IEEE Std 1584™-2002

IEEE Guide for Performing Arc-Flash Hazard Calculations

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Abstract: This guide provides techniques for designers and facility operators to apply in determining the arc-flash hazard distance and the incident energy to which employees could be exposed during their work on or near electrical equipment.
Keywords: arc fault currents, arc-flash hazard, arc-flash hazard analysis, arc-flash hazard marking, arc in enclosures, arc in open air, bolted fault currents, electrical hazard, flash protection boundary, incident energy, personal protective equipment, protective device coordination study, short-circuit study, working distances

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Introduction

(This introduction is not part of IEEE Std 1584-2002, IEEE Guide for Performing Arc-Flash Hazard Calculations.)

A technical paper by Lee, “The other electrical hazard: electric arc blast burns” [B19] provided insight that electrical arc burns make up a substantial portion of the injuries from electrical malfunctions.[a] He identified that electrical arcing is the term applied to current passing through vapor of the arc terminal conductive metal or carbon material. The extremely high temperatures of these arcs can cause fatal burns at up to about 5 ft and major burns at up to about 10 ft distance from the arc. Additionally, electrical arcs expel droplets of molten terminal material that shower the immediate vicinity, similar to, but more extensive than that from electrical arc welding. These findings started to fill a void created by early works that identified electrical shock as the major electrical hazard. Mr. Lee’s work also helped establish a relationship between time to human tissue cell death and temperature, as well as a curable skin burn time-temperature relationship.

Once forensic analysis of electrical incidents focused on the arc-flash hazard, experience over a period of time indicated that Ralph Lee’s formulas for calculating the distance-energy relationship from source of arc did not serve to reconcile the greater thermal effect on persons positioned in front of opened doors or removed covers, from arcs inside electrical equipment enclosures.

A technical paper by Doughty, Neal, and Floyd, “Predicting incident energy to better manage the electric arc hazard on 600 v power distribution systems” [B4] presented the findings from many structured tests using both “arcs in open air” and “arcs in a cubic box.” These three phase tests were performed at the 600 V rating and are applicable for the range of 16 000 to 50 000 A short-circuit fault current. It was established that the contribution of heat reflected from surfaces near the arc intensifies the heat directed toward the opening of the enclosure.

The focus of industry on electrical safety and recognition of arc-flash burns as having great significance highlighted the need for protecting employees from all arc-flash hazards. The limitations on applying the known “best available” formulas for calculating the “curable” and “incurable” burn injuries have been overcome. This guide does that with new, empirically derived models based on statistical analysis and curve fitting of the overall test data available.

Conducting an arc-flash hazard analysis has been difficult. Not enough arc-flash incident energy testing had been done from which to develop models that accurately represent all the real applications. The available algorithms are difficult for engineers in offices to solve and near impossible for people in the field to apply. This working group has overseen a significant amount of testing and has developed new models of incident energy. The arc-flash hazard calculations included in this guide will enable quick and comprehensive solutions for arcs in single- or three- phase electrical systems either of which may be in open air or in a box, regardless of the low or medium voltage available.

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[a]The numbers in brackets correspond to those of the bibliography in Annex F.

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Sophisticated statistical analysis was required to develop the empirically derived model which is presented in this guide. The IEEE Std 1584-2002 working group recognizes and thanks Dr. David Berengut for his work on this analysis.

The “Bolted Fault Calculator” worksheet in the “IEEE_1584_Bolted_Fault_Cal.xls” was contributed by Paul and Dick Porcaro. The IEEE Std 1584-2002 working group recognizes and thanks them for this contribution.

The calculators can be accessed via the auxiliary files, “IEEE_1584_Bolted_Fault_Cal.xls” and “IEEE_1584_Arc_Flash_Hazard.xls”, and test data can be accessed via the auxiliary files, “Data_set.xls”, “Test_results_database.xls”, and “CL_Fuse_test_data.xls” provided with this standard (CD ROM for print versions and spreadsheet files for the PDF version).

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IEEE Guide for Performing Arc-Flash Hazard Calculations

1. Overview

1.1 Scope

This guide provides techniques for designers and facility operators to apply in determining the arc-flash hazard distance and the incident energy to which employees could be exposed during their work on or near electrical equipment.

1.2 Purpose

This guide presents methods for the calculation of arc-flash incident energy and arc-flash boundaries in three-phase ac systems to which workers may be exposed. It covers the analysis process from field data collection to final results, presents the equations needed to find incident energy and the flash-protection boundary, and discusses software solution alternatives. Applications cover an empirically derived model including enclosed equipment and open lines for voltages from 208 V to 15 kV, and a theoretically derived model applicable for any voltage. Included with the standard are programs with embedded equations, which may be used to determine incident energy and the arc-flash-protection boundary.[1]

Single-phase ac systems and dc systems are not included in this guide.

[1]The calculators can be accessed via the auxiliary files, “IEEE_1584_Arc_Flash_Hazard.xls” and “IEEE_1584_Bolted_Fault_Cal.xls”, and test data can be accessed via the auxiliary files, “Data_set.xls”, “Test_results_database.xls”, and “CL_Fuse_test_data.xls”, provided with this standard (CD ROM for print versions and spreadsheet files for the PDF version).

2. References

This guide shall be used in conjunction with the following standards. When the following standards are superseded by an approved revision, the revision shall apply.

ASTM F-1506-01, Standard for Performance Specification for Flame Resistant Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards.[2]

ASTM F-1959/F-1959M-99, Standard Test Method for Determining the Arc Thermal Performance Value of Materials for Clothing.

CFR 29, Subpart R, Part 1910.269, Occupational Safety and Health Standards—Electric Power Generation, Transmission, and Distribution.[3]

CFR 29, Subpart S, Part 1910.301 through 1910.399, Occupational Safety and Health Standards—Electrical.

IEEE Std 141™-1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants *(IEEE Red Book™)*.[4, 5]

IEEE Std 142™-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems *(IEEE Green Book™)*.

IEEE Std 242™-2001, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems *(IEEE Buff Book™)*.

IEEE Std C37.010™-1999, IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

IEEE Std C37.20.7™-2001, IEEE Guide for Testing Medium-Voltage Metal-Enclosed Switchgear for Internal Arcing Faults.

NFPA 70-2002, National Electrical Code® (NEC®).[6]

NFPA 70E-2000, Electrical Safety Requirements for Employee Workplaces.

3. Definitions

The following definitions apply to this standard. Additional definitions can be found in *The Authoritative Dictionary of IEEE Standards Terms,* Seventh Edition [B13].[7]

3.1 arc-flash hazard: A dangerous condition associated with the release of energy caused by an electric arc.

[2]ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA (http://www.astm.org/).

[3]U.S. Regulatory Guides are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA (http://www.access.gpo.gov/).

[4]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

[5]The IEEE standards referred to in Clause 2 are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

[6]NFPA publications are available from Publications Sales, National Fire Protection Association, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101, USA.

[7]The numbers in brackets correspond to those of the bibliography in Annex F.

