BS EN IEC 61643-332:2024

BSI Standards Publication

Components for low-voltage surge protection

Part 332: Selection and application principles for metal oxide varistors (MOV)

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Full document details: BS EN IEC 61643-332:2024

National foreword

This British Standard is the UK implementation of EN IEC 61643-332:2024. It is identical to IEC 61643-332:2024.

The UK participation in its preparation was entrusted to Technical Committee PEL/37, Surge Arresters - High Voltage.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN IEC 61643-332

May 2024

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English Version

Components for low-voltage surge protection - Part 332: Selection and application principles for metal oxide varistors (MOV) (IEC 61643-332:2024)

Composants pour parafoudres basse tension - Partie 332: Choix et principes d'application des varistances à oxyde métallique (MOV) (IEC 61643-332:2024)

Bauelemente für den Überspannungsschutz bei Niederspannungen - Teil 332: Auswahl- und Anwendungsgrundsätze für Metalloxidvaristoren (MOV) (IEC 61643-332:2024)

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European foreword

The text of document 37B/243/FDIS, future edition 1 of IEC 61643-332, prepared by SC 37B "Components for low-voltage surge protection" of IEC/TC 37 "Surge arresters" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61643-332:2024.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2025-02-22
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2027-05-22

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In the official version, for Bibliography, the following notes have to be added for the standard indicated:

IEC 60364-5-51:2005	NOTE	Approved as HD 60364-5-51:2009 +A11:2013 +A12:2017
IEC 61000-4-2:2008	NOTE	Approved as EN 61000-4-2:2009 (not modified)
IEC 60068-1:2013	NOTE	Approved as EN 60068-1:2014 (not modified)
IEC 60068-2-20:2021	NOTE	Approved as EN IEC 60068-2-20:2021 (not modified)
IEC 60068-2-21:2021	NOTE	Approved as EN IEC 60068-2-21:2021 (not modified)
IEC 60068-2-78:2012	NOTE	Approved as EN 60068-2-78:2013 (not modified)
IEC 60721-3-3:2019	NOTE	Approved as EN IEC 60721-3-3:2019 (not modified)
IEC 61643-21:2000	NOTE	Approved as EN 61643-21:2001 (not modified)
IEC 61643-21:2000/A1:2008	NOTE	Approved as EN 61643-21:2001/A1:2009
IEC 61643-21:2000/A2:2012	NOTE	Approved as EN 61643-21:2001/A2:2013 (not modified)

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cencenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60664-1	2020	Insulation coordination for equipment within low-voltage supply systems - Part 1: Principles, requirements and tests	EN IEC 60664-1	2020
IEC 61051-1	2018	Varistors for use in electronic equipment - Part 1: Generic specification	EN IEC 61051-1	2018
IEC 61051-2	2021	Varistors for use in electronic equipment - Part 2: Sectional specification for surge suppression varistors	EN IEC 61051-2	2021
IEC 61643-11 (mod)	2011	Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods	EN 61643-11	2012
-	-		+ A11	2018
IEC 61643-331	2020	Components for low-voltage surge protection - Part 331: Performance requirements and test methods for metal oxide varistors (MOV)	EN IEC 61643-331	2020
IEC 62368-1	2023	Audio/video, information and communication technology equipment - Part 1: Safety requirements	EN IEC 62368-1	2024

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COMPONENTS FOR LOW-VOLTAGE SURGE PROTECTION –

Part 332: Selection and application principles for metal oxide varistors (MOV)

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IEC 61643 has been prepared by subcommittee 37B: Components for low voltage surge protection, of IEC technical committee 37: Surge arresters. It is an International Standard.

The text of this International Standard is based on the following documents:

Draft	Report on voting
37B/243/FDIS	37B/245/RVD

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 International Standard is English.

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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,
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COMPONENTS FOR LOW-VOLTAGE SURGE PROTECTION –

Part 332: Selection and application principles for metal oxide varistors (MOV)

1 Scope

This part of IEC 61643 describes the theory of operation, principles for the selection and application of MOVs to be connected to power lines or telecommunication or signalling circuits, up to 1 000 V AC or 1 500 V DC. These SPCs are designed to protect apparatus or personnel, or both, from high transient voltages.

This document applies to MOVs having two electrodes and voltage dependent elements with or without disconnectors. It does not apply to assemblies that include MOVs and their influence on the MOV's characteristics.

This standard specifically discusses the zinc-oxide type of MOVs.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60664-1:2020, *Insulation coordination for equipment within low-voltage supply systems – Part 1: Principles, requirements and tests*

IEC 61051-1:2018, *Varistors for use in electronic equipment – Part 1: Generic specification*

IEC 61051-2:2021, *Varistors for use in electronic equipment – Part 2: Sectional specification for surge suppression varistors*

IEC 61643-11:2011, *Low-voltage surge protective devices – Part 11: Surge protective devices connected to low-voltage power systems – Requirements and test methods*

IEC 61643-331:2020, *Components for low-voltage surge protection – Part 331: Performance requirements and test methods for metal oxide varistors (MOV)*

IEC 62368-1:2023, *Audio/video, information and communication technology equipment – Part 1: Safety requirements*

3 Terms, definitions, symbols and abbreviated terms

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

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3.1 Terms and definitions

3.1.1 Ratings

3.1.1.1
rating
limiting capability or limiting condition beyond which damage to the MOV may occur

Note 1 to entry: A limiting condition may be either a maximum or a minimum.

3.1.1.2
single-impulse [transient] maximum current
I_{TM}
rated maximum value of current which may be applied for a single impulse of specified waveform

Note 1 to entry: For power distribution SPDs, IEC 61643-11, Maximum Discharge Current I_{max} is used.

[SOURCE: IEC 61643-331:2020, 3.1.1.2]

3.1.1.3
nominal discharge current
I_n
crest value of the current through the MOV having a current waveshape of 8/20

[SOURCE: IEC 61643-331:2020, 3.1.1.3]

3.1.1.4
maximum continuous voltage
V_M
maximum voltage that may be applied continuously at a specified temperature

Note 1 to entry: May also be called U_C or MCOV (Maximum continuous operating voltage).

Note 2 to entry: See Figure 1.

[SOURCE: IEC 61643-331:2020, 3.1.1.7, modified (addition of "Maximum continuous operating voltage" to Note 1 to entry)]

3.1.1.5
maximum continuous AC voltage
$V_{M(AC)}$
maximum value of RMS power frequency voltage (less than 5 % total harmonic distortion) that may be applied continuously at a specified temperature

[SOURCE: IEC 61643-331:2020, 3.1.1.8]

3.1.1.6
maximum continuous DC voltage
$V_{M(DC)}$
maximum value of DC voltage that may be applied continuously at a specified temperature

[SOURCE: IEC 61643-331:2020, 3.1.1.9]

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3.1.1.7
maximum discharge current
I_{max}
crest value of a current through the SPD having an 8/20 waveshape and magnitude according to the manufacturer's specification.

Note 1 to entry: I_{max} is equal to or greater than I_n.

[SOURCE: IEC 61643-11:2011, 3.1.48]

3.1.1.8
impulse discharge current for class I test
I_{imp}
crest value of a discharge current through the SPD with specified charge transfer *Q* and specified energy W/R in the specified time

[SOURCE: IEC 61643-11:2011, 3.1.10]

3.1.1.9
rated average dissipation power
P_M
maximum average dissipation power of repetitive pulses allowed to be applied to the varistors at ambient temperature of 25 °C

[SOURCE: IEC 61051-1:2018, 3.23]

3.1.2 Characteristics

3.1.2.1
characteristics
inherent and measurable properties of an MOV

[SOURCE: IEC 61643-331:2020, 3.1.2.1]

3.1.2.2
standby current
I_D
current passing through MOV at maximum continuous voltage V_M

Note 1 to entry: The current passing through the MOV at less than V_M is called leakage current.

[SOURCE: IEC 61643-331:2020, 3.1.2.2]

3.1.2.3
varistor voltage
V_V
voltage across the MOV measured at a specified current (typically 1 mA) for a specific duration

Note 1 to entry: The MOV manufacturer specifies the current. Otherwise, 1 mA DC for a duration of 20 to 100 ms is normally used.

Note 2 to entry: See Figure 1.

[SOURCE: IEC 61643-331:2020, 3.1.2.3]

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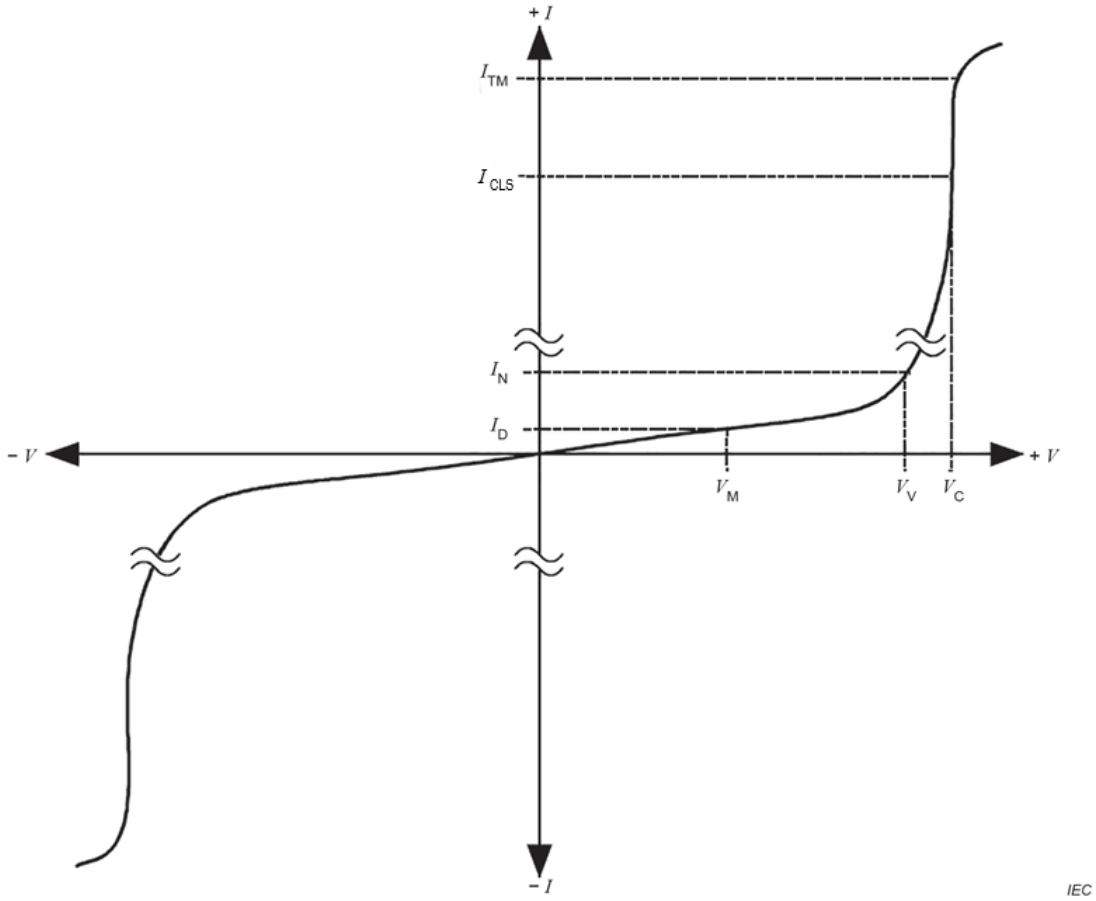

Figure 1 – *V-I* characteristic of an MOV

3.1.2.4
Clamping voltage
V_C
peak voltage across the MOV measured under conditions of a class current (I_{CLS}) and specified waveform

3.1.2.5
class current
I_{CLS}
peak value of current, which is 1/10 of the maximum peak current for 100 pulses for the 8/20 current pulse with a time interval of 30 s

[SOURCE: IEC 61051-1:2018, 3.21]

3.1.2.6
Capacitance
C_V
capacitance across the MOV measured at a specified frequency, voltage and time

[SOURCE: IEC 61643-331:2020, 3.1.2.6]

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3.1.2.7
SPD
device that contains at least one nonlinear component that is intended to limit surge voltages and divert surge currents

[SOURCE: IEC 61643-11 Clause 3.1.1]

3.1.2.8
SPC
discrete component whose primary function is to divert or limit excessive voltage and current surges to protect sensitive equipment and circuits from potential damage. Examples of SPCs are MOVs, GDTs, SITs, ABDs, and thyristors.

3.1.2.9
metal oxide varistor (MOV)
non-linear resistor made of a sintered mixture of metal oxides whose conductance, at a given temperature, increases rapidly with voltage

Note 1 to entry: This is also known as a voltage dependant resistor (VDR).

[SOURCE: IEC 61643-331:2020, 3.1.2.7]

3.1.2.10
thermally protected metal oxide varistor
varistor which includes a series non-resettable element that will disconnect the MOV when it is overheated due to excessive dissipation

[SOURCE: IEC 61643-331:2020, 3.1.2.8]

3.1.2.11
nonlinearity current index
β
starting from Formula (1) of 3.3, it is defined by the formula

$$\beta = \frac{I}{U} \times \frac{\mathrm{d}U}{\mathrm{d}I} \tag{1}$$

Note 1 to entry: For the convenience of calculation, the following formula may be used:

$$\beta = \frac{\log_{10}(U_1/U_2)}{\log_{10}(I_1/I_2)} \tag{2}$$

β is always less than 1.

[SOURCE: IEC 61051-1:2018, 3.4]

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3.1.2.12
non-linearity voltage index
γ
reciprocal of non-linearity current index β

Note 1 to entry: γ is always greater than 1.

Note 2 to entry: In varistor industry and literature, the non-linearity voltage index is usually denoted by α rather than γ.

[SOURCE: IEC 61051-1:2018, 3.5]

3.1.2.13
AC standby current
I_{AC}
current passing through MOV at maximum continuous voltage AC $V_{M(AC)}$

3.1.2.14
DC standby current
I_{DC}
current passing through MOV at maximum continuous voltage DC $V_{M(DC)}$

[SOURCE: IEC 61643-331:2020, 3.1.2.9]

3.2 Symbols and abbreviated terms

3.2.1 Symbols

Figure 2 and Figure 3 show the symbols for an MOV and a thermally protected MOV, respectively.

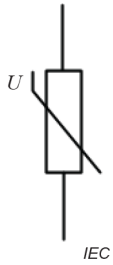

Figure 2 – Symbol for an MOV

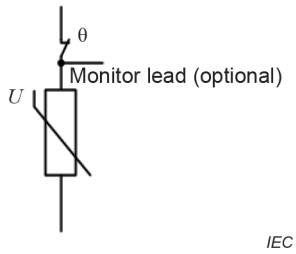

Figure 3 – Symbol for a thermally protected MOV

NOTE IEC 60027 recommends the letters V and v only as reserve symbols for voltage; however, in the field of MOV components, these are so widely used that in this publication they are preferred to U and u.

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3.2.2 Abbreviated terms

ESD	Electrostatic Discharge
GDT	Gas Discharge Tube
IC	Integrated Circuit
IT	Information Technology
IT	Isole-Terre (French for Isolated-Earth)
MCOV	Maximum Continuous Operating Voltage
MOV	Metal Oxide Varistor
SMD	Surface Mount Device
SPC	Surge Protective Component
SPD	Surge Protective Device
TCO	Thermal Cut off
TOV	Temporary Overvoltage
TN	Terre-Neutre (French for Earth-Neutral)
TT	Terre-Terre (French for Earth-Earth)

4 General

Due to the high complexity of the ceramics on which the functioning of the MOV is based, the performance of the MOV depends on the technology and processes used. Thus, the electrical properties and characteristics (tolerances, impulse withstand capability, etc.) may vary among manufacturers. The explanations of terms related to electrical properties and characteristics are described in Annex A.

5 Construction

Typically, MOVs consist of a round disc-shaped body of sintered zinc-oxide with suitable additives. Other types in use include rectangular and tubular shapes and multilayer structures. MOVs have metal particle electrodes consisting of a silver alloy or other metal. The electrodes may have been applied to the body by screen printing and firing or by other processes depending on the metal used. MOVs also often have wire leads or some other type of termination that may have been soldered to the electrode.

The basic conduction mechanism of MOVs results from semiconductor barriers at the boundary of the zinc-oxide grains formed during a sintering process. The MOV may be considered a multi-barrier component with many grains acting in series-parallel combination between the terminals. A schematic cross-sectional view of a typical MOV is shown in Figure 4.

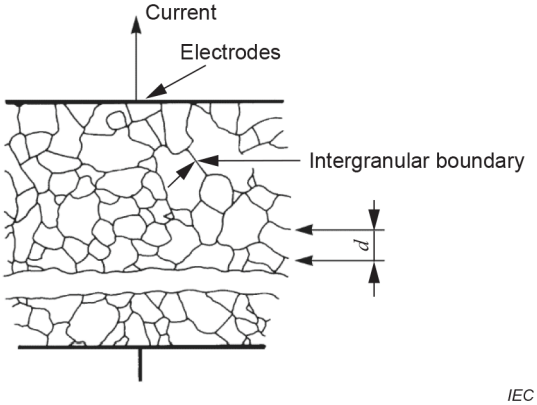

Figure 4 – Schematic depiction of microstructure of MOV

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6 Function

6.1 Theory of operation

MOVs have the property of maintaining a relatively small voltage change across their terminals while the surge current flowing through them varies over several decades. This non-linear action allows them to divert the current of a surge when connected in shunt across the line, and hold the voltage across the line to values that protect the equipment connected to that line. Since the voltage across the MOV is held at some level higher than the normal circuit voltage (but still protecting) while surge current flows, there will be energy dissipated in the MOV during its surge diversion function.

The MOV material consists of zinc-oxide grains separated by a thin intergranular material. Bismuth oxide and other metal oxides comprise the boundary between grains, and these form semiconducting barriers with the grains. A fundamental property of the material is that the voltage drop across a single interface between the grains is nearly constant, and is independent of the grain size. Figure 5 shows a typical V-I characteristic of an MOV in one direction of conduction, and the opposite direction would be similar.

The voltage and current values of the curve in Figure 5 were measured by using DC current when the current being less than 10^{-2} A, or by using 8/20 current when the current being greater than 100 A.

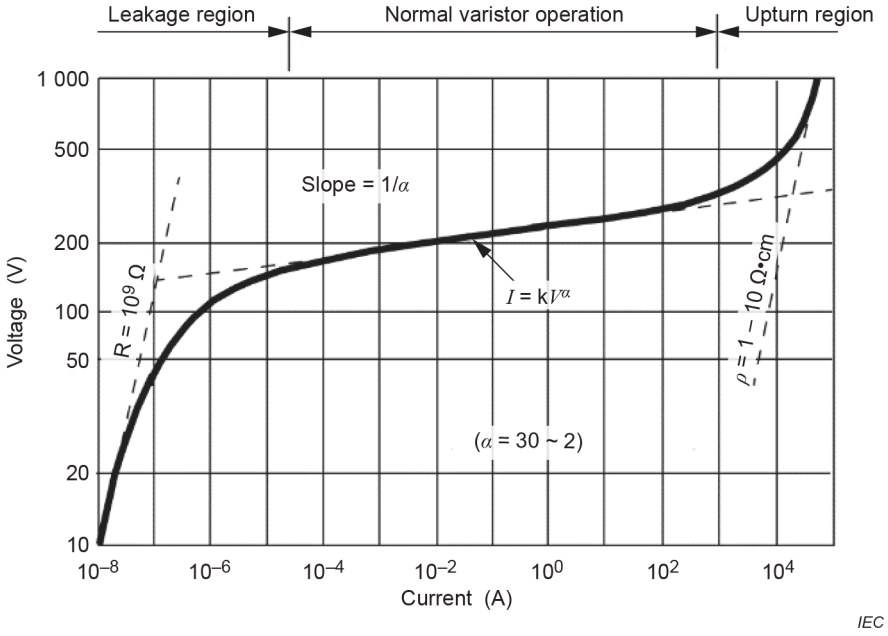

Figure 5 – Typical varistor V-I curve plotted log-log scale

The electrical behaviour of an MOV can be understood by reference to the V-I characteristic of Figure 5 and the equivalent circuit components of Figure 6 as follows:

1) Leakage Region: When the voltage across the MOV is below its varistor voltage (V_V), the non-linear resistance R_x approaches a high ohmic state and can be disregarded, hence the parallel resistance R_{off}, is the prevailing component. In the example of Figure 6, R_{off} is such a high value that the MOV is essentially in a nearly open-circuit state.

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2) Normal Varistor Operation Region: The non-linear resistance R_x becomes so small that it is much lower than the linear leakage resistance R_{off}, so that the R_{off} is ignored but R_x remains larger than R_{on}. The variable resistance R_x takes on continuously decreasing values, according to the power law relating current and voltage. In this region, current increases in several orders of magnitude as V_V remains rather constant.

3) Upturn Region: At large currents, the series resistance R_{on} becomes a significant part of the total device resistance, causing an upturn with the value of R_{on} as an asymptote. The MOV is essentially in a short-circuit state during this region.

The parametric values given in Figure 5 and Figure 6 are shown for illustration purposes only.

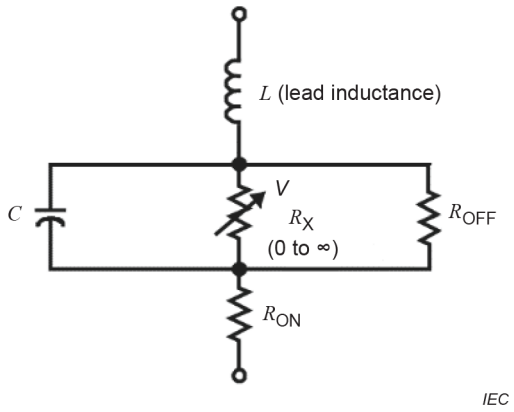

Figure 6 – MOV equivalent circuit model

Under AC or signal operating conditions as well as under surge conditions the reactive components (L and C) of Figure 6 may significantly affect the behaviour of the MOV. The parallel capacitance C can pass a current that may be larger than the DC standby current. The series inductance L, resulting from the leads can increase the voltage appearing across the component terminals when it passes surge currents with steep wave fronts. This inductive voltage drop may appear as an overshoot on the voltage waveform and appear to be a delay in MOV response.

Ambient temperature, and/or the temperature rise caused in the MOV by operating conditions or by a surge, produces little effect on the clamping voltage. However, the standby current will increase with increasing temperature. Therefore, if conditions result in temperatures that may exceed the component rating, consideration will have to be given to thermal design in the application.

6.2 Thermal protection of MOVs

Thermal protection can be effective in cases where current through an MOV might be so low as to not result in the operation of the overcurrent protection, and where currents could be high enough to cause an MOV to reach extremely high temperatures sufficient to result in extreme overheating. The following examples describe how thermal protection means could be applied to disconnect the MOV:

1) If a power frequency overvoltage occurs, AC standby power dissipation will rise. This could result in heating of an MOV.
2) If an MOV is exposed to stresses beyond its rating, it could be subject to a degradation failure mode. With severe degradation of an MOV, standby power dissipation could rise enough to cause heating.
3) If the power source impedance is relatively high, and the fault current available is too low to operate an overcurrent means, an MOV failed in the short-circuit mode could cause heating.

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Further work also needs to be done to evaluate the effect of surge transients on their operating characteristics of thermal protections.

6.3 Failure modes

6.3.1 General

The case shall be considered in which power frequency overvoltages or extreme surge values could occur, exceeding the predictions of limited-base statistics, and in which excess energy might be dissipated in the MOV. Like any other component over stressed in this manner, an MOV is subject to failure. The mode of failure will depend on the kind and degree of stress. The failure modes discussed in this subclause are short-circuit, degradation, and open-circuit and high clamping voltage.

The use of "safe failure mode" to describe a failure mode of an MOV is discouraged, since the consequences of failure, if not mitigated, may present a hazard to equipment or personnel. Some users may consider that the most desirable condition of a failed MOV is a low resistance, where the protective function is maintained. Others may prefer failure into a high resistance condition, so that the failed MOV does not induce a short circuit. Because "safe failure mode" means opposite things to different users, the recommended practice is to describe MOV failure only by the terms given in 6.3.2, 6.3.3 and 6.3.4.

High current flowing in a failed MOV can melt soldered connections or shatter the component. Since these ultimate failure modes are not generally desirable, the common practice is to provide a thermal or overcurrent protective means, or both, in order to disconnect the MOV and clear the fault from the circuit.

6.3.2 Short-circuit failure mode

In this failure mode an MOV may exhibit mechanical damage due to overheating by electrical current. The MOV element may have a punch- through hole between the electrodes, and some of the zinc-oxide material may have been reduced to metallic form. Outside of the damaged region, the MOV may have normal V-I characteristics. Hence, in terms of the equivalent electrical circuit of Figure 6 the parallel resistance component R_{off} has a much lower value in failed MOVs. When the failed MOV is measured out of its circuit and at room temperature, the non-linear exponent will be between 1 and 2. Typical values may be on the order of 10 Ω or more. The value could be lower at higher temperature at the time of failure.

6.3.3 Degradation failure mode

Overvoltage stresses that do not result in functional failure may nonetheless cause an observable change in V-I characteristics. In the degradation failure mode, an MOV has a V_{V} of less than 90 % of the initial value.

A degradation of V_{V} is likely to be associated with an increase in the MOV's DC standby current and AC standby power dissipation. Continuing degradation could lead to overheating and premature failure. For the reference, V_{V} changes in MOV durability evaluation under DC bias conditions are shown in Annex B. Consequently, users are cautioned against selecting MOVs with inadequate voltage ratings.

Degradation may be explained as due to a reduction in the value of parallel resistance R_{off} in the equivalent circuit of Figure 6. It is important to note that such a change would affect only the low-current extremity of the V-I characteristics, and the MOV would continue to perform its surge-protective function.

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