IEC 62226-3-1

Edition 1.1 2016-10
CONSOLIDATED VERSION

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body –
Part 3-1: Exposure to electric fields – Analytical and 2D numerical models

Exposition aux champs électriques ou magnétiques à basse et moyenne fréquence – Méthodes de calcul des densités de courant induit et des champs électriques induits dans le corps humain –
Partie 3-1: Exposition à des champs électriques – Modèles analytiques et numériques 2D

iTeh Standards
(https://standards.iteh.ai)
Document Preview
https://standards.iteh.ai/catalog/standards/sist/4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

IEC 62226-3-1:2007-05+AMD1:2016-10 CSV(en-fr)

THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2016 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 15 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

(https://standards.iteh.ai)
IEC 62226-3-1:2007

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue
Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org
Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 15 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 62226-3-1

Edition 1.1 2016-10
CONSOLIDATED VERSION

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 3-1: Exposure to electric fields – Analytical and 2D numerical models

Exposition aux champs électriques ou magnétiques à basse et moyenne fréquence – Méthodes de calcul des densités de courant induit et des champs électriques induits dans le corps humain – Partie 3-1: Exposition à des champs électriques – Modèles analytiques et numériques 2D

iTeh Standards
(https://standards.iteh.ai)
Document Preview
https://standards.iteh.ai/catalog/standards/sist/...-4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 17.220.20

ISBN 978-2-8322-3683-3

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

® Registered trademark of the International Electrotechnical Commission
Marque déposée de la Commission Electrotechnique Internationale

iTeh Standards
(https://standards.iteh.ai)
Document Preview

IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/e9be540f-5ffe-4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

IEC 62226-3-1

Edition 1.1 2016-10
CONSOLIDATED VERSION

REDLINE VERSION

VERSION REDLINE

colour inside

Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 3-1: Exposure to electric fields – Analytical and 2D numerical models

Exposition aux champs électriques ou magnétiques à basse et moyenne fréquence – Méthodes de calcul des densités de courant induit et des champs électriques induits dans le corps humain – Partie 3-1: Exposition à des champs électriques – Modèles analytiques et numériques 2D

iTeh Standards
(https://standards.iteh.ai)
Document Preview
https://standards.iteh.ai/catalog/standards/sist/4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

IEC 62226-3-1:2007-05+AMD1:2016-10 CSV(en-fr)

CONTENTS

FOREWORD 5
INTRODUCTION 7
1 Scope 8
2 Exposure to electric field 8
3 General procedure 11
3.1 Shape factor 11
3.2 Procedure 11
4 Human body models 12
4.1 General 12
4.2 Surface area 12
4.3 Semi-spheroidal model 13
4.4 Axisymmetrical body model 15
5 Calculation of induced current 16
5.1 General 16
5.2 Semi-spheroid 16
5.3 Axisymmetrical models 20
5.4 Comparison of the analytical and numerical models 27
6 Influence of electrical parameters 28
6.1 General 28
6.2 Influence of permittivity 28
6.3 Influence of conductivity 28
6.4 Non-homogeneous conductivity 29
7 Measurement of currents induced by electric fields 29
7.1 General 29
7.2 Current flowing to the ground 29
Annex A (normative) Analytical solutions for a spheroid in a uniform electric field 31
Annex B (normative) Human body axisymmetrical model 34
Annex C (informative) Child body model 39
Annex D (informative) Example of use of this standard 41
Annex E (informative) Numerical calculation methods 45
Bibliography 53

Figure 1 – Illustration of the phenomenon of currents induced by electric field in a human body standing on the ground 10
Figure 2 – Potential lines of the electric field generated by an energised wire in the absence of any objects (all distances in metres) 10
Figure 3 – A realistic body model 12
Figure 4 – Scheme of the semi-spheroid simulating a human being standing on a zero potential plane 13
Figure 5 – Equivalent spheroid radius, *R*, versus height, *L*, and for different mass, *M* 15
Figure 6 – The axisymmetrical body model for the reference man (left) and woman (right) 15

iTeh Standards
(https://standards.iteh.ai)
Document Preview
IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/e9be5401-5ffe-4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

Figure 7 – Conductive spheroid exposed to electric field 16
Figure 8 – Calculation of the *shape factor for electric field* K_E for ~~an~~ a spheroid exposed to an unperturbed electric field 17
Figure 9 – Current density J_S induced by an unperturbed electric field (1 kV/m, 50 Hz) in a spheroid versus parameter L/R (values in μA/m²) 18
Figure 10 – Dimensions and mesh of the semi-spheroid 19
Figure 11 – Distortion of power frequency electric field lines close to the conductive semi-spheroid 19
Figure 12 – Calculated induced current density $J_A(h)$ in the body standing in a vertical 50 Hz electric field of 1 kV/m 21
Figure 13 – Computation domain 23
Figure 14 – Mesh of the man body model and distortion of power frequency electric field lines close to model 23
Figure 15 – Distribution of potential lines and 50 Hz electric field magnitude (man model) 24
Figure 16 – Computation of induced currents J_A along a vertical axis, and distribution of induced currents in the man model at 50 Hz 25
Figure 17 – Mesh of the woman body model and distortion of power frequency electric field lines close to model 25
Figure 18 – Distribution of potential lines and 50 Hz electric field magnitude (woman model) 26
Figure 19 – Computation of induced currents J_A along a vertical axis, and distribution of induced currents in the woman model at 50 Hz 27
Figure A.1 – Conductive spheroid exposed to electric field 31
Figure B.1 – Normalised axisymmetrical models. Left: man, Right: woman 36
Figure C.1 – Computation of induced currents J_Z along a vertical axis, and distribution of induced currents in the 10 years reference child model 40
Figure E.1 – Spheroid model 46
Figure E.2 – Space potential model 47
Figure E.3 – Exemple of charge simulation method using rings 48
Figure E.4 – Superficial charges integral equation method, cutting of the body into N elements 49
Figure E.5 – Mesh of the body using finite element method 50
Figure E.6 – Impedance method 51
Figure E.7 – Yee-method: Electric and magnetic grids for spatial discretization 52

Table 1 – Data for reference man and reference woman 13
Table 2 – Values of *arcsin(e) / e* for different values of L/R 14
Table 3 – Derived data using spheroid model at 50 Hz 20
Table 4 – Electric field E_{BR} required to produce basic restrictions J_{BR} or E_{iBR} in the neck at 50 Hz 22
Table 5 – Comparison of values of the shape factor for electric field K_E and corresponding current densities for an unperturbed 50 Hz electric field of 1 kV/m 28
Table B.1 – Measures from antropomorphic survey used to construct vertical dimensions of axisymmetrical model [56] 35

iTeh Standards
(https://standards.iteh.ai)
Document Preview

Table B.2 – Measures from antropomorphic survey used to construct the radial dimensions of axisymmetrical model [56] 35
Table B.3 – Normalised model dimensions 37
Table B.4 – Axisymmetric model dimensions for reference man and reference woman whose mass and height are defined by ICRP [38] and are given in Table 1 38
Table C.1 – Reference values provided by ICRP for male and female children 39
Table C.2 – Dimensions of the reference children (in m excepted SB_R in m²) 39
Table C.3 – Results of analytical method for the reference children 40
Table D.1 – Normalised dimensions of the women model 41
Table D.2 – Calculation of the dimensions for a specific person 42

iTeh Standards
(https://standards.iteh.ai)
Document Preview
IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/e9be540f-5ffe-4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPOSURE TO ELECTRIC OR MAGNETIC FIELDS IN THE LOW AND INTERMEDIATE FREQUENCY RANGE – METHODS FOR CALCULATING THE CURRENT DENSITY AND INTERNAL ELECTRIC FIELD INDUCED IN THE HUMAN BODY –

Part 3-1: Exposure to electric fields – Analytical and 2D numerical models

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

iTeh Standards
(https://standards.iteh.ai)
Document Preview
IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/62226-3-1-2007

This consolidated version of the official IEC Standard and its amendment has been prepared for user convenience.

IEC 62226-3-1 edition 1.1 contains the first edition (2007-05) [documents 106/125/FDIS and 106/128/RVD] and its amendment 1 (2016-10) [documents 106/376/FDIS and 106/378/RVD].

In this Redline version, a vertical line in the margin shows where the technical content is modified by amendment 1. Additions are in green text, deletions are in strikethrough red text. A separate Final version with all changes accepted is available in this publication.

International Standard IEC 62226-3-1 has been prepared by IEC technical committee 106: Methods for the assessment of electric, magnetic and electromagnetic fields associated with human exposure.

This standard is to be used in conjunction with the first edition of IEC 62226-1:2004, *Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 1: General.*

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

This International Standard constitutes Part 3-1 of IEC 62226 series, which will regroup several international standards and technical reports within the framework of the calculation of induced current densities and internal electric fields.

A list of all parts of the IEC 62226 series, published under the general title *Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body,* can be found on the IEC website.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the stability 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

iTeh Standards
(https://standards.iteh.ai)
Document Preview

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

IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/e9be540f-5ffe-4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Public interest concerning human exposure to electric and magnetic fields has led international and national organisations to propose limits based on recognised adverse effects.

This standard applies to the frequency range for which the exposure limits are based on the induction of voltages or currents in the human body, when exposed to electric and magnetic fields. This frequency range covers the low and intermediate frequencies, up to 100 kHz. Some methods described in this standard can be used at higher frequencies under specific conditions.

The exposure limits based on biological and medical experimentation about these fundamental induction phenomena are usually called “basic restrictions”. They include safety factors.

The induced electrical quantities are not directly measurable, so simplified derived limits are also proposed. These limits, called “reference levels” are given in terms of external electric and magnetic fields. They are based on very simple models of coupling between external fields and the body. These derived limits are conservative.

Sophisticated models for calculating induced currents in the body have been used and are the subject of a number of scientific publications. These models use numerical 3D electromagnetic field computation codes and detailed models of the internal structure with specific electrical characteristics of each tissue within the body. However such models are still developing; the electrical conductivity data available at present has considerable shortcomings; and the spatial resolution of models is still progressing. Such models are therefore still considered to be in the field of scientific research and at present it is not considered that the results obtained from such models should be fixed indefinitely within standards. However it is recognised that such models can and do make a useful contribution to the standardisation process, specially for product standards where particular cases of exposure are considered. When results from such models are used in standards, the results should be reviewed from time to time to ensure they continue to reflect the current status of the science.

https://standards.iteh.ai/catalog/standards/iec/e9be5401-51fe-4375-8b9b-1d216ba87f05/iec-62226-3-1-2007

EXPOSURE TO ELECTRIC OR MAGNETIC FIELDS IN THE LOW AND INTERMEDIATE FREQUENCY RANGE – METHODS FOR CALCULATING THE CURRENT DENSITY AND INTERNAL ELECTRIC FIELD INDUCED IN THE HUMAN BODY –

Part 3-1: Exposure to electric fields – Analytical and 2D numerical models

1 Scope

This part of IEC 62226 applies to the frequency range for which exposure limits are based on the induction of voltages or currents in the human body when exposed to electric fields.

This part defines in detail the coupling factor K – introduced by the IEC 62226 series to enable exposure assessment for complex exposure situations, such as non-uniform magnetic field or perturbed electric field – for the case of simple models of the human body, exposed to uniform electric fields. The coupling factor K has different physical interpretations depending on whether it relates to electric or magnetic field exposure. It is the so called “shape factor for electric field”.

iTeh Standards
(https://standards.iteh.ai)
Document Preview

This part of IEC 62226 can be used when the electric field can be considered to be uniform, for frequencies up to at least 100 kHz.

This situation of exposure to a “uniform” electric field is mostly found in the vicinity of high voltage overhead power systems. For this reason, illustrations given in this part are given for power frequencies (50 Hz and 60 Hz).

IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/e9be540f-5ffe-4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

2 Exposure to electric field

Alternating electric fields are generated by energised conductors (i.e. under voltage). In the immediate vicinity of domestic electrical equipment, such as lights, switches, food mixers and irons, local electric-field strengths about 100 V/m may be found. Such fields are non-uniform, but their strengths are far below the levels recommended in safety guidelines, so there is no need of calculation of induced currents in such exposure situations.

Higher electric-field strengths may be found in the vicinity of high voltage equipment such as electric power line. In the frequency range covered by this standard, it is considered that exposure from power lines is the only significant exposure source for public regarding safety guidelines limits.

Guidelines on human exposure to electric fields are generally expressed in terms of induced current density or internal electric field. These quantities cannot be measured directly and the purpose of this document is to give guidance on how to assess these quantities induced in the human body by external (environmental) electric fields E_0.

The induced current density J and the internal electric field E_i are closely linked by the simple relation:

$$J = \sigma . E_i \quad (1)$$

where σ is the conductivity of the body tissue under consideration.

Although some guidelines on human exposure to electric fields adopt internal electric field as a limiting parameter, for reason of simplification, the content of this standard is presented mainly in terms of induced current densities J, from which values of internal electric field E_i can be easily derived using the previous formula.

All the calculation developed in this document use the low frequency approximation in which displacement currents are negligible, such that $\varepsilon\omega/\sigma$ is less than 1 in the body. This approximation has been checked using published tissue data [29,31] [1] in the low frequency range and it has been found to be valid for frequencies up to at least 100 kHz and is probably valid at higher frequencies.

Computations based on sophisticated numerical models of the human body [24] also demonstrate that this assumption is valid at frequencies up to more than 100 kHz by showing that the relationship between the induced current density in the body and the product of frequency and external electric field hardly varies at all between 50 Hz and 1 MHz, and is only slightly altered at 10 MHz.

Analytical models can be used for simple cases of calculations.

iTeh Standards
(https://standards.iteh.ai)
Document Preview
IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/e3ae5401-5ffe-4375-8b9b-1d21bba87f05/iec-62226-3-1-2007

Electric fields cause displacement of electric charges in conductive objects (including living bodies) and, because these fields are alternating, the electric charges move backwards and forwards. The result is an “induced” alternating current inside the conductive object. This current depends only on:

– the shape and size of the conducting object;
– the characteristics (magnitude, polarisation, degree of non-uniformity, etc.) of the unperturbed field (field which is measured in the absence of any conducting object);
– the frequency of the field
– the variation of conductivity of the object (in homogeneous media, the current density induced by electric fields does not depend on conductivity).

Figure 1 illustrates this induction phenomenon for the case where the body is in electrical contact with the ground.

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

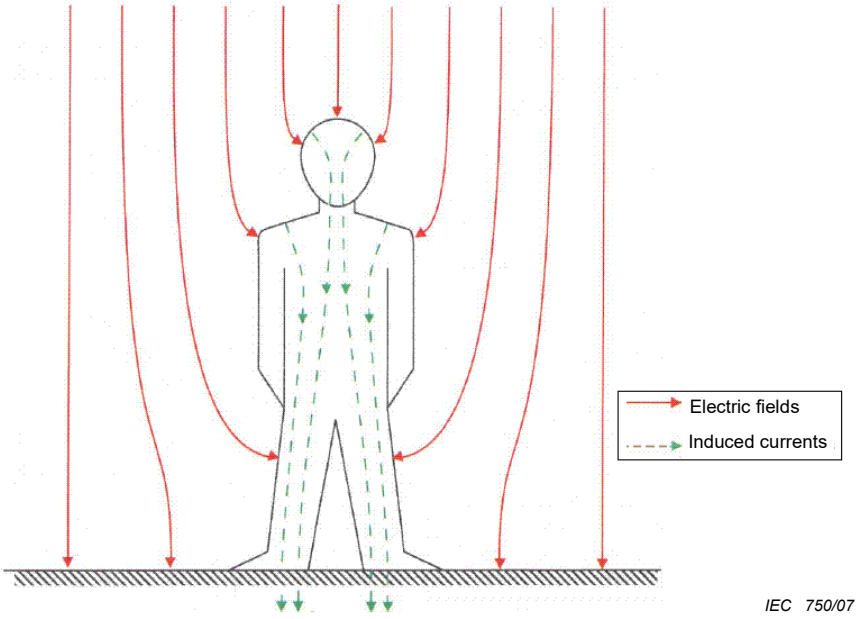

Figure 1 – Illustration of the phenomenon of currents induced by an electric field in a human body standing on the ground

The typical case of public exposure to an electric field is under high voltage power transmission lines. In this case, the distance between the source of field and the human body is large and the field in the zone close to the ground, in the absence of any conductive object, can be considered to be uniform (see Figure 2).

iTeh Standards
(https://standards.iteh.ai)
Document Preview
IEC 62226-3-1:2007
https://standards.iteh.ai/catalog/standards/iec/e9be540f-5ffe-4375-8b9b-1d2fbba87f05/iec-62226-3-1-2007

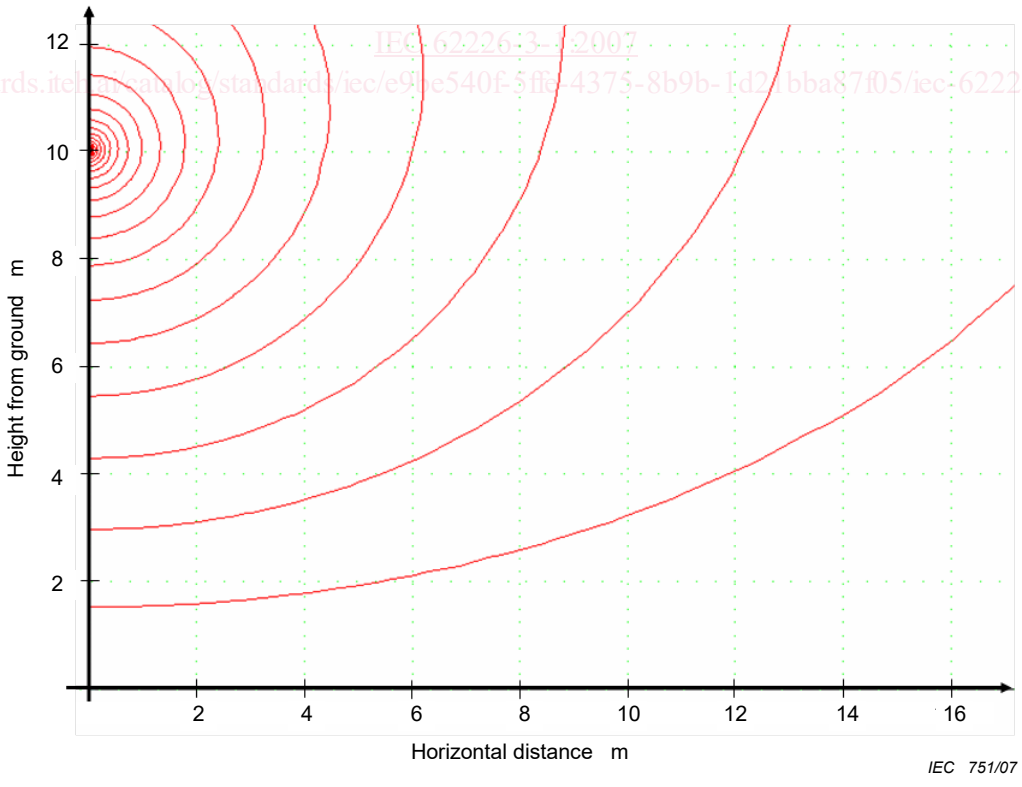

Figure 2 – Potential lines of the electric field generated by an energised wire in the absence of any objects (all distances in metres)