

American National Standard

Requirements for Power-Line Carrier Coupling Capacitors and Coupling Capacitor Voltage Transformers (CCVT)

Approved 19 May 1999

American National Standards Institute

The Institute of Electrical and Electronics Engineers, Inc.
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American National Standard

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Contents

	Foreword.....	v
1	Scope.....	1
2	Referenced and related standards	1
	2.1 Referenced American National Standards	1
	2.2 Other referenced standards.....	1
	2.3 Related standards	2
3	Definitions.....	2
4	Service conditions.....	6
	4.1 Usual service conditions	6
	4.2 Unusual service conditions	6
5	Ratings.....	6
	5.1 General	6
	5.2 Relaying service CCVTs.....	14
	5.3 Metering service CCVTs	14
6	Testing	16
	6.1 General	16
	6.2 Design test procedures	17
	6.3 Production test procedures	30
7	Manufacturing requirements	32
	7.1 Mounting	32
	7.2 Nameplate markings.....	32
	7.3 Certificate of test	33
	7.4 Symbols	33
	7.5 Polarity and terminal marking	33
	7.6 Safety devices	34
	7.7 High-voltage terminal.....	35

Figures

1	Circuit diagram of burden to be used for transient response test	12
2	Limits for accuracy class 1.2R for coupling capacitor voltage transformers for relaying service.....	15
3	Limits for accuracy classes 0.3, 0.6, and 1.2 for coupling capacitor voltage transformers for metering service	15
4	Transient response test circuits	29

Tables

1	Upper ambient temperature limit	6
2	Dielectric strength correction factors	6
3	Voltage ratings, dielectric strengths, leakage distances, and marked ratios.....	8
4	Radio-influence voltage	9
5	Burdens for accuracy rating.....	11
6	Burdens for transient response ratings.....	12
7	Accuracy class limits for relaying service	13
8	Limits of ratio correction factor and phase angle with voltage variations for relaying service	13
9	Duration of induced-potential test.....	31
10	Coupling capacitor voltage transformer symbols	34

Annexes

A	Coupling capacitor and CCVT circuit diagrams.....	37
B	Calculation of CCVT ratio and phase angle from known zero and rated burden data	39
C	Drain coil loading in power line carrier coupling circuits.....	41

Figures

A1	Coupling capacitor with carrier accessories	37
A2	Typical coupling capacitor voltage transformer with carrier coupling accessories.....	38
C1	Typical line tuner coupling capacitor connection.....	42

Foreword (This Foreword is not part of American National Standard ANSI/NEMA C93.1-1999)

This document was developed by Accredited Standards Committee C93, Power-Line Carrier Equipment and Coupling Capacitor Voltage Transformers. During the development of the standard, the Committee considered input from a balanced group representing consumer, producer, and general-interest viewpoints, which it harmonized and integrated into the standard in its present, approved form.

Accredited Standards Committee C93 was established to coordinate, revise, and update the existing documents into an effective group of American National Standards, including this standard for coupling capacitors and CCVTs. A separate standard will be developed to cover each type of equipment described in the Committee scope.

This standard is related to American National Standard Requirements for Power-Line Carrier Line Traps, ANSI/NEMA C93.3, and American National Standard Requirements for Power-Line Carrier Line Tuning Equipment, ANSI/NEMA C93.4.

It is recognized that there are no requirements for ferroresonance suppression or primary short-circuit transient response; however, the recommended test procedures are given in 6.2.16 and 6.2.17 of the standard. If meaningful requirements are determined by the industry, they will be adopted in future revisions of this standard.

For metering service coupling capacitor voltage transformers, this standard aligns with American National Standard Requirements for Instrument Transformers, ANSI C57.13, where applicable.

Suggestions for improvement of this standard will be welcome. They should be sent to the Secretary, ASC C93, c/o National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209.

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee on Power-Line Carrier Equipment and Coupling Capacitor Voltage Transformers, C93. Committee approval of the standard does not necessarily imply that all members voted for its approval. At the time it approved this standard, the C93 committee had the following members:

Walter Seamon, Chairman	Khaled Masri, Secretary
<i>Organization Represented</i>	<i>Name of Representative</i>
Edison Electric Institute	James Benton Gary Miller (Alternate) Robert Morton
Institute of Electrical & Electronics Engineers	George Morgan
Manufacturers	Ross Presta (Alternate) Roger Ray Jorge Ribeiro Miriam Sanders (Alternate) Tim Phillipe (Alternate) Hans Backskog Walter Seamon
Tennessee Valley Authority	Robert Bratton

for Power-Line Carrier Coupling Capacitors and Coupling Capacitor Voltage Transformers (CCVT) – Requirements

1 Scope

This standard applies to capacitors for coupling power-line carriers and for reducing rate of rise of breaker transient recovery voltage, and to coupling capacitor voltage transformers (CCVT) for connection to a high voltage power circuit, between line and ground, to supply a low voltage for measurement, control, and protective functions. A CCVT may or may not have provision for power-line carrier coupling.

This standard does not include bushing potential devices, or secondary compensated-field adjustable CCVTs.

2 Referenced and related standards

2.1 Referenced American National Standards

This standard is intended to be used with the following American National Standards. When these referenced standards are superseded by a revision approved by the American National Standards Institute, Inc., the revision shall apply:

ANSI/NEMA C93.4-1984,	<i>Requirements for Power Line Carrier Line Tuning Equipment</i>
ANSI/IEEE 4-1995,	<i>Techniques for High-Voltage Testing</i>
ANSI/IEEE 100-1992,	<i>The Standard Dictionary of Electrical and Electronics Terms</i>
ANSI/IEEE C62.11-1993,	<i>IEEE Standard for Metal-Oxide Surge Arresters for Alternating Current Power Circuits</i>
ANSI/IEEE C62.31-1987 (R1993),	<i>IEEE Standard Test Specifications for Gas-Tube Surge-Protective Devices</i>
ANSI/ISA S82.01-1988,	<i>Safety Standard for Electrical and Electronic Test, Measuring, Controlling and Related Equipment—General Requirements</i>
ANSI/ISA S82.02-1988,	<i>Safety Standard for Electrical and Electronic Test, Measuring, Controlling and Related Equipment—Electrical and Electronic Test and Measuring Equipment</i>
ANSI/ISA S82.03-1988,	<i>Safety Standard for Electrical and Electronic Test, Measuring, Controlling and Related Equipment—Electrical and Electronic Process Measurement and Control Equipment</i>

2.2 Other referenced standards

This standard is also intended to be used with the following standard:

NEMA Standards Publication No. 107-1964, *Methods of Measurement of Radio Influence Voltage (RIV) of High Voltage Apparatus* (R1971, 1976, 1981).

2.3 Related standards

These standards are listed here for information only and are not essential for the completion of the requirements of this standard:

ANSI C84.1-1989,	<i>Electric Power Systems and Equipment—Voltage Ratings (60 Hertz)</i>
ANSI C92.2-1987,	<i>Power Systems—Alternating Current Electrical Systems and Equipment Operating at Voltages above 230 Kilovolts Nominal—Preferred Voltage Ratings</i>
NEMA Standards Publication No. CC1-1993,	<i>Electric Power Connectors for Substations</i>

3 Definitions

All definitions, except as specifically covered in this standard, shall be in accordance with ANSI/IEEE 100 and ANSI C57.13.

accuracy classes: The limits, in terms of ratio correction factor and phase angle, that have been established.

accuracy of CCVT: The means of expressing the degree of conformity of the actual values obtained from the secondaries to the values that could have been obtained with the marked ratio. The performance characteristics associated with accuracy of a CCVT are expressed in terms of ratio correction factor and phase angle.

accuracy ratings: The accuracy class followed by a burden for which the accuracy class applies.

basic impulse insulation level (BIL): The electrical strength of insulation expressed in terms of the crest value of a standard impulse having a front time of 1.2 microseconds and a time to half value of 50 microseconds. The tolerance range is 1.2-5.0 x 40-60 microseconds.

basic switching impulse insulation level (BSL): The electrical strength of insulation expressed in terms of the crest value of a standard switching impulse having a front time of 250 microseconds and a time to half value of 2500 microseconds. The tolerance range is 100-500 x 2000 - 4000 microseconds.

burden of a CCVT: The property of the circuit connected to the secondary terminals that determines the active and reactive power at the secondary terminals. The burden is expressed either as total ohmic impedance with the effective resistance and reactance components, or as the total volt-amperes and power factor at the specified value of voltage and frequency.

capacitor: In this standard, the word "capacitor" is used when it is not necessary to lay particular stress upon the different meanings of "capacitor unit" or "capacitor stack."

capacitor divider: A capacitor stack consisting of two capacitances connected in series so as to form a capacitive voltage dividing device (see Annex A).

capacitor element: An indivisible part of a capacitor consisting of electrodes separated by a dielectric.

capacitor stack: A capacitor unit or assembly of one or more units.

capacitor unit: An assembly of capacitor elements in a single container with accessible connections.

carrier drain coil: An inductor connected between the low-voltage terminal and the ground terminal of a coupling capacitor, presenting a low impedance to the flow of power-frequency current and a high impedance to the flow of carrier-frequency current.

carrier-frequency capacitance: The capacitance at a given frequency in the carrier-frequency range. This capacitance is given by the joint effect of the internal capacitance and of the self-inductance of the capacitor.

carrier grounding switch: A switch connected between the low-voltage terminal and the ground terminal of a coupling capacitor.

carrier lead-in terminal: The terminal to which the lead from the carrier line tuning equipment is connected.

carrier protective device: A device connected between the low-voltage terminal and the ground terminal of a coupling capacitor for limiting transient overvoltages between these terminals.

coupling capacitor: An assembly of one or more capacitor units fastened together and including high-voltage, low-voltage, and ground terminals and, if used, a coupling capacitor base (see Annex A, Figure A1).

coupling capacitor base: A supporting enclosure which is fastened beneath the lower capacitor unit of a capacitor stack and may include accessories for functional or protective purposes.

coupling capacitor voltage transformer (CCVT): A voltage transformer comprised of a capacitor divider and an electromagnetic unit so designed and interconnected that the secondary voltage of the electromagnetic unit is substantially proportional to and in phase with the primary voltage applied to the capacitor divider for all values of secondary burdens within the rating of the coupling capacitor voltage transformer (see Annex A, Figure A2).

design tests: Tests made by the manufacturer on each design to establish the performance characteristics and to demonstrate compliance with the appropriate standards.

dissipation factor: The tangent of the angle delta by which the phase difference between the voltage applied to the capacitor and resulting current deviates from 90 degrees. The dissipation factor is usually expressed in percent.

electromagnetic unit: The component of a CCVT connected between the intermediate-voltage terminal and ground terminal of the capacitor divider.

NOTE—An electromagnetic unit comprises essentially an inductive reactance approximately equal to the capacitive reactance at power frequency of the two capacitances (C_1 and C_2) connected in parallel. C_1 and C_2 are defined below. A transformer is used with the capacitance to reduce the intermediate voltage to the required value of the secondary voltage. The inductive reactance may be incorporated entirely or partially in the transformer.

electromagnetic unit protective device(s): Device incorporated in a CCVT for the purpose of limiting overvoltages that may appear across one or more of its components, or preventing sustained ferroresonance, or both.

ferroresonance: An oscillatory phenomenon that can exist in circuits consisting of capacitance and iron core nonlinear inductance. Ferroresonance occurs as the result of saturation of the iron core and produces a sustained distorted waveform or overvoltage, or both.

ground terminal: The terminal to be connected to ground.

high-voltage capacitance, C_1 : The capacitance between the high-voltage and intermediate-voltage terminals.

high-voltage terminal (line terminal): The terminal to be connected to the power line.

insulation level: An insulation strength expressed in terms of a withstand voltage.

intermediate voltage: The voltage to ground at the intermediate-voltage terminal of the capacitor divider when the ground terminal of the divider is grounded directly or through a carrier drain coil.

intermediate-voltage capacitance, C_2 : The capacitance between the intermediate-voltage terminal and the low-voltage or ground terminal.

intermediate-voltage terminal: The terminal to be connected to an intermediate circuit such as the electromagnetic unit of a coupling capacitor voltage transformer.

leakage distance: The length of the external insulating surface from the high-voltage terminal to the ground terminal.

low-voltage terminal: The terminal at the lower end of the capacitor stack.

marked ratio: The ratio, as stated on the nameplate, of the performance reference voltage to the secondary voltage.

maximum rated voltage: The highest rms value of the sinusoidal voltage between terminals that the capacitor is intended to withstand continuously. The definition is applicable to a capacitor stack for the voltage between high-voltage and low-voltage terminals, or high-voltage and ground terminals.

NOTE—Maximum rated voltage corresponds to maximum system voltage divided by $\sqrt{3}$.

maximum system voltage: The highest sustained rms phase-to-phase voltage under normal operating conditions and at any point on the system, excluding temporary variations due to fault conditions or the sudden disconnection of large loads.

nominal system voltage: A nominal rms phase-to-phase voltage value assigned to a circuit or system for the purpose of conveniently designating its voltage class.

partial discharge: An electrical discharge that partially bridges the insulation between electrodes.

percent ratio: The true ratio expressed as a percentage of the marked ratio.

percent ratio correction: The difference between the ratio correction factor and unity, expressed as a percentage: $[(RCF-1) \times 100]\%$.

NOTE—The percent ratio correction is positive if the ratio correction factor is greater than unity. If the percent ratio correction is positive, the measured secondary voltage will be less than the voltage applied to the high-voltage terminal divided by the marked ratio.

performance reference voltage: The voltage selected as the basis for determining accuracy and transient response performance, and applied to the high-voltage terminal. The performance reference voltage is obtained by multiplying the secondary voltage (115 volts) by the lower marked ratio.

phase angle of a CCVT: The phase displacement, in minutes (or in milliradians), between the voltages at the high-voltage terminal and the polarity-identified secondary terminal.

NOTE—The phase angle of a CCVT is designated by the Greek letter gamma (γ). It is positive when the secondary voltage from the polarity-identified to the polarity-unidentified terminal leads the corresponding voltage at the high voltage terminal.

polarity: The designation of the relative instantaneous directions of the voltages on the high-voltage terminal and the secondary terminals during most of each half cycle.

NOTE—High-voltage and secondary terminals are said to have the same polarity when, at a given instant during most of each half-cycle, the voltages on the high-voltage terminal and the polarity-identified secondary terminal are in the same direction.

potential grounding switch: A switch connected between the intermediate-voltage circuit and the ground terminal of a CCVT.

production tests: Tests made by the manufacturer on each item of equipment to verify performance characteristics.

rated capacitance: The value of the capacitance at maximum rated voltage and power frequency for which the capacitor is designed. This definition applies:

- a) For a capacitor unit, to the capacitance between the terminals, of the unit
- b) For a capacitor stack, to the capacitance between high-voltage and low-voltage terminals, or high-voltage and ground terminals of the stack
- c) For a capacitor divider, to the resultant capacitance:
$$\frac{C_1 C_2}{C_1 + C_2}$$

ratio correction factor (RCF): The ratio of the true ratio to the marked ratio. The voltage by the high-voltage terminal is equal to the secondary voltage, multiplied by the marked ratio, multiplied by the ratio correction factor.

secondary terminals of a CCVT: The terminals to be connected to devices for measurement, control, or protective relaying.

short-circuit rating: The time in seconds during which the CCVT, while energized at the maximum rated voltage, is capable of withstanding a short-circuit directly across the secondary terminals.

stray capacitance of low-voltage terminal: The capacitance between the low-voltage terminal and the ground terminal.

stray conductance of low-voltage terminal: The conductance between the low-voltage terminal and the ground terminal.

thermal burden rating: The volt-ampere output that the CCVT will supply continuously at maximum rated voltage without causing the specified temperature limitations to be exceeded.

transient response of a CCVT: The measure of fidelity of the secondary-voltage waveform, compared with the voltage waveform at the high-voltage terminal under transient conditions.

true ratio: The ratio of the power-frequency root-mean-square (rms) voltage at the high-voltage terminal to the power-frequency rms voltage at secondary terminals under specified conditions.

4 Service conditions

4.1 Usual service conditions

- a) Outdoor service.
- b) Ambient temperature range: -40°C to $+45^{\circ}\text{C}$. With regard to the temperature range, Table 1 defines the upper temperature limit conditions.
- c) Maximum altitude: 3300 feet (1000 meters) above sea level.
- d) Power frequency: 60 Hz.
- e) Atmosphere: free of damaging fumes or excessive or abrasive dust, explosive mixtures of dust, or gases, steam, and salt spray.
- f) Carrier frequency range: 30-500 kHz.

Table 1 — Upper ambient temperature limit

Maximum Ambient Temperature (Degrees C)		
Mean Over 1 Hour	Mean Over 24 Hours	Mean over 1 Year
45	40	30

4.2 Unusual service conditions

- a) Altitude above 3300 feet (1000 meters). For coupling capacitors and CCVTs applied at altitudes greater than 3300 feet (1000 meters), the dielectric strength correction factors are given in Table 2.
- b) Gas-insulated substations.
- c) High-voltage power cable systems.
- d) Direct-current application (coupling capacitors).

Table 2 — Dielectric strength correction factors

Altitude (Above sea level)	Correction factor
3 300 feet (1000 meters)	1.00
5 000 feet (1500 meters)	0.95
10 000 feet (3000 meters)	0.80

5 Ratings

5.1 General

5.1.1 Voltage ratings and marked ratios

Voltage ratings for coupling capacitors and CCVTs, and marked ratios for CCVTs, shall be as listed in Table 3.

5.1.2 Dielectric strength requirements

5.1.2.1 Dielectric strength of the capacitor stack

The dielectric strength (power-frequency withstand, BIL and BSL) of the capacitor stack shall be in accordance with Table 3.

5.1.2.2 Dielectric strength of the electromagnetic unit

5.1.2.2.1 Dielectric strength of the intermediate-voltage circuit

The dielectric strength of the electromagnetic unit at the intermediate-voltage terminal shall be equal to the appropriate capacitor divider dielectric test values as specified in Table 3 multiplied by the ratio $C_1/(C_1 + C_2)$. The sparkover voltage of protective equipment, such as gaps, may be lower than the dielectric strength rating.

5.1.2.2.2 Dielectric strength of the secondary circuit

The secondary windings of the intermediate-voltage transformer and the reactive element of any auxiliary equipment to be connected to the secondary winding(s) shall withstand a test voltage of four times normal operating voltage for 1 minute. The secondary winding(s) shall also withstand a power frequency rms dielectric test voltage of 2.5 kV for one minute between the secondary circuit and ground and between the secondary windings.

5.1.3 Minimum leakage distance

The minimum leakage distance of the capacitor stack shall be in accordance with Table 3.

5.1.4 Radio-influence voltage

The maximum radio-influence voltage of a coupling capacitor or a CCVT shall be in accordance with Table 4.

Table 3 – Voltage ratings, dielectric strengths, leakage distances, and marked ratios

				Minimum power-frequency withstand voltage (kV)			CCVT				
Nominal system voltage (note 1) (kV)	Maximum system voltage (note 2) (kV)	Maximum rated voltage (note 3) (kV)	Minimum power-frequency withstand voltage (kV)		10 seconds wet Col 5	Minimum basic impulse insulation level (BIL) (kV) Col 6	Minimum basic switching impulse insulation level (BSL) (kV) Col 7	Minimum leakage distance (inches (mm)) Col 8	Performance reference voltage (note 4) (Volts) Col 9	Marked ratio (note 4)	
			1 minute dry Col 4							Lower ratio Col 10	Higher ratio Col 11
Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 11	
34.5	36.2	21	85	72	200	-	26 (660)	20125	175:1	300:1	
46	48.3	28	110	95	250	-	35 (890)	27600	240:1	400:1	
69	72.5	42	165	140	350	-	48 (1220)	40250	350:1	600:1	
115	121	70	265	230	550	-	79 (2010)	69000	600:1	1000:1	
138	145	84	320	275	650	-	92 (2340)	80500	700:1	1200:1	
161	169	98	370	325	750	-	114 (2900)	92000	800:1	1400:1	
230	242	140	525	460	1050	-	154 (3910)	138000	1200:1	2000:1	
345	362	209	785	680	1550	975	230 (5840)	207000	1800:1	3000:1	
500	550	318	900	780	1800	1300	350 (8890)	287500	2500:1	4500:1	
765	800	462	1200	1050	2425	1675	510 (12950)	431250	3750:1	6250:1	

NOTES

- Values from 34.5 kV through 230 kV correspond to the preferred nominal system voltage given in ANSI C84.1, and from 345 kV through 765 kV to typical "nominal" voltages given in ANSI C92.2.
- Values from 36.2 kV through 242 kV correspond to the maximum voltage of the tolerable zone for voltages at substations and on transmission systems given in ANSI C84.1, and values from 362 kV through 800 kV to the preferred maximum system voltages given in ANSI C92.2.
- These values are phase-to-ground voltage corresponding to maximum system voltages divided by $\sqrt{3}$.
- For CCVTs in this table that have a double ratio achieved by means of a tap in the secondary winding(s), the nonpolarity end of the winding shall be the common terminal. Application of performance reference voltage between the high-voltage terminal and the ground terminal will result in 115 volts across the secondary windings having the lower ratio.



Table 4 – Radio-influence voltage

System voltage (kV)		Radio-influence test Test Voltage (Note 1) (kV)	Maximum radio-influence voltage (Notes 2 and 3) (μ V)
Maximum	Nominal		
36.2	34.5	21	125
48.3	46	28	125
72.5	69	42	125
121	115	70	250
145	138	84	250
169	161	98	250
242	230	140	250
362	345	209	250
550	500	318	500
800	765	462	750

NOTES

- 1 The radio-influence test voltage is the line-to-ground value of the maximum system voltage from ANSI C84.1 and ANSI C92.2.
- 2 Maximum permissible background voltage level will be half the radio-influence voltage, according to which test is being performed. Correction for background voltage level shall be by the rms method.
- 3 These maximum radio-influence voltages, as conducted radio noise, will add a negligible amount to the radio noise normally radiated from the line, even at short distances from the coupling capacitor or CCVT.

5.1.5 Low-voltage terminal insulation level

Coupling capacitors with a low-voltage terminal shall have a one minute, 60 Hz withstand insulation level of 4 kV rms between the low-voltage terminal and ground, or 10 kV rms if the terminal is exposed to weather.

5.1.6 Low-voltage terminal stray capacitance and stray conductance

The value of the stray capacitance and stray conductance at the low-voltage terminal, at any frequency in the carrier-frequency range with the electromagnetic unit disconnected from the intermediate-voltage terminal, shall not exceed 200 pF and 20 mhos (20 microsiemens), respectively.

5.1.7 Carrier drain coil loading, power frequency voltage drop, and insulation level**5.1.7.1 Loading**

There are no requirements for drain coil loading.

For an explanation and discussion of the determination of drain coil inductance refer to Annex C. The manufacturer shall provide information on drain coil inductance and current rating.

5.1.7.2 Voltage drop

The voltage drop across the carrier drain coil shall not exceed 30 volts rms at power frequency and with maximum rated voltage applied to the high-voltage terminal of the capacitor.

NOTE—For an explanation and discussion of the 30 volt rms specification, see the Annexes of ANSI/ISA S82.01, ANSI/ISA S82.02, ANSI/ISA S82.03.

5.1.7.3 Insulation level

The basic impulse insulation level (BIL) of the carrier drain coil shall be a minimum of 10 kV at a standard impulse wave of 1.2-5.0 $\times$ 40-60 microseconds.