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INTERNATIONAL STANDARD

NORME INTERNATIONALE

AMENDMENT 1
AMENDEMENT 1

Wind energy generation systems –
Part 24: Lightning protection

Systèmes de génération d'énergie éolienne –
Partie 24: Protection contre la foudre

IEC 61400-24:2019-07/AMD1:2024-11(en-fr)

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WIND ENERGY GENERATION SYSTEMS –

Part 24: Lightning protection

AMENDMENT 1

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Amendment 1 to IEC 61400-24:2019 has been prepared by IEC technical committee 88: Wind energy generation systems.

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

Draft	Report on voting
88/1040/FDIS	88/1054/RVD

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

The language used for the development of this Amendment is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications/.

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

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION to Amendment 1

This amendment to IEC 61400-24:2019 addresses an update of the content in Annex L regarding monitoring systems for detecting lightning strikes on wind turbines.

2 Normative references

Add the following document to the existing list, after IEC 62305-4:2010:

IECRE OD-501, *Type and Component Certification Scheme (wind turbines)*

Replace the existing Annex L with the following new Annex L:

Annex L
(informative)

Lightning detection and measurement systems

L.1 General

L.1.1 Purpose

It is recommended that wind turbines are equipped with systems capable of detecting lightning, measuring its current components, and processing the parameters of the lightning strikes. The purpose of such systems is to:

- provide information to the operator on the occurrence of lightning strikes to the wind turbine and to give input to operation and maintenance regimes;
- provide valuable data on lightning strikes to wind turbines thus allowing post-assessment of the lightning magnitude/characteristics and contribution to the operator's risk assessment processes;
- enable the operator to compare the measured current parameters of lightning strikes to the lightning protection level, LPL, used for designing the wind turbine lightning protection system (e.g. for assessing if the lightning current intercepted by the LPS is below or above the values defined in Table 1);
- avoid hazardous activities such as maintenance when there is a risk of lightning strike.

L.1.2 Nomenclature

The following nomenclature applies to this annex.

a) Thunderstorm warning systems (TWS), composed of thunderstorm detector(s) able to monitor the lightning or upcoming lightning activity and tools for processing the acquired data to provide a valid alarm (warning). They are based on local sensors (either based on electrostatic or electromagnetic fields), a group of local sensors or lightning location systems (LLS).

b) Lightning measurement systems (LMS) measuring lightning events and their features with devices installed on the turbine. These systems range from a combination of simple electromechanical event counters to complex systems measuring and analyzing lightning parameters.

L.2 Benefits of lightning detection and measurement systems

There are many benefits of measuring actual lightning exposure. Depending on the specific stakeholder, a non-exhaustive list is included in Table L.1, Table L.2 and Table L.3. The industry is encouraged to share lightning data across all stakeholders (OEM/Owner/Insurance), to ensure benefits across the entire value chain.

Table L.1 – Considerations and benefits for the OEM (original equipment manufacturer)

Statement	Value aspect
For turbines delivered with long service contracts, the OEM (Original Equipment Manufacturer) with a service contract would like to know when the receptor/LPS has reached the design lifetime and needs to be replaced. This can be achieved by monitoring the accumulated charge and specific energy for each blade and correlating with test performance of the receptor/LPS.	This enables condition-based maintenance or repair, lowering downtime and unexpected damage costs significantly. Maintenance is cheaper than repair.
The OEM would like to know all information of strikes, to determine the efficiency of the receptors/LPS (the observed number of strikes intercepted correctly divided by the total number of strikes to the turbine/blade observed – see 3.12).	This information is used to market the OEM products, *"with a field efficiency of XX%, our turbines comply fully with YY"*.
Every strike will be different, and cross correlating strike information with other sensor signals can provide valuable information to the OEM to fully understand the turbine operation and design performance.	Get more information on the lightning susceptibility of the turbines, to enable stronger and cheaper designs for future turbines.
Turbine LPS have developed intensively during the past 10 years to 20 years, and OEMs are still following different paradigms for the design and verification air terminations, down conductors and lightning coordination with additional conductive components like CFRP. If a blade design, known from verification tests or modelling, is challenged by certain features of the lightning current, an active monitoring of the lightning exposure will allow targeted maintenance. Not all lightning strikes exhibit the same strike parameters, hence the consequence of strikes will differ.	By measuring all strikes in field, evaluating the strike parameters, and comparing them to design performance from laboratory tests and/or modelling verification, the consequence of specific strikes can be assessed. By evaluating the consequence of each lightning event, maintenance and inspections can be tailored and optimized.
In case lightning damages occur, the detailed measurements of the lightning parameters can be used to assign and split the cost of repair between OEM and owner/operator.	Enable the discussion on splitting costs of blade damages based on lightning impact.

Table L.2 – Considerations and benefits for owner and/or operator

Statement	Value aspect
The operator would like to know if a lightning flash exceeded IEC LPL current parameters to which the turbine has been certified as this is useful information in relation to warranty and insurance.	Lightning damage is paid by the responsible party.
The owner and/or operator would like to know if a lightning flash was potentially dangerous to the turbine.	In case the measurement can be used to identify a strike as representing a risk, the turbine could be checked (online or on site) before it is restarted. This could prevent further damage on the turbine.
The owner and/or operator would like to know when the receptor and/or LPS has reached the design lifetime and needs to be replaced. This is performed by monitoring the accumulated charge and/or specific energy in each blade and correlating it with the receptor and/or LPS performance as proven by testing according to Annex D. Additionally, the collection of lightning exposure will enable a determination of potential LPS performance degradation.	This enables condition-based maintenance/repair, lower downtime and unexpected damage cost significantly. Maintenance is cheaper than repair.
A correlation of lightning performance across large fleets with LMS will provide knowledge on the performance of a specific design and enable customisation of the LPS design to specific site conditions (altitude, lightning regime, number of WTs in the WF, etc.).	Enable the owner to select turbines with documented good experience on the lightning performance, as required by the specific site.
Every strike will be different, and cross correlating strike information with other sensor signals can provide valuable information to the owner and/or operator to fully understand the turbine operation and design performance.	Get more information to support condition-based maintenance strategies.
In case lightning damages occur, the detailed measurements of the lightning parameters can be used to assign and split the cost of repair between OEM and owner/operator.	Enable the discussion on splitting costs of blade damages based on lightning impact.

Table L.3 – Considerations and benefits for the Insurance company

Statement	Value aspect
Sites with severe lightning exposure will potentially have more downtime to allow for extra service and maintenance, and the damage rate in terms of failures per year could also be larger. The insurance company could customize the insurance tariff according to site conditions in terms of challenging lightning activity, such that sites experiencing significant lightning activity could be priced higher than sites with limited lightning activity.	Utilizing a dynamic insurance premium, where that insurance premiums scale with documented lightning activity, would allow the insurance company to target the premiums more correctly to the risk.
A correlation of lightning performance across large fleets will provide knowledge of which designs work well and which designs don't for similar lightning environments. Since the lightning environment is documented by LMS, a correlation between insurance claims and LMS data will provide the needed information (e.g. protection efficiency of the LPS).	Optimize insurance premiums and exclude designs with poor performance, to eventually optimise the insurance business.
A blade certified according to IEC/RE OD-501 (referencing to IEC 61400-24 for lightning matters) eventually means that the turbine should be able to continue operation without the need of repair until next scheduled maintenance; see 8.2.2. An additional perception is that strikes outside the range of the LPL are disregarded. In both cases, knowledge on the actual strike data is useful for deciding the insurance coverage.	Qualify discussion of insurance coverage by providing actual lightning strike data.
In the event that blades suffer damages due to lightning, a discussion on insurance coverage can be assisted by accurate measurements. The insurance companies could require the installation of proper LMS to quantify the lightning exposure (current magnitude, specific energy, flash charge, accumulated charge, di/dt, etc.).	Discussions on lightning exposure can be eliminated once suitable LMS complying to industry standards are used efficiently.

L.3 Lightning detection and measurement systems

L.3.1 General

Lightning detection and measurement systems are devices that provide information about lightning affecting wind turbines. By detecting the presence of lightning strikes on and/or around the wind turbine, different strategies for optimized operation or maintenance of the turbines can be implemented.

Brief descriptions of the different options are given below.

L.3.2 Lightning detection systems

IEC 62793 describes sensors and networks of sensors (including LLS) able to provide real-time information on the risk of lightning strikes. Sensors measuring electrostatic field detect lightning related conditions and are usually employed as local detectors since they measure the formation, approach or dissipation of the thunderstorm in the area where they are installed.

Sensors measuring electromagnetic field produced by lightning strokes can be used as standalone detectors or used in networks. LLS use multiple antennae to locate lightning strokes based on direction-finding, time of arrival, or interferometric techniques. Data from these systems are generally available in real-time according to IEC 62793 requirements.

It is important for the user of data from TWS to know several parameters that affect the performance of the system. Considerations relevant to lightning detection systems should be compliant in full with IEC 62793.

L.3.3 Lightning measurement systems (LMS)

L.3.3.1 General

Lightning measurement systems are devices that provide information about lightning strikes on a wind turbine by measuring various parameters caused by that lightning strike (e.g., current magnitude, specific energy, flash charge, accumulated charge, d*i*/d*t*, transient magnetic fields generated by lightning currents flowing through down conductors including the tower).

L.3.3.2 Lightning event counters and peak current sensors

Lightning counters and peak current sensor cards (PCS) provide minimal information about lightning events to a wind turbine. The simplest lightning counters (e.g. electromechanical) just provide the number of strikes. Electronic lightning counters can also provide time stamp and estimation of lightning parameters. Peak current sensor cards provide an estimation of the maximum peak current for the time period since the sensor was installed. Considerations relevant for lightning event counters and peak current sensors are listed in Table L.4.

Table L.4 – Considerations relevant for lightning event counters and peak current sensors

Types	Considerations
Lightning strike counters	Lightning counters designed in accordance with IEC 62561-6 could not be suitable for wind turbines exposed to large fractions of upward lightning. Some lightning counters also estimate one or several current parameters: peak current, charge, specific energy. Devices designed for the standard lightning currents (e.g. in IEC 62561-6) will not provide realistic data for all the strikes. The manufacturer should define test waveforms including continuing currents. The manufacturer should provide the reference waveforms and the uncertainties. The manufacturer should provide information about the frequency response of the sensitivity and uncertainty of the estimated parameters. The measurement capability of lightning counters used in wind turbines should demonstrate sensitivity to upward lightning. Manufacturer should provide the sensitivity versus frequency curve.
Peak current sensors	This type of sensors designed and calibrated only with the standard lightning current waveforms is not suitable for the registration of real lightning currents. The manufacturer should provide information about the performance of the sensor at typical lightning currents of wind turbines. The manufacturer should provide information about the minimum detectable current and the tested waveforms. This type of sensors is not suitable for detecting continuing currents. The manufacturer should provide the frequency response of the sensitivity and its uncertainty.

Users should be careful interpreting the information provided by the manufacturers of these types of devices.

L.3.3.3 Local lightning current measurement systems

Special systems, e.g. with sensors mounted on the tower and/or in the blades of a wind turbine to trigger a lightning alarm based on electromagnetic or optical criteria are called local lightning current measurement systems. The sensor measures what actually strikes the turbines and prevents remote lightning flashes from triggering a false alarm. Such systems can be connected to a SCADA system giving a useful indication of lightning strikes in real-time. The systems could give an indication of current waveform and strike severity and can hence be used by operators to evaluate the degree of wear and damage, and to prepare maintenance for the relevant turbines after a lightning storm.

The lightning parameters which individually or in combination are closely related to the wear of the lightning protection system and/or damages of the wind turbine are the current magnitude, total charge transfer, specific energy and front time of the lightning current, etc. Whether these parameters can be measured accurately depends largely on the frequency response and resolution of the system.

The subclauses below highlight important features of local lightning current measurement system to effectively capture the desired outcome of the lightning strikes.

L.3.3.4 Classifications

The characteristics of lightning current such as the current magnitude, charge, specific energy and front time, etc. vary and could depend on the installation areas. Therefore, it is recommended to investigate available information about characteristics of lightning currents for the installation area when selecting the lightning measurement system to actually meet the expected performance. To aid the selection, local lightning current measurement systems are classified into four types according to the measurement performance, and hence the adequacy of measuring the different lightning characteristics. The classification is shown in Table L.5.

Table L.5 – Requirement for each class of lightning measurement systems

Category	Range	Class I	Class II-PC	Class II-EC	Class III
Frequency bandwidth[a]	0,1 Hz to 1 MHz or wider	×			
	1 Hz to 1 MHz or wider		×		
	0,1 Hz to 100 kHz or wider			×	
	1 Hz to 100 kHz or wider				×
Maximum measurable current value[b]	200 kA or higher	×	×		
	100 kA or higher			×	×
Maximum measurable electric charge value[c]	1 000 C or higher	×		×	
	600 C or higher		×		×
Minimum detectable current value[d]	1 kA or lower	×		×	
	2 kA or lower		×		×
Digital resolution[e]	16 bit or higher	x			
	12 bit or better		x	x	
	8 bit or higher				x
Observation period[f]	0,5 s or longer		×		×
	1 s or longer	×		×	

[a] A high upper cut off frequency allows measurement of short stroke pulses, a low lower cut off frequency ensures measurement of long strokes.

[b] Upper boundary for current detection, only Class I and Class II-PC ensures measurement of LPL1 current magnitude.

[c] Sites exposed to winter lightning should consider the risk of large charge transfer.

[d] ICC strokes could transfer significant amount of charge at current magnitudes less than 1 kA. This charge transfer will add to the erosion of air terminations, which is why a minimum measurable current should consider this.

[e] Digital resolution is important when measuring small current signals with a system having a large dynamic range.

[f] Especially UW lightning and/or bipolar events are known to persist for up to 1 s and above.

A guidance on the suitable classes of measurement systems is provided below:

Class I:	Suitable for measuring all quantities of a lightning strike
Class II-PC:	Focus on measuring the peak current (PC) of the lightning strike
Class II-EC:	Focus on measuring the electric charge (EC) of the lightning strike
Class III:	Limited measurement performance
Class IV:	Any lightning measurement systems not complying with Class I-III

The classification of a lightning measurement system follows the lowest classification in any of the categories, i.e. a LMS complying with class I in five out of six categories, but only to Class II-PC in one category, is classified as Class II-PC.

L.3.3.5 Properties of lightning measurement systems

L.3.3.5.1 General

Several properties of a lightning measurement system for a wind turbine are important for ensuring that expectations are met, including the electrical properties of the front-end measuring system, the quantities which are recorded and stored by the system, and the ability to interface to the turbine or operator SCADA system. The following is a non-exhaustive informative list of topics to consider. The following subclauses of L.3.3.5 are a non-exhaustive informative list of topics to consider.

L.3.3.5.2 Electrical performances

L.3.3.5.2.1 Detection method

The front end of the lightning measurement system defines the detection method. Several principles exist ranging from full current measurements in individual blades, full current in the tower, or partial current measurement in earthing systems. When measuring lightning current in wind turbines, it is important to consider that the structure itself could affect the current measurement. This appears due to impedance mismatch at interfaces between blade and nacelle, and/or tower and ground. The result can be reflections in the measured lightning current, which are still part of the actual current component affecting the turbine but would not be present if the lightning current could be measured without the turbine.

Most of the systems that measure the lightning current flowing through the LPS (air termination, down conductor, tower and earthing system, etc.) and hence detect lightning strikes on wind turbines use various current sensors (Rogowski coil, CT, solenoid coil, resistive shunt, etc.) to measure the above-mentioned lightning parameters.

The manufacturer should specify the detection method used, the applicability of the chosen detection method for the frequency range considered, and for systems measuring partial current in the earthing system, the manufacturer should ensure that the current share is well defined across the frequency range stated.

L.3.3.5.2.2 Current detection frequency bandwidth

The current detection frequency bandwidth (the frequency bandwidth with a gain characteristic between –3 dB and +3 dB) should be defined by the manufacturer. Since lightning current is known to exhibit a wide range of frequencies from short strokes at downward lightning to long strokes experienced as ICC or winter lightning, the frequency range should be chosen for the application.

L.3.3.5.2.3 Observation period

The observation period, or total time of recording and processing, should ensure that the entire duration of the expected lightning flashes is covered.