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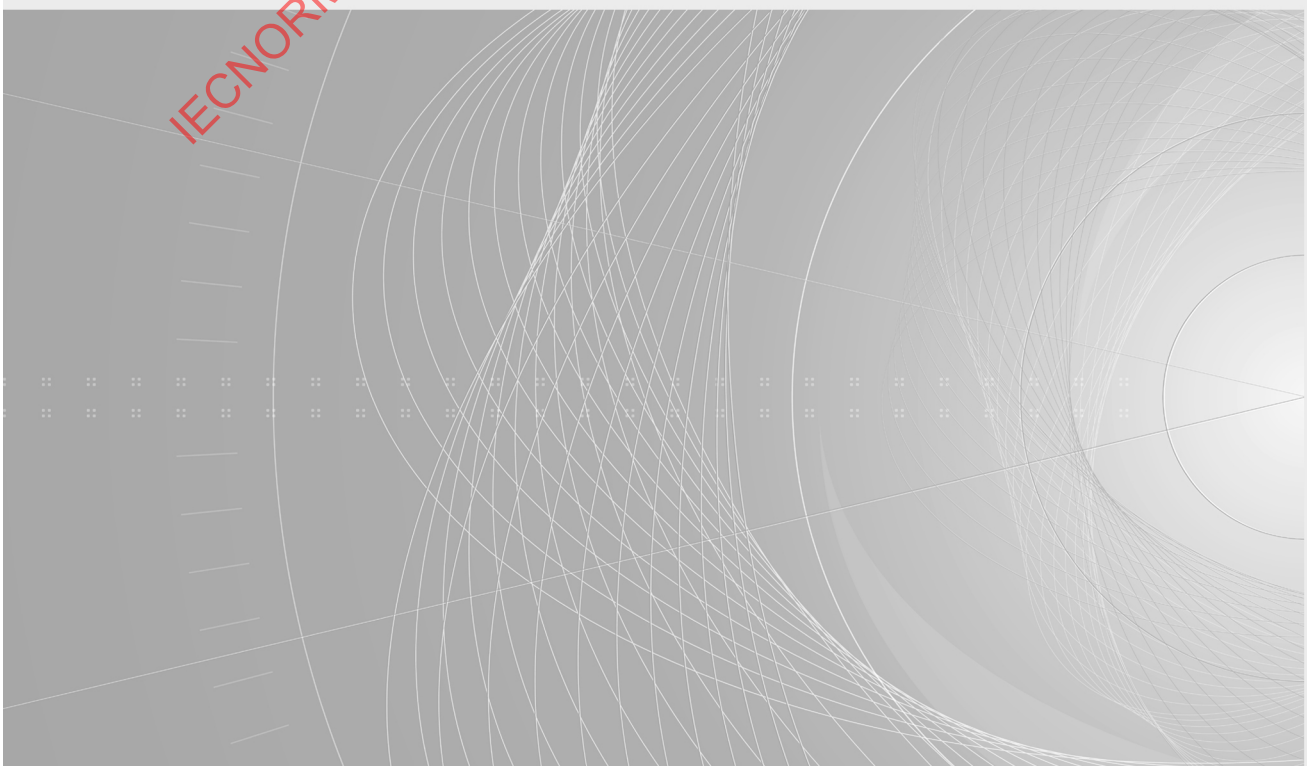
INTERNATIONAL STANDARD

Railway applications – DC surge arresters and voltage limiting devices – Part 2: Voltage limiting devices



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FOREWORD

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International Standard IEC 62848-2 has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This document is based on EN 50526-2:2014.

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

FDIS	Report on voting
9/2492/FDIS	9/2503/RVD

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.

A list of all parts in the IEC 62848 series, published under the general title *Railway applications – DC surge arresters and voltage limiting devices*, can be found on the IEC website.

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

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- withdrawn,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.

RAILWAY APPLICATIONS – DC SURGE ARRESTERS AND VOLTAGE LIMITING DEVICES –

Part 2: Voltage limiting devices

1 Scope

This document applies to Voltage Limiting Devices (VLDs) to be applied in DC traction systems in order to comply with protective provisions against electric shock from DC, and combined AC – DC voltages, in accordance with the IEC 62128 series, taking into account stray current provisions.

VLDs operate in such a way as to connect the track return circuit of DC railway systems to the earthing system or to conductive parts within the overhead contact line zone or current collector zone.

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

IEC 60085, *Electrical insulation – Thermal evaluation and designation*

IEC 60529:1989, *Degrees of protection provided by enclosures (IP Code)*

IEC 60850:2014, *Railway applications – Supply voltages of traction systems*

IEC 61643-311, *Components for low-voltage surge protective devices – Part 311: Performance requirements and test circuits for gas discharge tubes (GDT)*

IEC 61992-1:2006, *Railway applications – Fixed installations – DC switchgear – Part 1: General*
IEC 61992-1:2006/AMD1:2014

IEC 61992-7:2006 (all parts), *Railway applications – Fixed installations – DC switchgear – Part 7-x: Measurement, control and protection devices for specific use in d.c. traction systems*

IEC 62128-1:2013, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 1: Protective provisions against electric shock*

IEC 62128-3:2013, *Railway applications – Fixed installations – Electrical safety, earthing and the return circuit – Part 3: Mutual Interaction of a.c. and d.c. traction systems*

IEC 62497-1, *Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distances for all electrical and electronic equipment*

IEC 62498-2, *Railway applications – Environmental conditions for equipment – Part 2: Fixed electrical installations*

IEC 62848-1:2016, *Railway applications – DC surge arresters and voltage limiting devices – Part 1: Metal-oxide surge arresters without gaps*

ISO 4287:1997, *Geometrical Product Specifications (GPS) -Surface texture: Profile method – Terms, definitions and surface texture parameters*

ISO 4892-1, *Plastics – Methods of exposure to laboratory light sources – Part 1: General guidance*

ISO 4892-2, *Plastics – Methods of exposure to laboratory light sources – Part 2: Xenon-arc lamps*

ISO 4892-3, *Plastics – Methods of exposure to laboratory light sources – Part 3: Fluorescent UV lamps*

3 Terms and definitions

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

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
voltage-limiting device
VLD
protective device whose function is to prevent existence of an impermissible high touch voltage

[SOURCE: IEC 60050-811:2017, 811-29-41]

3.2
recoverable VLD
VLD that recovers after triggering

3.3
non-recoverable VLD
VLD remaining in its low resistance state permanently after triggering

3.4
welding shut spark gap
VLD which is triggered by electrical discharge across a gap causing a permanent short-circuit by welding shut of metallic parts

Note 1 to entry: Sometimes the term voltage fuse is used for this type of VLD.

3.5
rated current
I_r
<for a voltage-limiting device> maximum value of the direct current that may flow for the specified long term through the VLD in specified environmental conditions without exceeding the temperature rise limits

3.6
short time withstand current
I_W
current that a VLD can carry in closed status, during a specified short time under prescribed conditions of use and behaviour

3.7
making capacity
I_{NSS}
<of a switching device or a fuse> value of prospective making current that a switching device is capable of making at a stated voltage under prescribed conditions of use and behaviour

Note 1 to entry: The conditions to be prescribed are dealt with in the relevant specifications.

[SOURCE: IEC 60050-441:1984, 441-17-09, modified – The beginning of the Note has been changed.]

3.8
breaking capacity
<of a voltage-limiting device> maximum current that a recoverable VLD can interrupt at a stated voltage

3.9
leakage current
I_L
<of a voltage-limiting device> current which flows through the terminals when the VLD is in open status

3.10
lightning current impulse
$I_{imp\text{-}n}$
8/20 µs current impulse with limits on the adjustment of equipment such that the measured values are from 7 µs to 9 µs for the virtual front time and from 18 µs to 22 µs for the time to half value on the tail

Note 1 to entry: The time to half value on the tail is not critical and may have any tolerance during the residual voltage type tests.

[SOURCE: IEC 60099-4:2014, 3.31]

3.11
high current impulse
$I_{imp\text{-}high}$
peak value of discharge current having a 4/10 µs or 8/20 µs impulse shape which is used to test the ability of the VLD to withstand direct lightning strikes from the dielectric point of view

3.12
high charge impulse
$I_{imp\text{-}hc}$
crest value of a high charge impulse through the VLD with specified charge transfer Q and specified energy W/R in the specified time

Note 1 to entry: A crest value of a high charge impulse having a 10/350 µs waveshape is also a commonly known expression.

3.13
triggering voltage
U_T
voltage at which a VLD becomes conductive

3.14
nominal triggering voltage
U_{Tn}
voltage at which the VLD becomes conductive when a DC voltage is applied for long term

Note 1 to entry: This voltage is used to identify the VLD.

3.15
instantaneous triggering voltage
U_{Ti}
minimum triggering voltage at which the VLD becomes conductive shortly after its application

Note 1 to entry: A maximum delay of 5 ms is taken in this document.

3.16
non-triggering voltage
U_W
maximum voltage below which the VLD will not trigger for any duration of the applied voltage

3.17
residual voltage of a VLD
U_{res}
<of a voltage-limiting device> value of voltage that appears between the terminals of the VLD during the passage of a specified current

3.18
combined voltage
voltage having significant AC and DC components

3.19
response time
T_R
<of a voltage-limiting device> time between the application of a voltage until VLD becomes conductive

3.20
degree of protection
extent of protection provided by an enclosure against access to hazardous parts, against ingress of solid foreign objects and/or against ingress of water and verified by standardized test methods

[SOURCE: IEC 60529:1989, 3.3]

3.21
IP Code
coding system to indicate the degree of protection provided by an enclosure against access to hazardous parts, ingress of solid foreign objects, ingress of water and to give an additional information in connection with such protection

[SOURCE: IEC 60529:1989, 3.4]

4 Classes of VLD

This document identifies the properties and the technology of a VLD using the classes of VLD which are defined in Table 1.

Table 1 – Classes of voltage-limiting device

Class	Method for switching between the high and low resistance status	Auxiliary power supply necessary for normal operation	Polarity	Maximum response time T_R	Recoverable or not	Able to interrupt the current in the VLD
1	Welding shut of metallic parts	No	Bidirectional	5 ms	Can be recoverable in some conditions[a]	No
2.1	Triggering of thyristors	No	Unidirectional	5 ms (for voltages equal to or higher than U_{TI})	Yes	Passive at natural zero crossing of current
2.2	Triggering of thyristors	No	Bidirectional	5 ms (for voltages equal to or higher than U_{TI})	Yes	Passive at natural zero crossing of current
3.1	Contactor only	Yes	Bidirectional	Voltage dependent and not exceeding the limits given in IEC 62128-1:2013, 9.3.2.2 or IEC 62128-3:2013, 7.2 through 7.5	Yes	Yes
3.2	Contactor only	Yes	Bidirectional	Voltage dependent and not exceeding the limits given in IEC 62128-1:2013, 9.3.2.3, IEC 62128-3:2013, 7.6	Yes	Yes
3.3	Contactor only	Yes	Bidirectional	Specified by the manufacturer or the purchaser	Yes	Yes
4.1	Combination of thyristors and contactor	Yes	Bidirectional	For voltages up to U_{TI}, voltage dependent and not exceeding the limits given in IEC 62128-1:2013, 9.3.2.2 or IEC 62128-3:2013, 7.2 through 7.5. For voltages equal to or higher than U_{Ti} 5 ms.	Yes	Yes
4.2	Combination of thyristors and contactor	Yes	Bidirectional	For voltages up to U_{TI} , voltage dependent and not exceeding the limits given in IEC 62128-1:2013, 9.3.2.3, IEC 62128-3:2013, 7.6. For voltages equal to or higher than U_{Ti} 5 ms	Yes	Yes
4.3	Combination of thyristors and contactor	Yes	Bidirectional	Specified by the manufacturer or the purchaser	Yes	Yes

NOTE IEC 62128-1 defines two functionalities for VLDs, VLD-O and VLD-F. In this document a discrimination is not necessary.

[a] For transient low currents associated with low energy dissipation no welding shut may occur.

5 Characteristics and requirements of the VLDs

5.1 Marking

VLDs shall be identified by the following minimum information which shall appear on the rating plate (nameplate):

– manufacturer's name or trademark and manufacture type designation;

– class of VLD according to IEC 62848-2 (optional);
– rated current I_r in A;
– short time withstand current I_w in kA;
– nominal triggering voltage U_{Tn};
– year of manufacture;
– serial number.

The terminals of unidirectional devices shall be marked with the symbols + and -.

In case of small VLDs not having space for a rating plate with all information, the devices shall be marked with the manufacturer's name or trademark, the type designation and the nominal triggering voltage. The remaining information shall be given in a data-sheet.

5.2 Service requirements

5.2.1 Normal outdoor service conditions

VLDs which conform to this document shall be suitable for operation under the following normal service conditions:

– ambient temperature within the range of -40 °C to +40 °C;
– solar radiation lower than 1 120 W/m^2 as given in IEC 62498-2;
– altitude not exceeding 1 400 m (from Annex B in IEC 61992-1:2006);
– any pollution not exceeding PD 4 as given in IEC 62497-1.

The equipment shall be suitable for installation in the vicinity of a rail track on foundations designed so as to damp the main effects of the passage of the trains. Nevertheless, a limited vibration or limited shocks may affect the equipment, which shall be capable of operating satisfactorily when subjected to the following conventional accelerations separately applied:

– g_v: vertical acceleration:5 m/s^2;
– g_h: horizontal acceleration:5 m/s^2.

5.2.2 Normal indoor service conditions

VLDs which conform to this document shall be suitable for operation under the following normal service conditions:

– ambient temperature within the range of -5 °C to +40 °C (from Annex B in IEC 61992-1:2006);
– altitude not exceeding 1 400 m (from Annex B in IEC 61992-1:2006);
– any pollution not exceeding PD3 as given in IEC 62497-1.

5.2.3 Abnormal service conditions

The following are examples of abnormal service conditions which require special consideration in the manufacture or application of VLD and should be brought to the attention of the supplier:

– temperature in excess of +40 °C or below -5 °C for indoor installations or below -40 °C for outdoor installations;
– application at altitudes higher than 1 400 m; in this case the temperature-rise tests and dielectric tests (for VLDs inside a cabinet), carried out at laboratories at lower levels, shall take into account a correction in the temperature-rises and dielectric test values to be agreed between the involved parties;

– all excessive environmental conditions that may degrade insulating surface or mounting hardware: fumes, vapours dirt, salt spray or other conducting materials; moisture, humidity, dropping water or steam;
– explosive mixtures of dust, gases or fumes;
– special mechanical requirements (earthquakes, vibrations, high ice loads, high cantilever stresses);
– unusual transportation or storage;
– heat sources near the VLD.

5.3 General characteristics

The following characteristics shall be defined to identify each VLD:

– the class of VLD;
– if relevant, the auxiliary power supply voltage, with its tolerances.

The manufacturer shall specify whether the device is recoverable or non-recoverable at defined currents and durations.

5.4 Minimum requirements

5.4.1 Response time

A VLD shall become conductive in a time not greater than the specified response time depending on the applied voltage. The response time of the VLD shall be stated as function of the applied voltage.

For VLDs of Classes 2, 3 and 4 the triggering may be delayed intentionally in order that unwanted triggering will not take place due to switching transients and similar phenomena.

5.4.2 Additional requirements for VLDs of Class 1

If gas discharge tubes are used in VLDs, they shall comply with IEC 61643-311.

5.4.3 Additional requirements for VLDs of Classes 3 and 4

The VLD shall not open if the current through it exceeds its breaking capacity.

The VLD shall open at an adjustable time after it has closed unless the breaking capacity is exceeded. The range of variation of this time setting shall be specified.

If the VLD re-opens automatically and then re-triggers, after a set number of operations in a given time interval either:

– it shall be prevented from re-opening and a warning or an alarm shall be signalled; or
– only a warning or an alarm shall be signalled.

The VLD shall provide the possibility to be manually operated at site.

If the VLD requires a power supply for operation, the VLD shall be provided with a failsafe function such that it turns into the conductive state in case of failure of the power supply.

5.5 Electrical characteristics and thermal rating

In addition to the general characteristics indicated in 5.3, the manufacturer shall state the following electrical characteristics of each type of VLD if applicable. In case of adjustable parameters, the setting ranges shall be stated:

- for VLDs of Classes 3 and 4, the nominal voltages of the electric traction systems in which the VLDs are to be installed;
- the nominal triggering voltage U_{Tn};
- the non-triggering voltage U_W;
- the maximum response time as function of the voltage;
- the instantaneous triggering voltage U_{Ti};
- the maximum leakage current I_L at U_W, when the VLD is in its non-conducting state;
- the short-time withstand current I_W and the duration of the current flow;
- the rated current I_r;
- the maximum residual voltage at the short-time withstand current;
- the maximum residual voltage at the rated current;
- the conditions in which the VLD is recoverable;
- the lightning current impulse, or sequence of lightning impulses, which the VLD can withstand in the specified test conditions;
- for VLDs of Classes 3 and 4, the breaking capacity, determined in accordance with 6.8;
- for VLDs of Classes 3 and 4, the making capacity, in accordance with 6.4.3.

5.6 Protection of VLDs against lightning

If requested by the purchaser the VLD shall withstand the effects of the specified lightning surges. The requirements can be different according to the class of VLD. If necessary a surge arrester, according to IEC 62848-1, may be integrated into the VLD.

5.7 Command and control (Classes 3 and 4 only)

5.7.1 Local control

On the cabinet, the following characteristics and measuring indications should be foreseen to provide a monitoring and control locally:

a) the instantaneous DC voltage across the terminals of the VLD;
b) the instantaneous DC current flowing through the device;
c) the operating state of the VLD (open or closed);
d) a push or touch button to manually command the closing and the opening of the device;
e) a push or touch button to start a manual self-test (if possible);
f) access to recorded data as given in 5.7.3, the activations, warnings, alarms, etc., in the past and stored in a register file (if applicable).

NOTE 1 Conventionally the voltage in item a) is the voltage on the rails relative to earth. This means that if the rail potential is positive the figure displayed is positive.

NOTE 2 The manual self-test procedure in item e) will trigger the thyristor and will also close the contactor for a limited time (typically 1 s).

5.7.2 Remote signalling

If remote signalling is requested at least the following signals shall be offered:

a) contactor open;
b) contactor closed;
c) warnings, alarms.

Further information may be agreed between purchaser and manufacturer such as current or voltage.

5.7.3 Operation and alarm recordings

Recordings are optional. A list of the recordings that can be stored is indicated as an example in the following:

a) operation recordings:
   1) the status of the VLD;
   2) the total number of operations (1 operation = 1 x close + 1 x open);
b) alarm recordings with time stamp:
   1) interruption of the auxiliary power supply of the device;
   2) device in closed position state during a long period of time, eventually parameterised in 2 or more levels;
   3) internal operation faults: an internal self-diagnostic function controls the correct functioning of closing and opening the device; in case of an internal fault, an alarm is created;
   4) the exceeding of a given frequency of operations, eventually parameterised in 2 or more levels.

6 Type tests

6.1 General

The characteristics of the VLD shall be verified by type tests.

Type tests shall be carried out as indicated in Table 2. All tests are mandatory unless stated otherwise.

Once made, these type tests need not be repeated unless the design is changed so as to modify the VLD performance. In such a case only the relevant tests need be repeated.

For all the tests the ambient temperature shall be recorded.

An alternating current test is foreseen, if requested, because even if the VLD is not specified to conduct AC, the wave-form of the current in the VLD can flow in both directions due to ripple currents from the substations, tripping of the feeders during short-circuits or earth faults in the DC power system, transient effects due to switching of the current by the trains, regenerative braking currents of the trains or AC currents injected by AC power systems.

Table 2 – Type tests

Tests	Classes of VLD	Subclause
Nominal triggering voltage and non-triggering voltage:		6.2
Procedure for welding shut spark gap VLDs	1	6.2.1
Procedure for thyristor type VLDs	2	6.2.2
Procedure for mechanical switching VLDs and for combined thyristor with mechanical switching devices	3, 4	6.2.3
Leakage current	1, 2, 4	6.3
DC current withstand	All	6.4
Procedure to determine long-term current	All	6.4.2
Procedure to determine short time withstand	All	6.4.3
AC current withstand characteristics	All (Optional)	6.5
Response time characteristics	All	6.6
Lightning current withstand characteristics for VLDs exposed to direct lightning strikes	All	6.7
Recovery test	3, 4	6.8
Reverse voltage test	2.1	6.9
Dielectric test	3, 4	6.10
Degree of protection	All	6.11
Environmental tests for outdoor equipment	All	6.12
Determination of minimum current for safe short circuiting of Class 1 VLDs	1	6.13

The required number of samples and their conditions are specified in the individual subclauses.

VLDs are considered to be of the same design if the following conditions are fulfilled:

– they are based on the same components resulting in the same performance characteristics;

– they are characterised by similar construction resulting in equivalent heat dissipation conditions whereas mounting or arrangement on the supporting structure may differ.

If not specified otherwise in the individual clauses, tests shall be carried out on the complete VLD as used in service, i.e. with surge arrester in parallel, if applicable.

6.2 Nominal triggering voltage U_{Tn} and non-triggering voltage U_W

6.2.1 Procedure for welding shut spark gap VLDs (Class 1)

6.2.1.1 General

This test shall be carried out on 3 samples of VLD in dry condition at 20 °C ± 15 °C.

6.2.1.2 Non-triggering voltage test

The non-triggering voltage U_W of the VLD shall be applied for a duration greater than 300 s. This test shall be carried out at both polarities. The non-triggering voltage U_W should typically be 80 % of U_{Tn} as given in Table A.1 (see Annex A).

a) Pass criteria

No trigger shall occur.

6.2.1.3 Triggering voltage test

The test samples are connected to a DC voltage generator with a current ≥ 1 mA after triggering but such that the device recovers after the trigger.

NOTE For VLD class 1 the nominal triggering voltage and the instantaneous triggering voltage are equal.

The test samples shall be further tested by applying a DC voltage increasing from 0 V with a rise du/dt within 100 V/s up to 2 000 V/s according to IEC 61643-311 until the test sample VLD triggers.

The procedure shall be repeated 5 times per sample for positive and negative polarity within a period of 15 min.

The value of the trigger voltage shall be recorded.

a) Pass criteria

All measured triggering voltages are below or equal to the nominal triggering voltage U_{Tn}, no mechanical destructions occurred and the VLD will not trigger for any duration when non-triggering voltage U_W is applied. The nominal triggering voltage U_{Tn} should be in accordance with Table A.1.

6.2.2 Procedure for thyristor type VLDs (Class2)

6.2.2.1 General

This test shall be carried out on 3 samples of VLD in dry condition at 20 °C ± 15 °C. The test shall be carried out at both polarities for bidirectional VLDs.

6.2.2.2 Non-triggering voltage test

The non-triggering voltage of the VLD shall be applied for a duration greater than 300 s. The non-triggering voltage U_W should be 80 % of U_{Tn} as given in Table A.1.

a) Pass criteria

No trigger shall occur.

6.2.2.3 Triggering and instantaneous triggering voltage test

The test samples shall be further tested by applying a DC voltage increasing from 0 V with a rise to the:

– instantaneous triggering voltage within 5 ms;
– triggering voltage(s) according to a duration which is specified for the triggering voltage,

until the test sample VLD triggers.

The test of the triggering voltage(s) may be omitted, if the nominal triggering voltage coincides with the instantaneous triggering voltage.

The procedure shall be repeated 5 times per sample for positive and negative polarity within a period of 15 min. The value of the instantaneous triggering voltage and the triggering voltage(s) shall be recorded.

a) Pass criteria

All measured triggering voltages are below or equal to the specified nominal triggering voltage U_{Tn}. The nominal triggering voltage U_{Tn} should be in accordance with Table A.1.

6.2.3 Procedure for mechanical switching VLDs and for combined thyristors with mechanical switching devices VLDs (Class 3 and Class 4)

6.2.3.1 General

This test shall be carried out on 1 sample of VLD in dry condition at 20 °C ± 15 °C. The test shall be carried out at both polarities for bidirectional VLDs.

6.2.3.2 Non-triggering voltage test

The non-triggering voltage of the VLD shall be applied for a duration greater than 300 s. The non-triggering voltage U_W should be 80 % of U_{Tn} as given in Table A.1.

a) Pass criteria

No trigger shall occur.

6.2.3.3 Triggering and instantaneous triggering voltage test

The test samples shall be further tested by applying a DC voltage increasing from 0 V with a rise to the:

– instantaneous triggering voltage within 5 ms;
– triggering voltage(s) according to a duration which is specified for the triggering voltage until the test sample VLD triggers.

The procedure shall be repeated 5 times per sample for positive and negative polarity within a period of 15 min. The value of the instantaneous triggering voltage and the triggering voltage(s) shall be recorded.

a) Pass criteria

All measured triggering voltages are below or equal to the specified instantaneous triggering voltage U_{TI} and the nominal triggering voltage(s) U_{Tn}. The instantaneous triggering voltage U_{TI} should be in accordance with Table A.2. The nominal triggering voltage U_{Tn} shall be in accordance with Table A.1.

6.3 Leakage current

This test shall be carried out on one sample of VLD in dry condition at a temperature of 20 °C ± 15 °C for minimum duration of 1 min.

A DC voltage equal to the non-triggering voltage U_W of the VLD shall be applied and the leakage current through the VLD shall be recorded. This test shall be carried out at both polarities.

a) Pass criteria

The leakage current for each polarity should be within the specified limits of Table A.5.

6.4 DC current withstand

6.4.1 General

The test is intended to check that the device withstands the rated current.

6.4.2 DC rated current test

This test shall be carried out on one VLD in dry condition at an ambient temperature of 20 °C ± 15 °C.

The DC rated current shall be applied to the VLD for a time duration of 60 min. Values of DC rated current should be in the range of Table A.3.

The test sample shall be mounted and connected with connecting cables of equivalent cross-section such that the current density of 1,5 A/mm² of copper or equivalent is not exceeded based on the rated current.

The temperature of the device and its terminal temperatures shall be measured by at least 3 thermo elements or equivalent temperature sensors, one at each terminal and at least one on the surface of the device. Good thermal conductivity shall be ensured between the sensor and the surface of the VLD. The position of the temperature sensors shall be noted in the test report.

The current, residual voltage and temperatures shall be monitored during the test and plotted versus time in a diagram.

For VLDs of Classes 1, 3 and 4 the test current may also be an AC current with an RMS equal to the specified DC test current.

The test comprises:

– select polarity;

– apply the DC rated current value for 60 min after having triggered the device;

– for recoverable types, cool down to ambient temperature and determine the nominal triggering voltage $U_{T\,n}$ and the non-triggering voltage U_W of the test sample according to 6.2.

Bidirectional VLDs shall be tested at both polarities unless they are of symmetrical design. VLDs of Class 2.2 shall be always tested at both polarities.

a) Pass criteria for non-recoverable device

– no interruption of current during test;

– measured temperature rise at the surface of the device, if from insulation material, is equal or less than the temperature rise limits of the insulation class of the used insulation material (refer to IEC 60085);

– the resistance between the terminals of the device is less than 10 mΩ, measured with a test equipment having a test current of at least 10 A;

– no mechanical damage.

b) Pass criteria for recoverable device

– no interruption of current during test;

– measured temperature rise at the surface of the device which, if from insulation material, is equal or less than the temperature rise limits of the insulation class of the used insulation material;

– measured temperature rise of the terminals which is less than 75 K for bolted connections of bare copper, aluminium and copper alloys or less than 100 K for bolted connections of silver or nickel-plated terminals (limits according to IEC 61992-1:2006, Table 5);

– all measured trigger voltages are within the specified limits;

– the maximum RMS value of the residual voltage recorded in the tests is less than the specified DC residual voltage at rated current;

– no mechanical damage;

– the device is restored to its non-conducting state when the test current is switched off.

6.4.3 Short time withstand current test

This test shall be carried out on one sample of VLD in dry condition at a temperature of 20 °C ± 15 °C. Values of short time withstand current should be in accordance with the making capacity of Table A.6 in combination with Table A.4. If a manufacturer states for a VLD different short-time withstand currents and durations for recoverable behavior and for non-recoverable behavior the tests may be carried out on separate samples. The current and the residual voltage shall be recorded during the test at an appropriate sampling rate.

The specific energy shall be calculated and given for information.

The test sequence comprises:

– select polarity;

– apply the specified current for the specified duration after having triggered the device; for Class 1 VLDs the test current may be also an AC current with an RMS value equal to the specified DC test current if the duration foreseen for the current is higher than 50 ms;

– alternatively apply a current waveform for a duration between 8 ms and 10 ms with equivalent specific energy (kA^2s) as the specified short time withstand current;

– for recoverable types cool down to ambient temperature and determine nominal triggering voltage U_{Tn} and the non-triggering voltage U_W of the test sample according to 6.2 or the response time characteristics according to 6.6.

Bidirectional VLDs shall be tested at both polarities unless they are of symmetrical design. VLDs of Class 2.2 shall be always tested at both polarities.

a) Pass criteria for non-recoverable device

– the resistance between the terminals of the device is less than 10 mΩ, measured with a test current of at least 10 A;

– no interruption of current during test;

– the maximum RMS value of the residual voltage evaluated at intervals of the fundamental power frequency is less than or equal to the specified DC residual voltage at the short time withstand current;

– no mechanical damage shall occur that has influence on the current carrying capacity of the VLD;

– no flames after 2 min.

b) Pass criteria for recoverable device

– no interruption of current during test;

– residual voltage (RMS value) is less than or equal to the specified DC residual voltage at the short time withstand current;

– the measured trigger voltages are within the specified limits;

– no mechanical damage;

– the device is restored to its non-conducting state when the test current is reduced to zero.

6.5 AC current withstand characteristics (optional)

This test shall be carried out on one sample of VLD in dry condition at a temperature of 20 °C ± 15 °C. Apply AC or DC voltage that triggers the VLD. After triggering, apply the specified AC current value for the specified duration. The RMS value of the residual voltage shall be measured and reported. For recoverable types cool down to ambient temperature and determine nominal triggering voltage U_{Tn} and the non-triggering voltage U_W of the test sample according to 6.2 or the response time characteristics according to 6.6.

If the test in 6.4.2 is performed with AC current this test need not be performed.

a) Pass criteria for non-recoverable device

– the resistance between the terminals of the device is less than 10 mΩ, measured with a test current of at least 10 A;
– residual voltage (RMS value) is less than or equal to the specified AC residual voltage at the short time AC withstand current;
– no mechanical damage shall occur that has influence on the current carrying capacity of the VLD;
– no flames after 2 min.

b) Pass criteria for recoverable device

– residual voltage (RMS value) is less than or equal to the specified AC residual voltage at the short time AC withstand current;
– the measured trigger voltages are within the specified limits;
– no mechanical damage;
– the device is restored to its non-conducting state when the test current is reduced to zero.

6.6 Response time characteristics

6.6.1 Response time for DC voltage

This test shall be carried out on one sample of VLD in dry condition at a temperature of 20 °C ± 15 °C.

The device shall be tested using a test circuit as given in Figure 1, using a DC source U.

For all classes, the test shall be carried out at the DC voltages taken from Table 3, excluding all the values lower than or equal to U_{Tn}.

Table 3 – Maximum response time as a function of DC voltages

Voltage V	Maximum response time s
870	0,02
520	0,2
360	0,6
160	1
150	300

For VLDs of Classes 3.1, 3.2, 4.1 and 4.2, these values of the response time refer to the maximum time duration of the indicated voltage complying with IEC 62128-1:2013, Table 6. For VLDs of Classes 1, 2, 3.3 and 4.3, other values of response time may be applicable.

The voltage after triggering is not relevant for the response time test.

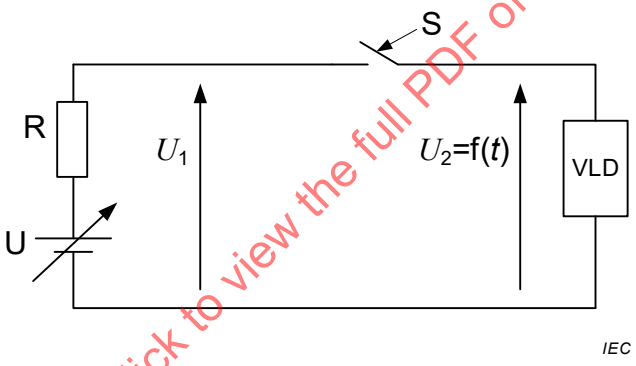
The test sequence comprises:

– select polarity;
– adjust the test voltage U_1 to the highest of the specified values;
– turn on the switch S, which is preferably of a bounce-free type;
– measure the response time T_R: from the first rise of voltage U_2 until breakdown of voltage U_2 (see Figure 2).
– repeat this test with the other specified voltages; measure the respective response times T_R;
– plot the different voltages U_1 versus response times T_R in a diagram according to Figure 3.

Bidirectional VLDs shall be tested at both polarities unless they are of symmetrical design.

a) Pass criteria

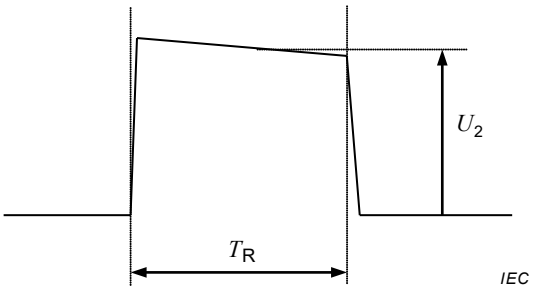
All measured response times are within the specified limits.



Key

VLD voltage limiting device
R resistor to limit the current.
S switch
U test voltage source
U_1 test voltage
U_2 measured voltage

Figure 1 – Test circuit for testing of response time



Key

T_R response time

U_2 measured voltage

Figure 2 – T_R evaluation

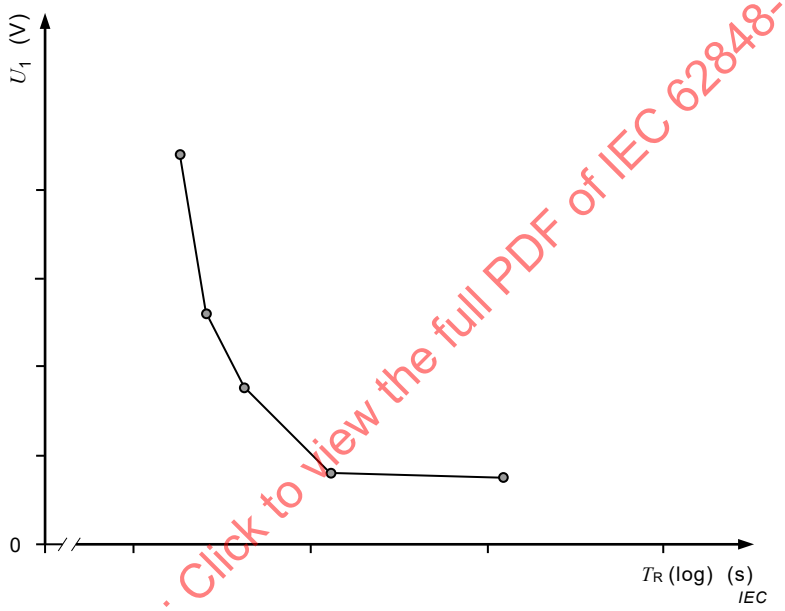


Figure 3 – Response time characteristic

For VLDs of Classes 3.2 and 4.2, the response time shall be measured additionally at the voltages given in IEC 62128-1:2013, 9.3.2.3 and IEC 62128-3:2013, 7.6 as applicable.

6.6.2 Response time for combined AC-DC voltage

This test applies only to bi-directional VLDs. It shall be carried out on one sample of VLD in dry condition at a temperature of 20 °C ± 15 °C.

The device shall be tested using a test circuit as given in Figure 4, using a combined AC-DC source U. The AC source has a frequency of the supply voltage of the AC traction system according to IEC 60850 and the frequency shall be noted.

The test shall be carried out at the combined voltages given in Table 4 except voltages lower than or equal to U_{Tn}.

Table 4 – Response time for combined AC-DC voltages

AC voltage V	DC voltage V	Maximum response time according to IEC 62128-3:2013 s
700	120	0,1
60	625	0,1
560	120	0,2
60	520	0,2
60	85	300
35	120	300
8	60	300[a]
25	35	300[a]

[a] For depots and workshop areas only permanent touch voltages are specified in the IEC 62128 series. For testing a maximum duration of 300 s is applied.

The test sequence comprises:

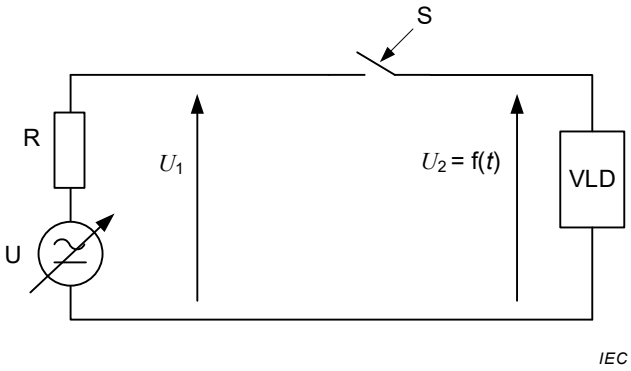
– select polarity of the DC part;
– adjust the test voltage pairs to the highest of the specified values;
– turn on the switch S, which is preferably of a bounce-free type;
– measure the response time T_R: from the first rise of voltage U_2 until breakdown of voltage U_2 (see Figure 5);
– repeat this test with the other specified voltage pairs; measure the respective response times T_R;
– make a table with the applied voltage pairs and the recorded response time.

The test shall be performed at both polarities of the DC part.

a) Pass criteria

All measured response times are within the specified limits.

For VLDs of Classes 3.2 and 4.2, the response time shall be measured additionally at the voltages given in IEC 62128-1:2013, 9.3.2.3 and IEC 62128-3:2013, 7.6 as applicable.



Key

VLD voltage limiting device

R resistor to limit the current.

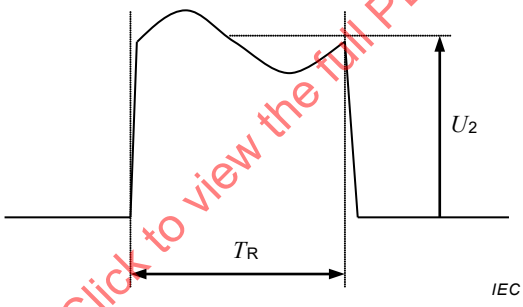
S switch

U test voltage source

U_1 test voltage

U_2 measured voltage

Figure 4 – Test circuit for testing of response time T_R for combined AC-DC voltage



Key

T_R response time

U_2 measured voltage

Figure 5 – Evaluation of response time T_R for combined AC-DC voltage

6.7 Lightning current impulse withstand characteristics for VLDs exposed to direct lightning strikes

The test procedure related to the determination of lightning current impulse withstand characteristics of the VLD is described in this subclause. It is intended to check that the device will withstand direct lightning surges.

The procedure described shall be applied to one sample of the VLD in dry condition at a temperature of 20 °C ± 15 °C. The test voltages are to be applied terminal to terminal of the VLD.

The test sequence comprises:

– select polarity;

– determine nominal triggering voltage U_{Tn} and the non-triggering voltage U_W of the test sample as initial measurement;

– apply one lightning current impulse, I_{imp-n}, according to Table A.7 wave 8/20 µs; measure the residual voltage;
– apply one high current impulse, $I_{imp-high}$, wave 8/20 µs or 4/10 µs specified in Table A.8;
– cool down to ambient temperature;
– apply one high charge impulse I_{imp-hc} specified in Table A.9 or Table A.11 and Table A.12;
– cool down to ambient temperature;
– apply one lightning current impulse, I_{imp-n} wave 8/20 µs; measure the residual voltage;
– determine nominal triggering voltage U_{Tn} and the non-triggering voltage U_W of the test sample;
– determine DC leakage current for Classes 2,3,4.

The test shall be performed at both polarities.

For the lightning current impulse the limits on the adjustment of equipment shall be such that the measured values are from 7 µs to 9 µs for the virtual front time and from 18 µs to 22 µs for the time to half value on the tail.

The high charge impulse shall either have a wave shape of 10/350 µs or shall have an approximately sinusoidal shape with a duration within 200 µs and 230 µs. Time duration is counted where the instantaneous value of the impulse current is greater than 5 % of its peak value.

NOTE A description is available in IEC 60099-4:2014, 8.5 for relationship.

a) Pass criteria (Class 1 non-recoverable)

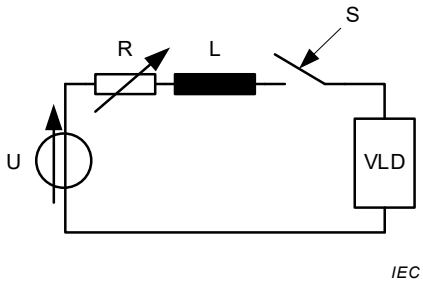
– the resistance between the terminals of the device is less than 10 mΩ, measured with a test current of at least 10 A;
– no flashover;
– no mechanical damage shall occur that has influence on the current carrying capacity of the VLD.

b) Pass criteria (Class 1 recoverable, Classes 2, 3, 4)

– all measured trigger voltages are within the specified limits;
– all measured leakage currents are within the specified limits (not applicable for Class 1);
– no flashover;
– measured residual voltages at lightning current impulse are not higher than the specified value and did not change by more than 5 % (not applicable for Class 1);
– no mechanical damage.

6.8 Recovery voltage test (Classes 3, 4)

This test shall be carried out on one sample of VLD in dry condition at a temperature of 20 °C ± 15 °C. Figure 6 shows the test assembly. The test arrangement shall consist of an inductor and a resistor in series with the VLD, and a test voltage source U, which is a value higher than the instantaneous triggering voltage U_{Ti}. The resistor R shall be such that the current flowing in the circuit equals the specified breaking capacity as given in Table A.6 (see Annex A). The inductor L shall be selected so that the time constant of the complete circuit is 7 ms ± 1 ms. The current in the VLD and the voltage across the contacts of the VLD shall be recorded versus time, using a suitable sampling rate. The results shall be reported. The energy dissipated in the VLD shall be calculated and reported.



Key

VLD voltage limiting device

R resistor to limit the current to the specified breaking capacity

S switch

L inductor to set the time-constant of the circuit

U test voltage source

Figure 6 – Circuit for the recovery voltage test

The test sequence comprises:

– the value of the resistor R is adjusted in such a way as to set the current at the specified value to be switched off;
– the value of inductor L is selected in such a way that the time constant of the complete circuit is 7 ms ± 1 ms;
– the test voltage is applied to the VLD by turning on the switch S and then the VLD closes automatically;
– thereafter the VLD is opened either automatically or under manual control: current through and voltage across the VLD are recorded;
– the switch S is then open and the test is concluded.

The test shall be repeated with reverse polarity.

a) Pass criteria

– VLD breaks the test current;
– no re-ignition after current zero.

6.9 Reverse voltage test (Class 2.1)

This test is applicable for unidirectional devices, only.

The test sequence comprises:

– select triggered polarity;
– determine nominal triggering voltage U_{Tn} and the non-triggering voltage U_W of the test sample at 20 °C ± 15 °C as initial measurement;
– apply specified permanent DC voltage for 30 min to the terminals of the device in reverse direction;
– apply specified short time DC voltage during the specified time to the terminals of the device in reverse direction;
– determine nominal triggering voltage U_{Tn} and the non-triggering voltage U_W of the test sample at 20 °C ± 15 °C.

a) Pass criteria

– no triggering in the reverse direction;
– all measured trigger voltages are within the specified limits;
– no mechanical damage.

6.10 Dielectric tests for panel type voltage limiting devices (Classes 3 and 4)

6.10.1 Test conditions

The panel to be tested shall be mounted complete as in normal service.

The test voltage specified shall be applied by connecting the conductor from the return circuit to the high-voltage terminal of the test supply. The earth conductor of the main circuit and the auxiliary circuits shall be connected to the frame and to the earth terminal of the test supply. The test shall be repeated with the earth conductor energised and the conductor to the return circuit to earth.

The dielectric test shall be made with mechanical short circuiting devices in open position.

Components not suitable to withstand the dielectric tests as surge arresters or voltage transducers shall be disconnected, earthed, shorted out or removed, as applicable, before testing. This equipment shall be separately tested in accordance with the applicable product standard.

6.10.2 Power-frequency voltage withstand test

The test voltages correspond to Max $\{\frac{U_{max3} \times 1{,}15}{\sqrt{2}}$; 2 000 V$\}$ in which U_{max3} are the overvoltage values given in Table A.1 of IEC 60850:2014. The test voltage shall be reached, from 0 V to the specified level, in 5 s and maintained for 60 s.

The test shall be carried out using a test voltage in the range of frequency between 45 Hz and 65 Hz of approximately sinusoidal form (see IEC 60060-1).

Equipment intended to be installed indoors shall be tested in dry conditions; equipment intended to be installed outdoors shall be tested in wet conditions as a type test and in dry conditions as a routine test.

The power frequency voltage test value for auxiliary and control circuits shall be 2 000 V. Lower test voltages may be agreed between purchaser and supplier.

a) Pass criteria

No flashover.

6.11 Degree of protection of enclosures

For devices having a given degree of protection higher than IP00 the following tests apply as type tests.

General requirements for the tests shall comply with Clause 11 of IEC 60529:1989.

The tests to verify the degree of protection indicated by the first numeral shall be performed in accordance with the requirements specified in Clause 12 of IEC 60529:1989 for protection against access to hazardous parts.

The tests to verify the degree of protection indicated by the second numeral shall be performed in accordance with the requirements specified in Clause 14 of IEC 60529:1989 for protection against water.

6.12 Environmental tests for outdoor equipment

Three specimens of housing materials shall be selected for this test (with markings included, if applicable).

The insulator housing shall be subjected to a 1 000 h UV light test using one of the following test methods.

a) xenon-arc methods: ISO 4892-1 and ISO 4892-2 using method “A” without dark periods:
   1) standard spray cycle;
   2) black-standard/black panel temperature of 65 °C;
   3) an irradiance of around 60 W/m²;
b) fluorescent UV Method: ISO 4892-1 and ISO 4892-3, using type “I” fluorescent UV lamp;
   1) exposure method 2.

Only tests with simultaneous water spraying and UV radiation are acceptable.

Markings on the housing, if any, shall be directly exposed to UV light.

a) Pass criteria

After the test, markings on housing material shall still be legible; surface degradations such as cracks and blisters are not permitted.

In case of doubt concerning such degradation, two surface roughness measurements shall be made on each of the three specimens. The crack depth, Rz as defined in ISO 4287, shall be measured along a sampling length of at least 2,5 mm. Rz shall not exceed 0,1 mm.

NOTE ISO 3274 gives details of surface roughness measurement instruments.

6.13 Determination of minimum current for safe short circuiting of Class 1 VLDs

For Class 1 VLDs the welding shut characteristic with a resistance of less than 10 mΩ at minimum current shall be verified.

The test shall be carried out on one sample of VLD in dry condition at a temperature of 20 °C ± 15 °C.

If a manufacturer states for a VLD different current-time characteristics the test shall be carried out for each parameter.

Preferred time and current characteristics are given in Table A.10.

The test sequence comprises:

– the test samples are connected to a DC voltage generator with an open circuit voltage equal to or higher than the triggering voltage of the VLD;
– the specified minimum current-time characteristic according to Table A.10 should be applied;
– the current, residual voltage and temperatures shall be monitored during the test and plotted versus time in a diagram.