IEC TR 61643-333

Edition 1.0 2026-06

TECHNICAL REPORT

Components for low-voltage surge protection -
Part 333: Characteristic equations and life evaluation for metal oxide varistors (MOV)

ICS 29.240.10

ISBN 978-2-8327-1260-3

IEC TR 61643-333:2026-06(en)

THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2026 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.

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

Tel.: +41 22 919 02 11
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 corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
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 It also gives information on projects, replaced and withdrawn publications.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 once a month by email.

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: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch
Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

FOREWORD 3
INTRODUCTION 5
1 Scope 6
2 Normative references 6
3 Terms and definitions 6
4 Characteristics of MOV 7
4.1 General 7
4.2 Important properties associated with MOV R-I-V characteristics 8
4.2.1 General 8
4.2.2 MOV clamping voltage waveforms at 8/20 current 10
5 MOV R-I and V-I characteristic equations 10
5.1 Early characteristic curves and equations 10
5.2 Types of R-I and V-I characteristic equations 13
5.3 Measuring circuit, testing procedures and method of R-I and V-I characteristic equations for upturn region with 8/20 impulse current 14
6 Degradation of MOV 16
6.1 General 16
6.2 Performance parameter degradations 17
6.3 Physical destruction 17
7 Life evaluation method of MOV 17
7.1 Overview of Weibull distribution 17
7.1.1 Weibull cumulative distribution function (CDF) 17
7.1.2 Evaluation method of β and η 18
7.1.3 Evaluation method of t_0 18
7.2 Life evaluation of MOV under continuous working voltage stress 18
7.2.1 General 18
7.2.2 Evaluation procedure of β and η 19
7.2.3 Evaluation procedure of the parameter t_0 20
7.3 Life evaluation procedure of MOV under impulse current stress 23
7.3.1 General 23
7.3.2 Life characteristics equations of MOV under impulse current stress 23
7.3.3 Evaluation method of the parameters I_p, τ, and n 24
7.3.4 Evaluation example 25
Annex A (informative) Characteristics of various surge voltages and currents 31
A.1 The sources of surge voltages and surge currents 31
A.2 Lightning surges 31
A.2.1 Lightning flash and stroke 31
A.2.2 Lightning parameters 32
A.2.3 Coupling mechanisms 34
A.3 System switching surge 35
A.4 Interactions between different systems, such as the power system and a communication system during surge events occurring in one system 35
A.5 Electrostatic discharge 35
A.6 System voltage fluctuation 36
A.7 Mis-operation overvoltage 36
Annex B (informative) Mathematical methods in statistics for life valuation 37

B.1 Best linear unbiased estimate (BLUE) 37
B.2 Maximum likelihood estimation (MLE) 38
B.3 Median rank regression estimation (MRRE) 39
Bibliography 40

Figure 1 – MOV equivalent circuit model 8
Figure 2 – Current waveforms of MOV under power frequency voltage 8
Figure 3 – R-V-I waveforms during half cycle of 50 Hz (Sample 34 × 34 mm, V_V = 560 V) 9
Figure 4 – Current waveforms (yellow) and voltage waveforms (blue) of an MOV subjected to 8/20 10
Figure 5 – Early characteristic curves 11
Figure 6 – A practical example of α value varying with test current 11
Figure 7 – Maximum leakage current (A) and maximum clamping voltage (B) 12
Figure 8 – Regression equation curves 16
Figure 9 – The fitting curve from the experiment results 20
Figure 10 – Evaluation curve of t_0 21
Figure 11 – Fitting line of CDF versus ln(t−110) curve 22
Figure 12 – Fitting line of CDF versus ln(t−120) curve 22
Figure 13 – Fitting line of CDF versus ln(t−130) curve 23
Figure 14 – Impulse life curve when n is constant 23
Figure 15 – Impulse life curve when τ is constant 24
Figure 16 – Three approximate impulse life characteristics curves. 30
Figure 17 – Impulse life characteristics curve (when I_p = 400 A) 30
Figure A.1 – An example of the waveform of lightning discharge 31

Table 1 – Measured values and their calculated values 14
Table 2 – Three different calculation methods of regression equation 15
Table 3 – Deviation of Vcal % with respect to the Measured value Vi 16
Table 4 – Calculation Procedure of Weibull Function Parameters 19
Table 5 – Evaluation Table of t_0 21
Table 6 – Test data of Sample 1 25
Table 7 – Test data of Sample 2 26
Table 8 – Test data of Sample 3 26
Table 9 – Test data of Sample 4 27
Table 10 – Test data of Sample 5 27
Table 11 – Test data of Sample 6 28
Table 12 – Median life of six samples 29
Table A.1 – Lightning current parameters from negative flashes (Berger et al., 1975) 32
Table A.2 – Maximum values of lightning parameters according to LPL 33
Table A.3 – Minimum values of lightning parameters and related rolling sphere radius corresponding to LPL 33

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

Components for low-voltage surge protection - Part 333: Characteristic equations and life evaluation for metal oxide varistors (MOV)

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) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at https://patents.iec.ch. IEC shall not be held responsible for identifying any or all such patent rights.

IEC TR 61643-333 has been prepared by subcommittee 37B: Components for low-voltage surge protection, of IEC technical committee 37: Surge arresters. It is a Technical Report.

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

Draft	Report on voting
37B/269/DTR	37B/272/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.

A list of all parts in the IEC 61643 series, published under the general title *Components for low-voltage surge protection*, can be found on the IEC website.

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.

INTRODUCTION

Since the invention of metal oxide varistors (MOV) which are also known as zinc oxide non-linear resistors, in 1968, MOV has become the key surge protection component with the widest use, largest production and mature technology. In addition, driven by the market demand and the efforts of researchers, production engineers and field application engineers, people have further deepened their understanding of it.

Although impulse life characteristic curve and life data under continuous working voltage stress have been given in current MOV product manuals and related technical data, they are only empirical and rough estimate. The life value of MOV (average value, median value and minimum value) is essentially a statistic, which needs to be dealt with by the theory of mathematical statistics.

Additionally, there is an increasing user's demands in recent years for the MOVs having estimated lifetime duration. The estimated value is evaluated and tested under continuous working voltage stress and impulse current stress. Although MOV manufacturers provide the service life characteristic curves under impulse current stresses, such curves are empirical. This is the reason why a theoretical approach is provided in this technical report.

1 Scope

This part of IEC 61643, which is a Technical Report, presents the *U-I/R-I* characteristic equations and the life evaluation method for MOVs, which are used for applications up to 1 000 V AC or 1 500 V DC in power line, or telecommunication, or signalling circuits. They are designed to protect apparatus or personnel, or both, from high transient voltages.

This document specifically addresses the zinc-oxide type of MOVs.

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
population
totality of items under consideration

[SOURCE: ISO 3534-1, 1.1]

3.2
sampling unit
one of the individual parts into which a population is divided

[SOURCE: ISO 3534-1, 1.2]

3.3
sample
subset of a population made up of one or more sampling units

[SOURCE: ISO 3534-1, 1.3]

3.4
sampling size *n*
number of sampling units in a sample

[SOURCE: ISO 3534-4, 3.1.9]

3.5
observed value
obtained value of a property associated with one member of a sample (3.3)

[SOURCE: ISO 3534-1, 1.4]