IEC/TR 62655

Edition 1.0 2013-05

TECHNICAL REPORT

RAPPORT TECHNIQUE

Tutorial and application guide for high-voltage fuses

Guide explicatif et d'application pour les fusibles à haute tension

IEC/TR 62655:2013

IEC/TR 62655

Edition 1.0 2013-05

TECHNICAL REPORT

RAPPORT TECHNIQUE

Tutorial and application guide for high-voltage fuses

Guide explicatif et d'application pour les fusibles à haute tension

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE
CODE PRIX
XF

ICS 29.120.50

ISBN 978-2-83220-811-3

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.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

TUTORIAL AND APPLICATION GUIDE FOR HIGH-VOLTAGE FUSES

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.

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 62655, which is a technical report, has been prepared by subcommittee 32A: High-Voltage Fuses, of IEC technical committee 32: Fuses

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

Enquiry draft	Report on voting
32A/296/DTR	32A/301/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.

Acknowledgments:
The Working Group thanks the Institute of Electrical and Electronics Engineers, Incorporated, (IEEE) for permission to reproduce information from its global Standards IEEE C37.48.1-2012. All such extracts are copyright of IEEE, Piscataway, New Jersey. All rights reserved. Further information on the IEEE is available from www.standards.ieee.org. IEEE has no responsibility for the placement and context in which the extracts and contents are reproduced by the authors, nor is IEEE in any way responsible for the other content or accuracy therein.

The committee has decided that the contents of this publication 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

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- withdrawn,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

INTRODUCTION

0.1 Aims and objectives of this technical report

a) To help prospective users and protection engineers understand the basics of high-voltage (>1 000 V a.c.) fuse technology and applications involving high-voltage (HV) fuses;

b) to illustrate the particular and unique advantages of fuse protection for most service applications;

c) to minimise possible misapplications of fuses which could lead to problems in the field;

d) to list and describe the many types of fuse in use today, and the international standards that apply to them, including fuse types not specifically included in IEC or other recognized standards.

This technical report gathers information previously published in IEC and other publications, as well as new material. Duplicate information presently in these publications is therefore likely to be eliminated during their future revision.

0.2 How to use this technical report

0.2.1 General

If read from start to finish, this technical report will provide an in-depth study of HV fuses and their applications. It is essentially a tutorial covering all common (and some not so common) types of fuses and most fuse applications. However, it is assumed that few users will read the technical report in this way, but rather read the appropriate sections covering fuses and applications for which they require information. Based on this assumption, there is therefore some inevitable duplication of information. To assist the user in making best use of the document, a description of the content and relevance of each clause follows.

0.2.2 Fuse tutorial

After clauses on scope, references and definitions, Clause 4 contains primarily "tutorial" style information. The clause starts with a simple introduction to fuses, first with an explanation of how fuses work followed by information on basic fuse classifications and common fuse terms. Subclause 4.1.4 continues with lists of advantages gained by using fuses and then 4.1.6 provides a listing of basic fuse types for which application information will be given later. An in-depth look at the most common types of fuses is given in 4.2, current-limiting fuses and 4.3 expulsion fuses. The high level of detail given in 4.2 and 4.3, including information describing construction, operation, classification and published ratings and characteristics, may be necessary in order to understand the application information that follows in Clause 5. For completeness, 4.4 gives an overview of less common types of fuse (or fuse related) devices that may require additional testing to that covered in existing standards, and for which no further application information is provided. Subclause 4.5 covers fuse mountings.

0.2.3 Application information

Application information appears in Clause 5 and Annex A, and is split into four sections.

a) Subclause 5.1: this covers information common to nearly all applications.

b) Subclause 5.2: this contains information on specific applications.

c) Subclause 5.3: this covers installation, operation, maintenance, and replacement of fuses.

d) Annex A: this reproduces the current-limiting fuse temperature de-rating information previously published in IEC 60282-1:2009.

If a knowledgeable user requires application information on a specific subject in 5.2 (e.g. motor circuit fuses), it is possible that only the relevant subclause needs to be read – however in most cases additional information from 5.1 will be required for satisfactory fuse selection. It should be emphasized that the information contained in this report is intended to supplement information supplied by the manufacturer of a fuse and not replace it. If there is any doubt or conflict of information, the fuse manufacturer should be consulted.

TUTORIAL AND APPLICATION GUIDE FOR HIGH-VOLTAGE FUSES

1 Scope

This technical report provides information for understanding the construction, operation and application of high-voltage fuses in general. Current-limiting, expulsion, electronic, and other, non-current-limiting, fuses rated above 1 kV a.c. are all covered, as are North American, European and other application practices. As a technical report, this document contains no requirement and is informative only.

2 Normative references

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

IEC 60038, *IEC standard voltages*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-7, *Power transformers – Part 7: Loading guide for oil-immersed power transformers*

IEC 60076-12, *Power transformers – Part 12: Loading guide for dry-type power transformers*

IEC 60282-1:2009, *High-voltage fuses – Part 1: Current-limiting fuses*

IEC 60282-2:2008, *High-voltage fuses – Part 2: Expulsion fuses*

IEC 60549, *High-voltage fuses for the external protection of shunt power capacitors*

IEC 60644, *Specification for high-voltage fuse-links for motor circuit applications*

IEC/TR 60890:1987, *A method of temperature-rise assessment by extrapolation for partially type-tested assemblies (PTTA) of low-voltage switchgear and controlgear*

IEC 60909-0, *Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents*

IEC 62271-100:2012, *High-voltage switchgear and controlgear – Part 100: Alternating current circuit-breakers*

IEC 62271-102, *High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches*

IEC 62271-103, *High-voltage switchgear and controlgear – Part 103: Switches for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-105:2012, *High-voltage switchgear and controlgear – Part 105: Alternating current switch-fuse combinations for rated voltages above 1 kV up to and including 52 kV*

IEC 62271-106, *High-voltage switchgear and controlgear – Part 106: Alternating current contactors, contactor-based controllers and motor-starters*

IEC 62271-107, *High-voltage switchgear and controlgear – Part 107: Alternating current fused circuit-switchers for rated voltages above 1 kV up to and including 52 kV*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

For the purpose of this document, the terms and definitions contained in IEC 60282-1:2009 and IEC 60282-2:2008 apply.

3.2 Abbreviations

The following abbreviations are used in this document:

A^2s – Amperes-squared-seconds, also $A^2 \times s$, the unit of Joule integral (I^2t, see 4.2.4.4)

CL – Current-limiting

CLF – Current-limiting fuse

FEP – Fuse enclosure package

HV – High-voltage

I_{encl} – de-rated current (of a fuse in an enclosure)

I_r – Rated current (of a fuse)

u_c – TRV peak voltage in kV

t_3 – Time in microseconds to voltage u_c

I_1, I_2 I_3 – Prospective current in test Duty 1, Test Duty 2, and Test Duty 3 of IEC 60282-1, respectively

MAT – Maximum application temperature

TCC[1] – Time-current characteristic

TRV – Transient recovery voltage

4 Tutorial section

4.1 A simple introduction to fuses

4.1.1 General

Fuses have been in use since the very beginnings of electrical power distribution. While the true inventor of the fuse is not known, pioneers of electrical distribution soon incorporated them as "weak points" in their circuits to prevent overheating of wiring, due to excessive

[1] Footnote 1 applies only to the French version.

current, and to prevent damage to fragile lamps from fluctuations in voltage. Fuses rapidly developed into devices able to sense a current higher than normal and quickly interrupt (break) that current, all in a self-contained easily replaceable unit. Although the variety and complexity of fuses has grown to the point where user's guides, such as this one, are necessary, fuses still provide the highest degree of protection for the lowest initial cost.

The simplest definition of a "fuse" is that it is a device that carries current through a conductive part called the fuse element that, when the fuse is subjected to an excessive current, melts due to self-heating and initiates the interruption of the current. All conventional fuses interrupt current after some arcing across breaks in the element produced by the melting process. The melting time of a fuse is therefore also termed the "pre-arcing" time. A characteristic of fuses is that, because current interruption is initiated by a melting process, there are almost no "mechanical" aspects involved in their arc initiation. Fuses therefore have a very inverse time-current relationship (higher currents giving shorter pre-arcing times) as illustrated in Figure 1. This enables extremely short pre-arcing times at high currents, virtually without limit. It is this apparently simple phenomenon that is primarily responsible for the universal success fuses have enjoyed for a very long time.

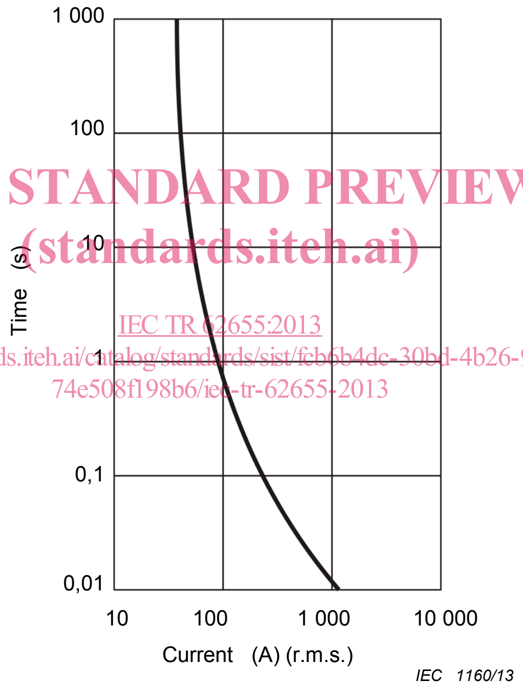

Figure 1 – Fuse pre-arcing time-current characteristic curve

In general, high-voltage fuses (defined as fuses rated above 1 000 V a.c.) are physically larger and generally more complex than low voltage fuses due to their need to operate at much higher voltages. HV fuses may perform one or both of two primary functions. The first function is to respond to moderately excessive currents, typically termed "overload" currents. In this case, the rated current of the fuse (the current it is designed to be capable of carrying indefinitely without deterioration) is exceeded by a relatively modest amount (typically less than 10 times). Such currents can be caused by too much load being connected to a circuit, or by a fault that by-passes only part of the load. It should be noted that not all types of fuses are designed to have the ability to operate successfully if melted by a very low overcurrent as some types are intended only for operation at high currents (see 4.1.2.1). If melted by a low current, such fuses may arc until a series device interrupts, possibly resulting in physical damage to the fuse and its surroundings. However, some fuses of this type can quickly initiate another device to interrupt such current, containing the arcing without damage until the second device interrupts.

The second function, which virtually all fuses are designed to perform, is to respond to overcurrents that are much higher, and that are usually termed "short-circuit" currents. In this case substantially all of the load is by-passed by a major fault and the available current (which, when not limited by a protective device, is termed the "prospective current") can be very high. However different types of fuse vary widely in exactly how high a current they can interrupt, and this may be a significant factor in choosing a fuse type for a particular application. The ways in which fuses respond to high and low overcurrents, as well as the ways in which they actually interrupt the current, causes HV fuses to be classified in various ways.

The first main classification is into "current-limiting" and "non-current-limiting" types (although because almost all commonly used non-current-limiting fuses are expulsion fuses, "expulsion fuse" is usually the term used in preference to "non-current-limiting"). "Current-limiting" (CL) describes a class of fuses defined by the behaviour that occurs when the current is so high that the fuse element melts before the first peak of the fault current (that is in less than a few ms). Upon melting, this type of fuse introduces resistance into the circuit so rapidly that the current stops rising and instead is forced quickly to zero (before a natural current zero would occur). Because the maximum prospective peak current is not reached, the fuse limits the current in magnitude as well as duration hence the "current-limiting" name. The current-limiting action is shown in Figure 2a. Note that during operation, the current-limiting fuse introduces a "spike" of overvoltage (the fuse switching voltage) into the system during the current-limiting action as shown in Figure 2a.

An expulsion fuse, melting under the same circumstances, introduces only a small resistance into the circuit, so the current continues to virtually the same peak as would occur if the fuse had not melted. An expulsion action (that is where gas is generated by the arc and expelled along with ionized material) produces a physical gap such that, at a natural current zero, the arc does not reignite and the current is interrupted. This type of fuse therefore limits the duration of a fault but not its magnitude. This action is illustrated in Figure 2b. For an explanation of TRV see 4.2.1.2).

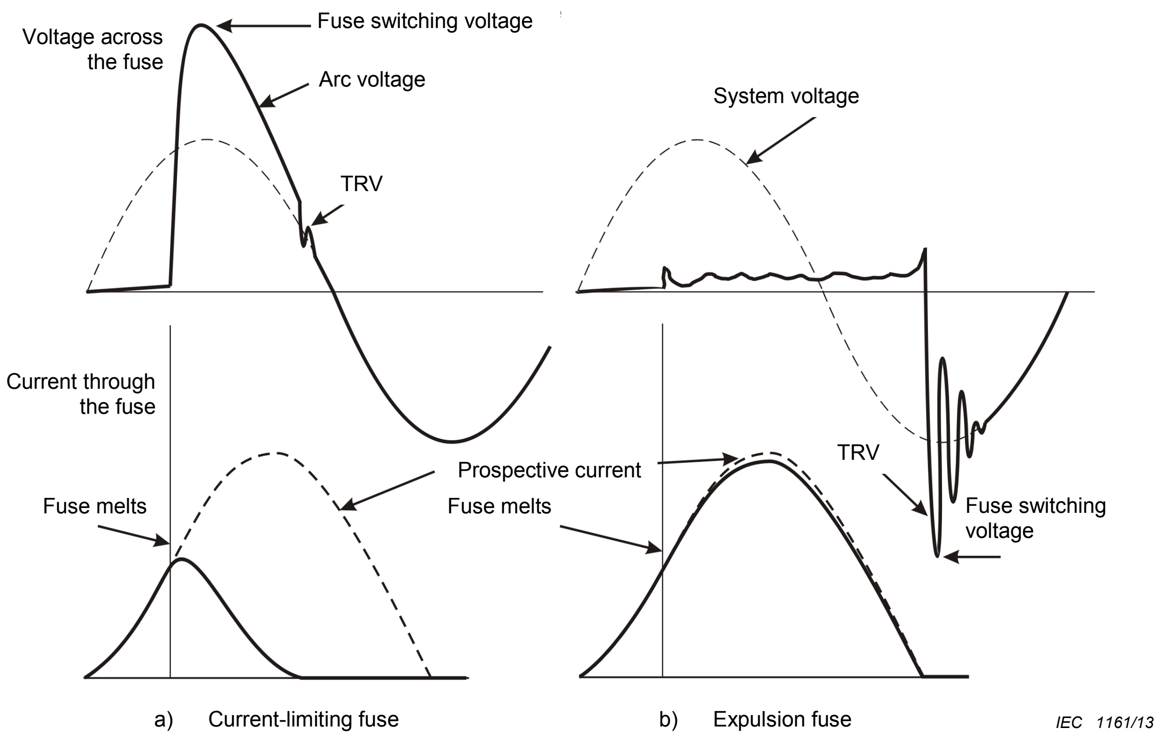

Figure 2 – High current interruption by current-limiting fuse and expulsion fuse [2]

4.1.2 Fuse classifications and terms

4.1.2.1 Current-limiting fuse classifications

The ability of different types of CL fuse to interrupt currents lower than those that produce a current-limiting action result in different classes of CL fuse. Some CL fuses are designed to interrupt only high currents (i.e. their primary function is to provide a current-limiting action). They therefore have a limited low current interrupting ability and are termed "Back-Up" fuses. They are usually used in conjunction with another device in series; such devices include switches (most commonly tripped by a striker in a "switch-fuse combination", see 5.2.7.2), contactors, circuit breakers or another fuse having a lower current interrupting ability. It may be considered that they are "backing up" this other device and in addition to the important current-limiting function, also usually provide increased interrupting capability. This is because the series device frequently has a limited interrupting capability while Back-Up fuses can normally interrupt very high currents i.e. they have a very high "rated maximum breaking current".

High-voltage fuses having the ability to interrupt low values of overcurrent as well as high short-circuit currents are classed as either "General-Purpose" or "Full-Range" types. The term "General-Purpose" (which has historical origins, being used before Full-Range fuses were introduced) does not mean that the fuse can be used for any sort of application but merely that the fuse is designed to clear low values of fault/overload current. Testing is performed by the fuse manufacturer to show that fuse-links classed as General-Purpose can clear currents down to a value that causes melting of the fuse element in 1 h or more. This means that General-Purpose fuses can be used with overload currents that will cause them to melt in times of up to one hour, but no longer. The term "Full-Range" is used for the Class of fuse

2 *IEEE Std C37.48.1 -2012, "IEEE Guide for Operation, Classification, Application, and Coordination of Current-Limiting Fuses with Rated Voltages 1-38kV"* - Reprinted with permission from IEEE, 3 Park Avenue, New York, NY 10016-5997 USA, Copyright 2002, by IEEE.