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**Vplivi električnega toka na ljudi in živali – 4. del: Vplivi udarov strele na ljudi in živali**

Effects of current on human beings and livestock - Part 4: Effects of lightning strokes on human beings and livestock

**iTeh STANDARD PREVIEW**

Effets du courant sur le corps humain et sur les animaux - Partie 4: Effets de la foudre sur le corps humain et sur les animaux

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**Effets du courant sur le corps humain  
et sur les animaux –**

**Partie 4:  
Effets de la foudre sur le corps humain  
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**Effects of current on human beings  
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**Part 4:  
Effects of lightning strokes  
on human beings and livestock**

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## INTERNATIONAL ELECTROTECHNICAL COMMISSION

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**EFFECTS OF CURRENT ON HUMAN BEINGS  
AND LIVESTOCK –**
**Part 4: Effects of lightning strokes  
on human beings and livestock**

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IEC 60479-4, is a technical report and has been prepared by technical committee 64: Electrical installations and protection against electric shock.

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

Enquiry draft	Report on voting
64/1382/DTR	64/1396/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 2.

IEC 60479 consists of the following parts under the general title *Effects of current on human beings and livestock*

- Part 1: General aspects
- Part 2: Special aspects:
  - Chapter 4: Effects of alternating current with frequencies above 100 Hz
  - Chapter 5: Effects of special waveforms of current
  - Chapter 6: Effects of unidirectional single impulse currents of short duration
- Part 3: Effects of currents passing through the bodies of livestock
- Part 4: Effects of lightning strokes on human beings and livestock

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

- reconfirmed; <https://standards.iteh.ai/catalog/standards/sist/ef8cd669-edc2-4971-826b-89e323b908a2/sist-tp-iec-tr-60479-4-2006>
- withdrawn;
- replaced by a revised edition, or
- amended.

## INTRODUCTION

IEC 60479 parts 1 to 3, deals with the effect of electric shock derived from electrical systems on the bodies of human beings and livestock. This part, which is a technical report, describes the influence and effect of natural electricity in the form of lightning strokes during thunderstorms. Lightning current can consist of several uni-polar and/or bi-polar impulses with different peak values and durations; Chapter 6 of IEC 60479-2 does not cover these effects.

The interaction of a lightning stroke with the victim's body is quite different from the usual experience with electric shock derived from electrical systems. The pathway often includes the head in lightning accidents. This implies a probable inclusion of the brain stem, which includes the respiratory centre, in contrast with pathways of shock current arising from electrical systems. In particular it must be pointed out that differences exist between accidents caused by a direct flash compared with those interactions which are caused by step voltages. Even very short single impulses of lightning can cause cardio-pulmonary arrest [5]<sup>1</sup>, [6], [12] and [13].

The intense electric interactions with living organisms are very dangerous but, surprisingly in many cases, not always lethal. It is accepted that 70 % or more lightning accidents involving humans are not fatal (see [1] and [9]). Corresponding reliable data for livestock are not known. There is a large variation in outcome due to different environments, different activities of people and knowledge of first aid and quality of medical care [1] and [5].

It has been necessary, therefore, to create a separate document concerning the special effects of lightning strokes. The physical behaviour of lightning is shown as a basis. The interaction with a living body is then described, followed by the consequences for the life of the victim.

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<sup>1</sup> Figures in square brackets refer to the bibliography.

## EFFECTS OF CURRENT ON HUMAN BEINGS AND LIVESTOCK –

### Part 4: Effects of lightning strokes on human beings and livestock

#### 1 Scope and object

This technical report summarizes the basic parameters for lightning and their variability insofar as they apply to human beings and livestock. The possible direct and indirect interactions of strikes with bodies of living beings are indicated. The resulting effects caused by lightning currents for the organism are described.

The intention is to show the differences of effects on human beings and livestock due to lightning strokes versus those effects of electric shocks derived from electrical systems.

#### 2 Normative references

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

IEC 60479-1:1994, *Effects of current on human beings and livestock – Part 1: General aspects*

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IEC 61024-1:1997, *Protection of structures against lightning*

#### 3 Terms and definitions

For the purposes of this document, the definitions given in IEC 60479-1 in addition to the following definitions, apply.

##### 3.1 Definitions of technical terms

###### 3.1.1

###### **lightning flash**

atmospheric discharge consisting of one or more strokes

###### 3.1.2

###### **lightning stroke**

single electrical discharge in a lightning flash

###### 3.1.3

###### **lightning channel**

conducting path of the lightning current



**3.1.4****stepped and connecting leader**

pre-discharge with low current and with low light emission, which opens the lightning channel as it grows

**3.1.5****main stroke, return stroke**

bright lightened part with strong current discharge, which is initiated at that moment when the stepped and connecting leader comes into contact with the earth

**3.1.6****downward flash**

lightning flash initiated by a downward leader from a cloud to earth

**3.1.7****upward flash**

lightning flash initiated by an upward leader from earth to cloud. That part of a stroke when the leader grows from earth to cloud

**3.1.8****continuing current**

mean current of the long lasting component of the lightning current

**3.1.9****peak value**

maximum value of the lightning current. This value ranges from 4 kA to 250 kA for the majority of positive and negative lightning strokes [7]

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**3.1.10****flash charge**

time integral of the lightning current for the entire lightning duration. This value ranges from 0,2 C to 350 C for the majority of positive and negative lightning strokes [7]

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**3.1.11****impulse charge, short stroke charge**

time integral of the lightning current for the impulse part of the lightning duration. This value ranges from 0,22 C to 150 C for the majority of positive and negative lightning strokes [7]

**3.1.12****specific energy**

energy dissipated by the lightning current in a unit resistance. It is the integral of the square of the lightning current for the duration of the lightning. This value ranges from  $6 \times 10^3$  J/Ω to  $1,5 \times 10^7$  J/Ω for the majority of positive and negative lightning strokes [7]

**3.1.13****average steepness**

average rate of change of current calculated over 10 % to 90 % of peak amplitude of the wave front [7]. This value ranges from 0,2 kA/μs to 99 kA/μs for the majority of positive and negative lightning strokes

**3.1.14****stroke duration**

range of 6,15 μs to 2 000 μs for the majority of positive and negative lightning strokes [7]

**3.1.15****stroke interval**

time interval between the beginnings of successive strokes

**3.1.16****total flash duration**

time range of 0,1 ms to 1 100 ms for the majority of positive and negative lightning strokes [7]

NOTE Experience show that the statistical distribution of the parameters in this subclause can be assumed to have a logarithmic normal distribution.

**3.2 Definitions of interactions****3.2.1****direct stroke**

interaction whereby the tip of the stepped and connecting leader attaches directly to the living being (see Figure A.2)

**3.2.2****contact voltage**

potential difference between accessible points when touched simultaneously by a living being (see Figure A.3)

NOTE In some texts, this has been erroneously referred to as “contact potential” or “touch voltage”.

**3.2.3****side flash**

electric arc between two objects, at least one of which is subject to lightning (see Figure A.4 and A.5c)

**3.2.4****step voltage**

voltage on the earth's surface between two points

NOTE The possible resulting currents are shown in Figures A.5a and A.5c.

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**3.2.5****flashover**

an electric arc over the surface of the body carrying a significant proportion of the current. It may occur with the other combinations above (see Figure A.2)

**3.3 Definitions of effects on organisms****3.3.1****physiological effects**

external electrical stimulation of excitable cells, such as all kinds of muscles, smooth muscles of arteries and veins, skeletal muscles, heart muscle, nerves and all the structures of the brain. These effects are transient

**3.3.2****pathophysiological effects**

stimulatory or inhibitory effects which lead to reversible or irreversible dysfunctions of the affected structures of the organism. These effects are of long duration

NOTE This group of effects includes keraunoparalysis which is a transient paralysis of the muscular structures in the line of the current. Its cause is uncertain.

**3.3.3****thermal effect**

effect of electrical current which results in local and transient heating of the affected structures up to temperatures where cells and organelles become denaturing

The effect of evaporation remains to be proved [14]

## 4 Physics of lightning

The explanation of the basic physical mechanisms for the onset and the dynamics of lightning is very complicated. The latest explanation takes into account that a tripolar layered cloud is generated by microscopic charge transfer between soft hail particles (also called graupel) and ice crystals [3].

Lightning is a transient, high-current discharge whose path length is measured in kilometres. Well over half of all flashes occur wholly within the cloud and are called intra-cloud (IC) discharges. Cloud-to-ground (CG) lightning has been studied more extensively than other forms of lightning because of its practical importance (for instance, as a cause for injuries and death, disturbances in power and communication systems, and the ignition of forest fires) and because lightning below a cloud is more easily studied with optical techniques. Cloud-to-cloud and cloud-to-air discharges occur less frequently than either IC or CG lightning. All discharges other than CG are often combined under the general term cloud discharges.

Four different types of discharges between cloud and earth have been identified (Figure A.1). Negative CG flashes probably account for about 90 % of the CG discharges world-wide (Figure A.1, category 1), and less than 10 % of lightning discharges are initiated by a downward-moving positive leader (category 3) [4]. Ground-to-cloud discharges are initiated by leaders that move upward from the earth (categories 2 and 4). These upward-initiated flashes are relatively rare and usually occur from mountain peaks and tall man-made structures [3].

Other important physical parameters are the specific energy per stroke, the average steepness of current rise within a stroke, as well as the stroke duration and total flash duration where there is more than one stroke in a flash.

The mechanical effects are related to the peak value of the current and specific energy. The thermal effects are related to the specific energy when resistive coupling is involved and to the total charge or impulse charge when arcs develop. The highest peak values, specific energy and impulse energy occur in positive lightning strokes.

The inductive coupling is related to the steepness of the lightning current front. The highest value of this parameter occurs in subsequent negative strokes [5].

Thunder accompanies lightning and is generated by superheated air at the channel, which causes air pressure waves.

## 5 Interaction of strokes with human beings and livestock

The possible interaction of lightning with living beings depends on the resulting time course and pathway of the current in the body and on its surface. As the temporal and spatial current distribution of strokes varies, so the effects on living organisms are different.

### 5.1 Description of direct strike

When the tip of the downward stepped leader has reached a height of some tens of metres above ground level, the resulting field strength attains a critical value so that a short upward streamer can be initiated from a vertical conductor or victim. The flow of current of the whole discharge goes direct via the victim's body (Figure A.2).

A description of direct lightning stroke interaction is given in 5.5.