

IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits

Sponsor
**Surge Protective Devices Committee
of the
IEEE Power Engineering Society**

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IEEE Standards Board

Abstract: IEEE C62.1-1989, *IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Systems*, describes the service conditions, classifications and voltage ratings, design tests with corresponding performance characteristics, conformance tests, and certification test procedures for station, intermediate, distribution and secondary class arresters. Terminal connections, housing leakage distance, mounting and identification requirements are defined. Definitions are provided to clarify the required test procedures and other portions of the text.

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Foreword

(This Foreword is not a part of IEEE C62.1-1989, IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits.)

This standard supersedes ANSI/IEEE C62.1-1984. In addition to a revised title and scope, there are three other substantive changes in the standard.

The title and scope are revised to clarify that the standard applies only to gapped silicon-carbide surge arresters.

The magnitude of the low current pressure-relief test currents, and the asymmetry factor of crest asymmetrical to the rms symmetrical current, were revised to harmonize with IEC standards.

A sealing system test has been added as an additional design test for distribution class surge arresters. Routine tests for distribution class surge arresters have been added, and require the manufacturer to perform the following on all arrester units:

- 1) Dry power-frequency sparkover test
- 2) Ionization voltage test
- 3) Leak test.

In addition to the above substantive changes, editorial changes clarify:

- 1) That voltage ratings of prorated sections utilized for discharge-current withstand tests for station and intermediate class arresters shall be 3 kV or more, but need not exceed 9 kV
- 2) The requirement for line and ground terminal of station and intermediate class arresters.

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IEEE Standard for Gapped Silicon-Carbide Surge Arresters for AC Power Circuits

1. Scope

This standard applies to gapped silicon-carbide surge-protective devices designed for repeated limiting of voltage surges on 50 Hz or 60 Hz power circuits by passing surge discharge current and subsequently automatically interrupting the flow of follow current. This standard applies to devices for separate mounting and to those supplied integrally with other equipment.

2. Definitions

The following definitions apply specifically to surge arresters and do not necessarily cover other applications.

arrester disconnecter: A means for disconnecting an arrester in anticipation of, or after, a failure in order to prevent a permanent fault on the circuit and to give indication of a failed arrester.

NOTE — Clearing of the power current through the arrester during disconnection generally is a function of the nearest source-side overcurrent-protective device.

basic impulse insulation level (BIL): A reference impulse insulation strength expressed in terms of the crest value of withstand voltage of a standard full impulse voltage wave.

NOTE — See ANSI C92.1-1982 [3].¹

certification tests: Tests made, when required, to verify selected performance characteristics of a product or representative samples thereof.

classification of arresters: Arrester classification is determined by prescribed test requirements. These classifications are:

- station arrester
- intermediate arrester
- distribution arrester
- secondary arrester

¹Numbers in brackets correspond to those in the references listed in Section 3. of this standard.

NOTE — See 5.2 for the test requirements.

coefficient of grounding: The ratio E_{LG}/E_{LL} , expressed as a percentage, of the highest root-mean-square line-to-ground power-frequency voltage E_{LG} , on a sound phase, at a selected location, during a fault to ground affecting one or more phases to the line-to-line power-frequency voltage E_{LL} which would be obtained, at the selected location, with the fault removed.

NOTES:

- 1 — Coefficients of grounding for three-phase systems are calculated from the phase-sequence impedance components as viewed from the selected location. For machines, use the subtransient reactance.
- 2 — The coefficient of grounding is useful in the determination of an arrester rating for a selected location.
- 3 — A value not exceeding 80% is obtained approximately when, for all system conditions, the ratio of zero-sequence reactance to positive-sequence reactance is positive and less than 3, and the ratio of zero-sequence resistance to positive sequence reactance is positive and less than 1.

conformance tests: Tests made, when required, to demonstrate selected performance characteristics of a product or representative samples thereof.

crest (peak) value (of a wave, surge, or impulse): The maximum value that it attains.

deflector: A means for directing the flow of the gas discharge from the vent of the arrester.

design tests: Tests made by the manufacturer on each design to establish the performance characteristics and to demonstrate compliance with the appropriate standards of the industry. Once made, they need not be repeated unless the design is changed so as to modify performance.

discharge counter: A means for recording the number of arrester discharge operations.

discharge current: The surge current that flows through an arrester when sparkover occurs.

discharge indicator: A means for indicating that the arrester has discharged.

discharge voltage: The voltage that appears across the terminals of an arrester during passage of discharge current.

discharge voltage-current characteristic: The variation of the crest values of discharge voltage with respect to discharge current.

NOTE — This characteristic is normally shown as a graph based on three or more current-surge measurements of the same wave shape but of different crest values.

discharge withstand current rating: The specified magnitude and wave shape of a discharge current that can be applied to an arrester a specified number of times without causing damage to it.

disruptive discharge: The sudden and large increase in current through an insulating medium, due to the complete failure of the medium under the electrostatic stress.

fault-current withstand: The maximum rms symmetrical fault current of a specified duration that a failed distribution class arrester will withstand without an explosive fracture of the housing.

fault current: The current from the connected power system that flows in a short circuit.

flashover: A disruptive discharge around or over the surface of a solid or liquid insulator.

follow (power) current: The current from the connected power source that flows through an arrester during and following the passage of discharge current.

grading or control ring: A metal part, usually circular or oval in shape, mounted to modify electrostatically the voltage gradient or distribution.

grounded system: An electric system in which at least one conductor or point (usually the neutral conductor or neutral point of transformer or generator windings) is intentionally grounded, either solidly or through a grounding device.

ground terminal: The conducting part provided for connecting the arrester to ground.

impulse: A surge of unidirectional polarity.

impulse sparkover volt-time characteristic: The sparkover response of the device to impulses of a designated wave shape and polarity, but of varying magnitudes.

NOTE — For an arrester, this characteristic is shown by a graph of values of crest voltage plotted against time to sparkover.

impulse withstand voltage: The crest value of an impulse that, under specified conditions, can be applied without causing a disruptive discharge.

impulse sparkover voltage: The highest value of voltage attained by an impulse of a designated wave shape and polarity applied across the terminals of an arrester prior to the flow of discharge current.

indoor arrester: An arrester that, because of its construction, shall be protected from the weather.

ionization current: The electric current resulting from the movement of electric charges in an ionized medium, under the influence of an applied electric field.

ionization voltage: A high-frequency voltage appearing at the terminals of an arrester, generated by all sources, but particularly by ionization current within the arrester, when a power-frequency voltage is applied across the terminals.

lightning: An electric discharge that occurs in the atmosphere between clouds or between clouds and ground.

lightning surge: A transient electric disturbance in an electric circuit caused by lightning.

line terminal: The conducting part provided for connecting the arrester to the circuit conductor.

NOTE — When a line terminal is not supplied as an integral part of the arrester, and the series gap is obtained by providing a specified air clearance between the line end of the arrester and a conductor, or arcing electrode, etc., the words line terminal used in the definition refer to the conducting part that is at line potential and that is used as the line electrode of the series gap.

maximum (highest) system voltage: The highest voltage at which a system is operated.

NOTE — This is generally considered to be the maximum system voltage as prescribed in ANSI C84.1-1989 [2].

nominal rate of rise (of an impulse wave front): The slope of the line that determines the virtual zero. It is usually expressed in volts or amperes per microsecond.

nominal system voltage: A nominal value assigned to designate a system of a given voltage class.

NOTE — See ANSI C84.1-1989 [2].

operating duty cycle: One or more unit operations, as specified.

oscillatory surge: A surge that includes both positive and negative polarity values.

outdoor arrester: An arrester that is designed for outdoor use.

power-frequency sparkover voltage: The root-mean-square value of the lowest power-frequency sinusoidal voltage that will cause sparkover when applied across the terminals of an arrester.

power-frequency withstand voltage: A specified root-mean-square test voltage at power frequency that will not cause a disruptive discharge.

prorated section: A complete, suitably housed part of an arrester, comprising all necessary components, including gaseous medium, in such a proportion as to accurately represent, for a particular test, the characteristics of a complete arrester.

radio influence 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.

rating: The designation of an operating limit for a device.

recovery voltage: The voltage that occurs across the terminals of a pole of circuit-interrupting device upon the interruption of the current.

NOTE — For an arrester, this occurs as a result of interruption of the follow current.

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.

sparkover: A disruptive discharge between electrodes of a measuring gap, voltage-control gap, or protective device.

series gap: An intentional gap(s) between spaced electrodes; it is in series with the valve element of the arrester, substantially isolating the element from line or ground, or both, under normal line-voltage conditions.

surge: A transient wave of current, potential, or power in an electric circuit.

surge arrester: A protective device for limiting surge voltages on equipment by discharging or bypassing surge current; it prevents continued flow of follow current to ground, and is capable of repeating these functions as specified.

NOTE — Hereafter, the term *arrester* as used in this standard shall be understood to mean *surge arrester*.

system (circuit) voltage: The root-mean-square power-frequency voltage from line to line as distinguished from the voltage from line to neutral.

terminals: The conducting parts provided for connecting the arrester across the insulation to be protected.

time to impulse sparkover: The time between virtual zero of the voltage impulse causing sparkover and the point on the voltage wave at which sparkover occurs.

unit operation: Discharging a surge through an arrester while the arrester is energized.

valve arrester: An arrester that includes a valve element.

valve element: A resistor that, because of its nonlinear current-voltage characteristic, limits the voltage across the arrester terminals during the flow of discharge current and contributes to the limitation of follow current at normal power-frequency voltage.

vent: An intentional opening for the escape of gases to the outside.

voltage rating: The designated maximum permissible operating voltage between its terminals at which an arrester is designed to perform its duty cycle. It is the voltage rating specified on the nameplate.

wave: The variation with time of current, potential, or power at any point in an electric circuit.

wave front (of a surge or impulse): That part which occurs prior to the crest value.

wave tail (of an impulse): That part between the crest value and the end of the impulse.

wave shape designation (of an impulse): The wave shape of an impulse (other than rectangular) of a current or voltage is designated by a combination of two numbers. The first, an index of the wave front, is the virtual duration of the wave front in microseconds as defined in 2.28. The second, an index of the wave tail, is the time in microseconds from virtual zero to the instant at which one-half of the crest value is reached on the wave tail. Examples are 1.2/50 and 8/20 waves.

wave shape (of an impulse test wave): The graph of the wave as a function of time.

wave shape of a rectangular impulse of current or voltage: This wave is designated by two numbers. The first designates the minimum value of current or voltage which is sustained for the time in microseconds designated by the second number. An example is the 75 A · 2000 μ s wave.

virtual zero point (of an impulse): The intersection with the zero axis of a straight line drawn through points on the front of the current wave at 10% and 90% crest value, or through points on the front of the voltage wave at 30% and 90% crest value.

virtual duration of wave front (of an impulse): The virtual value for the duration of the wave front is as follows:

- 1) For voltage waves with wave front duration less than 30 μ s, either full or chopped on the front, crest, or tail, 1.67 times the time for the voltage to increase from 30% to 90% of its crest value.
- 2) For voltage waves with wave front duration of 30 or more μ s, the time taken by the voltage to increase from actual zero to maximum crest value.
- 3) For current waves, 1.25 times the time for the current to increase from 10% to 90% of crest value.

3. References

This standard shall be used in conjunction with the following publications.

- [1] ANSI C37.42-1989, American National Standard Specifications for Distribution Cutouts and Fuse Links.²
- [2] ANSI C84.1-1989, American National Standard Voltage Ratings for Electric Power Systems and Equipment (60 Hz).
- [3] ANSI C92.1-1982, American National Standard Insulation Coordination.
- [4] ASTM A 153-82, Standard Specification for Zinc Coating (Hot-Dipped) on Iron and Steel Hardware.³
- [5] IEEE C62.2-1987, IEEE Guide for Application of Valve Type Surge Arresters for Alternating Current Systems (ANSI).⁴
- [6] IEEE Std 4-1978, IEEE Standard Techniques for High-Voltage Testing (ANSI).
- [7] NEMA LA1-1986, Surge Arresters.⁵
- [8] NEMA 107-1987, Methods of Measurement of Radio Influence Voltage of High-Voltage Apparatus.

4. Service Conditions

4.1 Usual Service Conditions

An arrester conforming to this standard shall be, at a minimum, designed for application under the following conditions:

4.1.1 Physical Conditions

- 1) Ambient temperature not exceeding 40 °C
- 2) Altitude not exceeding 1800 m (6000 ft)

4.1.2 System Conditions

- 1) Normal power-system frequency of 50 Hz or 60 Hz
- 2) System line to ground voltage within the rating of the arrester under all system operating conditions.

4.2 Unusual Service Conditions

The following service conditions may require special consideration in the design or application of arresters, and should be called to the attention of the manufacturer.

² ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

³ ASTM publications are available from the Sales Department, American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

⁴ IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331, or the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

⁵ NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

4.2.1 Physical Conditions

- 1) Ambient temperature exceeding 40 °C
- 2) Altitude exceeding 1800 m (6000 ft)
Arresters for service at higher altitudes shall be suitable for operation at either of the following altitude ranges:
 - a) 1801 m-3700 m (6000 ft-12 000 ft)
 - b) 3701 m-5500 m (12 001 ft-18 000 ft)
- 3) Exposure to:
 - a) Damaging fumes or vapors
 - b) Excessive dirt or other current-conducting deposits, particularly in applications where systems can operate with a grounded phase so that the arrester is at line-to-line voltage for extended periods of time
 - c) Excessive humidity, moisture, dripping water, steam, or salt spray
 - d) Explosive atmospheres
 - e) Abnormal vibrations or shocks
- 4) Limitation on weight or space, including clearances to nearby conducting objects, particularly at altitudes exceeding 1800 m (6000 ft)
- 5) Unusual transportation or storage

4.2.2 System Conditions

- 1) Nominal power frequency other than 50 Hz or 60 Hz
- 2) System operating conditions whereby the voltage rating of the arrester may be exceeded.
Some examples are:
 - a) Loss of neutral ground on a normally grounded circuit
 - b) Generator overspeed
 - c) Resonance during faults upon loss of major generation
 - d) System instability
- 3) Any other unusual conditions known to the user

5. Classification and Voltage Rating of Arresters

5.1 Voltage Ratings

The root-mean-square voltage ratings in kilovolts for arresters shall be as shown in Table 1.

5.2 Test Requirements

Arresters of the various classifications shall meet the test requirements listed in Table 2.

6. Performance Characteristics and Tests

The following tests were developed to evaluate the relative performance of arresters.

6.1 Voltage Withstand Tests

The voltage withstand tests of arrester insulation demonstrate that the insulation of the arrester is above the minimum specified level. See 8.1 and 9.1.

6.2 Power-Frequency Sparkover Test

The power-frequency sparkover tests serve to establish that the sparkover voltage at power frequency of the assembled arrester is above the rated voltage by a specified margin. See 8.2 and 9.2.

6.3 Discharge-Current Withstand Tests

The discharge-current withstand tests consisting of high-current short-duration, and low-current long-duration tests serve to demonstrate the adequacy of the electrical, mechanical, and thermal design of the arrester. See 8.6 and 9.5.

6.4 Impulse Sparkover Voltage-Time Characteristics

The impulse sparkover voltage-time characteristics show the relation between impulse sparkover voltage and time to sparkover for a specified impulse wave shape. See 8.3 and 9.3.

6.5 Discharge-Voltage Tests

Discharge-voltage tests serve to establish the relation between the voltage across the arrester terminals and discharge current at several values of discharge current of specified wave shape. They also show the relation between discharge voltage and voltage rating so that the discharge-voltage characteristics of high-voltage arresters may be determined by extrapolation. See 8.4 and 9.4.

Table 1—Arrester Voltage Ratings in kV

Secondary Arresters	Distribution Arresters	Intermediate Arresters	Station Arresters
0.175			
0.650			
	1		
	3	3	3
	6	6	6
	9	9	9
	10		
	12	12	12
	15	15	15
	18		
	21	21	21
		24	24
	25		
	27		
	30	30	30
		36	36
		39	39
		48	48
		60	60
		72	72
		90	90
		96	96
		108	108
		120	120
			144
			168
			180
			192
			240
			258
			276
			294
			312
			372
			396
			420
			444
			468
			492
			540
			576
			612
			648
			684
NOTE — Because of the more stringent requirements for protection of rotating machines, the use of arresters (all classes) rated 4.5, 7.5, 16.5, 18, 19.5, 22.5, 24, 25.5 and 27 kV is recognized for this application.			

6.6 Duty-Cycle Test

The duty-cycle test serves to establish the ability of the arrester to interrupt follow current successfully and repeatedly under specified conditions. See 8.7 and 9.6.

6.7 Radio-Influence Voltage Test

The radio-influence voltage test provides a measure of the high-frequency voltage generated by an arrester that may cause objectionable communication interference. See 8.8 and 9.7.

6.8 Internal-Ionization Voltage Test

The internal-ionization voltage test provides a measure of ionization current present within an arrester design that may cause deterioration of internal arrester parts. See 8.8 and 9.7.

6.9 Pressure-Relief and Fault-Current Withstand Tests

The pressure-relief and fault-current withstand tests serve to demonstrate that failed arresters will withstand ensuing fault current under specified conditions without violent disintegration. See 8.9 and 9.8.

6.10 Contamination Tests

The contamination tests serve to demonstrate that the arrester will withstand a prescribed power-frequency voltage without sparking over under prescribed surface contamination. See 8.10 and 9.10.

6.11 Disconnecter Tests

The disconnector tests serve to demonstrate that disconnectors can withstand, without operation, the arrester design tests (9.5, 9.6, and 9.10) and provide a current-time characteristic operating curve. See 9.9.

7. Test Procedures

7.1 Complete Arrester Test Specimens

New and clean arresters shall be used for each test unless specified otherwise.

7.1.1

All test specimens for arrester designs incorporating a disconnector, either as an integral part or as an accessory, shall include the disconnector.

7.1.2

The arrester shall be mounted in the position in which it is designed to be used.

7.1.3

The arrester mounting bracket, if used, shall be connected to the ground terminal.