

# TECHNICAL REPORT

# IEC TR 61400-24

First edition  
2002-07

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## Wind turbine generator systems – Part 24: Lightning protection

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## CONTENTS

FOREWORD .....	5
INTRODUCTION .....	7
1 Scope .....	8
2 Definitions .....	8
3 Lightning and wind turbines .....	12
3.1 The properties of lightning .....	12
3.2 Lightning discharge formation and electrical parameters .....	12
3.3 Cloud-to-ground flashes .....	13
3.4 Upward initiated flashes .....	17
3.5 Lightning protection of wind turbines – the generic problem .....	19
3.6 Existing IEC standards and technical reports dealing with lightning protection .....	20
4 Damage statistics .....	21
4.1 Data on wind turbine lightning damage .....	21
4.2 Damage statistics .....	21
4.3 Database merits and weaknesses .....	27
4.4 Conclusions and recommendations .....	28
5 Evaluation of the risk of lightning damage to a wind turbine .....	29
5.1 Introduction .....	29
5.2 Assessing the lightning flash frequency to a wind turbine .....	29
5.3 Use of IEC 61024-1-1 .....	30
5.4 Use of IEC 61662 .....	32
5.5 Analysis of blade lightning protection system costs .....	34
5.6 Analysis of lightning protection costs for wind turbine control systems .....	35
6 Lightning protection of wind turbine blades .....	36
6.1 Blade structure .....	36
6.2 Blade damage mechanism .....	38
6.3 Lightning protection for wind turbine blades .....	38
6.4 Interception efficiency .....	40
6.5 Sizing of materials .....	41
6.6 Blade to hub connection .....	43
6.7 Carbon reinforced plastic (CRP) .....	43
6.8 Wiring inside blades .....	43
7 Protection of bearings and gearbox .....	44
7.1 Damage to bearings due to AC and DC currents .....	44
7.2 Damage to bearings due to lightning currents .....	44
7.3 Laboratory investigations .....	44
7.4 Lightning damage to gearbox .....	45
7.5 Lightning protection of bearings and gearbox elements .....	45
8 Protection of electrical and control system .....	46
8.1 Introduction .....	46
8.2 Configuration of electrical equipment .....	46
8.3 Lightning protection zones .....	50
8.4 Surge coupling mechanisms .....	52
8.5 Bonding and shielding .....	53

8.6	Surge protection .....	56
8.7	Summary .....	58
9	Earthing .....	58
9.1	Lightning protection system earth termination for a single wind turbine .....	58
9.2	Lightning protection system earth terminations in a wind farm .....	60
10	Personnel safety .....	61
10.1	General .....	61
11	Conclusions and recommendations for further work .....	62
Annex A Typical lightning damage questionnaire .....		64
Bibliography .....		66
Figure 1	– Processes involved in the formation of a cloud-to-ground flash [4] .....	14
Figure 2	– Typical profile of a negative cloud-to-ground flash (not to scale) .....	15
Figure 3	– Typical profiles of negative cloud-to-ground flashes (not to scale) .....	16
Figure 4	– Typical profile of a positive cloud-to-ground flash .....	17
Figure 5	– Typical profile of a negative upward-initiated flash .....	17
Figure 6	– Different profiles of negative upward initiated flashes (not to scale) .....	18
Figure 7	– Faults by component (Germany) .....	23
Figure 8	– Faults by component (Denmark) .....	23
Figure 9	– Faults by component (Germany) .....	24
Figure 10	– Faults by component (Denmark) .....	24
Figure 11	– Repair costs by component and size (Germany) .....	25
Figure 12	– Average down time by component and size (Germany) .....	25
Figure 13	– Annual variation in lightning activity and damage (Denmark) .....	26
Figure 14	– Faults caused by lightning (Denmark 1990-1998) .....	26
Figure 15	– Lightning damage events (Germany 1991-1998) .....	27
Figure 16	– Equivalent collection area of the wind turbine .....	30
Figure 17	– Types of wind turbine blades .....	37
Figure 18	– Lightning protection for large modern wind turbine blades .....	39
Figure 19	– Alternative current path to reduce lightning current .....	46
Figure 20	– Principle configuration of electrical equipment in a grid-connected wind turbine .....	47
Figure 21	– Principle control system configuration .....	49
Figure 22	– Rolling sphere model .....	50
Figure 23	– Example of the division of the interior of a wind turbine into protection zones .....	51
Figure 24	– Differential and common mode coupling .....	53
Figure 25	– Two control cabinets located on different metallic planes inside a nacelle .....	54
Figure 26	– Magnetic coupling mechanism .....	55
Figure 27	– Example design of a combination type SPD .....	57
Figure 28	– Typical wind turbine earthing arrangement .....	59

Table 1 – Cloud-to-ground lightning current parameters .....	15
Table 2 – Upward initiated lightning current parameters .....	18
Table 3 – Standards and technical reports issued by IEC (Mid 2001) .....	20
Table 4 – IEC TC 81 work in progress (Mid 2001) .....	21
Table 5 – Lightning damage frequency .....	22
Table 6 – Regional effect on lightning damage (Germany) .....	22
Table 7 – Lightning fault summary (Sweden) .....	23
Table 8 – Energy and availability loss compared to other faults .....	26
Table 9 – Lightning protection system levels .....	31
Table 10 – Maximum values of lightning parameters corresponding to protection levels .....	32
Table 11 – Minimum dimensions of lightning protection system materials .....	41
Table 12 – Proposed minimum dimensions for lightning protection system materials .....	41
Table 13 – Physical characteristics of typical materials used in lightning protection systems .....	42
Table 14 – Temperature rise [K] for different conductors as a function of $W/R$ .....	42
Table 15 – Lightning protection zones .....	50
Table 16 – Examples of component requirements in given zones .....	52
Table 17 – Effect of various protection measures on screen transient voltages .....	56
Table 18 – Suitability of electrode types .....	60

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**WIND TURBINE GENERATOR SYSTEMS –****Part 24: Lightning protection**

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Technical reports do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful by the maintenance team.

IEC 61400-24, which is a technical report, has been prepared by IEC technical committee 88: Wind turbine systems.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
88/128/CDV	88/142/RVC

Full information on the voting for the approval of this technical report 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 3.

This document, which is purely informative, is not to be regarded as an International Standard.

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be either

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

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## INTRODUCTION

During the last few years damage to wind turbines due to lightning strokes has been recognized as an increasing problem. The increasing number and height of installed turbines have resulted in an incidence of lightning damage greater than anticipated with repair costs beyond acceptable levels. The influence of lightning faults on operational reliability becomes a concern as the capacity of individual wind turbines increases and turbines move offshore. This is particularly the case when several large wind turbines are operated together in wind farm installations since the potential loss of multiple large production units due to one lightning flash is unacceptable.

Unlike other electrical installations, such as overhead lines, substations and power plants, where protective conductors can be arranged around or above the installation in question, wind turbines pose a different lightning protection problem due to their physical size and nature. Wind turbines typically have two or three blades with a diameter up to 100 m or more rotating 100 m above the ground. In addition, there is extensive use of insulating composite materials, such as glass fibre reinforced plastic, as load-carrying parts. The lightning protection system has to be fully integrated into the different parts of the wind turbines to ensure that all parts likely to be lightning attachment points are able to withstand the impact of the lightning and that the lightning current may be conducted safely from the attachment points to the ground without unacceptable damage or disturbances to the systems.

To that end this report was developed to inform designers, purchasers, operators, certification agencies and installers of wind turbines on the state-of-the-art of lightning protection of wind turbines.

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WITHDRAWN

# WIND TURBINE GENERATOR SYSTEMS –

## Part 24: Lightning protection

### 1 Scope

During the last few years, all major wind turbine manufacturers have made dedicated efforts towards developing adequate lightning protection systems, and the first experiences with these new designs are beginning to be seen. It is therefore reasonable at this time to consider and prepare for a standardization effort that will give both manufacturers and operators a common framework for appropriate lightning protection of wind turbines.

On the above background the following elements of work have formed the scope of a new working group with the specific aim of preparing a technical report on the subject prior to considering development of a full standard:

- identify the generic problems involved in lightning protection of wind turbines;
- collect and systematize existing experience with both older and new designs of wind turbines;
- describe appropriate methods for evaluating the risk of lightning damage to wind turbines, thereby making reliable cost-benefit evaluations of lightning protection efforts possible;
- describe and outline appropriate methods for lightning protection of wind turbine components, considering the special nature of wind turbines and the extensive use of composite materials;
- compile a technical report outlining problems and solutions as seen today. The working group should identify and quantify areas where further research and proper standardization efforts are needed.

This technical report is structured as follows:

- clause 3 gives the background on the current understanding on lightning phenomenology and its impact on wind turbines;
- clause 4 presents the lightning damage experience as extracted from the various national wind turbine databases;
- clause 5 describes risk evaluation;
- clauses 6 through 10 discuss appropriate methods for protection against lightning damage;
- clause 11 identifies areas for further research.

### 2 Definitions

For the purposes of this technical report, the following definitions apply.

#### 2.1

##### **accepted lightning flash frequency ( $N_c$ )**

maximum accepted average annual frequency of lightning flashes which can cause damage to the structure

#### 2.2

##### **air-termination system**

part of the external LPS which is intended to intercept lightning flashes

**2.3****bonding conductor**

conductor interconnecting separate installation parts to equalize potentials between them

**2.4****bonding bar**

bar on which metal installations, electric power and telecommunication lines, and other cables can be bonded to an LPS

**2.5****dangerous sparking**

unacceptable electrical discharges caused by lightning currents in the structure to be protected

**2.6****direct lightning flash frequency to a structure ( $N_d$ )**

expected average annual number of direct lightning flashes to the structure

**2.7****down-conductor system**

part of an external LPS which is intended to conduct lightning current from the air-termination system to the earth-termination system

**2.8****downward flash**

lightning flash initiated by a downward leader from cloud to earth. A downward flash consists of a first short stroke, which can be followed by subsequent short strokes and may include a long stroke

**2.9****earth electrode**

part or a group of parts of the earth-termination system which provides direct electrical contact with and disperses the lightning current to the earth

**2.10****earth-termination system**

part of an external LPS which is intended to conduct and disperse the lightning current to the earth

**2.11****effective height ( $h$ )**

effective height of a wind turbine is the highest point the blades reach, i.e. hub height plus rotor radius

**2.12****efficiency of LPS ( $E$ )**

ratio of the average annual number of direct lightning flashes which cannot cause damage to the structure to the direct lightning flash number to the structure.  $E$  can be expressed as the product of the interception efficiency ( $E_i$ ) and sizing efficiency ( $E_s$ ) expressing the probability with which the LPS protects the structure against direct lightning flashes

**2.13****equivalent collection area ( $A_e$ )**

equivalent collection area of a structure is defined as an area of ground surface which has the same annual frequency of direct lightning flashes as the structure

**2.14**

**external lightning protection system**

consists of an air-termination system, a down conduction system and an earth termination system

**2.15**

**flash charge ( $Q_{\text{flash}}$ )**

time integral of the lightning current for the entire lightning flash duration

**2.16**

**foundation earth electrode**

reinforcement steel of foundation or additional conductor embedded in the concrete foundation of a structure and used as an earth electrode

**2.17**

**frequency of damage by direct lightning flashes**

average number of direct lightning flashes to the structure

**2.18**

**ground flash density ( $N_g$ )**

average annual ground flash density is the number of lightning flashes per square kilometre per year, concerning the region where the structure is located

**2.19**

**interception efficiency ( $E_i$ )**

probability with which the air-termination system of an LPS intercepts a lightning stroke

**2.20**

**internal lightning protection system**

all measures additional to those mentioned under external lightning protection system including the equipotential bonding, the compliance of the safety distance and the reduction of the electromagnetic effects of lightning current within the structure to be protected

**2.21**

**lightning protection system (LPS)**

the complete system used to protect a structure and its contents against the effects of lightning. Commonly it consists of both external and internal lightning protection systems

**2.22**

**lightning current ( $I$ )**

current flowing at the point of strike

**2.23**

**“natural” components of LPS**

component installed not specifically for lightning protection which can be used in addition to the LPS or in some cases could provide the function of one or more parts of the LPS

**2.24**

**peak value ( $I$ )**

maximum value of the lightning current

**2.25**

**lightning equipotential bonding**

bonding of separated conducting installation parts by means of direct conductors or SPD, involved into an internal LPS, to reduce potential differences between these parts caused by lightning current

**2.26****lightning stroke**

single discharge in a lightning flash to earth

**2.27****lightning flash to earth**

electric discharge of atmospheric origin between cloud and earth consisting of one or more strokes

**2.28****lightning protection zone (LPZ)**

zones where lightning electromagnetic environments are to be defined and controlled

**2.29****long stroke**

stroke with duration time  $T_{\text{long}}$  (time from the 10 % value on the front to the 10 % value on the tail) of the current typically more than 2 ms and less than 1 s (cf. IEC 61024-1)

**2.30****metal installations**

extended metal items in the structure to be protected which may form a path for the lightning current, such as the nacelle bed plate, the tower, ladders, elevator rails and wires and interconnected reinforcing steel

**2.31****multiple strokes**

lightning flash consisting in average of 3-4 strokes, with typical time interval between them of about 50 ms

**2.32****point of strike**

point where a lightning stroke contacts the earth, a structure or a lightning protection system

**2.33****protection level**

number denoting the classification of an LPS according to its efficiency

**2.34****risk of damage**

probable annual loss (human and goods) in a structure due to lightning

**2.35****safety distance**

minimum distance between two conductive parts within the structure to be protected between which no dangerous sparking can occur

**2.36****short stroke**

stroke with time to half value  $T_2$  of the impulse current typically less than 2 ms (cf. IEC 61024-1)

**2.37****sizing efficiency ( $E_s$ )**

probability that the intercepted lightning stroke does not cause damage to the structure to be protected

**2.38****specific energy ( $W/R$ )**

time integral of the square of the lightning current for the flash duration; it represents the energy dissipated by the lightning current in a unit resistance

**2.39****surge arrester**

device designed to protect electrical apparatus from high transient voltage and to limit the duration and frequently the amplitude of follow-current. The term “surge arrester” includes any external series gap which is essential for the proper functioning of the device as installed for service, regardless of whether or not it is supplied as an integral part of the device

**2.40****surge protective device (SPD)**

device that is intended to limit transient overvoltages and divert surge currents

**2.41****thunderstorm days ( $T_d$ )**

number of thunderstorm days per year obtained from isoceraunic maps

**2.42****upward flash**

lightning flash initiated by an upward leader from an earthed structure to cloud. An upward flash consists of a first long stroke with or without multiple superimposed short strokes, which can be followed by subsequent short strokes possible including further long strokes

**3 Lightning and wind turbines****3.1 The properties of lightning**

A lightning stroke can be regarded as a current source. The maximum recorded value of lightning current produced by a single stroke is in the region of 300 kA. Similarly, the maximum recorded values of charge transfer and specific energy are 400 C and 20 MJ/ $\Omega$  respectively.

These maximum values occur in only a small percentage of flashes worldwide. The median value of peak lightning current is approximately 30 kA with median values of charge transfer and specific energy of 5,2 C and 55 kJ/ $\Omega$ , respectively. In addition, the electrical characteristics of a stroke vary with the type of lightning flash and the geographical location.

**3.2 Lightning discharge formation and electrical parameters**

Lightning strokes are produced following a separation of charge in thunderstorm clouds, a process detailed in a number of publications [1]<sup>1</sup> [2] [3]. A lightning stroke is observed when this charge is discharged to the earth or to a neighbouring cloud. This chapter is concerned with the first of these discharges, the transfer of charge between a thundercloud and the earth.

A lightning discharge usually consists of several components. The whole event following the same ionized path is termed **flash** and may last more than 1 s. The individual components of a flash are called **strokes**.

Lightning discharges are one of two basic types, downward or upward initiated. A downward initiated discharge starts at the thundercloud and heads towards the earth. In contrast an upward initiated discharge starts at an exposed location of the earth (for example mountain top) or at the top of a tall earthed structure and heads towards a thundercloud. Commonly,

<sup>1</sup> Numbers in square brackets refer to the Bibliography.