Components for low-voltage surge protective devices – Part 331: Performance requirements and test methods for metal oxide varistors (MOV)
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# CONTENTS

- **CONTENTS** ........................................................................................................2
- **FOREWORD** ........................................................................................................5
- **1 Scope** ..................................................................................................................7
- **2 Normative references** ........................................................................................7
- **3 Terms, definitions, symbols and abbreviated terms** ...........................................7
  - 3.1 Ratings ..............................................................................................................8
  - 3.2 Characteristics ....................................................................................................9
  - 3.3 Symbols .............................................................................................................10
  - 3.4 Abbreviated terms ............................................................................................11
- **4 Service conditions** ............................................................................................11
  - 4.1 Operating and storage temperature ranges ......................................................11
  - 4.2 Altitude or atmospheric pressure range .........................................................11
  - 4.3 Relative Humidity ............................................................................................11
- **5 Mechanical requirements and materials** ............................................................12
  - 5.1 Robustness of terminations ..............................................................................12
  - 5.2 Solderability ......................................................................................................12
  - 5.3 Marking ............................................................................................................12
- **6 General** .............................................................................................................12
  - 6.1 Failure rates .....................................................................................................12
  - 6.2 Test standard atmospheric conditions ............................................................12
- **7 Electrical requirements** ......................................................................................12
  - 7.1 Nominal varistor voltage ..................................................................................12
  - 7.2 Maximum AC (DC) continuous operating voltage ........................................13
  - 7.3 Standby current I\text{DC} ..................................................................................13
  - 7.4 Capacitance ......................................................................................................13
  - 7.5 Clamping voltage ..............................................................................................13
  - 7.6 Electrostatic discharge (ESD) (for SMD type MOV only) ................................15
  - 7.7 Rated impulse energy (W\text{TM}) ..................................................................15
  - 7.8 Nominal discharge current I\text{N} ...................................................................15
  - 7.9 Endurance .......................................................................................................15
  - 7.10 Limited current temporary overvoltage ........................................................15
- **8 Standard design test criteria** .............................................................................15
  - 8.1 General ............................................................................................................15
  - 8.2 Ratings .............................................................................................................15
    - 8.2.1 Single-impulse maximum current (I\text{TM}) ..............................................15
    - 8.2.2 Next Impulse ...........................................................................................16
    - 8.2.3 Continuous rated voltage (V\text{M}) ..........................................................16
  - 8.3 Electrical characteristics ..................................................................................16
    - 8.3.1 Clamping voltage (V\text{C}) .....................................................................16
    - 8.3.2 Standby current (I\text{D}) .........................................................................17
    - 8.3.3 Nominal varistor voltage (V\text{N}) ............................................................17
    - 8.3.4 Capacitance (C\text{V}) ............................................................................17
  - 8.4 Endurance .......................................................................................................18
  - 8.5 ESD Test Method ............................................................................................18
- **9 Nominal discharge current and limited current temporary overvoltage** ............18
Figure 1 – $V$-$I$ characteristic of a MOV .................................................................10
Figure 2 – Symbol for MOV ..................................................................................10
Figure 3 – Symbol for thermally protected MOV .....................................................11
Figure 4 – Test circuit for impulse peak current clamping voltage ($V_C$) at peak impulse current ($I_P$) ...........................................................16
Figure 5 – Test circuit for measuring leakage current .............................................17
Figure 6 – Test circuit for measuring nominal varistor voltage ($V_V$) ....................17
Figure 7 – Nominal Discharge Current Flowchart ......................................................20
Figure 8 – Sequence of the $f_n$ Test ..................................................................21
Figure 9 – Temporary Overvoltage Limited Current test procedure Flowchart ........23
Figure A.1 – Flow chart of the operating duty test .................................................27
Figure A.2 – Test set-up for operating duty test .....................................................28
Figure A.3 – Flow chart of testing to determine the measured limiting voltage .......30
Figure A.4 – Operating duty test timing diagram for test classes I and II ...............31
Figure A.5 – Additional duty test timing diagram for test class I .........................32
Figure A.6 – Operating duty test timing diagram for test class III .........................32
Figure C.1 – Circuit of accelerated ageing test ......................................................37
Figure D.1 – Test Circuit of MTTF ....................................................................40

Table 1 – Voltage ratings for disc types .................................................................13
Table 2 – Typical Voltage Ratings for SMD types ...................................................14
Table A.1 – Comparison of IEC 61643-11 and IEC 61643-311 ..............................26
Table A.2 – Preferred parameters for class I test ....................................................33
Table A.3 – Preferred values for class I and class II tests .....................................34
Table A.4 – Preferred values for class III tests .....................................................35
Table D.1 – Sampling plans ..................................................................................39
INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMPONENTS FOR LOW-VOLTAGE SURGE PROTECTIVE DEVICES –

Part 331: Performance requirements and test methods for metal oxide varistors (MOV)

FOREWORD

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International Standard IEC 61643-331 has been prepared by subcommittee 37B: Specific components for surge arresters and surge protective devices, of IEC technical committee 37: Surge arresters.

This second edition cancels and replaces the first edition published in 2003. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Update of the nominal varistor voltage test method;

b) Addition of thermally protected varistors – component symbol and test methods;

c) Addition of nominal discharge current – test methods;

d) Addition of voltage ratings for disc types (Table 1);
e) Addition of test currents for clamping voltage of disc types (Table 2);
f) Addition of typical voltage ratings of SMD types (Table 3); and
g) Addition of Limited current and temporary overvoltage tests for thermally protected varistors.

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

<table>
<thead>
<tr>
<th>FDIS</th>
<th>Report on voting</th>
</tr>
</thead>
<tbody>
<tr>
<td>37B/160/FDIS</td>
<td>37B/164/RVD</td>
</tr>
</tbody>
</table>

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

A list of all parts of IEC 61643 series, under the general title *Components for low-voltage surge protective devices*, 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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

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

A bilingual version of this publication may be issued at a later date.

**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.
COMPONENTS FOR LOW-VOLTAGE SURGE PROTECTIVE DEVICES –

Part 331: Performance requirements and test methods for metal oxide varistors (MOV)

1 Scope

This part of IEC 61643 is a test specification for metal oxide varistors (MOV), 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 specification applies to MOVs having two electrodes and hybrid overvoltage protection components. This specification also does not apply to mountings and their effect on the MOV's characteristics. Characteristics given apply solely to the MOV mounted only in the ways described for the tests.

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 60068-1:2013, Environmental testing – Part 1: General and guidance


IEC 60068-2-78:2012, Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state


3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the following terms, definitions, symbols and abbreviated terms apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at http://www.iso.org/obp
3.1 Ratings

3.1.1 absolute maximum ratings
limiting values of operating and environmental conditions applicable to a component, device, equipment or machine as defined by its published specification data, which should not be exceeded under the worst possible conditions

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

[SOURCE: MODIFIED: IEC 62240-1:2013, Clause 3.1.1, modified ("any semiconductor device of a specific type" replaced by "a component, device, equipment or machine", addition of Note 1 to entry)]

3.1.2 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 surge protective devices (SPDs), IEC 61643-11, Maximum Discharge Current $I_{MAX}$ is used.

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

3.1.4 impulse life characteristic
graphical representation between impulse current peak ($I$), equivalent rectangular pulse width ($T$), and impulse numbers ($n$) for which the varistor can withstand

Note 1 to entry: Unless otherwise specified, the range of $T$ shall be 20 $\mu$s to 10 ms, the range of $n$ shall be $10^6$, $10^5$, $10^4$, $10^3$, $10^2$, $10^1$ and $10^0$ temperature derating curve.

3.1.5 temperature derating curve
graphical representation of parameter derating against temperature

Note 1 to entry: Typical parameters are rated voltage, impulse current, energy and average power dissipation.

3.1.6 single-pulse [ transient] maximum energy
$W_{TM}$
rated maximum value which may be absorbed for a single pulse of a specified waveform

Note 1 to entry: Unless otherwise specified, 2 ms rectangular pulse is used (IEC 60060).

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

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

Note 2 to entry: See Figure 1.
3.1.8  
**maximum continuous AC voltage**

\( V_{M(AC)} \)

Value of rms. power frequency voltage (less than 5 % total harmonic distortion) that may be applied continuously at a specified temperature.

3.1.9  
**maximum continuous DC voltage**

\( V_{M(DC)} \)

DC voltage that may be applied continuously at a specified temperature.

3.1.10  
**Mean Time To Failure**

MTTF

Basic measure of reliability for non-repairable items, the total number of life units of an item divided by the total number of failures within that population, during a particular measurement interval under stated conditions.

3.2  
**Characteristics**

3.2.1  
**characteristic**

Inherent and measurable property of an MOV.

3.2.2  
**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.

3.2.3  
**nominal varistor voltage**

\( V_N \)

Voltage across the MOV measured at a specified current of specific duration.

Note 1 to entry: See Figure 1.

3.2.4  
**clamping voltage**

\( V_C \)

Peak voltage across the MOV measured under conditions of a specified peak pulse current \( I_P \) and specified waveform.

Note 1 to entry: See Figure 1.

Note 2 to entry: Unless otherwise specified, a typical value of this parameter is measured with a pulsed current 8/20 waveform.

Note 3 to entry: Clamping voltage, \( V_C \), is referred to as Measured Limiting Voltage in IEC 61643-11.

3.2.5  
**capacitance**

\( C_V \)

Capacitance across the MOV measured at a specified frequency, voltage and time.

3.2.6  
**metal oxide varistor**

MOV

Component whose conductance, at a given temperature, increases rapidly with voltage.

Note 1 to entry: This is also known as a voltage dependant resistor (VDR).
3.2.7 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

![V-I characteristic of an MOV](image)

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

3.3 Symbols

Figures 2 and 3 represent the IEC 60617 symbols for MOV and thermally protected MOV, respectively.

![Symbol for MOV](image)

**Figure 2 – Symbol for 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.

3.4 Abbreviated terms

- **DUT**: Device Under Test
- **ESD**: Electrostatic Discharge
- **MCOV**: Maximum Continuous Operating Voltage
- **MOV**: Metal Oxide Varistor
- **MTTF**: Mean Time To Failure
- **SMD**: Surface Mount Device
- **SPD**: Surge Protective Device
- **VDR**: Voltage Dependent Resistor

4 Service conditions

4.1 Operating and storage temperature ranges

**Operating range**
- Normal: -5 °C to +55 °C
- Extended: -40 °C to +85 °C

**Storage range MOV**
- Normal: -40 °C to +85 °C
- Extended: -40 °C to +125 °C

**Storage range thermally protected MOV**
- Normal: -40 °C to +85 °C
- Extended: -40 °C to +85 °C

4.2 Altitude or atmospheric pressure range

The altitude of air pressure is within 80 kPa to 106 kPa (refer to IEC 60068-1).

4.3 Relative Humidity

Normal range: 5 % to 95 % at 25 °C (refer to IEC 60068-1 and IEC 60068-2-78).
5 Mechanical requirements and materials

5.1 Robustness of terminations
If applicable, the user shall specify a suitable test from IEC 60068-2-21.

5.2 Solderability
Solder terminations shall meet the requirements of IEC 60068-2-20, test Ta, method 1.

5.3 Marking
Legible and permanent marking shall be applied to the MOV as necessary to ensure that the user can determine the following information by inspection:

Each MOV shall be marked with the following information:
- Date of manufacture or batch number
- Manufacturer name or trademark
- Part number
- Safety approval markings

NOTE 1 The necessary information can also be coded.

When the space is not sufficient for printing this data, it should be provided in the technical documentation after agreement between the manufacturer and the purchaser.

6 General

6.1 Failure rates
Sampling size, electrical characteristics to be tested, etc. should be covered by the quality assurance requirements, which are not covered by this document.

6.2 Test standard atmospheric conditions
The following tests shall be performed on the MOVs as required by the application. Unless otherwise specified, ambient test conditions shall be as follows:
- temperature: 15 °C to 35 °C;
- relative humidity: 25 % to 75 %;

MOVs of various types should have the characteristics listed in Table 1 when tested in accordance with Clause 8.

7 Electrical requirements

7.1 Nominal varistor voltage
When tested according to 8.3.3, varistor voltage should be within the specified manufacturer’s limits. Table 1 shows the nominal varistor voltages of high voltage and low voltage disc types that are commonly used; their allowable tolerances are ±10 %.

The nominal varistor voltages and tolerances listed in Table 2 are typical for surface mount Device (SMD) types.
7.2 Maximum AC (DC) continuous operating voltage

Unless otherwise specified, MOVs shall have a maximum AC (DC) continuous voltage \( V_{M(AC)}/V_{M(DC)} \) as given in Tables 1 and 2, the conformity shall be evaluated according to 8.2.3.

**NOTE** Maximum AC (DC) continuous operating voltage is sometimes referred to as \( U_C \).

7.3 Standby current \( I_{DC} \)

When tested according to 8.3.2, the standby current, DC, under maximum continuous DC voltage \( V_{DC} \), shall be less than the maximum value specified by the manufacturer and there shall be no upward drifting during the application of the test voltage \( V_{DC} \).

7.4 Capacitance

When tested according to 8.3.4, the measured value of capacitance shall not exceed the value specified by the manufacturer.

7.5 Clamping voltage

The measured clamping voltage (see 8.3.1) at a specified impulse current shall be no more than the specified values or the values indicated in Tables 1 and 2. Unless otherwise specified, 8/20 impulse current having the peak as specified in shall be used.

**NOTE** Clamping voltage \( V_C \) is referred to as Measured Limiting Voltage in IEC 61643-11.

### Table 1 – Typical voltage ratings for disc types

<table>
<thead>
<tr>
<th>Nominal varistor voltage ( V_N ) (V)</th>
<th>Max. continuous voltage (( V_M ))</th>
<th>Clamping voltage (Note), ( V_C ) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC (rms) ( V_{M(AC)}/V_{M(DC)} )</td>
<td>DC ( V_{DC} )</td>
</tr>
<tr>
<td>18</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>22</td>
<td>14</td>
<td>18</td>
</tr>
<tr>
<td>27</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>33</td>
<td>20</td>
<td>26</td>
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<td>39</td>
<td>25</td>
<td>31</td>
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<tr>
<td>47</td>
<td>30</td>
<td>38</td>
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<tr>
<td>56</td>
<td>35</td>
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<tr>
<td>68</td>
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<td>56</td>
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<td>82</td>
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<td>85</td>
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<tr>
<td>120</td>
<td>75</td>
<td>100</td>
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<td>230</td>
<td>300</td>
</tr>
<tr>
<td>390</td>
<td>250</td>
<td>320</td>
</tr>
<tr>
<td>430</td>
<td>275</td>
<td>350</td>
</tr>
</tbody>
</table>
## Table 2 – Typical voltage ratings for SMD types

<table>
<thead>
<tr>
<th>Nominal varistor voltage ( V_N ) (V)</th>
<th>Maximum continuous voltage ( V_M )</th>
<th>AC (rms) ( V_{AC} )</th>
<th>DC ( V_{DC} )</th>
<th>( V_C ) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>470</td>
<td>300</td>
<td>385</td>
<td>775</td>
<td></td>
</tr>
<tr>
<td>510</td>
<td>320</td>
<td>410</td>
<td>845</td>
<td></td>
</tr>
<tr>
<td>560</td>
<td>350</td>
<td>450</td>
<td>930</td>
<td></td>
</tr>
<tr>
<td>620</td>
<td>385</td>
<td>505</td>
<td>1025</td>
<td></td>
</tr>
<tr>
<td>680</td>
<td>420</td>
<td>560</td>
<td>1120</td>
<td></td>
</tr>
<tr>
<td>715</td>
<td>440</td>
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<td>750</td>
<td>460</td>
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<td>820</td>
<td>510</td>
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<td>910</td>
<td>550</td>
<td>745</td>
<td>1500</td>
<td></td>
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<tr>
<td>1000</td>
<td>625</td>
<td>825</td>
<td>1650</td>
<td></td>
</tr>
<tr>
<td>1100</td>
<td>680</td>
<td>895</td>
<td>1815</td>
<td></td>
</tr>
<tr>
<td>1200</td>
<td>750</td>
<td>970</td>
<td>2000</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>1000</td>
<td>1280</td>
<td>2650</td>
<td></td>
</tr>
<tr>
<td>1800</td>
<td>1100</td>
<td>1465</td>
<td>2970</td>
<td></td>
</tr>
</tbody>
</table>

**NOTE**: Clamping voltage \( V_C \) is referred to as Measured Limiting Voltage in IEC 61643-11.

During the tests, there shall be no flashover or puncture of the samples, the MOV voltage of the samples shall be tested prior to and after the tests, the change of which shall not exceed ±10 %, when tested according to 8.3.3.
7.6 Electrostatic discharge (ESD) (for SMD type MOV only)

The SMD MOVs shall be subjected to electrostatic discharge (ESD) contact discharge test of 8 kV for 10 applications with an interval of 1 s according to 8.5.

During the tests, there shall be no evidence of flashover or puncture of the samples, and the Varistor voltage of the samples shall be tested prior to and after the tests, the change of which shall not exceed ±30 %.

7.7 Rated impulse energy ($W_{TM}$)

The MOV shall be capable of absorbing the impulse energy specified by the manufacturer when subjected to one impulse current of 2 ms or 10/1000 wave and tested according to 8.2.1.

7.8 Nominal discharge current $I_n$

The MOV shall be subjected to 15 applications of impulse currents of 8/20 wave with the peak specified by the manufacturer, and tested according to 9.3.

7.9 Endurance

The MOV used for power supply circuitry shall be subjected to an endurance test under the conditions of maximum operating temperature and maximum continuous operating voltage for 1 000 h and tested according to 8.4.

If all concerned parties agree the optional accelerated endurance screening test in Annex C may be used.

7.10 Limited current temporary overvoltage

This is an AC step stress test to evaluate MOV components for potential ignition sources when the component is subjected to a.c. overload, (see 9.4).

8 Standard design test criteria

8.1 General

The design tests described in 8.3 provide standardized methods for measuring specified characteristics of a MOV for the purpose of component selection for a surge protective device (SPD). These characteristics may vary from MOV to MOV, making it necessary to measure all components to be selected for a SPD. MOVs are bi-directional and they shall be tested with both positive and negative voltages.

8.2 Ratings

8.2.1 Single-impulse maximum current ($I_{TM}$)

In the absence of specified requirements, the test current shall be an 8/20 wave shape.

NOTE See Figure 4.
Figure 4 – Test circuit for single-impulse maximum current

8.2.2 Next Impulse

The next impulse shall be applied after the device under test (DUT) has returned to thermal equilibrium (for example, the initial conditions before the impulses were applied). In the absence of specified requirements, the test current shall be an 8/20 waveshape.

NOTE 1 MOVs intended for service in IEC 61643-11 surge protective devices require special class I, class II and class III testing procedures and waveforms. These tests are covered in Annex A.

NOTE 2 See Figure 4.

8.2.3 Continuous rated voltage (\(V'_{M}\))

This rating is verified in 8.3.2.

8.3 Electrical characteristics

8.3.1 Clamping voltage (\(V'_{C}\))

Maximum clamping voltage shall be measured during the single impulse current (\(I'_{C}\)), see clause 8.2.1. The peak clamping voltage and peak test current are not necessarily coincident in time. In the absence of specified requirements, the test current shall be an 8/20 waveshape.

NOTE 1 MOVs intended for service in IEC 61643-11 surge protective devices require special class II or class III testing procedures and waveforms. These tests are covered in Annex A.

NOTE 2 See Figure 4.
8.3.2 Standby current ($I_D$)

In this measurement, voltage should be maintained at a steady value regardless of the load impedance. A power supply of constant voltage source should be used. It is not recommended that the voltmeter be connected across the DUT due to the current bleeding through the meter. The leakage current reading would be inaccurate. The Voltage supplied PS should be set to the specified Maximum Continuous Operating Voltage $V_{M(DC)}$ of the MOV under test.

NOTE See Figure 5.

![Diagram](image)

**Components**

- A: Current meter
- PS: Voltage source (DC)
- V: Voltmeter

**Figure 5 – Test circuit for measuring leakage current**

8.3.3 Nominal varistor voltage ($V_N$)

In this measurement, current should be maintained at a steady value regardless of the load impedance. A power supply of constant current source should be used. The time of applied test current ($I_N$) shall be between 10 to 100 ms. Unless otherwise specified, the test current shall be 1 mA DC.

NOTE See Figure 6.

![Diagram](image)

**Components**

- A: Current meter
- P: Bipolar pulsed current source
- V: Voltmeter

**Figure 6 – Test circuit for measuring nominal varistor voltage ($V_N$)**

8.3.4 Capacitance ($C_V$)

This should be measured at a specified sinusoidal frequency and voltage at a specified temperature. Unless otherwise specified, a signal of 0.1 V rms. of 1 kHz at 25 °C is recommended.
8.4 Endurance

The nominal varistor voltage \( V_N \) and the leakage current of the samples are measured and recorded prior to this test.

The MOV is heated to the maximum operating temperature of 100 °C unless otherwise specified for the duration of 1 000 h.

The test voltage shall be \( V_M (AC) \) for AC and/or \( V_M (DC) \) for DC. The test should be performed in a chamber, at a temperature that shall be maintained within 5 oC. When the test is finished, the samples should be cooled down for not less than 1 h nor more than 2 h. The nominal varistor voltage, \( V_N \), and the leakage current should be within the specified limits when measured at ambient temperature.

8.5 ESD Test Method

Initial measurements: Varistor voltage and clamping voltage.

The samples shall be mounted on a circuit board with a large ground plane. The circuit board shall have a convenient discharge point for the ESD gun in contact mode and the SMD shall be mounted between the ESD gun discharge point and the board ground. The circuit board is then placed at the center of a minimum 0.5 m metal ground plane as described in ANSI/ESD SP5.6. The ground plane of the circuit board and the metallic ground plane shall make good electrical contact.

The samples shall be subjected to the test using the contact discharge method at 8 kV ± 5 % for 10 applications using an IEC 61000-4-2-compliant ESD gun. The ground strap of the ESD gun shall be connected to a corner of the metal ground plane. During and after the test, there shall be no evidence of flashover or puncture of the samples.

9 Nominal discharge current and limited current temporary overvoltage

9.1 Thermally protected varistors – Sequence of tests

- Temperature humidity and conditioning 9.2
- Dielectric test 9.5
- Nominal discharge current testing as described in 9.3
- Limited current test as specified in 9.4
- Dielectric test 9.5

9.2 Temperature and humidity cycle conditioning

The samples shall be subjected to three complete conditioning cycles. Each cycle shall consist of 24 h at 85 °C followed immediately (within 15 min) by at least 24 h at (35 ± 5) °C and (90 ± 5) % relative humidity, followed by 8 h at (0 ± 2) °C.

NOTE The dielectric and insulation resistance tests are performed after removal of the samples from the conditioning chamber.
9.3 Nominal discharge current $I(n)$ test description

9.3.1 General

Figure 7 shows the test sequence comprising of:

Before surge test, measure initial nominal varistor voltage and standby current.

Apply 1 surge with no MCOV, and within 1 second (T1 Figure 8), apply MCOV for 60 s ± 15 s (T2 Figure 8).

Repeat this cycle 15 times.

After each 5 cycles, the component should be allowed to cool for 30 min ± 5 min (T3 Figure 8).

After the last cycle, continue to apply MCOV for at least an additional 15 min (T4 Figure 8).

Measure nominal varistor voltage and standby current.

Caution, some of the tests specified can be hazardous to the persons carrying them out; all appropriate measures to protect personnel against possible fire or explosive hazards should be taken.
Figure 7 – Nominal Discharge Current Flowchart
9.3.2 Pass/fail criteria

The measured varistor voltage after 15 cycles should be not less than 90 % of the initial measured nominal varistor voltage and the leakage current should be less than the manufacturer’s specified value.

9.4 Limited current temporary overvoltage test description and procedure for thermally protected varistors

9.4.1 General

For thermally protected varistors intended to be installed in permanently connected applications, the limited currents tested shall be 0.625 A, 1.25 A, 2.5 A, 5.0 A and 10.0 A unless otherwise specified. For thermally protected varistors intended to be installed in cord connected applications, the limited currents tested shall be 0.625 A, 1.25 A, 2.5 A and 5.0 A unless otherwise specified.

Caution, some of the tests specified can be hazardous to the persons carrying them out; all appropriate measures to protect personnel against possible fire or explosive hazards should be taken.

9.4.2 Sample preparation

The varistor shall be mounted in accordance with the manufacturer’s recommendations. Cheesecloth is used for hazard monitoring. Two layers of cheesecloth shall be wrapped around the component at a distance of 10 mm from the component body forming a component enclosure.

9.4.3 Test conditions

Adjust an AC power supply to 1.6 times the specified rated voltage of the device at each perspective current according to Figure 9. Monitor the current of the device under test from the time the power is applied until the thermal link opens but not longer than 7 hours. After the thermal link has opened allow the device under test to cool for 5 minutes.
9.4.4 Pass/fail criteria

After the test the cheesecloth shall be examined. The cheesecloth shall not be damaged by any of the following hazards; ejection of fragments, ejection of molten materials, production of hot gases (which includes flames) and electrical sparking. The component mounting position shall not be changed by any solder reflow.

The cheesecloth shall be cotton and have a minimum of 13 threads by 11 threads in any square centimeter.
Thermal overload test for thermally protected varistors

What is declared rating of thermally protected varistor?

Thermal overload sequence = 0.625 A, 1.25 A, 2.5 A, 5.0 A

Adjust A-C power supply open circuit for 1.6 times rated varistor voltage

Adjust A-C power supply for short circuit current

Connect new sample across power supply until the thermal disconnect operates or until thermal stability is reached

Has thermal disconnect operated? Yes No

Has thermal stability been reached? Yes No

End of sequence? Yes No

Pass

Test dielectric Pass Fail

Pass

End

See section 9.3.1 for Pass/Fail criteria

Figure 9 – Temporary Overvoltage Limited Current test procedure Flowchart
9.5  Dielectric testing

9.5.1  Test conditions
Set the dielectric test equipment as follows:

Voltage = 2 times the rated voltage of the device under test.
Threshold Current = Voltage / 200 kΩ

Measure the dielectric strength across the thermal link for 1 minute.

9.5.2  Setup from foil to leads
Set the dielectric test equipment as follows:

Voltage = 2 times the rated voltage of the device under test + 1 000 V
Threshold Current = Voltage / 2 000 kΩ

Wrap a piece of foil around the component being careful to have a gap of at least 0.5 mm between the foil and the leads.

Tie the leads of the component together and connect the dielectric tester across the foil and the leads.

Measure the dielectric strength between the leads and the foil for 1 minute.

9.5.3  Pass criteria
No current greater than threshold current.

NOTE  Voltage is an rms. voltage, sine wave of 45 to 62 Hz.
Annex A
(informative)

MOV testing according to IEC 61643-11:2011 – Surge protective devices for the Class I, II and III

A.1 General

Surge protective devices (SPDs) compliant to IEC 61643-11 meet one or more defined impulse tests. These tests are termed: class I, class II and class III.

The Class I test is intended to simulate partial conducted lightning current impulses. SPDs subjected to Class I test methods are generally recommended for locations at points of high exposure, e.g., line entrances to buildings protected by lightning protection systems.

SPDs tested to Class II or III test methods are subjected to impulses of shorter duration.

Full testing details are contained in IEC 61643-11. This annex gives an overview of MOV testing for use in IEC 61643-11 compliant SPDs.

A.2 MOV selection

IEC 61643-11 SPD impulse ratings may be met with a single MOV or by combinations of MOVs connected in series or parallel or both.

A.3 Cross reference list of abbreviations, descriptions and definitions

Table A.1 provides the list of abbreviations, descriptions and definitions used in this document related to the standard IEC 61643-11.
### Table A.1 – Comparison of IEC 61643-11 and IEC 61643-311

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
<th>Definition /Clause</th>
<th>Abbreviation</th>
<th>Description (parametric terms)</th>
<th>Definition /Clause</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_C$</td>
<td>Maximum continuous operating voltage</td>
<td>3.1.11 $\nu_M$</td>
<td>Maximum continuous voltage</td>
<td>3.1.7</td>
<td>3.1.6.1</td>
</tr>
<tr>
<td>$U_{OC}$</td>
<td>Open circuit voltage of the combination wave generator</td>
<td>3.1.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$U_{res}$</td>
<td>Residual voltage</td>
<td>3.16 $\nu_C$</td>
<td>Clamping voltage</td>
<td>3.2.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Limiting voltage with the combination wave</td>
<td>$\nu_C$</td>
<td>Clamping voltage</td>
<td>3.2.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measured limiting voltage</td>
<td>3.1.15 $\nu_C$</td>
<td>Clamping voltage</td>
<td>3.2.3</td>
<td></td>
</tr>
</tbody>
</table>

#### Abbreviations, descriptions and definitions related to voltage

#### Abbreviations, descriptions and definitions related to current

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
<th>Definition /Clause</th>
<th>Abbreviation</th>
<th>Description</th>
<th>Definition /Clause</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I_n$</td>
<td>Nominal discharge current for class II test</td>
<td>3.1.9</td>
<td>$I_n$</td>
<td>Nominal discharge current</td>
<td>3.1.3</td>
</tr>
<tr>
<td>$I_{max}$</td>
<td>Maximum discharge current</td>
<td>3.1.48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{imp}$</td>
<td>Impulse discharge current for class I test</td>
<td>3.1.10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_f$</td>
<td>Follow current</td>
<td>3.1.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_p$</td>
<td>Prospective short-circuit current of a power supply</td>
<td>3.1.38</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Definitions related to impulse test classification

<table>
<thead>
<tr>
<th>Class</th>
<th>Definition /Clause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I tests</td>
<td>3.1.34.1</td>
</tr>
<tr>
<td>Class II tests</td>
<td>3.1.34.2</td>
</tr>
<tr>
<td>Class III tests</td>
<td>3.1.34.2</td>
</tr>
</tbody>
</table>

### A.4 Operating duty test

#### A.4.1 General

An overview is given in the flow chart for the operating duty test in Figure A.1.
Figure A.1 – Flow chart of the operating duty test

This is a test in which service conditions are simulated by the application of a stipulated number of specified impulses to the SPD while it is energized at the maximum continuous operating voltage $U_C$ via an AC source according to 8.3.4.2.

This test setup shall comply with the circuit diagram given in Figure A.2.
The power frequency source characteristics for the operating duty test for SPDs with follow current 500 A or less is described in 8.3.4.2.1.

The measured limiting voltage shall be determined using the test described in 8.3.3.

To avoid overstress of the samples, the test is performed:

- according to 8.3.3.1, but only at a crest value corresponding to $I_{\text{imp}}$ for test class I
- according to 8.3.3.1, but only at $I_n$ for test class II
- according to 8.3.3.3, but only at $U_{\text{OC}}$ for test class III

with one positive and one negative surge applied.

A.4.2 Measured limiting voltage

A.4.2.1 General

The tests on the different SPD types to determine their measured limiting voltages shall be performed according to the flow chart in Figure A.3.

A.4.2.2 Residual voltage with 8/20 current impulse (8.3.3.1)

If the SPD contains only voltage-limiting components, this test needs only to be performed at crest values of $I_{\text{imp}}$ for test class I or $I_n$ for test class II.

When $I_{\text{max}}$ is declared by the manufacturer an additional 8/20 current impulse with a crest value of $I_{\text{max}}$ shall be applied and the residual voltage shall be measured and recorded.

One sequence of positive polarity and one sequence of negative polarity are applied to the SPD.

The interval between individual impulses shall be long enough for the sample to cool down to ambient temperature.
The residual voltage used for determining the measured limiting voltage is the highest voltage value corresponding to the currents for:

- Class I: at $I_{\text{imp}}$
- Class II: at $I_n$

**NOTE** The residual voltage is the highest crest value measured during surge current flow. Any high frequency disturbances and spikes before and during current flow caused by specific generator design, like crowbar generators, are disregarded.

The value for determining $U_{\text{max}}$ is the highest residual voltage measured at $I_n$, $I_{\text{max}}$ or $I_{\text{imp}}$, as applicable depending on the SPD test class.
**A.4.2.3 Limiting voltage with the combination wave (8.3.3.3)**

To perform this test a combination wave generator is used.

The interval between the individual impulses shall be long enough for the sample to cool down to ambient temperature.

If the SPD only contains voltage-limiting components this test needs to be carried out at $U_{dc}$ only.
With these generator settings four surges will be applied to the SPD, two with positive and two with negative polarity.

The value for determining the measured limiting voltage and $U_{\text{max}}$ is the maximum voltage recorded during this test.

NOTE $U_{oc}$ is open circuit voltage of the combination wave generator, at the point of connection of the device under test.

### A.4.3 Class I and II operating duty tests (8.3.4.3)

Three groups of five impulses of 8/20 current impulses with positive polarity shall be applied. The test samples are connected to a power source according to 8.3.4.2. Each impulse shall be synchronized to the power frequency. Starting from 0° the synchronisation angle shall be increased in steps of 30° with a tolerance of ± 5° for each synchronisation angle. The tests are described in Figure A.4.

**Figure A.4 – Operating duty test timing diagram for test classes I and II**

The SPD shall be energized at $U_c$. The prospective short-circuit current of the power source shall comply with 8.4.3.2 during the application of groups of impulses. After the application of each group of impulses and after the interruption of the last follow current (if any) the SPD shall remain energized without interruption for at least 1 min to check for for stability. After the last group of impulses and the 1 min period the SPD either remains applied or is reapplied within less than 30 s to $U_c$ for another 15 min to check for stability. For that purpose, the short-circuit capability of the power source (at $U_c$) may be reduced to 5 A.

When testing MOVs to class I, 8/20 current impulses with a crest corresponding to $I_{\text{imp}}$ shall be applied.

When testing MOVs to class II, 8/20 current impulses with $I_n$ shall be applied.

If an MOV is classified for test class I and test class II this test may be performed only once, but with the most severe set of parameters of both test classes, subject to agreement by the manufacturer.

The interval between the impulses is 50 s to 60 s, the interval between the groups is 30 min to 35 min.

It is not required that the test sample is energized between the groups.

### A.4.4 Additional duty test for test class I

This test is carried out with current impulses in steps up to $I_{\text{imp}}$ passing through the SPD.

The MOV shall be energized at $U_c$. The prospective short-circuit current of the power source shall be 5 A during the application of impulses. After the application of each impulse and after
interruption of each follow current (if any) the SPD shall remain energized without interruption for at least 1 min to check for stability. After that period the SPD either remains applied or is reapplied within less than 30 s to $U_C$ for another 15 min to check for stability. For that purpose the short-circuit capability of the power source shall also be 5 A.

Current impulses of positive polarity shall be initiated at the corresponding positive crest value of the power frequency voltage source to the energized test sample as follows:

one current impulse at $0.1 I_{\text{imp}}$; check thermal stability; cool down to ambient temperature;

one current impulse at $0.25 I_{\text{imp}}$; check thermal stability; cool down to ambient temperature;

one current impulse at $0.5 I_{\text{imp}}$; check thermal stability; cool down to ambient temperature;

one current impulse at $0.75 I_{\text{imp}}$; check thermal stability; cool down to ambient temperature;

one current impulse at $1.0 I_{\text{imp}}$; check thermal stability; cool down to ambient temperature.

The timing diagram is described in Figure A.5.

![Additional duty test timing diagram for test class I](image)

**Figure A.5 – Additional duty test timing diagram for test class I**

### A.4.5 Class III operating duty tests

The SPD is tested with three groups of impulses corresponding to $U_{OC}$ with:

- five positive impulses initiated at crest value of positive half cycle ($\pm 5^\circ$)
- five negative impulses initiated at crest value of negative half cycle ($\pm 5^\circ$)
- five positive impulses initiated at crest value of positive half cycle ($\pm 5^\circ$)

The timing diagram is described in Figure A.6.

![Operating duty test timing diagram for test class III](image)

**Figure A.6 – Operating duty test timing diagram for test class III**
A.4.6 Pass criteria for all operating duty tests and for the additional duty test for test class I

The pass criteria A, B, C, D, E, F, G and M according to Table 4 of IEC 61643-11:2011 shall apply.

A.4.7 Preferred parameters of impulse discharge current $I_{\text{imp}}$ used for Class I additional duty tests

The impulse discharge current passing through the device under test (MOV) is defined by the crest value $I_{\text{imp}}$, the charge $Q$ and the specific energy $W/R$. The impulse current shall show no polarity reversal and shall reach $I_{\text{imp}}$ within 50 $\mu$s. The transfer of the charge $Q$ shall occur within 5 ms and the specific energy $W/R$ shall be dissipated within 5 ms.

The impulse duration shall not exceed 5 ms.

1) Table A.2 gives values of $Q$ (A$\cdot$s) and $W/R$ (kJ/Ω) for example values of $I_{\text{imp}}$ (kA).

The relationship between $I_{\text{imp}}$, $Q$ and $W/R$ is as follows:

\[
Q = I_{\text{imp}} \times a \quad \text{where} \quad a = 5 \times 10^{-4} \, \text{s}
\]

\[
W/R = I_{\text{imp}}^2 \times b \quad \text{where} \quad b = 2.5 \times 10^{-4} \, \text{s}
\]

**Table A.2 – Preferred parameters for class I test**

<table>
<thead>
<tr>
<th>$I_{\text{imp}}$ within 50 $\mu$s (kA)</th>
<th>$Q$ within 5 ms (A$\cdot$s)</th>
<th>$W/R$ within 5 ms (kJ/Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>12.5</td>
<td>156</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>12.5</td>
<td>6.25</td>
<td>39</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
<td>6.25</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>0.25</td>
</tr>
</tbody>
</table>

**NOTE 1** One of the possible test impulses which meet the above parameters is the 10/350 waveform proposed in IEC 62305-1.

The following tolerances shall apply:

- $I_{\text{imp}}$ $-10\%$/$+10\%$
- $Q$ $-10\%$/$+20\%$
- $W/R$ $-10\%$/$+45\%$

**NOTE 2** For further guidance on this subject see IEC 61643-11:2011 (Subclause 8.3.4.4 – Additional duty test for test class I).

A.4.8 Preferred values of impulse discharge current $I_n$ used for Class I and Class II residual voltage and operating duty tests

Table A.3 values are for a waveshape of 8/20.
Table A.3 – Preferred values for class I and class II tests

<table>
<thead>
<tr>
<th>( I_n ) (kA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
</tr>
<tr>
<td>70</td>
</tr>
<tr>
<td>60</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>40</td>
</tr>
<tr>
<td>30</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>10</td>
</tr>
</tbody>
</table>

The tolerances on the current waveshape passing through the device under tests are as follows:

- crest value ± 10 %
- front time ± 10 %
- time to half value ± 10 %

A small overshoot or oscillation is tolerated provided that the amplitude of any oscillation is not more than 5 % of the crest value. Any polarity reversal after the current has fallen to zero shall not be more than 30 % of the crest value.

NOTE For further guidance on this subject see IEC 61643-11:2011 (Subclause 8.3.3.1 – Residual voltage with 8/20 current impulses and Subclause 8.3.4.3 Class I and II operating duty tests).

A.4.9 Preferred values of combination waveshape used for Class III tests

Table A.4 values are for a 1.2/50-8/20 combination wave generator. The standard impulses of a combination waveform generator is characterized by the output voltage under open-circuit conditions and the output current under short-circuit conditions. The open circuit voltage shall have a front time of 1.2 \( \mu \)s and a time to half value of 50 \( \mu \)s. The short-circuit current shall have a front time of 8 \( \mu \)s and a time to half value of 20 \( \mu \)s.

The maximum values for crest open-circuit voltage \( U_{OC} \) and crest short-circuit current \( I_{sc} \) are 20 kV and 10 kA respectively. Above these values (20 kV /10 kA), class II tests shall be performed.
Table A.4 – Preferred values for class III tests

<table>
<thead>
<tr>
<th>$U_{OC}$ (kV)</th>
<th>$I_{SC}$ (kA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>2.5</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
</tr>
</tbody>
</table>

The tolerances of the open circuit voltage $U_{OC}$ at the points where the device under test (DUT) will be connected are as follows:

- crest value ± 5 %
- front time ± 30 %
- time to half value ± 20 %

These tolerances are for the generator alone, without of any MOV or power supply circuit being connected, depending whether the test has to be performed energized or un-energized.

NOTE 1 For further guidance on this subject see IEC 61643-11:2011 (Subclause 8.1.4 – Combination wave used for class III tests, paragraph a)).

The tolerances of the short-circuit current $I_{SC}$ at the points where the device under test (DUT) will be connected are as follows:

- crest value ± 10 %
- front time ± 10 %
- time to half value ± 10 %

These generator tolerances shall be met with or without any power supply circuit being connected, depending whether the test has to be performed energized or un-energized.

NOTE 2 For further guidance on this subject see IEC 61643-11:2011 (Subclause 8.1.4 – Combination wave used for class III tests, paragraph b)).

Test setup:

The fictive or effective impedance $Z_f$ of the generator shall be nominally 2 Ω. By definition, the impedance is the ratio of the crest value of the open-circuit voltage $U_{OC}$ divided by the crest value of the short-circuit current $I_{SC}$.

The above waveform and tolerance requirements only apply to the test performed at the value of $U_{OC}$ declared by the manufacturer, which may require some generator adjustments to achieve. For test performed below $U_{OC}$ (0.1; 0.2; 0.5; 1.0 times $U_{OC}$), no further generator adjustments are required, and the same settings shall be used.

NOTE 3 For further guidance on this subject see IEC 61643-11:2011 (Subclause 8.1.4 – Combination wave used for class III tests, paragraph c)).
Annex B
(informative)

IEC 61051 Varistors for use in electronic equipment

IEC 61051 covers varistors for use in electronic equipment and consists of two parts: 61051-1 for the generic specification and 61051-2 is a sectional specification for surge suppression varistors.

These parts are set up to address quality in that they have AQL levels and sample sizes.

The testing covers varistor voltage, leakage current, pulse current, insulation resistance, robustness of terminations, solderability, bump, shock, vibration, damp heat, environmental, fire, endurance at temperature and solvent resistance.
Annex C
(informative)

Accelerated endurance screening test

C.1 Accelerated endurance screening test

The purpose of the test is to check the MOV for initial term failure.

C.2 Preparation of sample

At least 10 samples from the same production lot should be used. The nominal varistor voltage $V_N$ of each sample should be measured and recorded prior to this test. In addition, $V_N$ variation of the samples shall be within ±1 %.

C.3 Test conditions

The samples to be tested are heated to 105 °C ± 5 °C in a chamber. The applied DC voltage shall be at the minimum $V_T$ of the samples tested.

Refer to the test circuit diagram as shown in Figure C.1.

![Figure C.1 – Circuit of accelerated ageing test](image)

The test period is 1 000 hours unless otherwise specified. Times of 168 h, 366 h and 1 000 h are recommended as intervals of $V_N$ measurement. A single 1 000 hours only measurement is also acceptable.

After 1 000 hours' application, $V_N$ is measured for all samples after a period of 1 hour or more at room temperature. For each $V_N$ measurement, if the change ratio of $V_N$ exceeds ±10 % from the initial value, or the fuse is open, the sample is assumed as defective. Testing (voltage application) may be stopped if defectives are found.
C.4 Pass criteria

The change rate of the nominal varistor voltage does not exceed ± 10 % from the initial value.

It is not acceptable for any over-current fuse or relay to have operated.
Annex D
(informative)

Proposed test method for determination of mean time to failure (MTTF)

D.1 Sampling plans

Four sampling plans are shown in Table D.1, which are based on the confidence levels of 60 % and 90 %, and the permitted number of failures, C, of zero and one. Users can select which of the four plans to use.

<table>
<thead>
<tr>
<th>Life time in years</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life time in kh</td>
<td>44</td>
<td>88</td>
<td>132</td>
<td>176</td>
<td>264</td>
</tr>
<tr>
<td>MTTF (failure number /10^6h)</td>
<td>22.7</td>
<td>11.4</td>
<td>7.57</td>
<td>5.7</td>
<td>3.8</td>
</tr>
<tr>
<td>Failure rate (%/1000) level symbol</td>
<td>L-2.27</td>
<td>L-1.14</td>
<td>M-0.76</td>
<td>M-0.57</td>
<td>M-0.38</td>
</tr>
<tr>
<td>Confidence Level (%)</td>
<td>Permitted Number of failures C</td>
<td>Cumulative unit-hours (× 10^6) of M-level</td>
<td>Cumulative unit-hours (× 10^6) of the test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>0</td>
<td>0.0916</td>
<td>0.0404</td>
<td>0.0804</td>
<td>0.1205</td>
</tr>
<tr>
<td>60</td>
<td>1</td>
<td>0.202</td>
<td>0.089</td>
<td>0.1772</td>
<td>0.2658</td>
</tr>
<tr>
<td>90</td>
<td>0</td>
<td>0.230</td>
<td>0.1013</td>
<td>0.2018</td>
<td>0.3026</td>
</tr>
<tr>
<td>90</td>
<td>1</td>
<td>0.389</td>
<td>0.1714</td>
<td>0.3412</td>
<td>0.5118</td>
</tr>
</tbody>
</table>

* The cumulative unit-hours (× 10^6) of M-level are benchmarks for calculating the cumulative unit-hours (× 10^6) of the test and are for information only.

D.2 Total test hours

It is a common practice to carry out the MTTF test for 2 000 h in total.

D.3 Samples

The total number of samples to be tested may be either \( N_A \) or \( (N_{B1} + N_{B2}) \) according to the required life time in years or life time in kh listed in Table D.1.

\[
N_A = \frac{\text{[cumulative unit-hours (× 10^6) of the test selected from Table D.1]}}{2000} \quad (D.1)
\]

\[
N_{B1} = \frac{N_A}{3}, \quad N_{B2} = \frac{2}{3}N_A/AF \quad (D.2)
\]

where the sample \( N_A \) and \( N_{B1} \) are tested under normal rated stresses of the voltage and the temperature \((V_M\) and maximum operating temperature\), the sample \( N_{B2} \) are tested under the accelerated stresses of which the acceleration factor is \( AF \).

The initial varistor voltages of all of the samples to be tested shall differ by not more than 1 % from each other.

NOTE The determination of \( AF \) is under consideration.
Test set up

The voltage source shall apply a specified test voltage (± 0.5 %) on all of the samples. The current rating of the voltage source shall not limit the increasing of the sample current.

The temperature of test chambers shall be the specified value (± 1 K).

One current sensing resistor \( R_y \) is connected in series with each sample. The \( R_y \) is placed outside of the chamber (see Figure D.1a). The value of the \( R_y \) is so selected that the voltage across it is no more than 0.5 % of the test voltage. Figure D.1b is an alternative test circuit which is suitable for low voltage MOVs, in this circuit the leakage current is converted to voltage by operational amplifier A and resistor \( R_y \). The accuracy of voltmeters V1 and V2, and resistor \( R_y \) shall be 1 %.

![Figure D.1 - Test Circuit of MTTF](image)

NOTE The test circuit shown in Figure D.1b is based on the Virtual-Zero Principle of the operational amplifier (OA), which has a very large amplification factor (greater than 10 000 is common). If the output voltage of the OA with an amplification factor of 10 000 changes from 0 mV to 1 000 mV, the input voltage of the OA (V1) changes from 0 mV to 0.1 mV that can be regarded as 0. Therefore, the potential of the low terminal of the MOV in Figure D.1b can be regarded as “zero potential” or “virtual-zero point”. For example, when the current passing the MOV is 1 mA and \( R_y = 1 \, 000 \, \Omega \), the output voltage of OA (V2) is 1 mA \( \times 1 \, 000 \, \Omega = 1 \, 000 \, \text{mV} \), the low terminal potential of the MOV is 0.1 mV.

D.4 Intermediate measurements

The current passing the sample shall be measured at the test hours of 1, 4, 24, 96, 200, 500, 750, 1 000, 1 250, 1 500, 1 750, 2 000. If a steady increasing reading is observed, a tracking measurement of shorter interval shall be taken.

D.5 Failure criteria

The current passing a sample goes up steadily and beyond the specified multiple of the initial value (the current value measured at 1 h).

D.6 Acceptance criteria

The numbers of failure shall be not more than the values specified in Table D.1.
Bibliography


IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*


IEC 60617, *Graphical symbols for diagrams*

