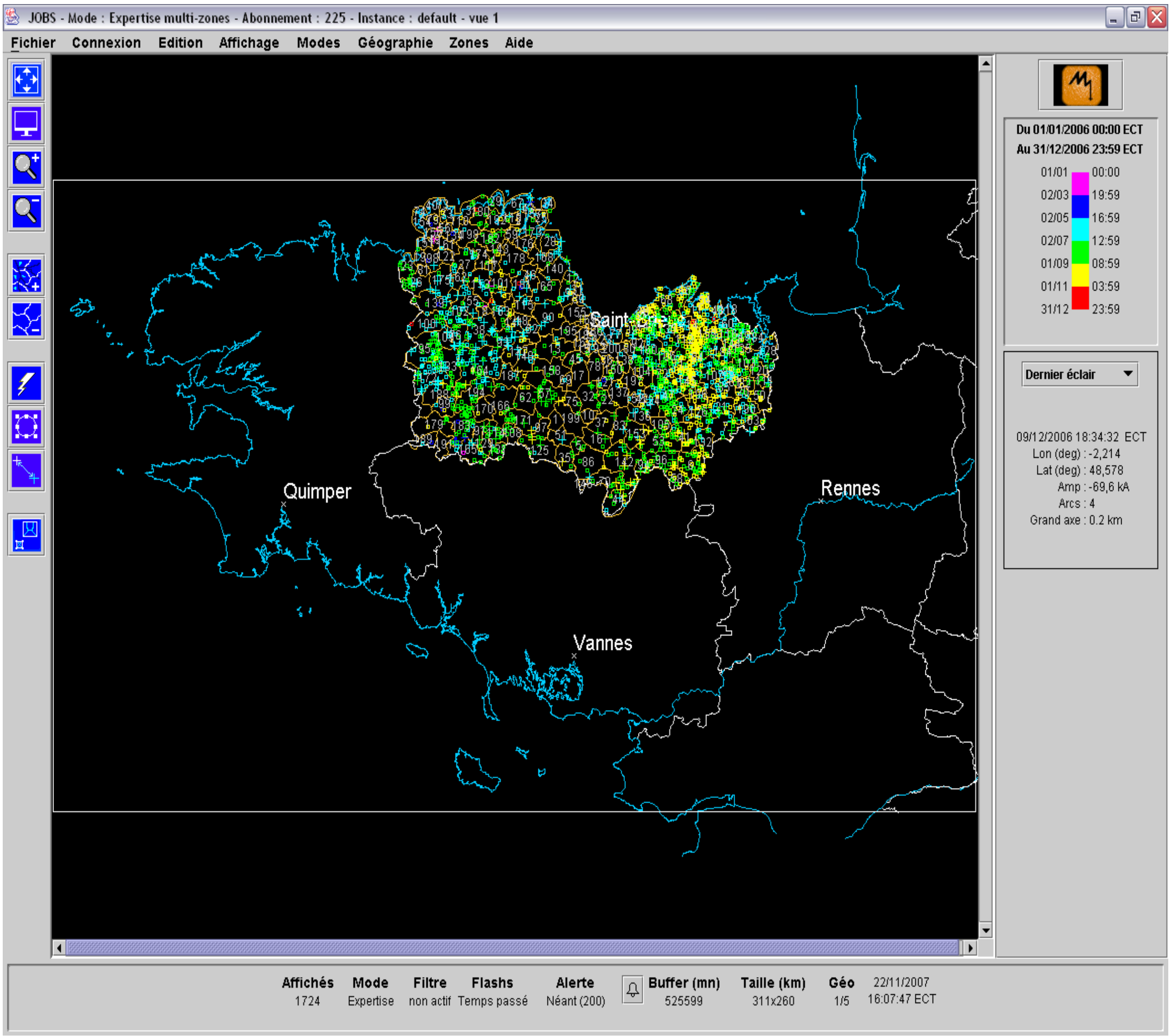


Figure II.3 – Example of territorial divisions concerned

Flash Care software helps those responsible for network quality to plan preventive maintenance specifically according to lightning strike effects, at the most sensitive areas. Figure II.4 shows the *Flash Care* interface.

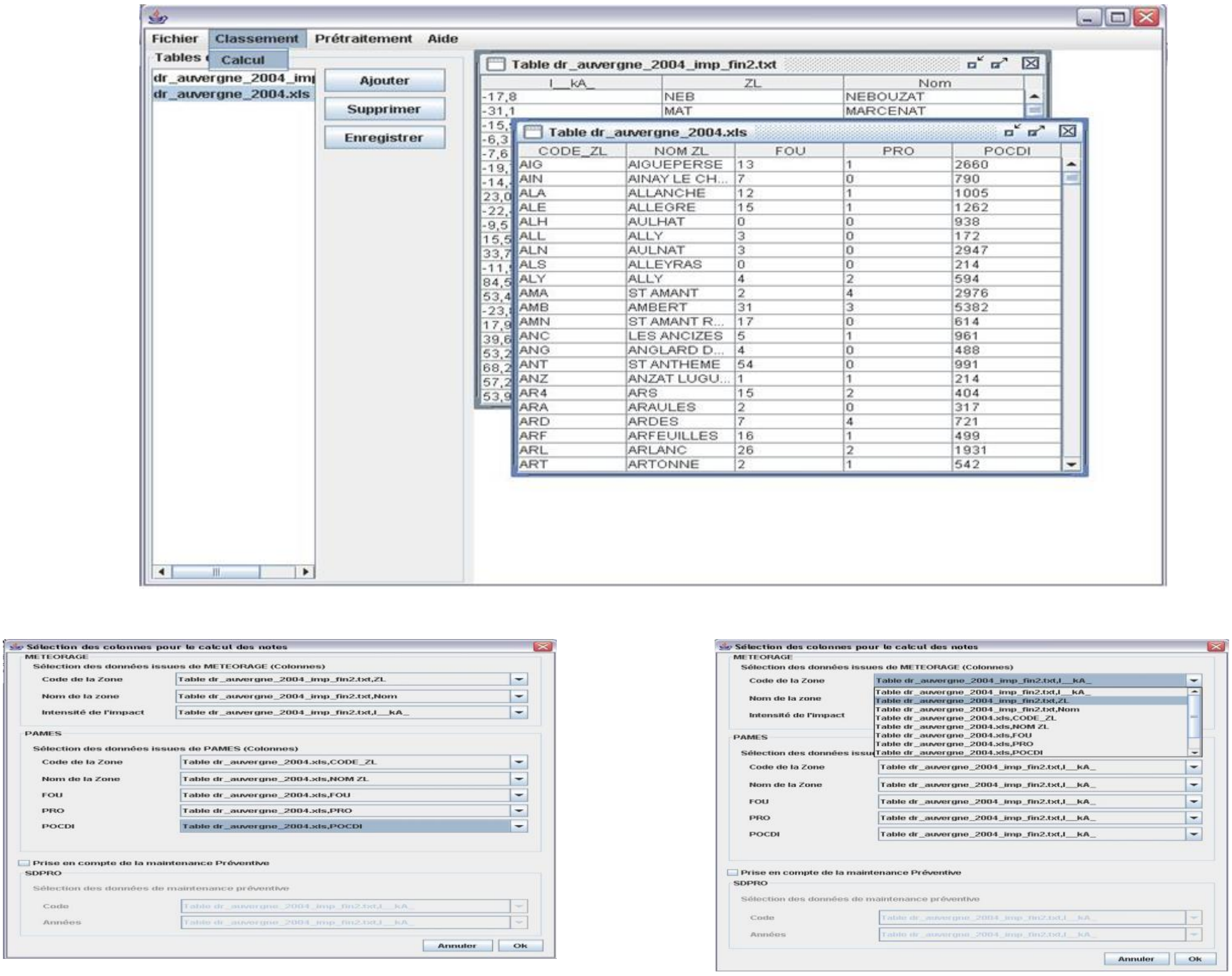


Figure II.4 – *Flash Care* software

Principle

Flash Care is based on the use of data coming from:

– *Meteorage* concerning lightning activities

– *France Telecom* information system concerning network events due to lightning strikes

Classification is obtained by giving a grade ("Note" in French) between +1 and −1 for each territorial division using the following equations:

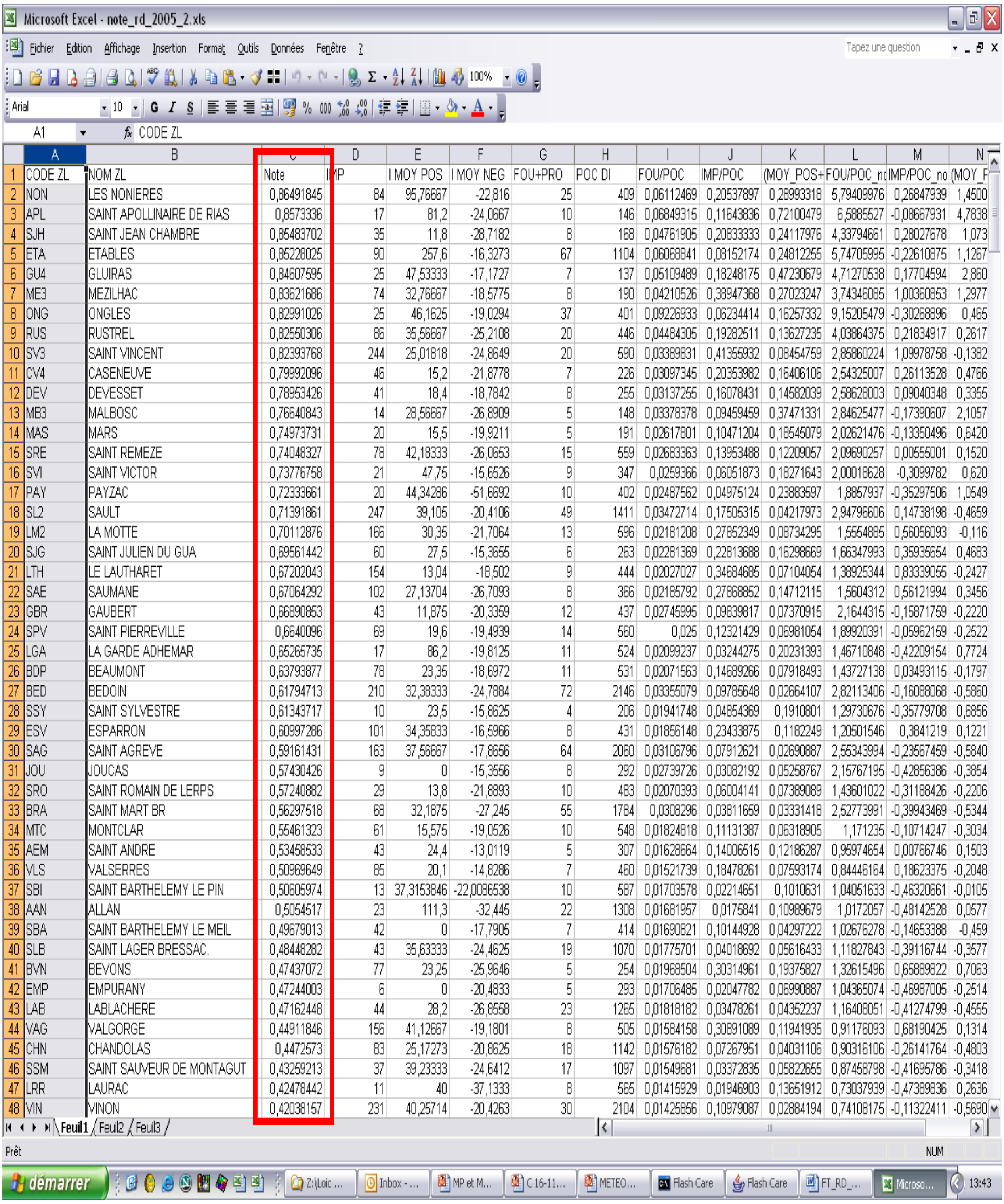
$$A_1 = \tanh\left(0.6580 \times \frac{FOU}{POC} - 0.4469 \times \frac{Imp}{POC} - 0.5593 \times \frac{MoyPos + MoyNeg}{POC} + 0.1671\right)$$

$$A_2 = \tanh\left(0.0510 \times \frac{FOU}{POC} + 0.8075 \times \frac{Imp}{POC} + 0.8016 \times \frac{MoyPos + MoyNeg}{POC} + 0.2875\right)$$

Alors la note est donnée par :

$$\text{Note} = \tanh\left(1.1588 \times A_1 + 0.5124 \times A_2 - 0.3336\right)$$

Figure II.5 shows an example of classification:



	CODE ZL	NOM ZL	Note	IMP	I MOY POS	I MOY NEG	FOU+PRO	POC DI	FOU/POC	IMP/POC	(MOY_POS+	FOU/POC_no	IMP/POC_no	(MOY_F
2	NON	LES NONIERES	0,86491845	84	95,76667	-22,816	25	409	0,06112469	0,20537897	0,28993318	5,79409976	0,26847939	1,4500
3	APL	SAINT APOLLINAIRE DE RIAS	0,8573336	17	81,2	-24,0667	10	146	0,06849315	0,11643836	0,72100479	6,5885527	-0,08667931	4,7838
4	SJH	SAINT JEAN CHAMBRE	0,85483702	35	11,8	-28,7182	8	168	0,04761905	0,20833333	0,24117976	4,33794661	0,28027678	1,073
5	ETA	ETABLES	0,85228025	90	257,6	-16,3273	67	1104	0,06068841	0,08152174	0,24812255	5,74705995	-0,22610875	1,1267
6	GU4	GLUIRAS	0,84607595	25	47,53333	-17,1727	7	137	0,05109489	0,18248175	0,47230679	4,71270538	0,17704594	2,860
7	ME3	MEZILHAC	0,83621686	74	32,76667	-18,5775	8	190	0,04210526	0,38947368	0,27023247	3,74346085	1,00360853	1,2977
8	ONG	ONGLES	0,82991026	25	46,1625	-19,0294	37	401	0,09226933	0,06234414	0,16257332	9,15205479	-0,30268896	0,465
9	RUS	RUSTREL	0,82550306	86	35,56667	-25,2108	20	446	0,04484305	0,19282511	0,13627235	4,03864375	0,21834917	0,2617
10	SV3	SAINT VINCENT	0,82393768	244	25,01818	-24,8649	20	590	0,03389831	0,41355932	0,08454759	2,85860224	1,09978758	-0,1382
11	CV4	CASENEUVE	0,79992096	46	15,2	-21,8778	7	226	0,03097345	0,20353982	0,16406106	2,54325007	0,26113528	0,4766
12	DEV	DEVESSET	0,78953426	41	18,4	-18,7842	8	255	0,03137255	0,16078431	0,14582039	2,58628003	0,09040348	0,3355
13	MB3	MALBOSC	0,76640843	14	28,56667	-26,8909	5	148	0,03378378	0,09459459	0,37471331	2,84625477	-0,17390607	2,1057
14	MAS	MARS	0,74973731	20	15,5	-19,9211	5	191	0,02617801	0,10471204	0,18545079	2,02621476	-0,13350496	0,6420
15	SRE	SAINT REMEZE	0,74048327	78	42,18333	-26,0653	15	559	0,02683363	0,13953488	0,12209057	2,09690257	0,00555001	0,1520
16	SVI	SAINT VICTOR	0,73776758	21	47,75	-15,6526	9	347	0,0259366	0,06051873	0,18271643	2,00018628	-0,3099782	0,620
17	PAY	PAYZAC	0,72333661	20	44,34286	-51,6692	10	402	0,02487562	0,04975124	0,23883597	1,8857937	-0,35297506	1,0549
18	SL2	SAULT	0,71391861	247	39,105	-20,4106	49	1411	0,03472714	0,17505315	0,04217973	2,94796606	0,14738198	-0,4659
19	LM2	LA MOTTE	0,70112876	166	30,35	-21,7064	13	596	0,02181208	0,27852349	0,08734295	1,5554885	0,56056093	-0,116
20	SJG	SAINT JULIEN DU GUA	0,69561442	60	27,5	-15,3655	6	263	0,02281369	0,22813688	0,16298669	1,66347993	0,35935654	0,4683
21	LTH	LE LAUTHARET	0,67202043	154	13,04	-18,502	9	444	0,02027027	0,34684685	0,07104054	1,38925344	0,83339055	-0,2427
22	SAE	SAUMANE	0,67064292	102	27,13704	-26,7093	8	366	0,02185792	0,27868852	0,14712115	1,5604312	0,56121994	0,3456
23	GBR	GAUBERT	0,66890853	43	11,875	-20,3359	12	437	0,02745995	0,09839817	0,07370915	2,1644315	-0,15871759	-0,2220
24	SPV	SAINT PIERREVILLE	0,6640096	69	19,6	-19,4939	14	560	0,025	0,12321429	0,06981054	1,89920391	-0,05962159	-0,2522
25	LGA	LA GARDE ADHEMAR	0,65265735	17	86,2	-19,8125	11	524	0,02099237	0,03244275	0,20231393	1,46710848	-0,42209154	0,7724
26	BDP	BEAUMONT	0,63793877	78	23,35	-18,6972	11	531	0,02071563	0,14689266	0,07918493	1,43727138	0,03493115	-0,1797
27	BED	BEDOIN	0,61794713	210	32,38333	-24,7884	72	2146	0,03355079	0,09785648	0,02664107	2,82113406	-0,16088068	-0,5860
28	SSY	SAINT SYLVESTRE	0,61343717	10	23,5	-15,8625	4	206	0,01941748	0,04854369	0,1910801	1,29730676	-0,35779708	0,6856
29	ESV	ESPARRON	0,60997286	101	34,35833	-16,5966	8	431	0,01856148	0,23433875	0,1182249	1,20501546	0,3841219	0,1221
30	SAG	SAINT AGREVE	0,59161431	163	37,56667	-17,8656	64	2060	0,03106796	0,07912621	0,02690887	2,55343994	-0,23567459	-0,5840
31	JOU	JOUCAS	0,57430426	9	0	-15,3556	8	292	0,02739726	0,03082192	0,05258767	2,15767195	-0,42856386	-0,3854
32	SRO	SAINT ROMAIN DE LERPS	0,57240882	29	13,8	-21,8893	10	483	0,02070393	0,06004141	0,07389089	1,43601022	-0,31188426	-0,2206
33	BRA	SAINT MART BR	0,56297518	68	32,1875	-27,245	55	1784	0,0308296	0,03811659	0,03331418	2,52773991	-0,39943469	-0,5344
34	MTC	MONTCLAR	0,55461323	61	15,575	-19,0526	10	548	0,01824818	0,11131387	0,06318905	1,171235	-0,10714247	-0,3034
35	AEM	SAINT ANDRE	0,53458533	43	24,4	-13,0119	5	307	0,01628664	0,14006515	0,12186287	0,95974654	0,00766746	0,1503
36	VLS	VALSERRES	0,50969649	85	20,1	-14,8286	7	460	0,01521739	0,18478261	0,07593174	0,84446164	0,18623375	-0,2048
37	SBI	SAINT BARTHELEMY LE PIN	0,50605974	13	37,3153846	-22,0086538	10	587	0,01703578	0,02214651	0,1010631	1,04051633	-0,46320661	-0,0105
38	AAN	ALLAN	0,5054517	23	111,3	-32,445	22	1308	0,01681957	0,0175841	0,10989679	1,0172057	-0,48142528	0,0577
39	SBA	SAINT BARTHELEMY LE MEIL	0,49679013	42	0	-17,7905	7	414	0,01690821	0,10144928	0,04297222	1,02676278	-0,14653388	-0,459
40	SLB	SAINT LAGER BRESSAC.	0,48448282	43	35,63333	-24,4625	19	1070	0,01775701	0,04018692	0,05616433	1,11827843	-0,39116744	-0,3577
41	BVN	BEVONS	0,47437072	77	23,25	-25,9646	5	254	0,01968504	0,30314961	0,19375827	1,32615496	0,65889822	0,7063
42	EMP	EMPURANY	0,47244003	6	0	-20,4833	5	293	0,01706485	0,02047782	0,06990887	1,04365074	-0,46987005	-0,2514
43	LAB	LABLACHERE	0,47162448	44	28,2	-26,8558	23	1265	0,01818182	0,03478261	0,04352237	1,16408051	-0,41274799	-0,4555
44	VAG	VALGORGE	0,44911846	156	41,12667	-19,1801	8	505	0,01584158	0,30891089	0,11941935	0,91176093	0,68190425	0,1314
45	CHN	CHANDOLAS	0,4472573	83	25,17273	-20,8625	18	1142	0,01576182	0,07267951	0,04031106	0,90316106	-0,26141764	-0,4803
46	SSM	SAINT SAUVEUR DE MONTAGUT	0,43259213	37	39,23333	-24,6412	17	1097	0,01549681	0,03372835	0,05822655	0,87458798	-0,41695786	-0,3418
47	LRR	LAURAC	0,42478442	11	40	-37,1333	8	565	0,01415929	0,01946903	0,13651912	0,73037939	-0,47389836	0,2636
48	VIN	VINON	0,42038157	231	40,25714	-20,4263	30	2104	0,01425856	0,10979087	0,02884194	0,74108175	-0,11322411	-0,5690

Figure II.5 – Example of classification

Having performed classification, the operator is able to select the most sensitive areas in order to carry out network maintenance based on a given list of actions contained in a specific guide.

Some of main maintenance actions concern:

– Telecom centres: earthing and bonding network connections and quality, gas discharge tube (GDT) presence

–	Cabinet: earthing value < 100 Ω, cable shield earthed)

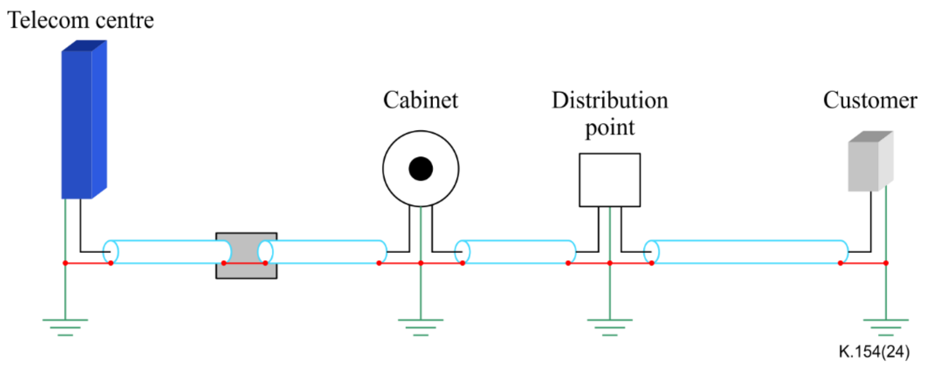


Figure II.6 – Network parts to be maintained

Meteor42 application

Principle

France Telecom has developed the *Meteor42* application whose principle is to geo position on a map: lightning strikes, telecommunication centres, cabinets and distribution points (see Figure II.7).

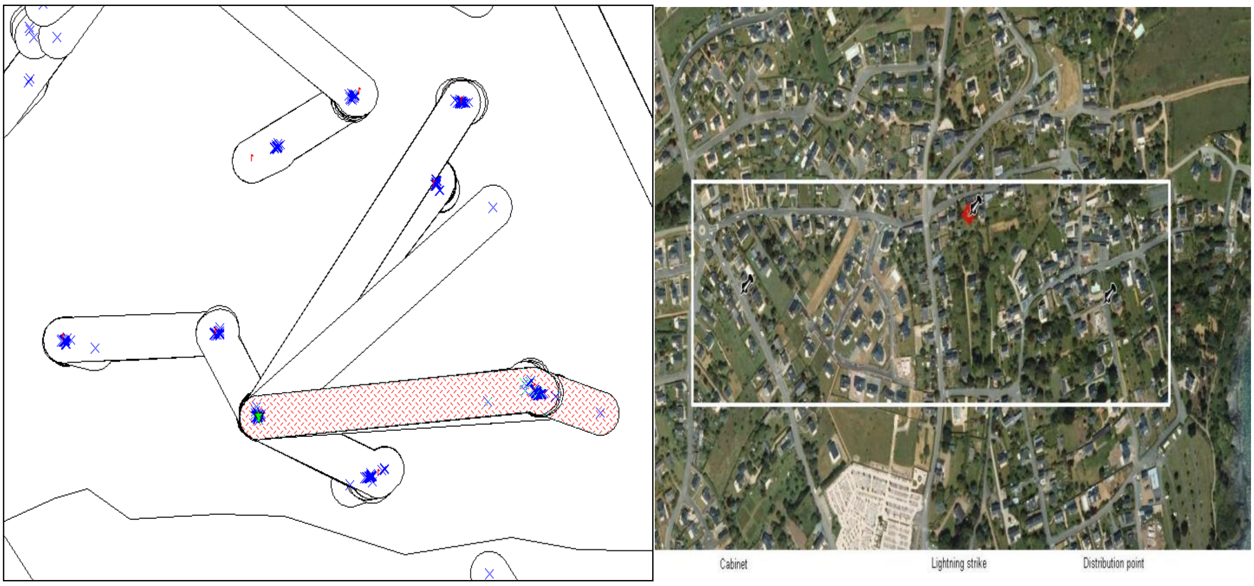


Figure II.7 – *Meteor42* France Telecom software (illustration)

The telecommunication network is roughly represented by straight lines between:

–	telecommunication centres and cabinets;

–	cabinets and distribution points.

Surface areas (rectangles) of hundreds of metres in width are traced around the virtual network (1 km for instance). Those which comprise lightning strike(s) are classified in a decreasing order. This list includes distribution point codes and as a consequence the operator is able to find cables and customers belonging to rectangles potentially affected by lightning strike(s).

Automatic system

France Telecom is developing a toolbox between *Meteor42* and the France Telecom information system in order to locate and to test the cables and customer lines that may be affected by lightning strikes.

Alarms will automatically be generated in the case where several customers encounter dysfunctions of their service (loss of synchronization or loss of PSTN) as a consequence of damaged cables.

Utility

Such a system will be used by recovery services and hotliners.

– Alarms will allow recovery services to anticipate and send operatives to repair damaged cables before the customers call the Hotline.
– Customers calling the Hotline and experiencing lightning activities in their area will help the Hotline operator to perform his diagnosis by identifying suspect equipment damaged by the lightning.

Remark: Such an application could also be used for network maintenance purposes. France Telecom performs maintenance on parts of its network located in areas affected by significant lightning activity.

Appendix III

LLS data use case – NTT

(This appendix does not form an integral part of this Recommendation.)

(NOTE – This Appendix is adapted from TD 409 (GEN/5), STUDY PERIOD 2009-2012)

III.1 Introduction

This contribution presents usage of lightning detection data for preventing damage to telecommunication installations. NTT has studied this issue since 1999. Using both the positions of lightning strikes obtained by lightning detection systems and maintenance data at each telecommunication service branch, the degree of damage caused by lightning strikes over a several square km area is estimated.

III.2 Procedure for using lightning position data

Figure III.1 shows an outline of the study that had already been carried out in NTT. The degree of lightning damage is estimated through following steps:

1) Lightning position data observed by detection systems, number of customers and damage data in the field, and on maps is prepared.

2) A target area is selected from the map and the area is divided into several square km^2 meshes.

3) Lightning position data are extracted into each sub-area and the density of lightning strikes is calculated.

4) Customer data per each telecommunication branch is also extracted into each sub-area and customer density is calculated at each area.

5) Estimated degree of lightning damage is calculated using following equation:

$$(\text{Estimated degree of lightning trouble}) = K \times \{(\text{lightning density}) \times (\text{customer density})\}^{0.5}$$

where K is a coefficient that is obtained from regression analysis between (lightning density) x (customer density) and (lightning trouble density).

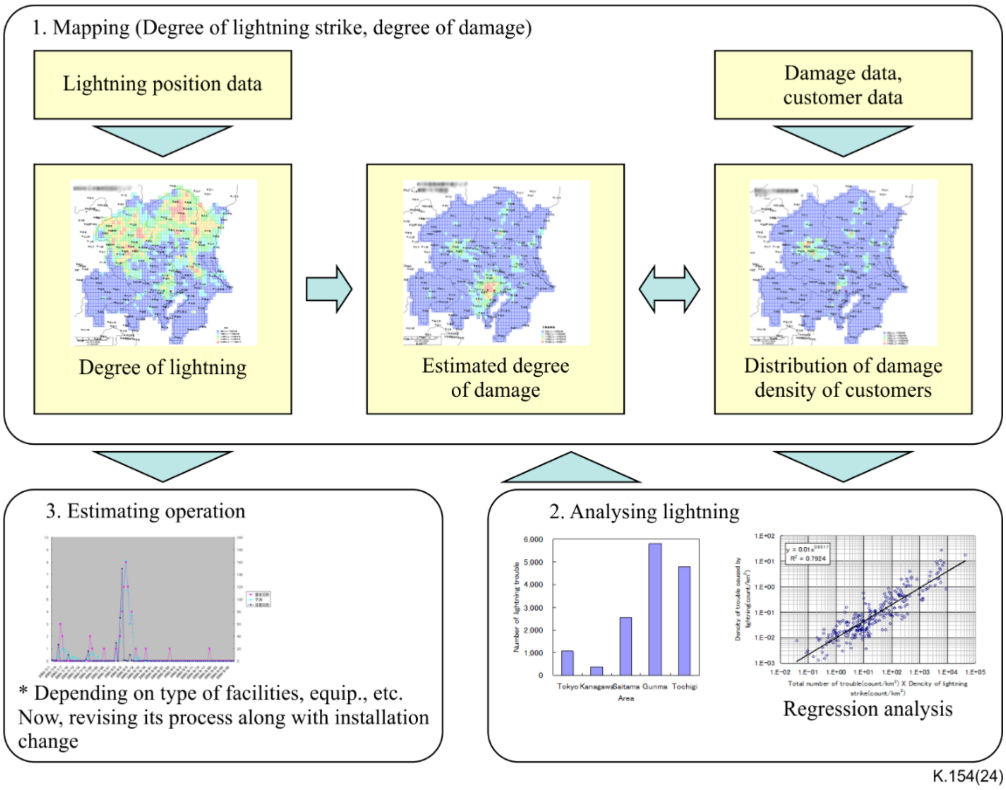


Figure III.1 – Overview of lightning position data usage

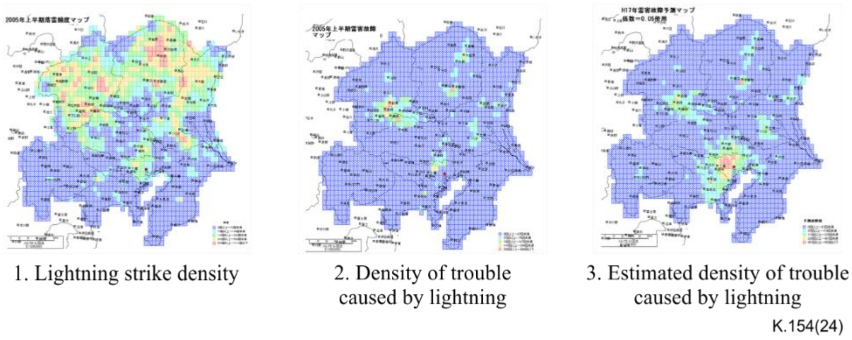


Figure III.2 – Example of estimation

Maps are used to indicate the estimated damage degree of an area where lightning damage may be higher. The accuracy of the estimation can be obtained by comparing estimated data and damage distribution.

An estimation example is shown in Figure III.2. Map (1) shows lightning strike density, Map (2) shows the density of lightning damage, and Map (3) shows the results of the estimation. The following points were concluded by comparing these maps:

– Results indicate that estimated densities of damage almost agree where lightning strike density is high. These areas are suburban or rural areas.

– In urban areas (in the middle of each map), estimated density is higher than the actual situation. This result may depend on the customer density and placement (overhead, underground, etc.) of telecommunication infrastructure.

III.3 Summary

Lightning-strike-position data was used to estimate the degree of damage to telecommunication installations. As a result, estimated data almost agreed with the damage data obtained from suburban and rural areas in the field. However, the estimation results in urban areas did not match actual lightning-damage situations. This indicates that the degree of damage is not only related to the number of lightning strikes, but also to the number of customers or the placement of telecommunication infrastructure (overhead, underground, etc.).

Future work will improve estimation accuracy in urban areas. Key issues are the type of telecommunication installation (e.g., for buildings or outdoor use) and customer (or premises) density.

Appendix IV

LMS information and best practice in China

(This appendix does not form an integral part of this Recommendation.)

IV.1 Case study of lightning monitoring system (LMS)

The lightning monitoring system (LMS) consists of a lightning monitoring instrument (including signal collectors such as lightning current sensors), a general packet radio service (GPRS) wireless communication module, and a monitoring centre (including data centre). The lightning monitoring instrument samples and processes lightning current, surge protective device (SPD) status, voltage signals, etc.

The GPRS wireless communication module is a device that enables communication between lightning monitoring instruments, the Internet, and monitoring centres. The monitoring centre is an operating platform for data storage, display, and control. It organizes, stores, and manages the data monitored by the lightning monitoring instrument according to the data structure, and displays the signals received from the lightning monitoring instrument or the data extracted from the data centre in the form of images and/or text through software. It can also integrate functions such as data processing, online printing, and issuing of commands to lightning monitoring devices as needed.

The main technical aspects involved in this system include the collection of lightning current signals, processing of lightning current signals, data communication, remote monitoring, etc. The collection of lightning current signals, that is, the lightning current sensor part, is based on the principle of a Rokovsky coil. The Rokovsky coil is essentially a current transformer with a single turn coil on the original side and a multi turn coil on the secondary side. The accuracy and range of lightning monitoring have been improved through detailed indicator calculations and the selection of materials such as skeleton, line type, and shell. The collected signals undergo attenuation, A/D conversion, peak holding, signal processing, etc. through the processing module of lightning current signals to record the amplitude, polarity, frequency, occurrence time, etc. of lightning current. The signal acquisition of SPD status monitoring is directly achieved through the remote communication terminal of SPD itself. The above signals are sent to the corresponding chips of the lightning monitoring instrument for processing, and then sent to the public network through the GPRS network.

IV.2 Methodology for obtaining lightning current data in telecommunication facilities

IV.2.1 General rules

The lightning monitoring system (LMS) is widely used in telecommunication networks, power, petrochemicals and other fields. The accuracy of lightning current data is very important, and is the foundation of lightning protection design, lightning risk analysis and lightning protection for telecommunication facilities/stations. Inaccurate lightning current data will likely increase network construction and maintenance costs and reduce the security and reliability of telecommunication networks.

Operators should select safe, reliable, advanced and applicable LMS as far as possible according to the operation conditions, environment and power supply of telecommunication buildings.

According to the lightning current coupling mechanism, the LMS of telecommunication buildings generally includes the following functions:

- Lightning parameter monitoring: lightning current waveform, amplitude, polarity, time and numbers of power supply port, antenna feed port, signal port and earthing port;
- Status monitoring: surge current amplitude, polarity, time, and service life of the SPD.

IV.2.2 Power port monitoring

For the lightning current monitoring of a three-phase AC power supply, the lightning parameter monitoring and SPD monitoring shall be carried out for the distribution trunk and each distribution branch respectively.

The lightning current sensor is installed on the power supply line before and after the lightning protection system and protective conductor (PE) of the lightning protection system.

A typical function of an LMS for power port monitoring is shown in Figure IV.1, red circles represent location points of LMS sensors.

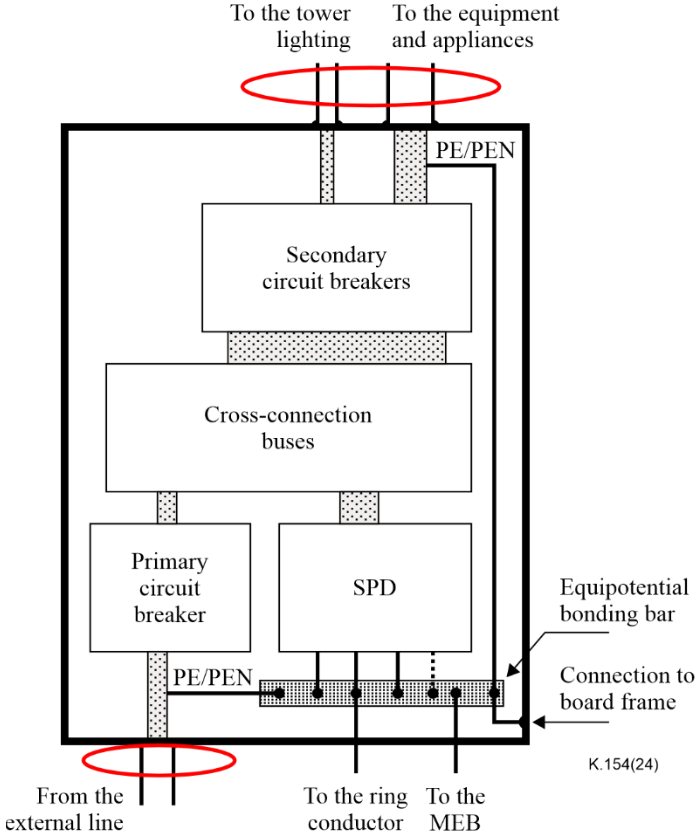


Figure IV.1 – Power port monitoring

IV.2.3 Antenna and signal port monitoring

Monitor the lightning currents through antenna and signal port, compare and analyse with the surge current recorded at the power port or down-conductor.

A typical function of an LMS for antenna port monitoring is shown in Figure IV.2, the red circle represents location points of LMS sensors. Signal port monitoring is shown in Figure IV.3, the red circle represents location points of LMS sensors.

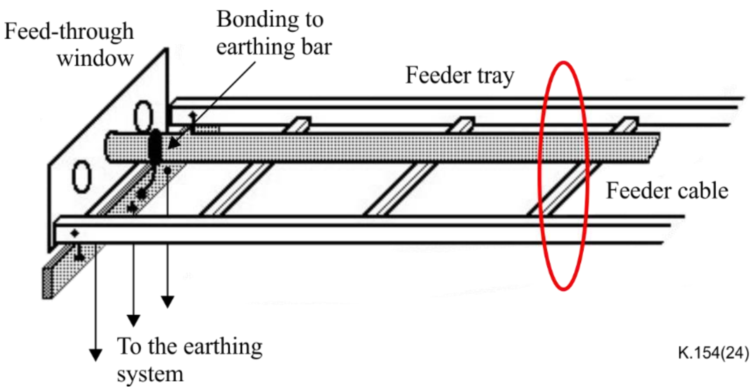


Figure IV.2 – Antenna port monitoring

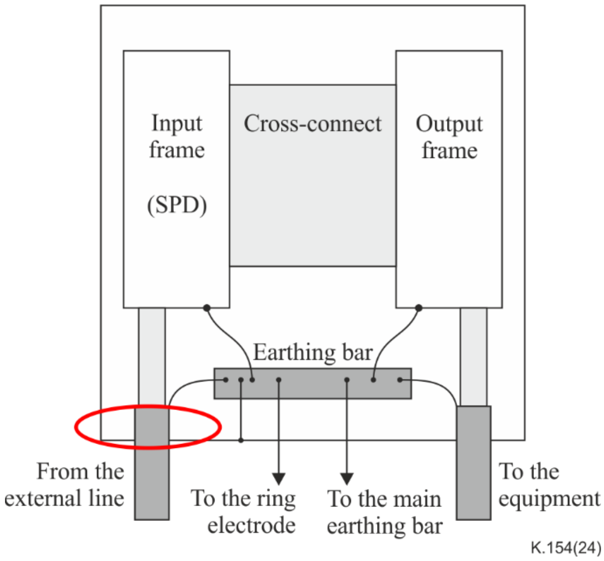


Figure IV.3 – Signal port monitoring

IV.2.4 Earthing port monitoring

Use the lightning current sensor to monitor the lightning current discharged into earth through the main earthing bar (MEB), and compare it with the lightning current parameters recorded by the power supply system, antenna feeder system, signal system, etc.

A typical function of LMS for earthing port monitoring is shown in Figure IV.4, the red circle represents location points of LMS sensors.

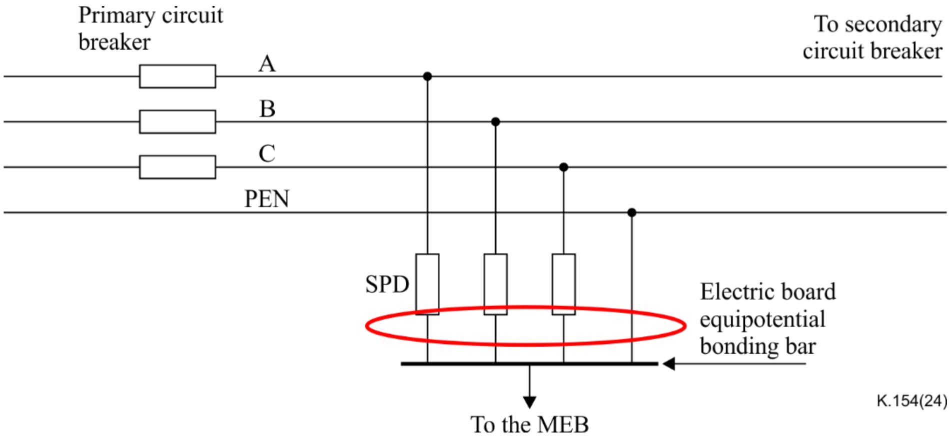


Figure IV.4 – Earthing port monitoring

IV.3 China telecom best practice for LMS

IV.3.1 Overview of the data acquisition system from lightning monitoring system (LMS) in telecommunication facilities

There are several kinds of data acquisition system that exist all over the world. Lightning location system (LLS) data is commonly used to determine the cause of malfunctions, damages, etc. in the maintenance stage of telecommunication facilities. Moreover, when ground strikes hit a telecommunications facility, lightning surge currents flowing through the facility can be also easily observed by using sensors or probes inside the facilities, and data, such as waveform, amplitude, etc. can be stored digitally and can be transmitted to any location through the Internet. It is therefore not difficult to construct a measurement system, such as LMS in telecommunication facilities.

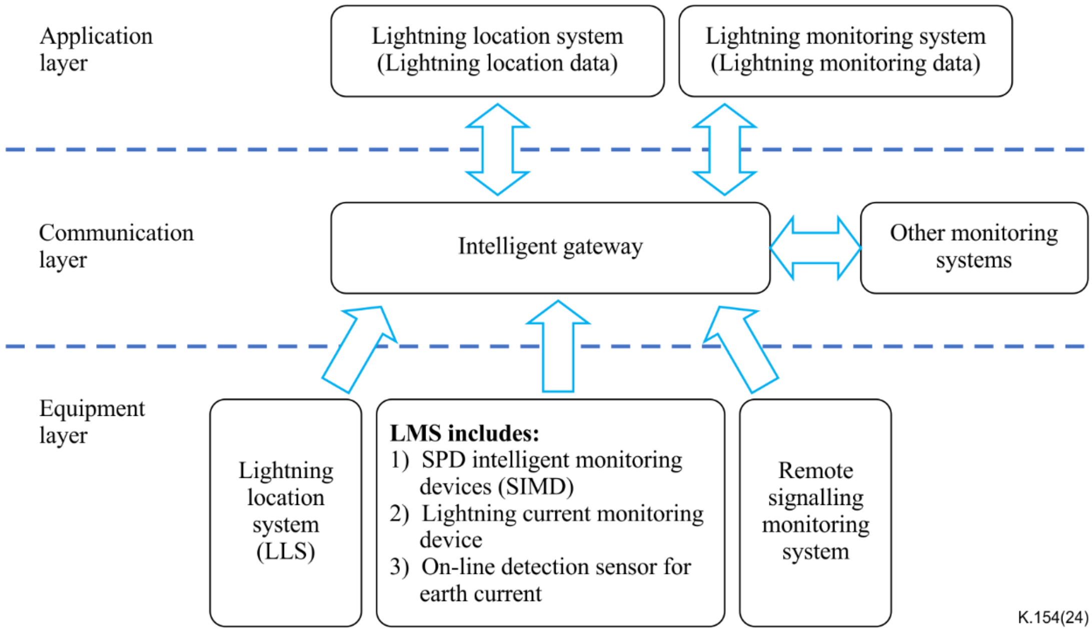


Figure IV.5 – Overview of the data acquisition system for lightning strikes

(1) LLS, where the location of lightning strike can be determined by measuring the electromagnetic waves produced by the lightning.

(2) LMS, where there is a system that measures/observes electric/magnetic phenomena in telecommunication facilities due to lightning strikes.

(3) Remote signalling monitoring system provide remote signalling data for monitoring.

IV.3.2 Composition of lightning monitoring system (LMS)

LMS is separated into three main functional layers, the first is the equipment layer, the second is the communication layer and the last is the application layer. The layered structure of the system is shown in Figure IV.5.

The equipment layer includes: SPD intelligent monitoring devices (SIMD), lightning current monitoring devices, remote signalling monitoring devices, and on-line detection sensors for earth current (such as lightning strike current flow to earth).

The communication layer is used for protocol conversion and data transmission between the equipment layer, application layer, and external systems, including other systems located in other locations. According to the complexity of the communication system, it can be composed of a serial port server, an intelligent gateway, and other communication devices.

The application layer has multiple functions that utilize data transmitted from other layers. These data, i.e., location data, monitoring data, data analysis and processing, statistics data, historical data query, operation status, error and alarm data of various hardware equipment, and so on. Moreover, the application layer can manage and operate all sub-systems in LMS, such as map operation, SIMD, user management system, and so on.

IV.3.3 Functions provided by a lightning monitoring system (LMS)

The functions of a lightning monitoring system include:

a) Carrying out atmospheric electric field monitoring and real-time early warning in the environment where lightning may occur;

b) Recording the lightning current peak value and occurrence time of the lightning strike;

c) Monitoring the operation status of SPD and SSD in real-time;

d) Predicting the degradation tendency of SPD performance and sending alarm signals in time;

e) Monitoring of earthing performance of lightning protection system in real time.

IV.3.4 Installation of a lightning monitoring system (LMS)

A lightning monitoring system is a lightning current peak recorder. Installation of an LMS is shown in Figure IV.6. The recorder must be installed by professional workers.

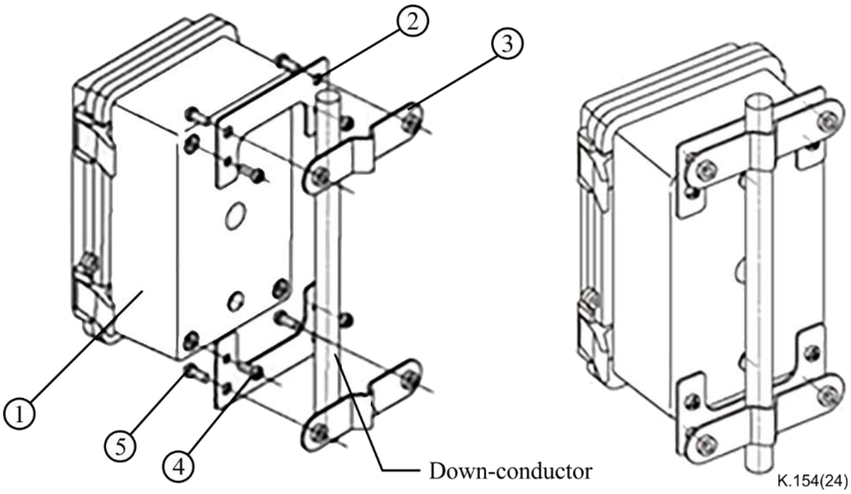


Figure IV.6 – Installation diagram of lightning current peak recorder

In this figure, ① is the recorder body, ② is the U-shaped fixing clip, ③ is the I-shaped fixing clip, ④ is the M4 × 10 screw, and ⑤ is the M5 × 25 screw. The recorder can be directly installed and fixed on the down-conductor, and the size of the down-conductor that can be installed is: Circular down-conductor diameter φ 8 ~ φ 20 mm, non-circular down-conductor size ≤ 15 × 50 mm. If the size of the down-conductor does not meet the conditions, the installation method can be changed.

The LMS can be powered by a DC 12V power supply or directly by a USB interface. The communication interface of the LMS is a USB interface. Connect the antenna to the antenna interface of the LLS, install a mobile phone card into the UIM card slot, and connect LLS to a PC through the USB cable.

IV.3.5 Mounting method for a lightning monitoring system (LMS)

Here a lightning monitoring system is mounted near to a radio base station in a scenic spot. The lightning current peak recorder is installed on the bionic tree and fixed with a stainless steel hoop.

Figure IV.7 –LMS mounting method

When an LMS is mounted on an outdoor cabinet, the lightning current peak recorder is installed on the independent support pillar of the lightning rod and fixed with a stainless steel hoop.

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The aim of this Contribution is to provide some inputs for the drafting of the ITU-T Recommendation.
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Published in Switzerland
Geneva, 2024