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Grading capacitors for high-voltage alternating current circuit-breakers

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Functions concerned
Fonctions concernées

☒ Safety / Sécurité ☐ EMC / CEM ☐ Environment / Environnement ☐ Quality assurance / Assurance qualité

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Titre :

Title : IEC 62146-1 Ed. 1.0: Grading capacitors for high-voltage alternating current circuit-breakers

Note d'introduction-

La version française sera diffuse ultérieurement

Introductory note:

This project was studied by the JWG (TC 33/JWG TC 33-SC 17A) which prepared the first CD that was discussed during the TC 33 meeting held in Florence in October 2001. A second CD was discussed in Montreal in October 2003. A third CD was prepared, but having the relevant project more than five years, the SMB (SMB/2946/INF, 2004-12-06) decided to put the project to the preliminary stage.
The text of the attached NP/CDV document is integrated taking into consideration the NC comments on the last third CD 33/408/CD according to the procedures. It is therefore decided to apply the procedure given in AC/8/2003 for the simultaneous submission of NPs and CDVs. If this NP is not approved the RVN will immediately be issued and the CDV ballot will be cancelled. When this NP is accepted, the CDV ballot will continue and the project will be considered as being at CDV stage.
- French version will be circulated later

ATTENTION	ATTENTION
CDV soumis en parallèle au vote (CEI) et à l'enquête (CENELEC)	**Parallel IEC CDV/CENELEC Enquiry**

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CONTENTS

GRADING CAPACITORS FOR HIGH-VOLTAGE ALTERNATING CURRENT CIRCUIT-BREAKERS

1 Scope

This standard is applicable to the grading capacitors used on circuit-breakers to control the voltage distribution across the individual interrupting chambers.

The capacitors are also used to equalise the voltage distribution across the interrupting chambers both during circuit-breaker opening and closing operations.

Grading capacitors can also be used in parallel on single break circuit-breakers to improve the circuit-breaker capability.

This standard applies to grading capacitors falling into one or both of the following categories for:

a) mounting on air-insulated circuit-breakers;

b) mounting on immersed (e.g. SF6 in GIS, oil, etc.) circuit-breakers.

This standard is applicable also to the grading capacitors used as replacement for both categories a) and b).

The object of this standard is:

– to define uniform rules regarding performances, testing and rating;

– to define specific safety rules;

– to provide a guidance for installation and operation.

The testing necessary for each of the above applications is different

For new circuit-breaker applications, the environmental and mechanical testing should be undertaken as part of the testing of the circuit-breaker as far as the requirements regarding the grading capacitors are met. This ensures that the correct stresses, taking into account mounting conditions, can be applied. Similarly grading capacitors should be fitted to the circuit-breaker during electrical switching tests (e.g. short-circuit) to verify their ability to withstand these conditions.

For replacement grading capacitors for circuit-breakers already in service, environmental and mechanical tests are recommended. It should be recognised that these tests may be inadequate to guarantee adequate performance in actual applications and prospective purchasers must satisfy themselves of the validity or otherwise of these tests for specific applications.

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.

IEC 60050(212):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 212: Insulating solids, liquids and gases*

IEC 60050(436):1990, *International Electrotechnical Vocabulary (IEV) – Chapter 436: Power capacitors*

IEC 60050(441):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 441: Switchgear, controlgear and fuses*

IEC 60050(471):1984, *International Electrotechnical Vocabulary (IEV) – Chapter 471: Insulators*

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

IEC 60068-2-17:1994, *Basic environmental testing procedures – Part 2: Tests – Test Q: Sealing*

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

IEC 60270:2000, *Partial discharge measurements*

IEC 60376:1971, *Specification and aceptance of new sulphur hexafluoride*

IEC 60507:1991, *Artificial pollution tests on high-voltage insulators to be used on a.c. systems*

IEC 60694:1996, *Common specifications for high-voltage switchgear and controlgear Standards*

IEC 60721: *Classification of environmental conditions*

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

IEC 61166:1993, *High-voltage alternating current circuit-breakers – Guide for seismic qualification of high-voltage alternating current circuit-breakers*

IEC 61462:1998, *Composite insulators-Hollow insulators for use in outdoor and indoor electrical equipment – definitions, test methods, acceptance criteria and design recommendations*

IEC 62155:2003, *Hollow pressurized and unpressurizzed ceramic and glass insulators for use in electrical equipment with rated voltages greater than 1000 V*

IEC 62271-100:2003, *High-voltage switchgear and controlgear – Part 100 High voltage alternating-current circuit-breakers*

IEC 62271-203:2003, *High-voltage switchgear and controlgear – Part 203: Gas-insulated metalenclosed switchgear for rated voltages above 52 kV*

Project IEC 60815-3 TS Ed. 1.0: *Selection and dimensioning of high-voltage insulators for polluted conditions – Part 3: Composite insulators for a.c. systems*

IEC Guide 109: *Environmental aspects – Inclusion in electrotechnical product standards*

CISPR 18-2:1986, *Radio interference characteristics of overhead power lines and high-voltage equipment – Part 2: Methods of measurement and procedure for determining limits*

3 Definitions

3.1
capacitor element (or element)
device consisting essentially of two electrodes separated by a dielectric (IEV 436-01-03).

3.2
capacitor unit (or unit)
assembly of one or more capacitor elements in the same container with terminals brought out (IEV 436-01-04).

NOTE A common type of unit for grading capacitors has a cylindrical housing of insulating material and metal end flanges which serve as terminals.

3.3
Capacitor stack (or stack)
assembly of capacitor units connected in series (IEV 436-01-05).

3.4
Capacitor
general term used when it is not necessary to state whether reference is made to a capacitor unit or to a capacitor stack.

3.5
dielectric of a capacitor
insulating material between the electrodes.

NOTE The major insulation generally consists of paper, plastic film, or a mixed of paper and plastic film subsequently treated and impregnated with oil or gas at atmospheric pressure or higher.

3.6
rated capacitance of a capacitor (C_r)
capacitance value for which the capacitor has been designed.

3.7
rated frequency of a capacitor (f_r)
frequency for which the capacitor has been designed (IEV 436-01-14).

3.8
rated voltage of a capacitor (U_r)
r.m.s. value of the alternating voltage assigned to the capacitor for identification and at which the capacitor is designed to operate continuously.

3.9
rated temperature category of a capacitor
range of temperature of the ambient air or other medium in which the capacitor is immersed during the service life and for which it has been designed.

3.10
grading capacitor
capacitor installed on high-voltage circuit-breakers to control the voltage distribution across the individual interrupter unit or in parallel on single break circuit-breakers to improve the breaker capability.

3.11
Indoor capacitor
capacitor, both ends of which are intended to be in ambient air at atmospheric pressure, but not exposed to outdoor atmospheric conditions

(IEV 471-02-03).

NOTE This definition include the completely immersed capacitor according to definition 3.13.

3.12
outdoor capacitor
capacitor, both ends of which are intended to be in ambient air at atmospheric pressure, and exposed to outdoor atmospheric conditions.

(IEV 471-02-04).

3.13
completely immersed capacitor
capacitor both ends of which are intended to be immersed in an insulating medium other than ambient air (e.g. oil or gas).

(IEV 471-02-08).

NOTE This definition includes capacitors operating in air or immersed in an insulating medium at temperatures above ambient, such as occur with air-insulated or gas-insulated enclosure (e.g.: GIS).

3.14
capacitor terminals
terminals intended for electrical and mechanical connection to the terminals of the interrupter units of circuit-breakers.

3.15
capacitance tolerance
permissible difference between the actual capacitance and the rated capacitance under specified conditions

(IEV 436-04-01).

NOTE The actual capacitance should be measured at, or referred to, the temperature at which the rated capacitance is defined.

3.16
resonance frequency
frequency for which the reactance of the intrinsic capacitance of the capacitor is equal to the reactance of the self-inductance of the capacitor.

3.17
capacitor losses
active power dissipated in the capacitor

(IEV 436-04-10).

3.18
tangent of the loss angle (tan δ) of a capacitor
ratio between the equipment series resistance and the capacitive reactance of a capacitor at specified sinusoidal alternating voltage and frequency

(IEV 436-04-11).

3.19
insulating envelope
Hollow insulator which is open from end to end, with or without sheds

(IEV 471-01-17).

NOTE 1 An insulating envelope may consists of one insulator unit or two or more permanently assembled insulator units.

NOTE 2 The insulating envelope may be in ceramic, glass or analogous inorganic material, cast or moulded resin, composite insulating material, in one piece or more pieces permanently assembled.

3.20
creepage distance
shortest distance along the surface of an insulator between two conductive parts

(IEV 471- 01-08).

NOTE 1 The surface of cement or any other non-insulating jointing material is not considered as forming part of the creepage distance.

NOTE 2 If high-resistance coating is applied to parts of the insulating part of an insulator, such parts are considered to be effective insulating surface and the distance over them is included in the creepage distance.

3.21
flashover distance
Shortest distance in air external to the insulator between metallic parts which normally have the operating voltage between them

(IEV 471-01-07).

3.22
voltage grading factor F_{VG} of circuit-breaker
The voltage grading factor F_{VG} is the value that defines the standard values of rated voltages for the grading capacitor.

This factor is the ratio between the actual maximum power frequency voltage fraction across one interrupting unit of a multi-break circuit-breaker and the calculated linear power frequency voltage distribution per interrupting unit.

It is dependant on the circuit-breaker design, of the capacitance value of the grading capacitor and its tolerance and of the safety margin.

The voltage grading factor shall be defined by the circuit-breaker manufacturer.

3.23
highest voltage for equipment (Um)
highest r.m.s. phase-to-phase voltage for which the equipment (e.g. circuit-breaker) is designed, in respect of its insulation as well as other characteristics which relate to this voltage in the relevant equipment standards.

The circuit-breaker with the grading capacitors installed is considered an equipment and Um is the rated voltage of the circuit-breaker according to IEC 60694; the grading capacitors alone are only accessories of the equipment.

3.24
external insulation
distance in air and the surfaces in contact with open air of insulation of the grading capacitor which are subject to dielectric stresses and to the effects of the atmospheric and other external conditions such as pollution, humidity, ice, vermin, etc.

3.25
internal insulation
internal solid, liquid or gaseous parts of the insulation of the grading capacitor which are protected from the effects of atmospheric and other external conditions such as pollution, humidity, ice, vermin, etc.

3.26
rated short duration power frequency withstand voltage
prescribed r.m.s. value of sinusoidal power frequency voltage that the equipment shall withstand during tests made under specified conditions and for a duration of 1 min unless otherwise specified.

3.27
rated switching impulse withstand voltage
prescribed peak value of the switching impulse withstand voltage which characterises the insulation of an equipment as regards the withstand tests.

NOTE The standard switching impulse has a time-to-crest of 250 μs and a time-to-half-value of 2500 μs as specified in IEC 60060-1.

3.28
rated lightning impulse withstand voltage
prescribed peak value of the lightning impulse withstand voltage which characterises the insulation of an equipment as regards the withstand tests.

NOTE The standard lightning impulse has a front time of 1.2 μs and a time-to-half-value of 50 μs as specified in IEC 60060-1.

3.29
rated chopped lightning impulse withstand voltage
prescribed peak value of the chopped lightning impulse withstand voltage which characterises the insulation of a grading capacitor as regards the withstand tests.

NOTE The definitions and the standard parameters applicable to chopped impulses are specified in IEC 60060-1.

3.30
rated insulation level

a) The rated chopped and lightning impulse and short duration power frequency withstand voltages for capacitors installed on circuit-breaker with rated voltage lower than 300 kV.

b) The rated switching, lightning, chopped impulse and short duration power frequency withstand voltages for capacitors installed on circuit-breaker with rated voltage equal to or greater than 300 kV.

The rated insulation levels of the grading capacitor should be equal to or higher than the relevant requirements for the circuit-breaker interrupting unit.

3.31
overvoltage (in a system)
Any voltage between one phase and earth or between phases having a peak value or values exceeding the corresponding peak of the highest voltage for equipment.

(IEV 604- 03-09).

NOTE Overvoltages are always transient phenomena. A broad distinction may be made between highly damped overvoltages of relatively short duration (e.g. 3.27 and 3.28) and undamped or only weakly damped overvoltages of relatively long duration (see 3.33). The border-line between these two groups cannot be clearly fixed.

3.32
temporary overvoltage
An oscillatory overvoltage at a given location of relatively long duration and which is undamped or only weakly damped.

Temporary overvoltages usually originate from switching operations or faults (e.g. load rejection, single phase faults) and/or from non-linearities (ferro-resonance effects, harmonics). They may be characterised by their amplitude, their oscillation frequencies, and by their total duration or their decrement.

3.33
out-of-phase conditions
condition characterised by the loss of synchronism of two parts of a network resulting in exceptionally high voltage across the open circuit-breaker. In the worst case the phase angle of the voltage across the circuit-breaker can reach a value of 180° (phase opposition).

3.34
mechanical stress
Any mechanical stress applied to the insulating envelope and to the terminals of the grading capacitor.

It is a function of the following main forces:

– forces on the terminals due to the circuit-breaker connection;
– forces due to the wind and ice;
– seismic forces;
– forces due to the operating conditions, opening and closing, of the circuit- breaker;
– thermal forces due to the ambient medium conditions;
– forces due to the transportation of the circuit-breaker or grading capacitors.

3.35
flashover
breakdown between electrodes in a gas or in a liquid, at least partly along the surface of solid insulation

IEV 60050(212), 212-01-37.

3.36
puncture
path produced through a solid by a breakdown producing permanent damage. The term is also used as a synonym for electrical breakdown in solid

IEV 60050(212), 212-01-38.

4 Ratings and characteristics

4.1 Standard values of rated frequency

Standard values are 50 and 60 Hz.

4.2 Standard values of rated voltages U_r

The standard value of rated voltages U_r for grading capacitor is the highest voltage of the circuit-breaker, on which the grading capacitor shall be installed, given in Column 1 of Tables 1, 2, 3, and 4, divided by √3, divided by the number n of breaks in series and multiplied by the voltage grading factor of the circuit-breaker .

$$U_r = \frac{U_m \times F_{VG}}{\sqrt{3} \times n}$$

4.3 Standard insulation level and test voltage

Tables 1, 2, 3, and 4 specify the standard insulation levels with the corresponding highest voltage for equipment, on which the grading capacitor is installed, U_m (r.m.s.).

The insulation level is defined by the r.m.s. value of the rated short duration power frequency withstand voltage and the peak value of the rated lightning impulse withstand voltage for U_m < 300 kV and by the peak values of the rated switching and lightning impulse withstand voltages for $U_m \geq 300$ kV.

The value listed in the bellow tables, by the criteria defined in the type and routine test clauses are the base to calculate the standard insulation level of the grading capacitor.