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TECHNICAL REPORT

colour inside

Assessment of contact current related to human exposure to electric, magnetic and electromagnetic fields

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CONTENTS

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ASSESSMENT OF CONTACT CURRENT RELATED TO HUMAN EXPOSURE TO ELECTRIC, MAGNETIC AND ELECTROMAGNETIC FIELDS

FOREWORD

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IEC TR 63167 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2018. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) revised in accordance with the latest revision of international EMF guidelines;

b) revised in accordance with updates of relevant IEC standards on electrical safety.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
106/641/DTR	106/656/RVDTR

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 Technical Report 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.

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- withdrawn, or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.

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INTRODUCTION

In the guidelines limiting human exposure to electric, magnetic and electromagnetic fields (EMF guidelines), limits or a guidance for the contact current are given to avoid adverse indirect effects, i.e. electric shocks and burn hazards caused by contact with a conductive object located in an electric field or magnetic field or both, when the object has an electric potential owing to electric or magnetic induction to the object.

At the moment, no standardized method for evaluating the contact current, in the context of human exposures to the above fields has been well established. On the other hand, there is a vast amount of knowledge, as well as many standards and regulations on the issue of electrical safety (i.e. direct contact with live part of conductive object) to avoid severe electric shock hazards. Therefore, the evaluation methods used in the field of electrical safety ~~might~~ can be useful references. This document summarizes general information on the assessment of contact current related to human exposure to electric, magnetic and electromagnetic fields.

ASSESSMENT OF CONTACT CURRENT RELATED TO HUMAN EXPOSURE TO ELECTRIC, MAGNETIC AND ELECTROMAGNETIC FIELDS

1 Scope

This document, which is a Technical Report, provides general information on the assessment of contact current related to human exposure to electric, magnetic and electromagnetic fields. The contact currents in this context occur when a human body comes into contact with a ~~not electrified~~ conductive object that is non-electrified but exposed to an electric field or magnetic field or both at a different electric potential owing to electric ~~and/~~or magnetic induction to the object. This is distinguished from the issue of electrical safety where contact with live parts of a conductive object is dealt with.

In reference to the international EMF guidelines [1], [2], and [3][1], the frequency range of contact current covered in this document is DC to 110 MHz, and only steady-state (continuous) contact currents are covered. Transient contact currents (spark discharges) which ~~may~~ can occur immediately before the contact with the object are not covered.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
contact current
~~current flowing into the body resulting from contact with a conductive object in an electric, magnetic or electromagnetic field~~

<to human exposure> current flowing through the body resulting from contact with an insulated conductive object that has been energized in an electric, magnetic or electromagnetic field or from an insulated body that has been energized in an electric, magnetic or electromagnetic field and is in contact with a grounded conductive object

~~**3.2**~~
~~**electric field strength**~~
~~magnitude of a field vector at a point that represents the force (F) on an infinitely small charge (q) divided by the charge~~

[1] Numbers in square brackets refer to the Bibliography.

3.2
exposure
<to human> ~~state~~ situation that occurs when a person is subjected to an electric, magnetic or electromagnetic field, or to a contact current other than those originating from physiological processes in the body and other natural phenomena

3.3
indirect effect
~~effect resulting from physical contact between a person and a not electrified object, such as a metallic structure in an electric, magnetic or electromagnetic field, at an electric potential that is at least at a point of the object different from the potential of the person~~

effect arising when an object present in an electromagnetic field becomes a cause of safety or health hazard

3.4
touch current
electric current ~~flowing~~ passing through a human body when it touches one or more accessible and energized parts of an installation or of equipment, or object, used in the field of electrical safety

Note 1 to entry: The term "leakage current" had also been used as a synonym for touch current in the field of electrical safety.

[SOURCE: IEC 60050-195:2021, 195-05-21, modified – In the definition, "or through livestock" has been deleted, "and energized" has been added, "or object, used in the field of electrical safety" has been added. Note 1 to entry has been added.]

3.5
spark discharge
transfer of current through an air gap prior to making contact with another conductive object at a different potential

4 Abbreviated terms

3D	three dimensional
AC	alternating current
AM	amplitude modulation
DC	direct current
EMF	electric, magnetic or electromagnetic field
EV	electric vehicle
FM	frequency modulation
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEEE	Institute of Electrical and Electronics Engineers
IH	induction heating
~~MPE~~	~~maximum permissible exposure~~
MRI	magnetic resonance imaging
PC	personal computer
RF	radio frequency
WPT	wireless power transfer

5 Contact current in EMF ~~exposure~~ guidelines

Clause 5 overviews contact currents described in the EMF guidelines [1], [2], and [3].

In the frequency range up to approximately 10 MHz (predominantly up to 100 kHz), the flow of electric current from an object in a field to the body of an individual ~~may~~ can result in the stimulation of muscles ~~and/~~or peripheral nerves. With increasing current, this ~~may~~ can be manifested as perception, pain from an electric shock ~~and/~~or burn, the inability to release the object, difficulty in breathing and, at higher currents, cardiac ventricular fibrillation.

In the frequency range of about 100 kHz to 110 MHz, shocks and burns can result either from an individual touching an ungrounded metal object that has acquired a charge in a field or from contact between a charged individual and a grounded metal object.

In the EMF guidelines, reference levels or a guidance for steady state (continuous) contact current are given for frequencies up to 110 MHz to avoid shock and burn hazards (see Annex A) , rather than to avoid ventricular fibrillation. ~~The reference levels are not intended to avoid ventricular fibrillation, which is the basis of standards for electrical safety.~~ The upper frequency of 110 MHz is the upper frequency limit of the FM broadcast band. Here, the transient currents resulting from spark discharges [4], which can occur when an individual comes into very close proximity with an object at a different electric potential, are not considered in the reference levels of contact current. Instead, the effect of spark discharge is considered in the reference levels of electric field exposure for the general public by including a sufficient margin to prevent surface electric-charge effects such as perception by most people.

~~It is noteworthy that different methods for evaluation of conformity to the guidelines are provided for multiple-frequency exposure for low-frequency (below 100 kHz) and high-frequency (above 10 kHz) ranges. In the frequencies between 10 kHz and 100 kHz, both evaluation methods are applied (see Annex A).~~

6 Consideration in evaluating contact currents

6.1 General

Clause 6 describes items to be considered in evaluating contact currents:

a) assumed situations of human exposure to a contact current (6.2);
b) methods for evaluating a touch current used in electrical safety standards for references (6.3);
c) some proposed methods for evaluating contact currents (6.4).

6.2 Assumed situations of human exposure to contact current

6.2.1 General

There are several situations to be considered for human exposure to a contact current. Different cases ~~have to be~~ are considered depending on the type of coupling between fields (electric or magnetic) and human bodies~~/~~ or objects.

6.2.2 Capacitive coupling (power line)

An electric field induces, by capacitive coupling (electrostatic induction), a voltage in a person or a conductive object that is isolated from the ground. When a person touches an object having a different potential, a contact current flows so as to cancel the potential difference. This can be categorized into two cases: (a) an isolated person touches a grounded object and (b) a grounded person touches an isolated object (especially a large object such as a bus or a truck) [5]. Comprehensive studies have been carried out for typical cases encountered under overhead transmission lines [6].

6.2.3 Inductive coupling (power line)

By inductive coupling (electromagnetic induction), a magnetic field induces a voltage, especially in long conductive objects such as telecommunication lines, fences and gas pipelines, having

at least one reasonable grounding, when they are installed close to and parallel to magnetic field sources such as overhead power lines [7]. When a person touches the object, a contact current flows. In particular, in the case of fault condition in overhead power lines, the limit values for the open-circuit voltage in nearby telecommunication lines are set by an international regulation-setting body [8]. In contrast to the capacitive coupling, grounding a conductive object at a large distance from the point of contact will actually increase the amplitude of the open-circuit voltage, thereby increasing the contact current.

6.2.4 Induction heating equipment

Induction heating (IH) equipment is heating equipment using the Joule effect produced by magnetically induced currents. For a domestic IH cooker, a metal pan or pot is heated by a magnetic field, and when a person touches a conductive part of the pan or pot, a contact current can occur typically in the frequency ranges of around 20 kHz to 100 kHz. The method used to evaluate human exposure to magnetic fields produced by IH cookers is standardized in IEC 62233 [9]; however, the contact currents are not mentioned in IEC 62233. ~~Note that it may be appropriate to categorize this exposure situation as an issue of electrical safety.~~

For industrial IH equipment, a method of evaluating touch current in terms of electrical safety is ~~being standardized in IEC TC 27 (industrial electroheating and electromagnetic processing)~~ specified in IEC TS 62996 [10] for the frequency ranges between 1 kHz and 6 MHz.

6.2.5 Wireless power transfer (WPT)

A wireless power transfer (WPT) system is a system capable of transferring power between a transmitter and receiver using wireless technologies including electromagnetic induction, resonance, or capacitance. They are used for wirelessly charging mobile phones, tablet PCs, electric vehicles (EVs) and, so forth. There are several types of WPT, and the frequency ranges ~~is~~ can vary from tens of kilohertz to tens of megahertz. When a conductive object is placed in the immediate vicinity of a system and a person touches it, a contact current can occur, such as by touching the metal body of an EV when charging with a WPT charging system [11]. ~~As touching the metal body of an EV when charging using a WPT charging system may be the case [12], it may be appropriate to categorize the exposure situation as an issue of electrical safety.~~ Details regarding exposure assessment methods for WPT systems are reported in IEC TR 62905 [12] and IEC PAS 63184 [13]. In ~~IEC TR 62905~~ these publications, contact currents are considered for the conditions where an ungrounded or grounded metal object is placed in the vicinity of WPT systems.

6.2.6 Broadcasting

Burns can occur at a point of contact between a human body and a metallic structure that is exposed to RF electromagnetic fields from nearby sources such as AM broadcast antennas. The contact point between the body and the structure often has a small area and the current injected into the body is concentrated near this point. This can result in localized current ~~density near the contact sufficiently~~ densities strong enough to raise the local temperature and cause surface or deep burns [14].

6.3 Methods of measurement of touch current used in electrical safety standards

6.3.1 General

When considering the evaluation method for contact currents in the context of human exposure to electric, magnetic and electromagnetic fields, existing IEC standards related to electrical safety ~~may be~~ can provide some useful ~~inputs~~ guidance.

6.3.2 IEC standards related to electrical safety

There are several IEC technical committees in charge of electrical safety. These include:

– TC 64: Electrical installations and protection against electric shock;

- TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology;
- TC 61: Safety of household and similar electrical appliances;
- TC 99: System engineering and erection of electrical power installations in systems with nominal voltages above 1 kV AC and 1,5 kV DC, particularly concerning safety aspects;
- TC 66: Safety of measuring, control and laboratory equipment;
- TC 62/SC 62A: Common aspects of electrical equipment used in medical practice.

Table 1 summarizes the selected standards related to the electrical safety and the committees in which they were created. Note that the "touch voltage", the product of the touch current and the assumed body impedance, is commonly used as a parameter for setting limits for touch currents.

In IEC ~~TS~~ 60479-1 [15], a diagram of physiological effects for different touch currents and durations is shown (reproduced in Figure 1 and Table 2), which is commonly referenced in electrical safety standards as a basis for limiting touch currents.

Table 1 – Selected IEC technical committees and standards related to electrical safety

IEC TC	IEC standards related to electrical safety	Notes
TC 108, Safety of electronic equipment within the field of audio/video, information technology and communication technology	IEC 60065:2014, Audio, video and similar electronic apparatus – Safety requirements [16]	Stipulates touch voltage limits
	IEC 60950-1:2005, Information technology equipment – Safety – Part 1: General requirements IEC 60950-1:2005/AMD1:2009 IEC 60950-1:2005/AMD2:2013 [17]	Stipulates touch current limits
	IEC 60990:2016, Methods of measurement of touch current and protective conductor current [18]	Stipulates measuring method of touch current
	IEC 62368-1:~~2014~~2023, Audio/video, information, and communication technology equipment – Part 1: Safety requirements [19]	~~"Hazard based safety engineering (HBSE)" is adopted~~ Stipulates prospective touch voltage and touch current limits
TC 61, Safety of household and similar electrical appliances	IEC 60335-1:~~2010~~2020, Household and similar electrical appliances – Safety – Part 1: General requirements [20] ~~IEC 60335-1:2010/AMD1:2013~~ ~~IEC 60335-1:2010/AMD2:2016 [18]~~	Stipulates touch current limits
TC 64, Electrical installations and protection against electric shock	IEC 60364-4-41:2005, Low-voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock [21] IEC 60364-4-41:2005/AMD1:2017	
	IEC ~~TS~~ 60479-1:~~2005~~2018, Effects of current on human beings and livestock – Part 1: General aspects [15] ~~IEC TS 60479-1:2005/AMD1:2016 [20]~~	A diagram of physiological effects for different body currents and durations is shown
	IEC ~~TS~~ 60479-2:~~2017~~2019, Effects of current on human beings and livestock – Part 2: Special aspects [22]	
	IEC 61140:2016, Protection against electric shock – Common aspects for installation and equipment [23]	
	IEC TS 61201:2007, Use of conventional touch voltage limits – Application guide [24]	
TC 99, Insulation co-ordination and system engineering of high voltage electrical power installations above 1,0 kV AC and 1,5 kV DC	IEC 61936-1:~~2010~~2021, Power installations exceeding 1 kV AC and 1,5 kV DC – Part 1: ~~Common rules~~ AC [25] ~~IEC 61936-1:2010/AMD1:2014~~	Stipulates touch voltage limits
TC 66, Safety of measuring, control and laboratory equipment	IEC 61010-1:2010, Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements IEC 61010-1:2010/AMD1:2016 [26]	Stipulates touch current limits
TC 62/SC 62A, Common aspects of ~~electrical equipment used in medical practice~~ medical equipment, software, and systems	IEC 60601-1:2005, Medical electrical equipment – Part 1: General requirements for basic safety and essential performance IEC 60601-1:2005/AMD1:2012 IEC 60601-1:2005/AMD2:2020 [27]	Stipulates "leakage current" limits