

Series capacitors for power systems —

Part 1: General

The European Standard EN 60143-1:2004 has the status of a
British Standard

ICS 31.060.70

National foreword

This British Standard is the official English language version of EN 60143-1:2004. It is identical with IEC 60143-1:2004. It supersedes BS EN 60143-1:1993 which will be withdrawn on 1 March 2007.

The UK participation in its preparation was entrusted to Technical Committee PEL/33, Power capacitors, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

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Summary of pages

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Part 1: General
(IEC 60143-1:2004)

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à être installés sur des réseaux
Partie 1: Généralités
(CEI 60143-1:2004)

Reihenkondensatoren
für Starkstromanlagen
Teil 1: Allgemeines
(IEC 60143-1:2004)

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Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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CENELEC

European Committee for Electrotechnical Standardization
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Foreword

The text of document 33/400/FDIS, future edition 4 of IEC 60143-1, prepared by IEC TC 33, Power capacitors, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60143-1 on 2004-03-01.

This European Standard supersedes EN 60143-1:1993 + corrigendum October 1994.

The main changes with respect to the previous edition regard in particular the old section 3 "Insulation level" that has been deeply modified and the new subclause 6.3 "Air clearances" has been added. In addition, many technical changes have been introduced throughout the text regarding tests and operation.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2004-12-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2007-03-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60143-1:2004 was approved by CENELEC as a European Standard without any modification.

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

IEC 60273	NOTE	Harmonized as HD 578 S1:1992 (not modified).
IEC 60060-2	NOTE	Harmonized as EN 60060-2:1994 (not modified).
IEC 60721-2-6	NOTE	Harmonized as HD 478.2.6 S1:1993 (not modified)
IEC 60110-1	NOTE	Harmonized as EN 60110-1:1998 (not modified).
IEC 60252-1	NOTE	Harmonized as EN 60252-1:2001 (not modified).
IEC 61048	NOTE	Harmonized as EN 61048:1993 (modified).
IEC 61049	NOTE	Harmonized as EN 61049:1993 (modified).
IEC 61071	NOTE	Harmonized in EN 61071 series (partly modified).

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SERIES CAPACITORS FOR POWER SYSTEMS –

Part 1: General

1 Scope and object

This part of IEC 60143 applies both to capacitor units and capacitor banks intended to be used connected in series with an a.c. transmission or distribution line or circuit forming part of an a.c. power system having a frequency of 15 Hz to 60 Hz.

The primary focus of this standard is on transmission application.

The series capacitor units and banks are usually intended for high-voltage power systems. This standard is applicable to the complete voltage range.

This standard does not apply to capacitors of the self-healing metallized dielectric type.

The following capacitors, even if connected in series with a circuit, are excluded from this standard:

- capacitors for inductive heat-generating plants (IEC 60110-1);
- capacitors for motor applications and the like (IEC 60252-1);
- capacitors to be used in power electronics circuits (IEC 61071);
- capacitors for discharge lamps (IEC 61048 and IEC 61049).

Standard types of accessories such as insulators, switches, instrument transformers, external fuses, etc. should comply with the pertinent IEC standard.

NOTE 1 Additional requirements for capacitors to be protected by internal fuses, as well as the requirements for internal fuses, are found in IEC 60143-3.

NOTE 2 Additional requirements for capacitors to be protected by external fuses, as well as the requirements for external fuses, are found in Annex A.

NOTE 3 A separate standard for series capacitor accessories (spark-gaps, non-linear resistors, discharge reactors, current-limiting damping reactors, damping resistors, circuit-breakers, etc.), IEC 60143-2, was completed in 1994. A separate standard for internal fuses for series capacitors, IEC 60143-3 (formerly IEC 60595), has been revised and was completed in 1998.

The object of this standard is:

- to formulate uniform rules regarding performance, testing and rating;
- to formulate specific safety rules;
- to serve as a guide for installation and operation.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE If there is a conflict between this standard and a standard listed below, the test of IEC 60143-1 prevails.

IEC 60060-1:1989, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60071-1:1993, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2:1996, *Insulation co-ordination – Part 2: Application guide*

IEC 60143-2:1994, *Series capacitors for power systems – Part 2: Protective equipment for series capacitor banks*

IEC 60143-3:1998, *Series capacitors for power systems – Part 3: Internal fuses*

IEC 60549:1976, *High-voltage fuses for the external protection of shunt power capacitors*

IEC 60815:1986, *Guide for the selection of insulators in respect of polluted conditions*

IEC 60871-2:1999, *Shunt capacitors for a.c. power systems having a rated voltage above 1 000 V – Part 2: Endurance testing*

IEEE Std. 693:1997, *IEEE Recommended Practice for Seismic Design of Substations*

3 Terms and definitions

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

NOTE Certain terms come from IEC 60050(436) or IEC 60050(604) and where this is the case, the concept from that publication is referenced in square brackets after the definition.

3.1

ambient air temperature (for capacitors)

temperature of air at the proposed location of the capacitor installation

3.2

bypass switch

device such as a switch or circuit-breaker used in parallel with a series capacitor and its overvoltage protector to shunt line current for some specified time or continuously

NOTE This device should also have the capability of inserting and bypassing the capacitor into a circuit carrying a specified level of current.

3.3

capacitor

word used when it is not necessary to distinguish between the different meanings of the words capacitor unit and the assembly of capacitors associated with a segment

3.4

capacitor unit

unit

assembly of one or more capacitor elements in the same container with terminals brought out

[IEC 60050, 436-01-04]

3.5

(capacitor) element

device consisting essentially of two electrodes separated by a dielectric

[IEC 60050, 436-01-03]

3.6

capacitor losses

active power dissipated in the capacitor

[IEC 60050, 436-04-10]

NOTE All loss-producing components should be included. For a unit, this includes losses from the dielectric, discharge device, internal fuses (if applicable) and internal connections. For the bank, this includes losses from the units, external fuses (if applicable) and busbars. See Annex B for additional discussion.

3.7

cooling air temperature

temperature of cooling air measured at the hottest position in the capacitor assembly of a segment, under rated current and steady-state conditions, midway between two units. If only one unit is involved, it is the temperature measured at a point approximately 0,1 m away from the capacitor container and at two-thirds of the height from its base

3.8

degree of compensation

k

degree of series compensation, k (of a line section) is

$$k = 100 (X_C / X_L) \%$$

where

X_C is the capacitive reactance of the series capacitor;

X_L is the total positive sequence inductive reactance of the transmission line section on which the series capacitor is applied.

3.9

discharge device (of a capacitor)

device connected across the terminals of the capacitor or built into the capacitor unit, capable of reducing the residual voltage across the capacitor effectively to zero after the capacitor has been disconnected from the supply

[IEC 60050, 436-03-15, modified]

NOTE Further requirements on the size of the discharge device are found in 8.1

3.10

external fuse (of a capacitor)

fuse connected in series with a capacitor unit or with a group of parallel units

3.11**fuseless capacitor bank**

capacitor bank without any fuses, internal or external, constructed of parallel strings of capacitor units. Each string consists of capacitor units connected in series

NOTE See Annex C for an explanation of “string”.

3.12**highest voltage of a three-phase system**

highest r.m.s. phase-to-phase voltage which occurs under normal operating conditions at any time and at any point of the system

NOTE It excludes voltage transients (such as those due to system switching) and temporary voltage variations due to abnormal system conditions (such as due to faults or sudden disconnection of large loads).

3.13**highest voltage for equipment** U_m

highest r.m.s. value of phase-to-phase voltage for which the equipment is designed in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards

[IEC 60050, 604-03-01]

NOTE This voltage is the maximum value of the highest voltage of the system for which the equipment may be used.

3.14**insulation level** U_i

non-simultaneous combination of test voltages (power-frequency (U_{ipf}) or switching impulse, and lightning impulse) which characterizes the insulation of the capacitor with regard to its capability of withstanding the electric stresses between terminals and earth, between phases and between terminals and metalwork (e.g. platform) not at earth potential

3.15**internal fuse of a capacitor**

fuse connected inside a capacitor unit, in series with an element or group of elements

[IEC 60050, 436-03-16]

3.16**limiting voltage** U_{lim}

maximum peak of the power frequency voltage occurring between capacitor unit terminals immediately before or during operation of the overvoltage protector, divided by $\sqrt{2}$ (see 5.1.4)

3.17**line terminal**

terminal to be connected to the power system

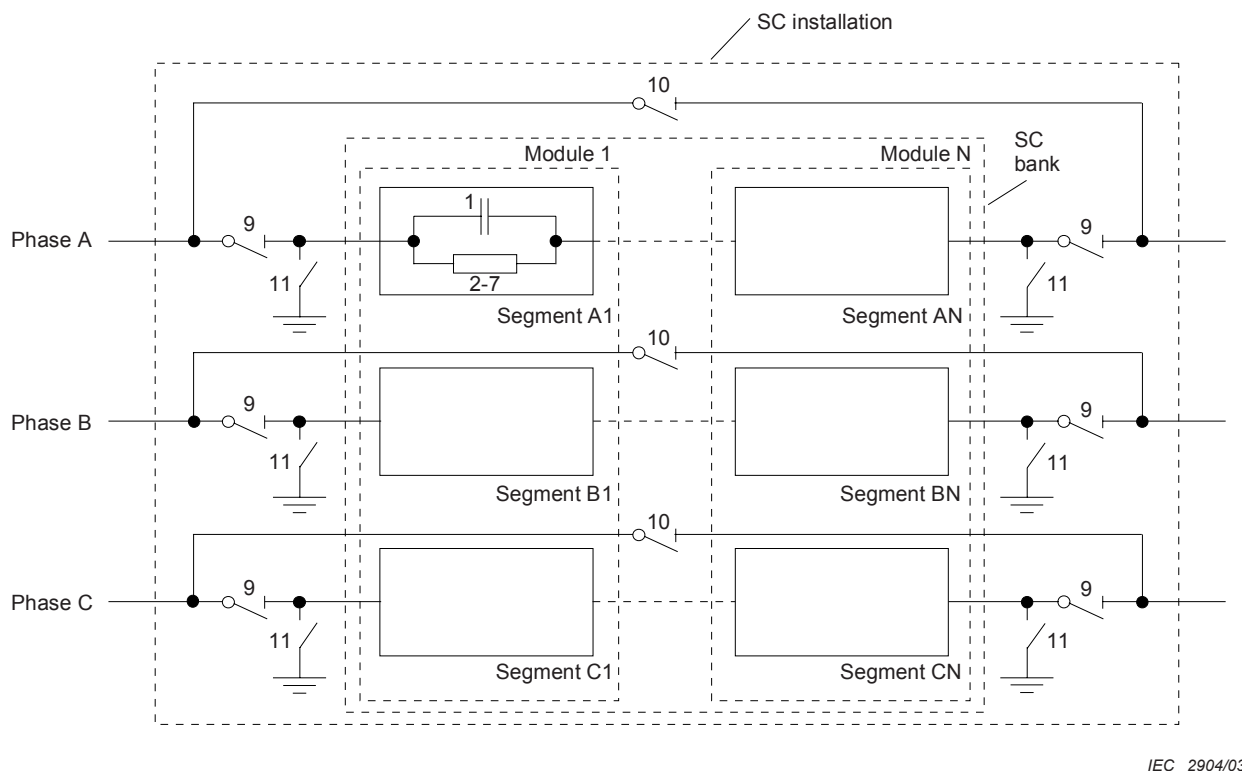
[IEC 60050, 436-03-01, modified]

3.18

module (of a series capacitor)

switchable step of a series capacitor consisting of identical segments in each phase (see Figure 1), which furthermore are also equipped with provisions for a common operation of the bypass switch of each of these segments

NOTE The bypass switch of a module is normally operated on a three-phase basis. However, in some applications for protection purposes, the bypass switch may be required to temporarily operate on an individual phase basis.



Key

- 1 assembly of capacitor units
- 2-7 main protective equipment (Figure 2/M2 and Annex D)
- 9 isolating disconnector
- 10 bypass disconnector
- 11 earth switch

Figure 1 – Typical nomenclature of a series capacitor installation

3.19

overvoltage protector (of a series capacitor)

quick-acting device which limits the voltage across the capacitor to a permissible value when that value would otherwise be exceeded as a result of a circuit fault or other abnormal power system conditions

[IEC 60050, 436-03-14, modified]

3.20

power frequency withstand voltage

U_{ipf}

wet power frequency withstand voltage of bushings and insulators

3.21**protective level** U_{pl}

magnitude of the maximum peak of the power frequency voltage appearing across the overvoltage protector during a power system fault

NOTE The protective level may be expressed in terms of the actual peak voltage across a segment or in terms of the per unit of the peak of the rated voltage across the capacitor (see 5.1.4, 10.4 and 10.5)

3.22**rated capacitance (of a capacitor)** C_N

capacitance value for which the capacitor has been designed

[IEC 60050, 436-01-12, modified]

3.23**rated current of a capacitor** I_N

r.m.s. value of the alternating current for which the capacitor has been designed

[IEC 60050, 436-01-13]

3.24**rated frequency (of a capacitor)** f_N

frequency of the system in which the capacitor is intended to be used

[IEC 60050, 436-01-14, modified]

3.25**rated output (of a capacitor)** Q_N

reactive power derived from rated reactance and rated current

[IEC 60050, 436-01-16, modified]

NOTE For the bank, the rated three-phase reactive power rating in Mvar (Q_N) is defined by the equation:

$$Q_N = 3 \times I_N^2 \times X_N$$

where

I_N is the rated current, in kA;

X_N is the rated reactance, in Ω .

3.26**rated reactance (of capacitor)** X_N

reactance of each phase of the series capacitor at rated frequency and 20 °C dielectric temperature

3.27**rated voltage (of the bank)**

power system phase-to-phase voltage for which the phase-to-ground insulation system is designed

3.28**rated voltage (of a capacitor)** U_N

r.m.s. value of the voltage between the terminals, derived from rated reactance and rated current $U_N = X_N \times I_N$

[IEC 60050, 436-01-15, modified]

3.29

residual voltage (of a capacitor)

voltage remaining between terminals of a capacitor at a given time following disconnection of the supply

3.30

segment (of a series capacitor)

where each phase of a bank is divided into one or more series connected parts, of which each part contains its own assembly of capacitor units, overvoltage protector, protective functions and bypass switch, each such complete part is called segment (see Figure 1)

NOTE Segments are not normally separated by isolating disconnectors. More than one segment can be on the same insulated platform.

3.31

series capacitor bank (or bank)

three-phase assembly of capacitors with the associated protection and insulated support structure

NOTE The bank may include one or more modules (see Figure 1).

3.32

series capacitor installation

series capacitor bank and its accessories including the bypass and isolating disconnectors

[IEC 60050, 436-01-07, modified]

3.33

steady-state condition

thermal equilibrium attained by the capacitor at constant output and at constant ambient air temperature

3.34

sub-segment

where a segment is divided into more than one series connected part, and each part includes an assembly of capacitors with an overvoltage protector and selected protective functions, each part is called a sub-segment

NOTE A sub-segment does not have its own bypass switch.

3.35

tangent of loss angle (of a capacitor)

$\tan \delta$

ratio between the equivalent series resistance and the capacitive reactance of a capacitor at specified sinusoidal alternating voltage and frequency

NOTE Tangent of loss angle can also be expressed as the capacitor losses divided by the reactive power of the capacitor.

3.36

varistor coordinating current

magnitude of varistor current associated with the protective level

NOTE The varistor coordinating current waveform is considered to have a virtual front time of 30–50 μ s. The tail of the waveform is not significant in establishing the protective level voltage.

4 Service conditions

4.1 Normal service conditions

Series capacitor banks shall be suitable for operation at their specified current, voltage, and frequency ratings and specified fault sequences under the following conditions:

- a) The elevation does not exceed 1 000 m above sea level.
- b) The indoor and outdoor ambient temperatures are within the limits specified by the purchaser.
- c) The ice load does not exceed 19 mm (if applicable).
- d) Wind velocities are no greater than 128 km/h.
- e) The horizontal seismic acceleration (if applicable) of the equipment does not exceed 0,2 *g* and the vertical acceleration does not exceed 0,16 *g* when applied simultaneously at the base of the support insulators. For the purposes of this requirement, the values of acceleration are static.

NOTE This is the "low seismic qualification level" defined in IEEE Std 693. The seismic acceleration and the maximum wind do not have to be considered to occur simultaneously.

- f) The snow depth (if applicable) does not exceed the height of the foundations for the platform support insulators. (A typical maximum height is 1 m.)
- g) The solar radiation does not exceed 1 000 W/ m².

4.2 Ambient air temperature categories

Capacitors are classified in temperature categories, each category being specified by one number followed by one letter. The number represents the lowest ambient air temperature at which the capacitor may operate. The letter represents the upper limit of temperature variation range, having the maximum value specified in Table 1.

Table 1 – Letter symbols for upper limit of temperature range

Symbol	Ambient air temperature °C		
	Maximum	Highest mean over any period of	
		24 h	1 year
A	40	30	20
B	45	35	25
C	50	40	30
D	55	45	35

The temperature categories cover a total temperature range from –50 °C to +55 °C. The lowest ambient air temperature at which the capacitor may be operated should be chosen from the five preferred values +5 °C, –5 °C, –25 °C, –40 °C and –50 °C.

Any combination of minimum and maximum values can be chosen for the standard temperature category of a capacitor, for example –40/A or –5/C.

Table 1 is based on service conditions in which the capacitor does not influence the ambient air temperature (e.g. outdoor installations). If the capacitor influences the air temperature, the ventilation and/or choice of capacitor shall be such that the limits of Table 1 are maintained. The cooling air temperatures in such installations shall not exceed the temperature limits of Table 1 by more than 5 °C.

NOTE The temperature values according to Table 1 can be found in the meteorological temperature tables covering the installation site.

4.3 Abnormal service conditions

The application of series capacitor banks at other than the normal service conditions shall be considered as special and shall be identified in the purchaser's specification. Examples of such conditions are as follows:

- a) Service conditions other than those listed in 4.1.
- b) Exposure to excessively abrasive and conducting dust.
- c) Exposure to salt, damaging fumes, or vapors.
- d) Swarming insects.
- e) Flocking birds.
- f) Conditions requiring over-insulation or extra leakage distance on insulators.
- g) Seismic accelerations at the "moderate or high seismic qualification levels" as defined in IEEE Std 693.

4.4 Abnormal power system conditions

Abnormal power system conditions include:

- a) Continuous harmonic currents in the power system.
- b) The transmission line on which the series capacitor bank is located does not have phase transpositions so the reactances of each phase of the line are not approximately equal.

5 Quality requirements and tests

5.1 Test requirements for capacitor units

5.1.1 General

This clause gives the test requirements for capacitor units.

NOTE Test requirements for other equipment is found in IEC 60143-2, IEC 60143-3 and Annex A of this standard.

Supporting insulators, switches, instrument transformers, external fuses, etc., shall be in accordance with the pertinent IEC standard.

5.1.2 Test conditions

Unless otherwise specified for a particular test or measurement, the temperature of the capacitor dielectric shall be in the range +5 °C to +35 °C. When a correction has to be applied, the reference temperature to be used is +20 °C, unless otherwise agreed between the manufacturer and the purchaser. It may be assumed that the dielectric temperature of the capacitor unit is the same as the ambient air temperature, provided that the capacitor has been left in a non-energized state in a constant ambient air temperature for an adequate period.

The a.c. tests and measurements shall be carried out at a frequency of 50 Hz or 60 Hz irrespective of the rated frequency of the capacitor unless otherwise specified.

5.1.3 Voltage limits as established by overvoltage protector

a) Purpose

The overvoltage protector is a quick-acting device which limits the voltage across the series capacitor to a permissible value when that value would otherwise be exceeded as a result of a power-system fault or other abnormal network condition.

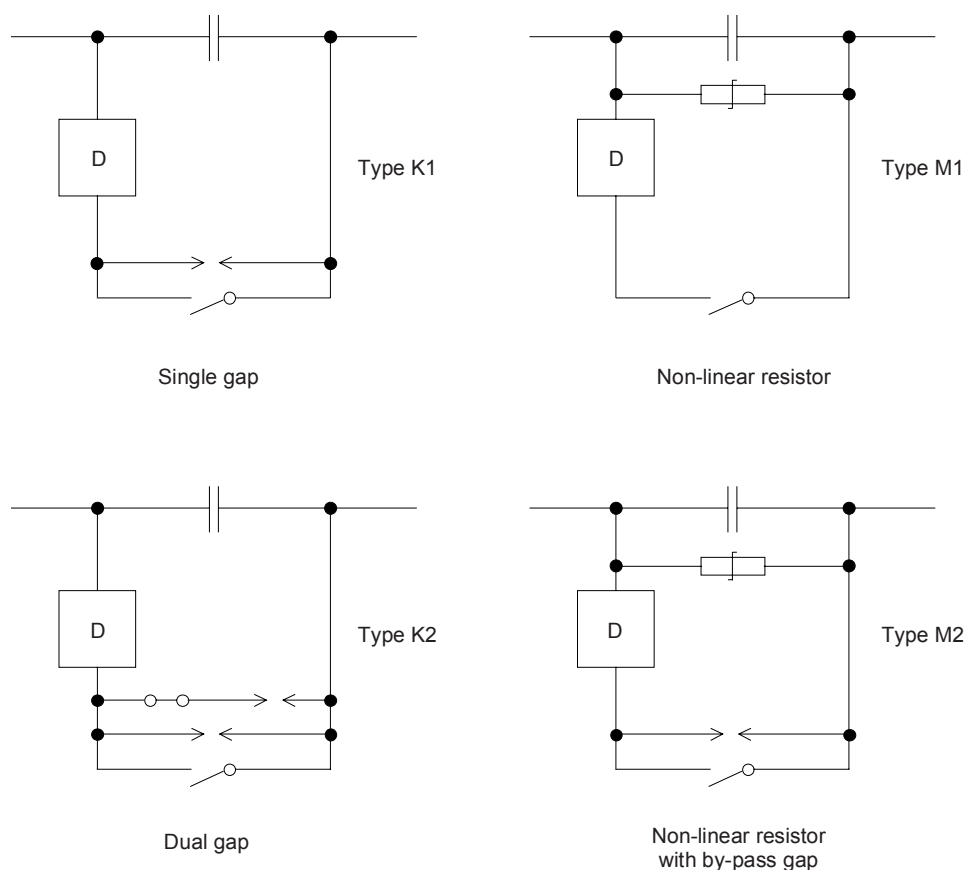
b) Classification

Four common alternatives are listed below (see Figure 2):

- single protective spark gap (type K1),
- two different set single-protective spark gaps forming a dual-gap system (type K2),
- non-linear resistor (type M1),
- non-linear resistor with bypass gap (type M2).

NOTE 1 If the sparkover voltage of an overvoltage protector is dependent on air density, U_{pi} is understood to correspond to the conditions resulting in the highest sparkover voltage, i.e. to the highest air pressure and the lowest temperature. Also, the tolerance on sparkover voltage should be taken into account when determining U_{pi} .

NOTE 2 For scheme K2 (dual gap) U_{pi} and consequently all test voltages and insulation levels should be determined by the high set gap.



IEC 2905/03

Figure 2 – Classification of overvoltage protection

5.1.3.1 Type K overvoltage protector

When the gap sparks over due to an excessive line current caused by a fault in the system, an arc is sustained until de-energizing the line or closing a bypass switch.

During arcing of the gap, the capacitor is exposed to one voltage peak whose value shall not exceed U_{pl} . The capacitor is subjected to a transient discharge once only at every operation of the gap.

5.1.3.2 Type M overvoltage protector

The non-linear resistor is permanently connected across the capacitor terminals. When the bank is operated at normal load current, a given but very low current passes through the non-linear resistor.

In the case of a fault external to the line concerned, the series capacitor becomes automatically reinserted when the fault is disconnected. Even during such a fault the series capacitor exerts a certain compensating effect. For this reason, in many cases, the U_{pl} chosen with Type M can be lower than with Type K overvoltage protectors. On the other hand, in the event of a short-circuit at the compensated line itself, the circuit-breakers at the ends of the line will be opened.

The non-linear resistor shall be designed to withstand the thermal stresses occurring during the overload conditions and during the system swing according to 10.3, and those of the maximum line fault current.

In the event of prolonged duration of an external fault, e.g. due to malfunction of the line protection, the non-linear resistor may become thermally overloaded. Also short-circuits at the compensated line may imply such high currents that it is not economical to dimension the non-linear resistor accordingly. In order to protect the non-linear resistor in such cases, it may be bypassed by a switch or a forced, triggered spark-gap.

5.1.4 Determination of protective level voltage U_{pl} and U_{lim}

The value of a test voltage (U_t) between terminals depends on the type of the overvoltage protector and its protective level voltage U_{pl} (see 5.1.3).

The limiting voltage U_{lim} (kV r.m.s.) for the capacitor unit is related to the protective level voltage of the actual phase or segment U_{pl} (kV peak) according to equation (1).

$$U_{lim} = U_{pl} / (s \times \sqrt{2}) \quad (1)$$

where s is the number of capacitor units in series which spans U_{pl} .

Further clarifications are given in 10.4 and 10.5.

5.2 Classification of tests

Tests on equipment that constitute the capacitor bank are designated as routine tests, type tests and special tests. Additional tests are typically performed after the bank is installed. These tests are discussed in IEC 60143-2.

5.2.1 Routine tests

- a) Capacitance measurement (see 5.3)
- b) Capacitor loss measurement (see 5.4)
- c) Voltage test between terminals (see 5.5)
- d) AC voltage test between terminals and container (see 5.6)
- e) Test on internal discharge device (see 5.7)
- f) Sealing test (see 5.8)
- g) Discharge test of internal fuses (see 3.1.2 of IEC 60143-3).

The test sequence is not necessarily that indicated above.

The routine tests shall be carried out by the manufacturer on every capacitor unit before delivery.

5.2.2 Type tests

- a) Thermal stability test (see 5.9)
- b) AC voltage test between terminals and container (see 5.10)
- c) Lightning impulse voltage test between terminals and container (see 5.11).
- d) Cold duty test (see 5.12)
- e) Discharge current test (see 5.13).

The type tests are carried out in order to ensure that the capacitor unit complies with the contractual characteristics and with the operational requirements as specified in this standard.

It is not essential that all type tests are carried out on the same capacitor unit.

The above list of type tests does not indicate any test sequence.

Unless otherwise specified, every capacitor sample to which a type test will be applied shall have first withstood satisfactorily the application of all the routine tests.

When a type test has previously been successfully performed on equipment of similar design at stress or duty levels that are equal to or greater than that required for the specific application, then the manufacturer does not have to repeat the test if a written report describing the previous test is provided. The manufacturer shall also provide an explanation of how the previous test satisfies the requirements for the specific application.

New type tests shall be performed for a specific project, only if the equipment design is new or if a critical manufacturing process is new, or if it is to be applied at a higher stress or duty level than previously tested designs or if specifically contracted by the purchaser.

5.2.3 Special test (endurance test)

The endurance test shall be carried out only after a contractual agreement between the manufacturer and purchaser (see 5.14).

5.3 Capacitance measurement (routine test)

5.3.1 Measuring procedure

The capacitance of each capacitor unit shall be measured at 0,9 to 1,1 times the rated voltage, using a method that excludes errors due to harmonics. Measurement at another voltage is permitted, provided that an appropriate correction factor is agreed upon between the manufacturer and purchaser.

The accuracy of the measuring method shall be such that the tolerances according to 5.3.2 can be respected. The repeatability of the measuring method shall be such that a punctured element or an operated internal fuse can be detected.

The final capacitance measurement shall be carried out after the voltage test (see 5.5). In order to reveal any change in capacitance, e.g. due to puncture of an element, or failure of an internal fuse, a preliminary capacitance measurement shall be made before the other voltage routine tests. This preliminary measurement shall be performed with a voltage not higher than 0,15 U_N .

The manufacturer shall, on agreement, provide curves or tables showing:

- the capacitance in steady-state condition at rated output as a function of ambient air temperature within the temperature category;
- the capacitance as a function of the dielectric temperature within the temperature category.

5.3.2 Capacitance tolerance

The tolerances refer to capacitance values measured at 0,9 to 1,1 times the rated voltage under the conditions of 5.3.1.

The capacitance at reference temperature (see 5.1.2) shall not differ from the rated capacitance by more than:

- $\pm 7,5$ % for units;
- $\pm 5,0$ % for banks with a rated output less than 30 Mvar;
- $\pm 3,0$ % for banks with a rated output of 30 Mvar or more.

Furthermore, the capacitance shall not differ by more than:

- 3,0 % between any two phases or segments within the same module with a bank rated output less than 30 Mvar;
- 1,0 % between any two phases or segments within the same module with a bank rated output of 30 Mvar or more.

Closer tolerances may be required for capacitors in more critical applications.

The manufacturer shall organize the assembly of the capacitor units.

5.4 Capacitor loss measurement (routine test)

5.4.1 Measuring procedure

The capacitor losses (or $\tan \delta$) shall be measured at 0,9 to 1,1 times rated voltage using a method that excludes errors due to harmonics.

NOTE 1 The measuring equipment should be calibrated according to IEC 60996 or to another method that will give the same or an improved accuracy.

NOTE 2 The tangent of loss angle of impregnated low-loss dielectrics decreases considerably during the first hours of initial energization. This decrease is not correlated to the $\tan \delta$ variation with temperature. The initial $\tan \delta$ may vary also between identical units manufactured simultaneously. The final “stabilized” values are, however, usually within close limits. The $\tan \delta$ measured initially at the routine test should be regarded as a rough indication only. For contractual purposes, only measurements of units should be used which have undergone the thermal stability test before or, alternatively, units may be conditioned according to manufacturers’ practice.

5.4.2 Loss requirements

The capacitor losses refer to values measured under the conditions of 5.4.1.

The requirements regarding capacitor losses may be agreed upon between the manufacturer and purchaser.

Further information regarding capacitor losses are given in Annex B.

The manufacturer should, by agreement, provide curves or tables showing the stabilized capacitor losses (or $\tan \delta$) under steady-state condition at rated output as a function of ambient air temperature within the temperature category.

5.5 Voltage test between terminals (routine test)

The capacitor units shall be subjected to a d.c. test at $1,7 U_{lim}$ ($1,2 \times \sqrt{2} \times U_{lim}$) for overvoltage protectors Type K and M. The test voltage value shall not be less than $4,3 U_N$. The duration of the test shall be 10 s.