IEC/PAS 60044-5

Edition 1.0
2002-07

Instrument transformers –

Part 5:
Capacitor voltage transformers

Transformateurs de mesure –

Partie 5:
Transformateurs condensateurs de tension

PUBLICLY AVAILABLE SPECIFICATION

INTERNATIONAL
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FOREWORD

A PAS is a technical specification not fulfilling the requirements for a standard, but made available to the public.

IEC-PAS 60044-5 has been processed by IEC technical committee 38: Instrument transformers.

The text of this PAS is based on the following document:	This PAS was approved for publication by the P-members of the committee concerned as indicated in the following document:
Draft PAS	**Report on voting**
38/279/PAS	38/284/RVD

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INSTRUMENT TRANSFORMERS –
Part 5: Capacitor voltage transformers

1 Scope

This PAS which is a part of International Standard IEC 60044 applies to new single-phase capacitor voltage transformers connected between line and ground for system voltages $U_m \geq$ 72,5 kV at power frequencies from 15 Hz to 100 Hz. They are intended to supply a low voltage for measurement, control and protective functions.

The capacitor voltage transformer can be equipped with or without carrier-frequency accessories for power line carrier-frequency (PLC) application at carrier frequencies from 30 kHz to 500 kHz.

The future standard that should supersede the present PAS will replace the IEC 60186 regarding capacitor voltage transformers.

Three standards formed the basis for this IEC-PAS 60044-5:

– IEC 60044-2; concerning inductive voltage transformers;
– IEC 60358, concerning coupling capacitors and capacitor dividers;
– IEC 60481, concerning coupling devices for power line carrier (PLC) systems.

The application measurement function includes both indication measuring and revenue measuring.

NOTE Diagrams of capacitor voltage transformer to which this document applies are given in figures A.1 and A.2.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However parties to agreements based on this document are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60028:1925, *International standard of resistance for copper*

IEC 60038:1983, *IEC standard voltages*

IEC 60044-2:1997, *Instrument transformers – Part 2: Inductive voltage transformers*

IEC 60050-321:1986, *International Electrotechnical Vocabulary – Chapter 321: Instrument transformers*

IEC 60050-436:1990, *International Electrotechnical Vocabulary – Chapter 436: Power capacitors*

IEC 60050-601:1985, *International Electrotechnical Vocabulary – Chapter 601: Generation, transmission and distribution of electricity – General*

IEC 60050-604:1987, *International Electrotechnical Vocabulary – Chapter 604: Generation, transmission and distribution of electricity – Operation*

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 60085:1984, *Thermal evaluation and classification of electrical insulation*

IEC 60233:1974, *Tests on hollow insulators for use in electrical equipment*

IEC 60270:1981, *Partial discharge measurements*

IEC 60358:1990, *Coupling capacitors and capacitor dividers*

IEC 60481:1974, *Coupling devices for power line carrier systems*

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

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

For the purpose of this part of IEC 60044, the following definitions shall apply. Some of these definitions are identical with or are similar to those of IEC 60050, Chapters 321, 436, 601 and 604. These are indicated by the relevant IEV reference number in brackets.

3.1 General definitions

3.1.1 capacitor voltage transformer (CVT)

a voltage transformer comprising a capacitor divider unit and an electromagnetic unit so designed and interconnected that the secondary voltage of the electromagnetic unit is substantially proportional to the primary voltage, and differs in phase from it by an angle which is approximately zero for an appropriate direction of the connections and rated frequency. [IEV 321-03-14 modified]

3.1.2 rated frequency of a capacitor voltage transformer (f_R)

the frequency for which the capacitor voltage transformer has been designed.

3.1.3 standard reference range of frequency

the range of frequency for which the rated accuracy is applicable.

3.1.4 rated primary voltage (U_{PR})

the r.m.s. value of the primary voltage which appears in the designation of the capacitor voltage transformer and on which its performance is based. [IEV 321-01-12 modified]

3.1.5 rated secondary voltage (U_{SR})

the r.m.s. value of the secondary voltage which appears in the designation of the capacitor voltage transformer and on which its performance is based. [IEV 321-01-16 modified]

3.1.6 secondary winding

the winding which supplies the voltage circuits of measuring instruments, meters, relays or similar apparatus.

3.1.7 secondary circuit

the external circuit supplied by the secondary winding of a transformer.

3.1.8 actual transformation ratio

the ratio of the actual primary voltage to the actual secondary voltage. [IEV 321-01-18 modified]

3.1.9 rated transformation ratio (K_R)

the ratio of the rated primary voltage to the rated secondary voltage. [IEV 321-01-20 modified]

3.1.10 voltage error (ratio error) for steady state conditions (ε_u)

the error which a capacitor voltage transformer introduces into the measurement of a voltage and which arises when the actual transformation ratio is not equal to the rated transformation ratio K_R. [IEV 321-01-22 modified]

NOTE This definition is only related to components at rated frequency of both primary and secondary voltages, and does not take into account direct voltage components and residual voltages.

Voltage error $$\varepsilon_U = \frac{K_R U_S - U_P}{U_P} 100\,\%$$

where: K_R is the rated transformation ratio,

U_p is the actual primary voltage and

U_s is the actual secondary voltage when U_P is applied under the conditions of measurement.

3.1.11 phase displacement (φ_U)

the difference in phase between the primary and the secondary voltage phasors:

$$\varphi_U = (\varphi_S - \varphi_P)$$

The direction of the phasors being so chosen that the angle (φ_U) is zero for a perfect transformer. The phase displacement is said to be positive when the secondary voltage phasor (φ_S) leads the primary voltage phasor (φ_P). It is usually expressed in minutes or centiradians. [IEV 321-01-23 modified]

NOTE This definition is strictly correct for sinusoidal voltages only.

3.1.12 accuracy class

designation assigned to a capacitor voltage transformer, the errors of which remain within specified limits under prescribed conditions of use.

3.1.13 burden

admittance of the secondary circuit expressed in siemens and with an indication of the power factor (lagging or leading).

NOTE The burden is usually expressed as the apparent power in volt-amperes, absorbed at a specified power factor and at the rated secondary voltage.

3.1.14 rated burden

value of the burden on which the accuracy requirements of this document are based.

3.1.15 output

a) rated output
the value of the apparent power (in volt-amperes at a specified power factor), which the capacitor voltage transformer is intended to supply to the secondary circuit at the rated secondary voltage and with rated burden connected to it. [IEV 321-01-27 modified]

b) thermal limiting output
the value of the apparent power in volt-amperes referred to rated voltage which can be taken from a secondary winding, at rated primary voltage applied, without exceeding the limits of temperature rise of 6.5.

NOTE 1 In this condition the limits of error may be exceeded.

NOTE 2 In the case of more than one secondary winding, the thermal limiting output is to be given separately for each winding.

NOTE 3 The simultaneous use of more than one secondary winding is not permitted unless there is an agreement between the manufacturer and purchaser.

3.1.16 highest voltage for equipment (U_m)

the highest r.m.s. value of phase-to-phase voltage for which the equipment is designed and may be used in respect of its insulation.

3.1.17 rated insulation level

the combination of voltage values which characterises the insulation of a transformer with regard to its capability to withstand dielectric stresses.

3.1.18 isolated neutral system

a system where the neutral point is not intentionally connected to earth, except for high impedance connections for protection or measurement purposes. [IEV 601-02-24]

3.1.19 solidly earthed neutral system

a system whose neutral point(s) is(are) earthed directly. [IEV 601-02-25]

3.1.20 impedance earthed (neutral) system

a system whose neutral point(s) is(are) earthed through impedances to limit earth fault currents. [IEV 601-02-26]

3.1.21 resonant earthed (neutral) system

system in which one or more neutral points are connected to earth through reactances which approximately compensate the capacitive component of a single-phase-to-earth fault current. [IEV 601-02-27]

NOTE With resonant earthing of a system, the residual current in the fault is limited to such an extent that an arcing fault in air is self-extinguishing.

3.1.22 earth fault factor

at a given location of a three-phase system, and for a given system configuration, the ratio of the highest r.m.s. phase-to-earth power frequency voltage on a healthy phase during a fault to earth affecting one or more phases at any point on the system to the r.m.s. phase-to-earth power frequency voltage which would be obtained at the given location in the absence of any such fault. [IEV 604-03-06]

3.1.23 earthed neutral system

system in which the neutral is connected to earth either solidly or through a resistance or reactance of sufficiently low value to reduce transient oscillations and to give a current sufficient for selective earth fault protection.

a) A three-phase system with effectively earthed neutral at a given location is a system characterized by an earth fault factor at this point which does not exceed 1,4.

NOTE This condition is obtained approximately when, for all system configurations, the ratio of zero-sequence reactance to the positive-sequence reactance is less than 3 and the ratio of zero-sequence resistance to positive-sequence reactance is less than one.

b) A three-phase system with non-effectively earthed neutral at a given location is a system characterized by an earth fault factor at this point that may exceed 1,4.

3.1.24 exposed installation

an installation in which the apparatus is subject to overvoltages of atmospheric origin.

NOTE Such installations are usually connected to overhead transmission lines either directly or through a short length of cable.

3.1.25 non-exposed installation

an installation in which the apparatus is not subject to overvoltages of atmospheric origin.

NOTE Such installations are usually connected to underground cable networks.

3.1.26 measuring capacitor voltage transformer

a capacitor voltage transformer intended to supply indicating instruments, integrating meters and similar apparatus.

3.1.27 protective capacitor voltage transformer

a capacitor voltage transformer intended to provide a supply to electrical protective relays.

3.1.28 residual voltage winding

the winding of a single-phase capacitor voltage transformer intended, in a set of three single-phase transformers, for connection in broken delta for the purpose of producing a residual voltage under earth-fault conditions.

3.1.29 rated voltage factor (F_V)

the multiplying factor to be applied to the rated primary voltage U_{PR} to determine the maximum voltage at which a transformer must comply with relevant thermal requirements for a specified time and with the relevant accuracy requirements.

3.1.30 rated temperature category of a capacitor voltage transformer

the range of temperature of the ambient air or of the cooling medium for which the capacitor voltage transformer has been designed.

3.1.31 high voltage terminal

terminal intended for connection to a line conductor of a network. [IEV 436-03-01]

3.1.32 ferro-resonance

sustained resonance of a circuit consisting of a capacitance with a non-linear saturable magnetic inductance

NOTE The ferro-resonance can be initiated by switching operations on the primary side or secondary side.

3.1.33 transient response

the measured fidelity of the secondary-voltage waveform, compared with the voltage waveform at the high-voltage terminal under transient conditions.

3.1.34 mechanical stress

the stresses on different parts of the capacitor voltage transformer as a function of four main forces:

– forces on the terminals due to the line connections,

– forces due to the wind on the cross-section of the capacitor voltage transformer with and without line trap mounted on the top of the coupling capacitor,

– seismic forces and

– electro dynamic forces due to short circuit current.

3.1.35 voltage-connected CVT

the CVT is voltage-connected when there is only one connection to the high voltage line.

NOTE Under normal conditions the top connection carries only the current of the capacitor voltage transformer.

3.1.36 current-connected CVT

the CVT is current-connected when there are two connections to the high voltage line.

NOTE The terminals and the top connection are designed to carry under normal conditions the line current.

3.1.37 line trap-connected CVT

the CVT is line trap-connected when it supports a line trap on its top. In this case, the two connections to the line trap carry the HV line current and one connection from the line trap to the CVT carries the CVT current.

NOTE The pedestal mounting line traps in two phases are generating additional forces during a short circuit in more than one phase.

3.2 Capacitor voltage divider definitions

3.2.1 capacitor voltage divider

a capacitor stack forming an alternating voltage divider. [IEV 436-02-10]

3.2.2 capacitor element

a device consisting essentially of two electrodes separated by a dielectric. [IEV 436-01-03]

3.2.3 capacitor unit

an 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 coupling capacitors has a cylindrical housing of insulating material and metallic flanges which serve as terminals.

3.2.4 capacitor stack

an assembly of capacitor units connected in series. [IEV 436-01-05]

NOTE The capacitor units are usually mounted in a vertical array.

3.2.5 capacitor

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

3.2.6 rated capacitance of a capacitor (C_R)

the capacitance value for which the capacitor has been designed.

NOTE This definition applies:

- for a capacitor unit, to the capacitance between the terminals of the unit;
- for a capacitor stack, to the capacitance between line and low voltage terminals or between line and earth terminals of the stack;
- for a capacitor divider, to the resultant capacitance: $C_R = C_1 C_2/(C_1 + C_2)$.

3.2.7 coupling capacitor

a capacitor used for the transmission of signals in a power system. [IEV 436-02-11]

3.2.8 high voltage capacitor (of a capacitor divider) (C_1)

the capacitor connected between the line terminal and the intermediate voltage terminal of a capacitor divider. [IEV 436-02-12 modified]

3.2.9 intermediate voltage capacitor (of a capacitor divider) (C_2)

the capacitor connected between the intermediate voltage and the low voltage terminals of a capacitor divider. [IEV 436-02-13]

3.2.10 intermediate voltage terminal of a capacitor divider

a terminal intended for connection to an intermediate circuit, such as the electromagnetic unit of a capacitor voltage transformer. [IEV 436-03-03]

3.2.11 low voltage terminal of a capacitor divider

a terminal (N) intended for connection to earth either directly or via a drain coil of negligible value of impedance, at rated frequency, for power line carrier (PLC) application. [IEV 436-03-04 modified]

3.2.12 capacitance tolerance

the permissible difference between the actual capacitance and the rated capacitance under specified conditions. [IEV 436-04-01]

3.2.13 equivalent series resistance of a capacitor

virtual resistance which, if connected in series with an ideal capacitor of capacitance value equal to that of the capacitor in question, would have a power loss equal to the active power dissipated in that capacitor under specified operating conditions at a given high frequency.

3.2.14 high frequency capacitance

the effective capacitance at a given frequency resulting from the joint effect of the intrinsic capacitance and the self-inductance of a capacitor. [IEV 436-04-03]

3.2.15 intermediate voltage of a capacitor divider (U_C)

the voltage between the intermediate voltage terminal of the capacitor divider and the low voltage terminal, when the primary voltage is applied between the high and low voltage terminals or high voltage terminal and earth terminal.

3.2.16 rated voltage ratio of a capacitor divider (K_{CR})

the ratio of the voltage applied to the capacitor divider to the open-circuit intermediate voltage. [IEV 436-04-05]

NOTE 1 This ratio corresponds to the sum of the capacitances of the high voltage and intermediate voltage capacitors divided by the capacitance of the high voltage capacitor: $(C_1 + C_2) / C_1 = K_{CR}$.

NOTE 2 C_1 and C_2 include the stray capacitances, which are generally negligible.

3.2.17 capacitor losses

the active power dissipated in the capacitor. [IEV 436-04-10]

3.2.18 tangent of the loss angle (tanδ) of a capacitor

the ratio between the active power P_a and the reactive power P_r: $\tan\delta = P_a/P_r$.

3.2.19 temperature coefficient of capacitance (T_C)

the fractional change of the capacitance for a given change in temperature:

$$T_C = \frac{\frac{\Delta C}{\Delta T}}{C_{20\,^\circ C}} \left[\frac{1}{K}\right]$$

ΔC represents the observed change in capacitance over the temperature interval ΔT

$C_{20°C}$ represents the capacitance measured at 20 °C.

NOTE The term $\Delta C/\Delta T$ according to this definition is usable only if the capacitance is an approximate linear function of the temperature in the range under consideration. If not, the temperature dependency of the capacitance should be shown in a graph or a table.

3.2.20 stray capacitance of the low voltage terminal

the stray capacitance between the low voltage terminal and the earth terminal.

3.2.21 stray conductance of the low voltage terminal

the stray conductance between the low voltage terminal and the earth terminal.

3.2.22 dielectric of a capacitor

the insulating material between the electrodes.