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Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

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SUPERSEDES DOCUMENTS:
37/493/NP, 37/496/RVN

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SECRETARIAT: United States of America		SECRETARY: Mr Austen Rau
OF INTEREST TO THE FOLLOWING COMMITTEES: TC 36		HORIZONTAL FUNCTION(S):
ASPECTS CONCERNED: Electricity transmission and distribution		

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TITLE:

Surge Arresters - Part 11: Metal-oxide Surge Arresters to Protect Power Line Insulation

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

Surge Arresters - Part 11: Metal-oxide Surge Arresters to Protect Power Line Insulation

FOREWORD

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International Standard IEC/IEEE 60099-11 has been prepared by IEC technical committee 37: Surge arresters, in cooperation with Working Group 3.3.11 of the IEEE PES Surge Protective Devices Committee (SPDC), under the IEC/IEEE Dual Logo Agreement.

This publication is published as an IEC/IEEE dual logo standard.

International Standard IEC/IEEE 60099-11 has been prepared by IEC Technical Committee 37 and IEEE Surge Protective Devices Committee of the Power & Engineering Society.

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

FDIS	Report on voting
37/XX/FDIS	37/XX/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.

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

A list of all parts of IEC/IEEE 60099 series, under the general title *Surge arresters*, can be found on the IEC website.

IEC Technical Committee 37 and IEEE Surge Protective Devices Committee have 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.

INTRODUCTION

This part of IEC 60099 applies to line surge arresters (LSA) that may be Non-Gapped Line Arresters (NGLA) or Externally Gapped Line Arresters (EGLA) for use on transmission and distribution power lines with system voltages > 1kV a.c.

NOTE At this time, insufficient information is available for LSAs used on d.c. systems.

This type of surge arrester is connected directly in parallel with an insulator assembly. It's main purpose is to protect the parallel-connected insulator assembly from lightning surge or switching surge over-voltages.

EGLA comprises a series varistor unit (SVU), made up from non-linear metal-oxide resistors, encapsulated in a polymer or porcelain housing, and an external series gap (see [Figure 1](#)).

The external series gap should spark over only due to fast-front over-voltages. The gap should withstand all power-frequency and slow-front over-voltages occurring on the system.

In the event of SVU failure, the external series gap should be able to isolate the SVU from the system.

NGLA comprises a varistor unit (VU), made up from non-linear metal-oxide resistors encapsulated in a polymer or porcelain housing (see [Figure 1](#)). It is installed along with a disconnecting device if it is rendered a short circuit from an overload.

For unshielded or inadequately shielded lines, LSAs may experience higher charge transfer and current stresses due to lightning compared to LSAs installed on shielded or properly shielded lines. Under such conditions of unshielded or inadequately shielded lines, a careful review of the minimum required charge transfer ratings is necessary.

On lines with $U_s > 245$ kV, where the LSA is used for switching surge control, the energy levels may also be higher due to the charge levels attained during a switching event. In these cases higher charge or energy rated LSAs may be needed.

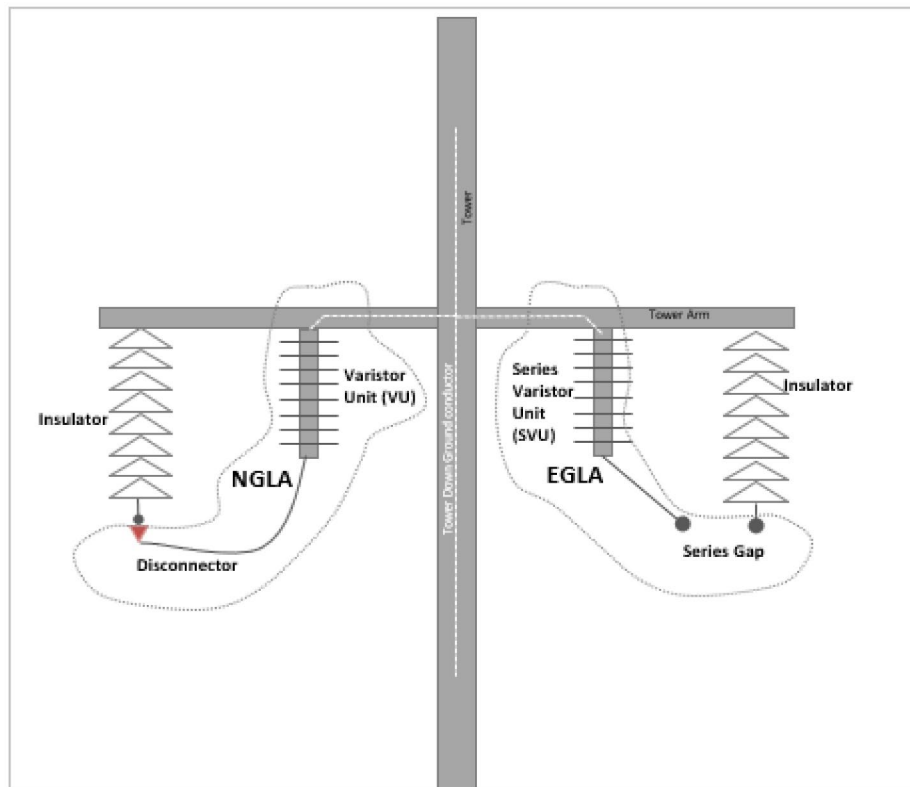


Figure 1 – Representative examples of NGLA and EGLA showing similar configurations

1 Scope

This part of IEC/IEEE 60099 covers metal-oxide line surge arresters (LSA) that may be Non-Gapped Line Arresters (NGLA) or Externally Gapped Line Arresters (EGLA) for use on transmission and distribution power lines with system voltages > 1kV a.c., to mainly protect insulator assemblies from lightning-caused flashovers.

1.1 Purpose

To define tests that demonstrate that the line surge arrester (LSA) can survive the rigors of reasonable environmental conditions and system phenomena while protecting equipment and/or the system from damaging overvoltages caused by lightning, switching, and other system disturbances.

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.

ISO 3274, *Geometrical Product Specifications (GPS) — Surface texture: Profile method — Nominal characteristics of contact (stylus) instruments*

ISO 4287, *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 sources*

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

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

IEC 60060-2:2010, *High-voltage test techniques - Part 2: Measuring systems*

IEC 60068-2-11:2021, *Environmental testing - Part 2-11: Tests - Test Ka: Salt mist*

IEC 60068-2-14, *Environmental testing - Part 2-14: Tests - Test N: Change of temperature*

IEC 60068-2-14, *Environmental testing - Part 2-14: Tests - Test N: Change of temperature*

IEC 60068-2-17:2023, *Environmental testing - Part 2-17: Tests - Test Q: Sealing*

IEC 60071-1:2019, *Insulation co-ordination - Part 1: Definitions, principles and rules*

IEC 60071-2:2023, *Insulation co-ordination - Part 2: Application guidelines*

IEC 60270, *High-voltage test techniques - Partial discharge measurements*

IEC 60507, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on a.c. systems*

IEC 60507:2013, *Artificial pollution tests on high-voltage ceramic and glass insulators to be used on a.c. systems*

IEC TS 60815-1:2008, *Selection and dimensioning of high-voltage insulators intended for use in polluted conditions - Part 1: Definitions, information and general principles*

IEC 62217:2012, *Polymeric HV insulators for indoor and outdoor use - General definitions, test methods and acceptance criteria*

CISPR TR 18-2, *Radio interference characteristics of overhead power lines and high-voltage equipment - Part 2: Methods of measurement and procedure for determining limits*

CIGRE Technical Brochure No. 488, *Resistance to Weathering and UV Radiation of Polymeric Materials for Outdoor Insulation*

CIGRE Technical Brochure No. 696, *MO Surge Arresters - Metal Oxide Resistors and Surge Arresters for Emerging System Conditions*

IEEE C37.301, *IEEE Standard for High-Voltage Switchgear (Above 1000 V) Test Techniques - Partial Discharge Measurements*

NEMA 107, *Methods of Measurement of Radio Influence Voltage (RIV)*

3 Terms and definitions

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

ISO, IEC, and IEEE maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEEE Dictionary Online: available at <http://dictionary.ieee.org>

3.1

acceptance tests

tests made on LSAs or representative samples after agreement between manufacturer and user

Note 1 to entry: Acceptance tests are referred to as certification tests in IEEE standards

3.2

LSA disconnecter

a device for disconnecting an LSA from the system in the event of LSA failure, to prevent a persistent fault on the system and optionally, but not necessarily, to give a visible indication of the failed LSA

Note 1 to entry: Clearing of the fault current through the LSA during disconnection generally is not a function of the device

3.3

bending moment

force perpendicular to the longitudinal axis of an LSA multiplied by the vertical distance between the mounting base (lower level of the flange) of the LSA and the point of application of the force

3.4**breaking load**

The load at which any part of the LSA fails to perform its mechanical function.

3.5**classifying current**

the designated current magnitude used for insulation coordination and to perform the residual voltage tests and insulation coordination tests.

Note 1 to entry: used in two forms: lightning lassifying current impulse and switching classifying current impulse with different magnitudes depending on the LSA class.

Note 2 to entry: Classifying current is referred to as nominal discharge current in other IEC standards

3.5.1**lightning classifying current impulse**
 I_{pl}

peak value of discharge current having a 2/20 impulse shape, which is used for residual voltage tests and insulation coordination tests on LSAs for lightning protection acc. to [Table 1](#)

3.5.2**switching classifying current impulse**
 I_{ps}

peak value of discharge current having a virtual front time greater than 30 μ s but less than 100 μ s and a virtual time to half-value on the tail of roughly twice the virtual front time, which is used for residual voltage tests and insulation coordination tests on LSAs for switching overvoltage control acc. to [Table 2](#)

3.6**conditioning current impulse**

peak value of discharge current having a 4/10 impulse shape, which is used to electrically age the MO resistors during the operation duty and power-frequency temporary overvoltage test [8.9](#)

3.7**continuous operating voltage of an NGLA**
 U_c

designated permissible r.m.s. value of power-frequency voltage that may be applied continuously between the LSA terminals

Note 1 to entry: U_c is referred to as MCOV in IEEE standards

3.8**corona ring**

a metal part, usually circular or oval in shape, mounted to provide electrical shielding to terminals and other metal fittings, to suppress the generation of corona

3.9**design tests**

tests made on each design to establish the performance characteristics and to demonstrate compliance with the appropriate standards of the industry.

Note 1 to entry: Once made, these tests need not be repeated unless the design is changed so as to modify its performance. In such a case, only the relevant tests need be repeated.

Note 2 to entry: Design tests are sometimes referred to as type tests in IEC standards

3.10**designation of an impulse shape**

The wave shape of a voltage or current impulse is designated by a combination of two indices T1 and T2. The first index T1 defines the virtual front time of the impulse and the index T2 defines the virtual time to half-value on the tail in microseconds.

3.11**discharge current**

the impulse current that flows through a LSA

3.12**disruptive discharge**

phenomenon associated with the failure of insulation under electric stress, which includes a collapse of voltage and the passage of current

Note 1 to entry: The term applies to electrical breakdowns in solid, liquid and gaseous dielectric, and combinations of these.

Note 2 to entry: A disruptive discharge in a solid dielectric produces permanent loss of electric strength. In a liquid or gaseous dielectric the loss may be only temporary.

3.13**evaluation current impulse**

Peak value of discharge current having a 8/20 impulse shape, which is used for evaluation tests only

Note 1 to entry: The evaluation current impulse is used for evaluation parts before/after specific design tests, where 8/20 waveshape is sufficient to provide a qualitative estimation of the test result and where the steepness of the lightning classifying current is not relevant. The evaluation current impulse is not used for classification of LSAs.

Note 2 to entry: 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

3.14**external series gap**

intentional air gap between spaced electrodes in series with the SVU of an EGLA

3.15**externally gapped line arrester**

EGLA

Metal-oxide surge arrester with external series gap for installation on overhead lines to protect an insulator assembly from lightning-caused fast-front over-voltages or switching overvoltages.

3.16**fault indicator**

device intended to provide an indication that the LSA is faulty and which does not disconnect the LSA from the system

3.17**flashover**

a disruptive discharge over a solid surface

3.18**follow current**

I_{follow}

the current immediately following a current impulse through an EGLA with the power-frequency voltage as the source

3.19**front of an impulse**

part of an impulse which occurs prior to the peak

3.20**grading ring**

metal part, usually circular in shape, mounted to electrostatically modify the voltage distribution along the NGLA

3.21**high current impulse**

peak value of discharge current having a 2/20 impulse shape, which is used to test the withstand capability of the LSA on extreme lightning occasions

3.22**housing**

external insulating part of an LSA, which provides the necessary creepage distance and protects the internal parts from the environment

Note 1 to entry: A housing may consist of several parts providing mechanical strength and protection against the environment.

3.23**impulse**

unidirectional wave of voltage or current which, without appreciable oscillations, rises rapidly to a maximum value and falls, usually less rapidly, to zero with small, if any, excursions of opposite polarity, with defining parameters being polarity, peak value, front time and time to half-value on the tail

3.24**internal parts**

MO resistor with supporting structure and internal grading system, if equipped

3.25**lightning impulse discharge**

an approximately sine half-wave current impulse having a time duration within 200 μ s to 230 μ s during which the instantaneous value of the impulse current is greater than 5 % of its peak value

3.26**lightning impulse protection level**

LIPL

U_{pl}

Maximum peak value of voltage that appears across the complete LSA during the passage of lightning classifying current impulse

Note 1 to entry: including series gap, accessories and connection leads

3.27**lightning impulse withstand voltage**

LIWV

Standard rated lightning impulse withstand voltage of an equipment or insulator configuration

Note 1 to entry: For LSAs, the required LIWV is based on its lightning residual voltage with suitable safety factors and shall not be selected from standardized LIWV/BIL values.

3.28**line surge arrester**

LSA

arrester designed for installation on overhead lines to protect an insulator assembly from lightning-caused fast-front over-voltages or switching overvoltages

3.29**long-duration current impulse**

rectangular current impulse which rises rapidly to maximum value, remains substantially constant for a specified period and then falls rapidly to zero, with defining parameters being polarity, peak value, virtual duration of the peak and virtual total duration.

3.30**LSA active parts**

MO resistors and any metal spacers directly in series with them.

3.31**maximum system voltage**

U_s

highest value of the phase-to-phase operating voltage (RMS value) which occurs under normal operating conditions at any time and at any point in the system

3.32**mean breaking load of a Unit/SVU**

MBL

average breaking load for porcelain or cast resin-housed Unit/SVU determined from tests

3.33**non-gapped line arrester**

NGLA

arrester without internal or external series gaps intended for installation in overhead lines in parallel to the line insulators in order to prevent impulse flashovers

3.34**non-linear metal-oxide resistor**

MO resistor

part of the LSA which, by its non-linear voltage versus current characteristics, acts as a low resistance to overvoltages, thus limiting the voltage across the LSA terminals, and as a high resistance at normal power-frequency voltage

3.35**partial discharge**

a localized electric discharge resulting from ionization in an insulation system when the voltage stress exceeds the critical value. This discharge partially bridges the insulation between electrodes.

3.36**peak (crest) value of an impulse**

maximum value of a voltage or current impulse

3.37**peak (crest) value of opposite polarity of an impulse**

maximum amplitude of opposite polarity reached by a voltage or current impulse when it oscillates about zero before attaining a permanent zero value

3.38**polymer-housed LSA**

LSA using polymeric and/or composite as housing material

3.39**porcelain-housed LSA**

LSA using porcelain as housing material

3.40**power-frequency voltage versus time characteristic of an NGLA**

the maximum time durations for which corresponding power-frequency voltages may be applied to NGLAs without causing damage or thermal instability

3.41**power-frequency withstand voltage**

a specified root-mean-square (rms) test voltage at a power frequency that will not cause a disruptive discharge

3.42**pressure-relief device of a LSA**

means for relieving internal pressure in a LSA and preventing violent shattering of the housing following prolonged passage of fault current or internal flashover of the LSA

3.43**prorated section of a LSA**

complete, suitably assembled part of an LSA necessary to represent the thermal, mechanical or dielectrical behaviour of a complete LSA with respect to a particular test.

Note 1 to entry: A section of an LSA is not necessarily a complete **NGLA** or **EGLA** and, for certain tests, a MO resistor alone constitutes a prorated section.

3.43.1**dielectrically prorated section of an LSA**

A sliced portion of the LSA with the same diameters and materials, including the MO resistors, the housing and the supporting structure and other materials at distributed positions in the LSA being modelled, such as distance holders and spacers.

3.43.2**mechanically prorated section**

A model of an LSA including the MO resistors and housing components of the LSA being modelled, which are necessary to represent the mechanical behavior of the complete arrester for a specific test.

3.43.3**thermally prorated section of an NGLA**

A model of the NGLA including one or more of the MO resistors, thermally equal to the complete NGLA comprising the same components as used for the NGLA or eventually components that are usually not part of the design.

3.44**prospective current of a circuit**

current that would flow at a given location in a circuit if it were short-circuited at that location by a link of negligible impedance

3.45**protective characteristics of an LSA**

a combination of lightning impulse protection level (LIPL), switching impulse protection level (SIPL) and steep current impulse protection level (STIPL). Certain designs of LSA may not have a defined characteristic for all types of impulse.

3.46**puncture (breakdown)**

disruptive discharge through a solid that produces permanent loss of dielectric strength

3.47**radio-interference voltage**

RIV

a high-frequency voltage, generated by all sources of ionization current that appears at the terminals of electric-power apparatus or on power circuits.

Note 1 to entry: This term is referred to as radio-influence voltage in IEEE standards.

3.48

rated frequency of an LSA

frequency of the power system on which the LSA is designed to be used

3.49

rated short-circuit current

I_s

maximum claimed power frequency rms fault current that may flow through a shorted NGLA or SVU, as verified in the short circuit design test

3.50

rated voltage of an EGLA

U_{rEGLA}

the maximum permissible power frequency r.m.s. voltage that can be applied across the complete EGLA for which the EGLA is capable of interrupting power frequency follow current after gap sparkover.

Note 1 to entry: The rated voltage of an EGLA is comparable to U_c of all other types of MO-arresters.

3.51

rated voltage of an NGLA

U_r

minimum permissible 10 s power frequency r.m.s. overvoltage that can be applied between the LSA terminals, as verified in the TOV test and the operating duty test

Note 1 to entry: The rated voltage is used as a reference parameter for the specification of operating and current interrupting characteristics.

3.52

reference current

I_{ref}

peak value (the higher peak value of the two polarities if the current is asymmetrical) of the resistive component of a power-frequency current used to determine the reference voltage of the NGLA or SVU

Note 1 to entry: The reference current should be high enough to make the effects of stray capacitances at the measured reference voltage of the NGLA or SVU units negligible. It is to be specified by the manufacturer.

3.53

reference voltage

U_{ref}

peak value of power-frequency voltage divided by $\sqrt{2}$, which should be applied to the NGLA or SVU to obtain the reference current

Note 1 to entry: The reference voltage of a multi-unit [SVU \(3.60\)](#) is the sum of the reference voltages of the individual units.

3.54

repetitive charge transfer rating

Q_{rs}

maximum specified charge transfer capability of an LSA, in the form of a single event or group of surges that may be transferred through an LSA without causing mechanical failure or unacceptable electrical degradation to the MO resistors or the external gap if required or disconnectors where applicable.

Note 1 to entry: The charge is calculated as the absolute value of current integrated over time. For the purpose of this standard this is the charge that is accumulated in a single event or group of surges lasting for not more than 2 s and which may be followed by a subsequent event at a time interval not shorter than 60 s.

3.55

residual voltage of an NGLA/SVU

U_{res}

peak value of voltage that appears between the terminals of an NGLA/SVU during the passage of classifying current

Note 1 to entry: residual voltage is referred to as discharge voltage in other IEEE standards

3.56

routine tests

tests made by the manufacturer on every device or representative samples, or on parts or materials, as required, to verify that the product meets the design specifications

3.57

salt deposit density

SDD

amount of salt in the deposit on a given surface of the SVU housing, divided by the area of this surface; generally expressed in mg/cm²

3.58

seal (gas/water tightness)

ability of an NGLA /SVU to avoid ingress of matter affecting the electrical and/or mechanical behaviour

3.59

section of an LSA

complete, suitably assembled part of a complete NGLA or SVU necessary to represent the behaviour of a complete NGLA or SVU with respect to a particular test

3.60

series varistor unit of an EGLA

SVU

non-linear metal-oxide resistor part, contained in a housing, which must be connected with an external series gap to construct the complete EGLA

Note 1 to entry: The series varistor unit may include several units.

3.61

shed

insulating part projecting from the housing, intended to increase the creepage distance

3.62

sparkover

a disruptive discharge between electrodes of an EGLA

3.63

sparkover voltage

U_G

minimum voltage at which sparkover occurs

3.64

specified extended long-term load

SXL

greatest vibration load perpendicular to the longitudinal axis of an LSA caused by recurring winds, allowed to be applied with a large number of cycles without causing mechanical fatigue damage to the LSA

3.65**specified intermittent load**

SIL

intermittent load perpendicular to the longitudinal axis as part of the cyclical bending moment verification of SLL-cantilever to represent occasional 1 – 3 second duration storm gusts that could be withstood without causing mechanical fatigue damage to the LSA.

3.66**specified long-term load**

SLL

mechanical force perpendicular to the longitudinal axis of an LSA, allowed to be continuously applied during service without causing any mechanical damage to the LSA

3.67

Specified Long-term Load for Accessories

SLL-A

3.68**specified long-term load for tension**

SLL-TN

mechanical force tensile force, allowed to be continuously applied during service without causing any mechanical damage to the LSA

3.69**specified long-term load for torsion**

SLL-TQ

torque, allowed to be continuously applied during service without causing any mechanical damage to the LSA

3.70**specified short-term load**

SSL

greatest mechanical force perpendicular to the longitudinal axis of an LSA, allowed to be applied during service for short periods and for relatively rare events (for example, short-circuit current loads and extreme wind gusts) without causing any mechanical damage to the LSA

3.71**Specified Short-term Load for Accessories**

SSL-A

Accessories' Specified Short-term Load

3.72**specified short-term load for tension**

SSL-TN

greatest mechanical tensile force, allowed to be applied during service for short periods and for relatively rare events (for example, short-circuit current loads or galloping) without causing any mechanical damage to the LSA

3.73**specified short-term load for torsion**

SSL-TQ

greatest torque, allowed to be applied during service for short periods and for relatively rare events (for example storm condition) without causing any mechanical damage to the LSA

3.74**surface leakage current of an SVU**

current that flows on the surface of the SVU

3.75**switching impulse protection level**

SIPL

 U_{ps}

the maximum protection level of the LSA during the passage of switching classifying current impulse

3.76**switching impulse withstand voltage**

SIWV

Standard rated switching impulse withstand voltage of an equipment or insulator configuration

Note 1 to entry: For LSAs, the required SIWV is based on its SIPL with suitable safety factors and shall not be selected from standardized SIWV/BSL values.

3.77**tail of an impulse**

part of an impulse which occurs after the peak

3.78**temporary overvoltage** U_{TOV}

TOV

maximum permissible power frequency r.m.s. overvoltage for a specified time duration that can be applied between the NGLA, as verified in the operating duty and power-frequency temporary overvoltage test (8.9)

3.79**terminals**

terminals are metallic parts at the ends of an unit or SVU of a LSA which are used to electrically and perhaps also mechanically connect the unit or SVU to a voltage or ground connector, an adaptor, a bracket, an electrode or an insulating base.

Note 1 to entry: Separate electrical connectors that are supplied with the LSA but not part of the unit or SVU are not defined as terminals.

3.80**thermal charge transfer rating** Q_{th}

maximum specified charge that may be transferred through a NGLA or NGLA section within 3 minutes in a thermal recovery test without causing a thermal runaway

Note 1 to entry: This rating is verified by the operating duty and temporary power-frequency overvoltage test.

3.81**thermal energy rating** W_{th}

maximum specified energy, given in kJ/kV of U_r , that may be injected into an NGLA or NGLA section within 3 minutes in a thermal recovery test without causing a thermal runaway

Note 1 to entry: This rating is verified by the operating duty and temporary power-frequency overvoltage test.

3.82**thermal runaway of an NGLA**

situation when the sustained power loss of an NGLA exceeds the thermal dissipation capability of the housing and connections, leading to a cumulative increase in the temperature of the MO resistor elements culminating in failure

3.83**thermal stability of an NGLA**

state of an NGLA if, after an operating duty causing temperature rise, the temperature of the MO resistors decreases with time when the NGLA is energized at specified continuous operating voltage and at specified ambient conditions

3.84**torsional loading**

each torque applied to the top of the LSA top

3.85**tracking**

irreversible degradation of the surface of insulating material from the formation of conductive carbonized paths.

3.86**unipolar sine half-wave current impulse**

a unipolar current impulse consisting of one half-cycle of an approximately sinusoidal current

3.87**unit of an LSA****LSA unit**

completely housed part of an LSA which may be connected in series and/or in parallel with other units to construct an LSA of higher voltage and/or current rating

3.88**virtual duration of the peak of a rectangular impulse**

time during which the amplitude of the impulse is greater than 90 % of its peak value

3.89**virtual front time of a current impulse**

T_1

time in microseconds equal to 1,25 multiplied by the time in microseconds for the current to increase from 10 % to 90 % of its peak value

Note 1 to entry: If oscillations are present on the front, the reference points at 10 % and 90 % should be taken on the mean curve drawn through the oscillations.

3.90**virtual origin of an impulse**

point on a graph of voltage versus time or current versus time determined by the intersection between the time axis at zero voltage or zero current and the straight line drawn through two reference points on the front of the impulse

Note 1 to entry: For current impulses the reference points shall be 10 % and 90 % of the peak value.

Note 2 to entry: This definition applies only when scales of both ordinate and abscissa are linear.

Note 3 to entry: If oscillations are present on the front, the reference points at 10 % and 90 % should be taken on the mean curve drawn through the oscillations.

3.91**virtual steepness of the front of an impulse**

quotient of the peak value and the virtual front time of an impulse

3.92**virtual time to half-value on the tail of an impulse**

T_2

time interval between the virtual origin and the instant when the voltage or current has decreased to half its peak value, expressed in microseconds

3.93**virtual total duration of a rectangular impulse**

time during which the amplitude of the impulse is greater than 10 % of its peak value

Note 1 to entry: If small oscillations are present on the front, a mean curve should be drawn in order to determine the time at which the 10 % value is reached.

4 Classification

Line surge arresters intended to be used for lightning protection are classified according to their lightning classifying currents, high current impulse withstands, repetitive charge transfer ratings and, for NGLA, thermal charge transfer ratings, as summarized in [Table 1](#).

Line surge arresters intended to be used for switching overvoltage control are classified according to their switching impulse classifying current, high current impulse ratings, repetitive charge transfer ratings and thermal energy ratings, as summarized in [Table 2](#).

It is possible that a given LSA could be qualified for both a lightning protection class and a switching overvoltage control class.

NOTE While EGLA and NGLA may have the same class designations, they are differentiated and qualified through different sets of design tests

Table 1 – Classification of line surge arresters intended for lightning protection

Class designation	L1	L2	L3	L4	L5	L6
Lightning classifying current impulse, I_{pl} (kA) ^a	5	10	10	15	15	20
High current impulse withstand (kA)	10	25	25	30	40	40
Repetitive charge transfer rating, Qrs (C)	≥ 0,2	≥ 0,3	≥ 0,4	≥ 0,6	≥ 0,8	≥ 1,2
Thermal charge transfer rating, Qth, (C) ^b	≥ 0,4	≥ 0,6	≥ 0,8	≥ 1,2	≥ 1,6	≥ 2,4
^a Other currents may be specified upon agreement between manufacturer and user						
^b Applicable only for NGLA						

Table 2 – Classification of line surge arresters intended for switching overvoltage control

Class designation	S1	S2	S3
Switching classifying current impulse, I_{ps} (kA)	0,5	1	2
High current impulse withstand (kA)	30	40	40
Repetitive charge transfer rating, Qrs (C)	≥ 1,0	≥ 1,6	≥ 2,4
Thermal energy rating, W_{th} (kJ/kV of Ur)	≥ 4	≥ 7	≥ 10

5 Standard ratings and service conditions**5.1 Standard rated voltages**

Standard values of rated voltages for LSAs are specified in [Table 3](#) in equal voltage steps within specified voltage ranges.

Table 3 – Preferred values of rated voltage, U_r or U_{rEGLA}

Range of rated voltage (kV r.m.s.)	Steps of rated voltage (kV r.m.s.)
3 to 30	1

Range of rated voltage (kV r.m.s.)	Steps of rated voltage (kV r.m.s.)
30 to 54	3
> 54	6

Other steps of rated voltage may be accepted, but shall then be noted on the LSA nameplate (see 6.1).

5.2 Standard rated frequencies

The standard rated frequencies are between 48 Hz and 62 Hz.

5.3 Service conditions

5.3.1 Normal service conditions

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

- a) ambient air temperature within the range of $-40\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$;
- b) altitude not exceeding 1000 m;
- c) frequency of the a.c. power supply not less than 48 Hz and not more than 62 Hz;
- d) power-frequency voltage applied continuously between the terminals of the EGLA not exceeding its rated voltage;
- e) power-frequency voltage applied continuously between the terminals of the NGLA not exceeding its continuous operating voltage;
- f) mechanical conditions: not specified (see Note of 5.3.1);
- g) wind speed:
 - 1) 10 m/s for continuous winds of the micro meteorological range
 - 2) 45 m/s for continuous storm condition winds
 - 3) 50 m/s for 1-3 second storm gusts
- h) pollution conditions: pollution by dust, smoke, corrosive gases, vapours or salt may occur; pollution does not exceed "heavy" as defined in IEC TS 60815-1.

NOTE It is recognized that mechanical and environmental issues are important for service, but due to the large variety of possible installation configurations it is not possible to provide standard values for 5.3.1, list item f).

5.3.2 Special service conditions

LSAs subject to other than normal application or service conditions may require special consideration in design, manufacture or application. The use of this standard in case of special service conditions is subject to agreement between the manufacturer and the purchaser. A summary of possible special service conditions and environments is given in Annex D.

6 Requirements

6.1 Identification

A LSA shall be identified by the following minimum information, which shall appear on a nameplate permanently attached to the LSA or accessible via digital labeling technologies, such as a QR code or a NFC tag:

- rated voltage U_r [rated voltage of an NGLA \(3.51\)](#) or $U_{r\text{EGLA}}$ [rated voltage of an EGLA \(3.50\)](#) in kV;
- continuous operating voltage (for NGLA) U_c in kV;
- rated frequency in Hz, only if it is less than 48 Hz or larger than 62 Hz;

- class designation (if intended for both lightning and switching surge protection, both designations shall be included)
- repetitive charge transfer rating Q_{rs} (3.54) in C;
- rated short-circuit current I_s (3.49) in kA;
- identification of the assembling position of the unit (for multi-unit LSAs only);
- manufacturer's name or trade mark;
- year of manufacture;
- serial number (at least for LSAs for $U_s > 52$ kV);

Information on required gap spacing including tolerances shall be given in an appropriate way, for example in the manual.

6.2 Verification of LSA characteristics and performance

All LSAs shall be tested according to requirements specified for design tests (see [Clause 8](#)), routine tests (see [Clause 9](#)) and, when required by the purchaser, acceptance tests (see [Clause 10](#)). General requirements for sample selection and test measuring equipment shall be according to [Clause 7](#).

6.3 Protection Level Verification

With information regarding application of the LSA, the manufacturer shall, at the user's request, supply LSA protection levels determined by the procedure of [Annex H](#)

7 General testing procedure

7.1 Measuring equipment and uncertainty

The measuring equipment shall meet the requirements of IEC 60060-2. The values obtained shall be accepted as uncertainty for the purpose of compliance with the relevant test clauses.

Unless stated elsewhere, all tests with power-frequency voltages shall be made with an alternating voltage having a frequency between the limits of 48 Hz and 62 Hz and an approximately sinusoidal wave shape.

7.2 Reference voltage measurements

The reference voltage of an NGLA or SVU of an EGLA is measured at the reference current on sections and units when required. The measurement shall be performed at an ambient temperature of $20\text{ °C} \pm 15\text{ K}$, and this temperature shall be recorded.

As an acceptable approximation, the peak value of the resistive component of current may be taken to correspond to the momentary value of the current at the instant of voltage peak.

7.3 Evaluation current measurements

Some design tests require an evaluation of the residual voltage of the test sample as part of the final measurement or even as initial test. Therefore an evaluation current impulse shall be used, unless otherwise defined in the test section. An evaluation current impulse can also be used for residual voltage routine and acceptance tests instead of classifying current. Magnitudes for evaluation current impulse shall be chosen from [Table 4](#)

Table 4 – Evaluation current impulse magnitudes

LSA class	Evaluation current magnitude [kA]
L1	$\geq 2,5$
L2	≥ 5
All other classes	≥ 10

7.4 Test samples

7.4.1 General

Unless otherwise specified, all design tests shall be made on the same LSAs, LSA sections or LSA units. For each design test, the samples shall be new, clean, completely assembled (for example, with grading rings if applicable) and arranged to simulate as closely as possible the conditions in service. Each design test clause describes the requirements and type of test sample.

When tests are made on sections it is necessary that the sections represent the behaviour of all possible LSAs within the manufacturer's tolerances with respect to a specific test.

Unless otherwise specified, for each design test, the complete test sequence shall be carried out on the same test sample.

7.4.2 EGLA

When tests are made on sections or units, the following shall be fulfilled:

- The ratio between rated voltage of the complete EGLA to the rated voltage of the section or unit is defined as n .
- The volume of the resistor elements used as test samples shall not be greater than the minimum volume of all resistor elements used in the complete EGLA divided by n .
- The reference voltage [U_{ref} \(3.53\)](#) of the SVU of the test section should be equal to the minimum reference voltage of the SVU of the EGLA divided by n . If the reference voltage of the SVU of the test section is greater than the minimum reference voltage of the SVU of the complete EGLA divided by n , the factor n shall be reduced correspondingly. If the reference voltage of the SVU of the test section is less than the minimum reference voltage of the SVU of the complete EGLA divided by n , the test section is not allowed to be used.

The factor n of the test samples shall be recorded in the test report.

7.4.3 NGLA

In general, the samples shall cover the highest residual voltage and the lowest reference voltage of the type of MO resistors used in the NGLA. If thermal charge transfer rating is specified in the operating duty and power-frequency temporary overvoltage test (see [8.9](#)) the samples shall have the highest lightning impulse protection level U_{pl} per unit length of the design. If thermal energy rating is specified in the operating duty test the test samples shall have a reference voltage value at the lower end of the variation range declared by the manufacturer. In case of multi-column NGLAs, the highest value of uneven current distribution shall be considered. In order to comply with these demands the following shall be fulfilled:

- The ratio between the rated voltage of the complete NGLA to the rated voltage of the section is defined as n . The volume of the MO resistor elements used as test samples shall not be greater than the minimum volume of all MO resistor elements used in the complete NGLA divided by n .
- The reference voltage of the test section shall be equal to $k U_r/n$ where k is the ratio between the minimum reference voltage of the NGLA and its rated voltage. If $U_{ref} \geq k U_r/n$ for an available test sample, the factor n shall be reduced correspondingly. (If $U_{ref} < k U_r/n$ the

NGLA may absorb too much energy. Such a section can be used only after agreement from the manufacturer.)

- c) For multi-column NGLAs the distribution of the current between the columns shall be measured at the impulse current for current distribution test (see item e) of [Clause 9](#)). The highest current value shall not be higher than an upper limit specified by the manufacturer. Furthermore, for tests that are required to be performed on test sections with multiple columns the discharge energy shall be increased by a factor β_g/β_a where β_g is the guaranteed current sharing factor and β_a is the actual current sharing factor for the test section. If the test is performed on single columns the energy shall be increased by a factor β_g .
- d) The samples in the test to verify the repetitive charge transfer rating shall be of the type used in the design and consist of either the longest length of MO resistor or a stack of two series connected MO resistors each having different rated voltage whereof at least one in each stack is of the longest length.

The individual MO resistors used shall have a 10-kA residual voltage stress of not less than $0,97 \times (U_{10 \text{ kA per mm of MO resistor length}})_{\text{max}}$, where $(U_{10 \text{ kA per mm of MO resistor length}})_{\text{max}}$ is the highest 10-kA residual voltage stress specified by the manufacturer for any length of the type of MO resistors used in the NGLA.

If only MO resistors of lower 10-kA residual voltage stress are available, the required transferred charge for the individual MO resistors shall be increased for the test by the factor $(U_{10 \text{ kA per mm of MO resistor length}})_{\text{max}} / (U_{10 \text{ kA per mm of MO resistor length}})_{\text{actual}}$. The choice to test samples of individual MO resistors or a stack of series connected MO resistors is at the discretion of the manufacturer.

NOTE The choice by the manufacturer to test a stack of MO resistors may be due, for example, to preferential test lab set up or the desire to verify different lengths of MO resistor by a single round of testing.

- e) The continuous operating voltage applied in tests involving thermal recovery shall fulfil the following requirement: The ratio of the continuous operating voltage to the rated voltage of the section shall be not less than the maximum ratio claimed for the NGLA type.

7.4.4 Dielectrically prorated section

The section of an NGLA or SVU used for high current withstand test acc. to [8.5](#) shall represent a sliced portion of the NGLA or SVU being modelled, including the MO resistors, the housing and the supporting structure.

The rated voltage shall be at least 3 kV.

The section shall meet the following requirements:

- It shall copy the actual NGLA with regard to diameters, materials etc.
- The mechanically supporting structure shall be included.
- Elements that are only located at distributed positions in the NGLA being modelled, such as distance holders and spacers, shall be present in the model.
- The active part shall have the same surrounding medium as in the real NGLA.

A dielectrically prorated section may also be a complete NGLA or unit or SVU of the design.

An exact drawing of the dielectrically prorated section shall be published in the test report.

7.4.5 Mechanically prorated section

The section of an NGLA or unit or the section of an EGLA or SVU used for specific mechanical tests acc. to [8.16](#) shall represent the NGLA or SVU being modelled, including the MO resistors, the housing and the supporting structure and all components or scaled components of the complete NGLA or EGLA. Also tests on separate housing components might require mechanically prorated sections consisting of unit/SVU and other components like electrodes or

gap insulators. The mechanically prorated section can be scaled in size acc. to the specific test clause and in relation to the magnitude of the mechanical test parameters.

The section shall meet the following requirements:

- It shall copy the actual LSA with regard to diameters, materials, components etc.
- The mechanically supporting structure shall be included.
- Elements that are only located at distributed positions in the NGLA being modelled, such as distance holders and spacers, shall be present in the model.
- The active part shall have the same surrounding medium as in the real NGLA.
- Electrode and SVU shall be included for tests on separate components for EGLAs in the specific test section of 8.16 for SVU/Electrode
- gap insulator, if used, shall be included for tests on separate components for EGLAs in the specific test section of 8.16 for gap insulator
- connectors, hardware and adaptors shall be included for tests on separate components for the specific test section of 8.16 for connectors and hardware

A mechanically prorated section may also be a complete NGLA or unit or a complete EGLA, SVU or a symmetrical part of an EGLA of the design.

An exact drawing of the mechanically prorated section shall be published in the test report.

7.4.6 Thermally prorated section

The NGLA section for thermal recovery tests shall thermally represent the NGLA being modelled. Thermal equivalence shall be verified according to the procedure specified in Annex B.

The thermally prorated section need not be a sliced portion of the NGLA and need not contain only the same material as in the NGLA. It may have a design different to that of the modelled NGLA, as long as thermal equivalence and sufficient dielectric strength for the energy and charge injection, respectively, are assured.

A thermally prorated section may also be a complete NGLA or NGLA unit of the design. In order to achieve thermal equivalence it may be necessary to introduce components that are usually not part of the design. It has to be assured that these measures do not affect the dielectric strength of the sample during energy or charge injection.

The rated voltage of the prorated section shall be at least 3 kV.

In case of designs with two or more MO columns in parallel the thermally prorated section shall contain the same number of parallel columns as the actual NGLA.

Upon agreement between manufacturer and user the thermally prorated section of a multicolumn design NGLA may contain only one single column if thermal equivalence is achieved.

An exact drawing of the thermally prorated section shall be published in the test report.

8 Design tests

8.1 General

The introduction of design test categories aims to facilitate the technical evaluation of LSA projects. Design tests are divided into two distinct categories:

"Critical" tests (Category A) refer to design tests on the surge NGLAs/SVUs themselves, which are essential for preventing flashovers while ensuring long-term stability, safety, and durability.

"Non-critical" tests (Category B), on the other hand, refer to insulation coordination tests, line-specific tests related to the project, or tests that need to be repeated due to modifications or evolutions in components or accessories.

Category B tests cannot be avoided under any circumstances; they are all mandatory if required, as specified in the relevant test sections. However, they offer some flexibility, as they can be conducted during acceptance tests.

8.1.1 Design tests for NGLA

Table 5 identifies the design tests that shall be performed for NGLA.

Table 5 – Design tests for NGLA

Test item	Category	Clause number
Insulation withstand tests		
Tests for LSA intended for a.c. systems of $U_S \leq 245$ kV	A	8.2.2
Tests for LSA intended for use on a.c. systems of $U_S > 245$ kV	A	8.2.3
Residual voltage tests	A	8.3
High current impulse withstand test	A	8.5
Test to verify the repetitive charge transfer rating, Q_{rs}	A	8.6
Test to verify long term stability under continuous operating voltage	A	8.7
Heat dissipation behaviour of test sample	A	8.8
Operating duty and power-frequency temporary overvoltage test	A	8.9
Tests of NGLA disconnecter and fault indicator	B	8.10
Short-circuit tests	A	8.11
Seal leak rate	A	8.12
Radio interference voltage (RIV) test	B	8.13
Test of internal grading components of LSA	A	8.14
Mechanical tests		
Bending moment test	A	8.16.2
Tensile withstand test	B	8.16.3
Torsional twisting withstand test	B	8.16.4
Vibration withstand test	B	8.16.5
Component / Accessories test	B	8.16.6
Environmental tests	A	8.17

8.1.2 Design tests for EGLA

Table 6 identifies the design tests that shall be performed for EGLA.

Table 6 – Design tests for EGLA

Test item	Category	Clause number
Insulation withstand tests		
Tests for LSA intended for a.c. systems of $U_s \leq 245$ kV	A	8.2.2
Tests for LSA intended for use on a.c. systems of $U_s > 245$ kV	B	8.2.3
Insulation withstand tests on EGLA with failed SVU	B	8.2.9
Residual voltage test	A	8.3
Standard lightning impulse sparkover test	B	8.4
High current impulse withstand test	A	8.5
Test to verify the repetitive charge transfer rating, Q_{rs}	A	8.6
Short-circuit tests	A	8.11
Seal leak rate	A	8.12
Radio interference voltage (RIV)	B	8.13
Follow current interrupting test	B	8.15
Mechanical tests		8.16
Bending moment test	A	8.16.2
Tensile withstand test	B	8.16.3
Torsional twisting withstand test	B	8.16.4
Vibration withstand test	B	8.16.5
Component / Accessories test	B	8.16.6
Environmental tests	A	8.17

8.2 Insulation withstand tests

8.2.1 General

The voltage withstand tests on individual NGLA/EGLA-SVU unit housings or complete NGLA/EGLA-SVU housing assemblies demonstrate the voltage withstand capability of the external insulation of the NGLA/EGLA-SVU housing.

8.2.2 Tests for LSA intended for a.c. systems of $U_s \leq 245$ kV

For all LSA designs intended for use on a.c. systems of $U_s \leq 245$ kV, lightning impulse voltage test shall be performed according to [8.2.6](#) and power-frequency voltage test according to [8.2.8](#) on individual NGLA or SVU unit housings.

The applicable tests shall be run on the longest NGLA/SVU housing. If this does not represent the highest specific voltage stress per unit length, additional tests shall be performed on the unit housing having the highest specific voltage stress. For these tests, the standard MO resistors shall be removed from the housing or replaced by insulators.

8.2.3 Tests for LSA intended for use on a.c. systems of $U_s > 245$ kV

For all LSA designs intended for use on a.c. systems of $U_s > 245$ kV, lightning impulse voltage test according to [8.2.6](#) shall be performed. For NGLA and for EGLA intended for use for switching overvoltage protection, the switching impulse voltage test according to [8.2.7](#) shall be performed.

The impulse tests shall be performed with the NGLA/SVU housing assemblies suspended or placed on a pedestal. Details of the installation arrangement used shall be stated in the test report. The switching impulse test shall be performed under wet conditions.

The housing shall be equipped with the complete external grading system. The MO resistors shall be replaced by resistors, capacitors or higher resistance MO resistors to obtain, approximately, the same voltage grading during high current discharges as would be given by the actual MO resistors used in the NGLA/SVU housing assemblies. When using MO resistors, the resistors shall have a protection characteristic that will result in at least 0.1 A peak during the insulation withstand test.

8.2.4 Ambient air conditions during tests

The voltage to be applied during a withstand test is determined by multiplying the specified withstand voltage by the correction factor taking into account density and humidity (see IEC 60060-1).

Humidity correction shall not be applied for wet tests.

8.2.5 Wet test procedure

The external insulation of NGLA/SVU shall be subjected to wet withstand tests under the test procedure given in IEC 60060-1.

8.2.6 Lightning impulse withstand voltage test

The NGLA/SVU shall be subjected to a standard lightning impulse voltage dry test according to IEC 60060-1.

8.2.6.1 Test Voltage

For LSA the test voltage shall be at least 1,3 times the maximum residual voltage at lightning classifying discharge current.

Fifteen consecutive impulses at the test voltage value shall be applied for each polarity. The NGLA/SVU shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two in each series of 15 impulses and if no external disruptive discharges occur in the last three impulses.

NOTE In case of an external disruptive discharge at one of the impulse numbers 13 to 15, up to three additional pulses can be applied (maximum 18). If no further disruptive discharge occurs, the test object has passed the test.

If the dry arcing distance or the sum of the partial dry arcing distances is larger than the test voltage divided by 500 kV/m, this test is not required.

8.2.7 Switching impulse withstand voltage test

The switching impulse voltage test applies to LSA with classification S1, S2, or S3 intended for system voltages of $U_S > 245$ kV (a.c.) shall be subjected to a wet standard switching impulse voltage test according to IEC 60060-1.

The test voltage shall be at least the maximum switching impulse residual voltage at the NGLAs switching impulse discharge current according to [Table 2](#) multiplied by $1,1 \times e^{m \times 1000/8150}$ where:

- $m = 1$ for NGLAs with $1,1 \times \text{USIPL} \leq 320$ kV
- $m = -0,002094 \times (1,1 \times \text{USIPL})^{0,7873+1,185}$, for NGLAs with $1,1 \times \text{USIPL} > 320$ kV, m is taken from Figure 10 of IEC 60071-2:2023, phase-to-earth insulation.

NOTE 1 The factor $1,1 \times e^{m \times 1000/8150}$ reflects a 10% co-ordination factor to take into account discharge currents higher than normal and the statistical nature of the withstand voltage of the insulation, and a 13% margin to account for variation in air pressure from sea level up to normal service altitudes not exceeding 1 000 m

NOTE 2 When the insulation requirements of NGLAs intended for use on systems of $U_s > 800$ kV calculated from the above are still higher than selected for the protected equipment the same insulation levels should apply also for the LSA.

Fifteen consecutive impulses at the test voltage value shall be applied for each polarity. The NGLA or SVU shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two in each series of 15 impulses and if no external disruptive discharges occur in the last three impulses.

NOTE 3 In case of an external disruptive discharge at one of the impulse numbers 13 to 15, up to three additional pulses can be applied (maximum 18). If no further disruptive discharge occurs, the test object has passed the test.

If the dry arcing distance or the sum of the partial dry arcing distances is larger than given by the equation $d = 2,2 \times [e^{(U/1118)} - 1]$, where d is the distance and U is the test voltage, this test is not required.

NOTE 4 The equation is derived from formula F.3 of IEC 60071-2:2023, where U_{50} is given as $k \times 1080 \times \ln(0,46 \times d + 1)$, k is the gap factor and d is the distance. The factor 1118 is the result of test experience according to CIGRE Technical Brochure No. 696 and corresponds to $k = 1.15$ and two standard deviations of 0,05 each are taken into account to achieve the withstand voltage.

8.2.8 Power-frequency voltage test

The power-frequency voltage test applies to all LSA intended for a.c. applications on a.c. systems of $U_s \leq 245$ kV.

Housings of NGLA type NGLAs with lightning impulse classifying current of 5 kA shall withstand a wet power-frequency voltage with a peak value equal to the maximum residual voltage at lightning classifying discharge current multiplied by 0,82 for a duration of 1 min.

Housings of NGLAs with lightning classifying discharge current above 5 kA intended for application on a.c. systems of $U_s \leq 245$ kV shall withstand a wet power-frequency voltage with a peak value equal to the maximum switching impulse residual voltage at the LSAs switching impulse discharge current according to [Table 2](#) multiplied by 1,06 for a duration of 1 min.

If the dry arcing distance or the sum of the partial dry arcing distances is larger than given by the equation $d = [1,82 \times (e^{(U/859)} - 1)]^{0,833}$, where d is the distance in m and U is the peak value of the power-frequency test voltage in kV, this test is not required.

NOTE The equation is derived from formula F.1 of IEC 60071-2:2023, where the peak value of U_{50} is given as $750 \times \sqrt{2} \times \ln(1 + 0,55 \times d^{1,2})$, d being the distance. Following the recommendations given in IEC 60071-2, for the purpose of this standard the gap factor k is assumed to be equal to 1, the withstand voltage is assumed to be 90 % of U_{50} , and a 10 % reduction in U_{50} is assumed for wet conditions compared to dry.

8.2.9 Insulation withstand tests on EGLA with failed SVU

8.2.9.1 General

The voltage withstand tests on EGLA with a failed SVU demonstrates that no sparkover under switching surge and power-frequency overvoltages will occur if, as the worst case scenario, the SVU is shorted by a failure. The tests shall be performed in wet conditions and with the test voltages according to clauses [8.2.9.2](#) and [8.2.9.3](#). The outside surface of insulating parts shall be carefully cleaned, and the internal parts removed or rendered inoperative to permit these tests. For EGLA design that includes an insulator parallel to the gap, that insulator shall be also part of the test sample.

8.2.9.2 Switching impulse wet withstand voltage test

This test is required for EGLA intended for a.c. applications.

Test procedure

The test procedure shall be as follows:

Test sample: EGLA with shorted SVU. The failed SVU shall be simulated by shorting the SVU (e.g. with a metal wire), while the electrode condition shall be specified after agreement between the manufacturer and the purchaser. The minimum external series gap length for the test shall be specified by the manufacturer.

Test voltage and test condition:

The withstand voltage value shall be claimed by the manufacturer or determined by agreement between the manufacturer and the purchaser, considering the actual switching impulse withstand voltage level of the line.

The 50% flashover voltage ($U_{50, \text{EGLA}}$) is measured by the up-and-down method in accordance with IEC 60060-1 for each polarity on the EGLA with the SVU shorted. The wave shape of the test voltage shall be 250/2500. Additionally the 10% flashover voltage shall be confirmed. Fifteen consecutive impulses at the test voltage value shall be applied for each polarity. The EGLA or SVU shall be considered to have passed the test if no internal disruptive discharges occur and if the number of the external disruptive discharges does not exceed two in each series of 15 impulses and if no external disruptive discharges occur in the last three impulses.

The characteristic of the rain shall be in accordance with the requirements of IEC 60060-1.

Evaluation: The withstand voltage of the EGLA is determined as

$$U_{10, \text{EGLA}} = U_{50, \text{EGLA}}(1 - 1,3 \times \sigma) \quad (1)$$

calculated from the measured 50% flashover voltage and the standard deviation σ , which is assumed to be 6% ($\sigma = 0,06$) for switching impulse voltage. The EGLA has passed the test if the withstand value is equal to or higher than the claimed or agreed value.

NOTE For a normal distribution, as assumed here, the 10% probability value results from the 50% probability value minus 1,3 times the standard deviation.

8.2.9.3 Power-frequency wet withstand voltage test

The test procedure shall be as follows:

Test sample: EGLA with shorted SVU. The failed SVU shall be simulated by shorting the SVU with a metal wire. The minimum external series gap length and the conditions of the gap electrodes shall be specified by the manufacturer or agreed upon between the manufacturer and the user.

Test voltage and test condition:

The power-frequency wet withstand voltage test shall be performed in accordance with IEC 60060-1 on the EGLA with the SVU shorted.

The test voltage shall be 1,2 times the rated voltage of the EGLA.

The characteristic of the rain shall be in accordance with the requirements of IEC 60060-1.

Evaluation: The EGLA has passed the test if the sample withstands the test voltage for one minute.

8.3 Residual voltage tests

8.3.1 General

This test demonstrates that the residual voltages of the LSA under specified impulse currents are in accordance with the claimed values. It includes the calculation of the ratio between voltages at specified impulse currents and the voltage level checked in routine tests. The latter voltage can be either the reference voltage or the residual voltage at a suitable current impulse in the range 0,01 to 2 times the lightning classifying current depending on the manufacturer's choice of routine test procedure.

All residual voltage tests shall be made on the same three samples of a NGLA, SVU or LSA section. The time between discharges shall be sufficient to allow the samples to return to approximately ambient temperature.

The residual voltage of the EGLA is calculated from the measured residual voltage of the SVU sections times a scale factor plus a calculated inductive voltage drop across the SVU, the gap and the connection leads.

For the current impulses, there is no requirement for virtual time to half value on the tail.

8.3.2 Procedure for correction and calculation of inductive voltages

In case of current wave shape 2/20 μ s, the following procedure shall be used to determine if an inductive correction is required:

- A current impulse of wave shape 2/20 μ s shall be applied to a non-ferrous metal block having the same dimensions as the resistor samples being tested. The peak value and the shape of the voltage appearing across the metal block shall be recorded.
- If the peak voltage on the metal block is less than 2 % of the peak voltage of the MO resistor samples, no inductive correction to the MO resistor measurements is required.
- If the peak voltage on the metal block is between 2 % and 20 % of the peak voltage on the MO resistor sample, then the impulse shape of the metal block voltage shall be subtracted from the impulse shape of each of the MO resistor voltages, and the peak values of the resulting impulse shapes shall be recorded as the corrected MO resistor voltages. If the peak voltage on the metal block is higher than 20 % of the peak voltage on the MO resistor samples the test circuit and the voltage measuring circuit shall be improved and the test shall be repeated.

NOTE A possible way to achieve identical current wave shapes during all measurements is to perform them with both the test sample and the metal block in series in the test circuit. Only their positions relative to each other need to be interchanged for measuring the voltage drop on the metal block or on the test sample.

The sample impulse voltage wave shape (corrected if necessary) with the highest peak value shall be used to determine the current impulse residual voltage of the NGLA or the SVU and the complete EGLA, respectively, according to one of the following procedures a) or b):

Procedure a)

- a) Multiply the sample impulse voltage by the scale factor (see 7.4).
- b) From the wave shape of the current impulse, determine the rate of change of current (di/dt) over the entire wave shape and multiply it by the inductance in order to determine the inductive voltage drop:

$$u(t) = L \cdot \frac{di}{dt} = L' \cdot h \cdot \frac{di}{dt} \quad (2)$$

- $u(t)$ is the inductive voltage drop in kV as a function of time;
 L' is the inductance per unit length in $\mu\text{H}/\text{m}$; $L' = 1 \mu\text{H}/\text{m}$;
 h is either the terminal-to-terminal length in m of the NGLA, SVU or of the complete EGLA including series gap and connection leads;
 di/dt is the rate of change of current with time in $\text{kA}/\mu\text{s}$.

- c) Add the results of 1) and 2) on a wave shape basis; the peak value of the resulting wave shape shall be taken as the actual current impulse residual voltage of the LSA.

Procedure b)

- a) Multiply the peak value of the sample impulse voltage by the scale factor (see 7.4).
b) Determine the inductive voltage drop between the LSA terminals using the following formula:

$$U_L = L \cdot \frac{di}{dt} = L' \cdot h \cdot \frac{I_d}{T_f} \quad (3)$$

- U_L is the peak value of the inductive voltage drop in kV;
 L' is the inductance per unit length in $\mu\text{H}/\text{m}$; $L' = 1$;
 h is either the terminal-to-terminal length in m of the NGLA, SVU or of the complete EGLA including series gap and connection leads;
 T_f is the front time of the current impulse in μs ; $T_f = 2$;
 I_d is the actual discharge current amplitude in kA.

- c) Add the results of 1) and 2); the resulting value shall be taken as the actual current impulse residual voltage of the LSA.

8.3.3 Lightning impulse residual voltage test

One lightning current impulse with 2/20 μs waveshape shall be applied to each of the three samples for each of the following three peak values of approximately 0,5, 1 and 2 times the lightning classifying current impulse of the LSA according to Table 1. Virtual front time shall be within 1.7 μs to 2.3 μs while the half-value time (which is not critical) may have any tolerance.

If the manufacturer wishes to relate this voltage to routine tests on MO-resistors that have been performed in routine tests with a 8/20 μs waveshape, then one additional lightning current impulse shall be applied to each of the three samples with peak value of approximately the evaluation current of the LSA according to Table 1. Virtual front time shall be within 7 μs to 9 μs while the half-value time (which is not critical) may have any tolerance.

The lightning impulse residual voltage for all LSA is determined as per procedure a) or b) in 8.3.2.

The maximum values of the determined residual voltages shall be drawn in a residual voltage versus discharge current curve.

If the routine test cannot be carried out on a complete SVU or NGLA at classifying current, then additional design tests shall be carried out at a current in the range of 0,01 to 2 times the evaluation current for comparison with the complete SVU or NGLA.

8.3.4 Switching impulse residual voltage test

This clause applies to all LSA with classification S1, S2, or S3.

One switching classifying current impulse shall be applied to each of the three samples with peak values according to [Table 2](#) with a tolerance of $\pm 5\%$. The residual voltages are determined in accordance with 6.3. The highest value of these three sample voltages is defined as the switching impulse residual voltage of the LSA section at the switching impulse classifying current.

8.4 Standard impulse sparkover test

This test applies to EGLA only, to determine the 50% impulse sparkover voltage of the gap.

The test shall be performed on one test sample consisting of the EGLA with maximum gap distance for the designated applied system voltage.

The 50% sparkover voltage shall be determined with standard lightning impulses (1,2/50) under dry condition by the up-and-down method according to IEC 60060-1:2010.

For EGLAs intended for switching overvoltage control, the 50% sparkover voltage shall be determined with standard switching impulses (250/2500) under dry condition by the up-and-down method according to IEC 60060-1:2010

The test may be performed with or without the insulator assembly. If the test is performed with the insulator assembly, a flashover on the insulator shall be considered as a test failure.

8.5 High current impulse withstand test

8.5.1 General

This test applies to all LSA types.

The test shall be performed on three dielectrically prorated sections of a LSA. The sections shall have a residual voltage at evaluation current at the highest end of the variation range declared by the manufacturer.

8.5.2 Test procedure

Each test sample shall be subjected to the following initial tests, in the order specified:

- reference voltage test at specified reference current
- residual voltage test at evaluation current or classifying current; the current wave shape shall be in the range of $T_1/T_2 = (2 \text{ to } 10)/(10 \text{ to } 25) \mu\text{s}$

Two high current impulses of same polarity, having peak values and wave shapes according to [Table 1](#) and [Table 2](#), shall then be applied to the three sections. Time interval between the impulse applications shall allow the sample to cool to ambient temperature.

After the samples have cooled to ambient temperature, the initial tests shall be repeated.

Oscillograms of current and voltage shall be taken for the impulse applications.

The tolerances on the adjustment of the equipment shall be such that the measured values of the high current impulses are within the following limits:

- from 100 % to 110 % of the specified peak value;
- from 1,7 μs to 2,3 μs for virtual front time;
- from 18 μs to 22 μs for virtual time to half value on the tail;
- the peak value of any opposite polarity current wave shall be less than 20 % of the peak value of the current;

- small oscillations on the impulse are permissible provided their amplitude near the peak of the impulse is less than 5 % of the peak value. Under these conditions, for the purpose of measurement, a mean curve shall be accepted for determination of the peak value.

8.5.3 Test evaluation

The samples have passed the test if all the following criteria are met:

- There is no evidence of a dielectric breakdown in the oscillograms.
- The reference voltage measured before and after the test shall have changed by not more than 5 % .
- Any change in residual voltage at evaluation current or classifying current measured before and after the test shall be within (– 5 % to + 5 %).
- Visual examination of the test samples after the test shall reveal no evidence of puncture, flashover and cracking or other significant damage of the test sample. If the metal-oxide resistors cannot be removed from the test samples for visual examination, the following additional test shall be performed to ensure that no damage occurred during the test:
- After the residual voltage test (c), two impulses at the lower of 0,5 kA/cm² or 2 times the magnitude of evaluation current shall be applied to the test sample. The first impulse shall be applied after sufficient time to allow cooling of the sample to ambient temperature. The second impulse is applied 50 s to 60 s after the first impulse. During the two impulses, the oscillograms of both voltage and current shall not reveal any breakdown, and the difference of the residual voltage between the initial measurement before the test and the last of the two impulses after the test shall not exceed a range of (– 5 % to + 5 %).

8.6 Test to verify the repetitive charge transfer rating, Q_{rs}

8.6.1 General

The purpose of the test is to define the LSA capability to discharge a defined charge with a specific duration. Repetitive charge transfer capability is specified as an impulse current stress that can be withstood by the LSA twenty times without mechanical or unacceptable electrical damage. One impulse current stress is considered to represent a charge transfer event that may occur under real system conditions. It is assumed that the performance of the individual MO resistors can also be assigned to a full LSA built from these MO resistors, and series gap in the case of EGLA, based on the test requirements and the chosen statistical approach.

8.6.2 MO resistors

The repetitive charge transfer rating is related to a certain very low failure probability and is thus not a deterministic but a statistical value. The test is performed on MO resistors at a charge value in the range 1,1 to 1,2 times the rated value selected from the list in 8.6.6. Charge has been chosen as a test basis for the purpose of better comparison between different makes of MO resistors.

LSA rated for lightning impulse discharge capability shall be tested for repetitive charge transfer with an impulse duration of around 200 µs, which is considered as a suitable compromise to cover both the typical applications and the effect of multiple strokes. The current impulse shape shall be approximately sinusoidal. The time duration for which the instantaneous value of the impulse current is between 5 % and 100 % of its peak value shall be within 200 µs to 230 µs. The peak of any opposite polarity current wave shall be less than 5 % of the peak value of the current.

For LSA application intended for use of switching overvoltage protection, the repetitive charge transfer test shall be performed with long-duration (rectangular) impulses of 2 ms to 4 ms virtual total duration or unipolar sine half-wave impulses of 2 ms to 4 ms total duration. The choice is at the discretion of the manufacturer.

In the case where the LSA application is required to handle both lightning and switching impulse duty, the LSA shall be separately tested to assign both ratings. The rated switching impulse discharge capability selected from the list in 8.6.6 can be different to that selected for lightning discharges.

A first test sequence shall be performed on 10 samples selected according to 8.6.2.1. If not more than one MO resistor fails, the entire test is passed. If two MO resistors fail, a second sequence identical to the first shall be performed on an additional 10 samples. The entire test shall then be passed if there is no failure of an MO resistor during this second sequence. If more than two MO resistors fail in the first test sequence or any MO resistor fails in the second test sequence, the entire test is failed.

The sample type of either a single MO resistor or stack of two series connected MO resistors shall be the same for all samples tested. When the sample consists of a stack of two MO resistors, a failure of any MO resistor in the stack is considered as a failure of two MO resistors.

8.6.2.1 Selection of test samples

The test samples shall include MO resistors which have not been subjected to any previous tests except as necessary for evaluation purposes of this test. In the case of EGLA, complete SVUs or SVU sections may be used.

The samples to be chosen for the test to verify the repetitive charge transfer rating shall have a residual voltage at evaluation current at the highest end of the variation range declared by the manufacturer. Furthermore, in the case of multi-column LSAs the highest value of uneven current distribution shall be considered. In order to comply with these specifications, the following shall be fulfilled.

- a) The ratio between the residual voltage at evaluation discharge current of the complete LSA, or SVU in the case of EGLA, and the residual voltage at evaluation discharge current of the section is defined by n . The volume of the resistor elements used as test samples shall not be greater than the minimum volume of all resistor elements used in the complete LSA divided by n .
- b) The reference voltage U_{ref} of the test section should be equal to the minimum reference voltage of the LSA divided by n . If the reference voltage of the test section is greater than the minimum reference voltage of SVU of the complete EGLA divided by n , the factor n shall be reduced correspondingly. If the reference voltage of the test section is less than the minimum reference voltage of the complete LSA divided by n , the test section is not allowed to be used.
- c) For multi-column LSAs the distribution of the current between the columns shall be measured at the impulse current for current distribution test (see item e) of Clause 9). The highest current value shall not be higher than an upper limit specified by the manufacturer. Furthermore, for tests that are required to be performed on test sections with multiple columns the discharge energy shall be increased by a factor β_g/β_a where β_g is the guaranteed current sharing factor and β_a is the actual current sharing factor for the test section. If the test is performed on single columns the energy shall be increased by a factor β_g .
- d) The individual MO resistors shall be of the type used in the design and consist of either the maximum nominal length of MO resistor or a stack of two series connected MO resistors each having different rated voltage whereof at least one in each stack is of the maximum nominal length. The individual MO resistors used shall have a 10-kA residual voltage stress of not less than $0,97 \times (U_{10 \text{ kA per mm of MO resistor length}})_{\text{max}}$, where $(U_{10 \text{ kA per mm of MO resistor length}})_{\text{max}}$ is the highest 10-kA residual voltage stress specified by the manufacturer for any length of the type of MO resistors used in the LSA. If only MO resistors samples of lower 10-kA residual voltage stress are available, the required transferred charge for the individual MO resistors shall be increased for the test by the factor $(U_{10 \text{ kA per mm of MO resistor length}})_{\text{max}} / (U_{10 \text{ kA per mm of MO resistor length}})_{\text{actual}}$. The choice to test samples of individual MO resistors or a stack of series connected MO resistors is at the discretion of the manufacturer.

NOTE The choice by the manufacturer to test a stack of MO resistors may be due, for example, to preferential test lab set up or the desire to verify different lengths of MO resistor by a single round of testing.

8.6.3 Test procedure

Figure 2 gives an overview of the test procedure.

Initial tests
- Residual voltage test at evaluation current - Reference voltage test at specified reference current
Application of 1,1 times Q_{rs}
1st sequence: 20 impulses per sample (10 samples) - if not more than one sample failure during 1st sequence: test passed - if not more than two sample failures during 1st sequence: conduct 2nd sequence with 10 samples, 20 impulses per sample - if more than two sample failures in 1st sequence or any sample failure in 2nd sequence: test failed
Test evaluation: check for
- no mechanical damage at visual inspection - change of reference voltage within $\pm 5\%$ - change of residual voltage at evaluation current within $\pm 5\%$ - withstand capability to one 8/20 current impulse of at least $0,5 \text{ kA/cm}^2$ peak current density or 2 times the magnitude of evaluation current, whichever is lower
IEC

Figure 2 – Test procedure to verify the repetitive charge transfer rating, Q_{rs}

Ten test samples shall be tested in the first sequence. Depending on the results, it may be necessary to test an additional ten samples in a second sequence.

The samples shall fulfil the requirements in 8.6.2.1.

The following procedure shall be followed:

- Each sample shall be subjected to a residual voltage test at evaluation current and a reference voltage test at specified reference current before and after the test.
- Each sample shall be subjected to twenty current impulses administered in ten groups of two impulses, with time between impulses within a group of 50 s to 60 s and time between groups sufficient for cooling to ambient temperature.
- The wave shape and duration of the current impulses shall be as indicated in 8.6.2.
- For single-column LSA, the charge content of each impulse shall be at least equal to the claimed repetitive charge transfer rating (selected from the list given in 8.6.6) multiplied by 1,1.
- for multi-column LSA, the charge content of each impulse shall be at least equal to the claimed repetitive charge transfer rating (selected from the list given in 8.6.6) multiplied by 1,1, then divided by the number of columns, and then multiplied by the current sharing factor β_g (see 8.6.2.1, list item c)).

NOTE 1 The requirement of testing at least 1,1 times the rated charge values is considered to give sufficient confidence that the performance of the individual MO resistors can also be assigned to complete LSAs built from this type of MO resistors.

NOTE 2 If MO resistors tested with charge values for single-column LSAs are used in a multi-column LSA and no new test is performed the repetitive charge transfer rating for the complete multi-column LSA is the next lower or equal value (in the list shown in 8.6.6) to the repetitive charge transfer rating of the MO resistors times the number of columns and divided by the current sharing factor.

8.6.4 Test evaluation

The full test shall be considered passed if either.

- a) not more than one sample failed during the first sequence, or
- b) not more than two samples failed during two sequences.

Otherwise, the test is considered as failed and a lower charge level, Q_{rs} , from the list shown in 8.6.6 shall be selected, and the test shall be repeated for this lower charge level following the procedure given in 8.6.3.

NOTE 1 If only one failure occurs during the first sequence and this happens, in the worst case, at the very first impulse application, 180 impulses without failure will have been applied at the end, giving a failure probability of max. $1/181 = 0,0056$ or 0,56 % for the complete test. If two failures occur during the first sequence and this happens, again as a worst case, at the very first applications on two of the samples, 360 impulses without failure will have been applied at the end of both sequences, giving again a failure probability of max. $2/362 = 0,0056$ or 0,56 % for the complete test.

Each individual sample shall be considered to have withstood the complete series of impulses if all the following criteria are met:

- c) there is no indication of mechanical damage (puncture, flashover or cracking);
- d) any change of the reference voltage before and after the test, measured at the same temperature ± 3 K, is within ± 5 %;
- e) any change of the residual voltage at evaluation current before and after the test is within ± 5 %;
- f) a final application of a current impulse $8/20$ μ s of an amplitude resulting in a current density of at least $0,5$ kA/cm² or in 2 times the magnitude of evaluation current, whichever is lower, is passed without mechanical damage.

NOTE 2 Puncture of the metallization is not considered a mechanical damage if all other pass criteria are met.

8.6.5 Series gap of EGLA

8.6.5.1 General

This test applies to the series gap for EGLA with gap spacing of 20 cm or less.

The purpose of this test is to verify the repetitive charge withstand capability of the series gap under lightning impulse discharges. The test shall be performed on one series gap with a Q_{rs} value not less than the Q_{rs} value specified for the MO resistors of SVU.

8.6.5.2 Test procedure

Figure 3 gives an overview of the test procedure.

Pre- tests - Determination of the 50 % spark-over voltage of the series gap under lightning impulse voltage stress for both polarities. The shortest flashover distance for the design shall be used. The test can be performed without the insulator assembly. The 50 % spark-over voltage ($U_{50, \text{EGLA series gap}}$) shall be verified by the up-and-down method according to IEC 60060-1 (refer to 8.4). - For the application of impulse discharges, the series gap can be integrated in series with one of the ten test samples of test used in 8.6.3 to verify the repetitive charge transfer rating, Q_{rs}. In this case, it may be necessary to reduce the gap spacing to get spark-over. The gap spacing may be reduced to not less than 10 mm for this purpose. If an arc cannot be established with a gap of 10 mm, the test voltage shall be increased until spark-over occurs.
Application of Q_{rs}