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IEEE Standard Requirements, Terminology, and Test Procedure for Neutral Grounding Devices

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

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Abstract: IEEE Std 32-1972 (Reaff 1990); *IEEE Standard Requirements, Terminology, and Test Procedures for Neutral Grounding Devices*. This standard applies to devices (other than surge arresters) used for the purpose of controlling the ground current or the potentials to ground of alternating current systems. It defines usual and unusual service conditions, and gives bases for rating such devices. Specifications are given for temperature limitations, dielectric tests, routine tests, losses and impedance measurements, and construction items.

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Foreword

This standard is a revision of AIEE Standard 32, 1947, to which many changes and additions have been made.

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IEEE Standard Requirements, Terminology, and Test Procedure for Neutral Grounding Devices

1. General

1.1 Scope

This standard applies to devices used for the purpose of controlling the ground current or the potentials to ground of an alternating current system. These devices are: grounding transformers, ground-fault neutralizers, resistors, reactors, capacitors, or combinations of these.

1.2 Service Conditions

1.2.1 Usual Temperature and Altitude Service Conditions.

Devices conforming to this standard shall be suitable for operation at their ratings provided that:

- 1) The temperature of the cooling air (ambient temperature) does not exceed 40°C and the average temperature of the cooling air for any 24-hour period does not exceed 30°C.

NOTE — It is recommended that the average temperature of the cooling air be calculated by averaging 24 consecutive hourly readings. When the outdoor air is the cooling medium, the average of the maximum and minimum daily temperatures may be used. The value which is obtained in this manner is usually slightly higher than the true daily average but not by more than $\frac{1}{2}^{\circ}\text{C}$.

- 2) The altitude does not exceed 3300 ft (1000 m).

1.2.2 Unusual Temperature and Altitude Service Conditions.

Devices conforming to this standard may be applied to higher ambient temperatures or at higher altitudes than specified in 1.2.1, but their performance will be affected and special consideration should be given to these applications.

1.2.3 Other Unusual Service Conditions.

Where unusual conditions other than those discussed in 1.2.2 exist, they should be brought to the attention of those responsible for the design and application of the equipment. Examples of such conditions are:

- 1) Exposure to damaging fumes, radiation, or vapors; excessive abrasive or magnetic dust; explosive mixtures of dust, vapors, or gases; steam, excessive moisture, dripping water, fog or spray; salt or acid; etc.
- 2) Abnormal vibration, shock, or tilting from earthquakes or other causes.
- 3) Unusual transportation or storage conditions.
- 4) Unusual space limitations.
- 5) Abnormal operating duty, frequency of operation, difficulty of maintenance, poor waveform, excessive unbalance voltage, special insulation requirements, lack of normal lightning arrester protection, unusual magnetic shielding problems, harmonics in excess of or other than those expressed in Note of Section 2.2.
NOTE — Unless an air-core reactor is fully shielded magnetically, consideration should be given to its location relative to other apparatus and to metallic structures which may suffer overheating due to stray fields and mechanical damage under fault conditions.
- 6) System having a ratio of reactance to resistance X/R greater than 10. See Section 2.2.

1.3 Operation at Altitudes in Excess of 3300 ft (1000 m)

Standard devices may be applied in locations having an altitude in excess of 3300 ft (1000 m), but the dielectric strength of air-insulated parts and the current-carrying capacity will be affected.

1.3.1 Insulation.

The dielectric strength of air-insulated parts of a given insulation class at or above 3300 ft (1000 m) should be multiplied by the proper correction factor, as given in Table 1, to obtain the dielectric strength at the required altitude.

An altitude of 15 000 ft (4500 m) is considered a maximum for standard devices.

1.3.2 Operation at Rated Current.

Devices with standard temperature rise may be used at rated current at altitudes greater than 3300 ft (1000 m) provided the average temperature of the cooling air does not exceed the values in Table 2 for the respective altitudes. Under these conditions, standard temperature limits will not be exceeded.

Table 1— Dielectric Strength Correction Factors for Standard Devices at Altitudes Greater than 3300 ft (1000 m)

Altitude		Factor for Correction
meters	feet	
1000	3300	1.00
1200	4000	0.98
1500	5000	0.95
1800	6000	0.92
2100	7000	0.89
2400	8000	0.86
2700	9000	0.83
3000	9900	0.80
3600	12 000	0.75
4200	14 000	0.70
4500	15 000	0.67

2. Basis for Rating

2.1 Conditions

Ratings for devices are based on standard operating conditions and shall include the following:

- 1) Current
- 2) Voltage
- 3) Frequency
- 4) Basic Impulse Insulation Level (BIL) and Insulation Class
- 5) Circuit Voltage of System
- 6) Service (Indoor or Outdoor)
- 7) Time

2.2 Rated Current

Unless otherwise specified, the basis for this rating shall be the thermal current. This will be the current through the neutral device during a ground-fault condition at the device location.

Implicit in the thermal current rating is an associated continuous current which, unless otherwise specified, shall bear the following relationship to the thermal current rating:

Rated Time of Device	Continuous Duty Current in Percent of Thermal Current Rating	
	Reactors, Ground-Fault Neutralizers, and Transformers Used For Grounding	
	Resistors	
10 s	3	0
1 min	7	0
10 min	30	0
Extended Time	30	0

NOTE — Where there is a third harmonic component of current, it shall not exceed 15 percent of the rated continuous duty current.

Devices shall be able to withstand, without mechanical failure, forces associated with the crest of the offset current wave, assuming subtransient reactance fault conditions. This current crest, for devices other than resistors, shall be determined from the following equation:

$$I_c = KI_T \quad (1)$$

where

I_c = Crest of the initial offset current

K = Multiplier from Table 3
 I_T = Thermal current rating

2.3 Rated Voltage (see definition in Section 13)

The rated voltage except for certain resistors (see 10.1.1) and grounding transformers (see 9.2.3), shall be taken as the product of the rated thermal current and the impedance of the device at rated frequency and at 25 °C.

**Table 2—
Maximum Allowable Average Temperature,* Degrees Celsius
of Cooling Air for Carrying Rated Current**

Methods of Cooling Apparatus	3300 ft (1000 m)	6600 ft (2000 m)	9900 ft (3000 m)	13 200 ft (4000 m)
Oil-Immersed Self-Cooled	30	28	25	23
Dry-Type Self-Cooled				
55 °C rise	30	27	24	21
80 °C rise	30	26	22	18
150 °C rise	30	22	15	7
Resistors	30	3	−14	−25

*For recommended calculation of average temperature, see Note in 1.2.1.

Table 3— Value of K for Eq 1

X/R	K	X/R	K	X/R	K
1000	3.390	28	3.215	13	3.026
250	3.379	24	3.186	12	3.000
100	3.342	20	3.148	11	2.970
65	3.312	18	3.121	10 or less	2.940
45	3.278	16	3.089		
34	3.245	15	3.070		

NOTE — $K = 1.2 \{ 1 + \exp [-\pi (R/X)] \} \sqrt{2}$

When sequence impedances for the system are not specified, the ratio X/R shall be taken to be the ratio of ohms reactance to ohms resistance (dc) in the winding of the device through which the current flows.

When the system to which the neutral device is connected has an X/R ratio at that point which is greater than 10, the ohmic values of sequence impedances should be specified. When specified, the manufacturer shall combine them with the X and R of the device to determine the value of K to be used in calculating I_T . The 1.2 factor is based on use of transient reactance in calculating thermal current.

A device consisting of tapped sections or sections connected in series may have a rated voltage for each section determined from the impedance and the rated thermal current of the section as above.

2.4 Rated Frequency (see definition in Section 13)

The rated frequency shall be the fundamental, except that for some devices such as neutral wave traps, the rating may include additional harmonic frequencies which the device is designed to control.

2.5 Rated Time (see definition in Section 13)

Rated time shall be 10 seconds, 1 minute, 10 minutes, and extended time. Extended-time operation shall not exceed an average of 90 days per year.

3. Insulation Classes and Dielectric Withstand Levels

3.1 Basic Impulse Insulation Levels and Insulation Classes (see definition in Section 13)

All apparatus covered by this standard shall be assigned BIL (basic impulse insulation levels) and/or insulation class designations.

Table 4— Insulation Classes for Neutral Grounding Devices

Insulation Class			
System Insulation Class, kV (See Note 1)	Fault Voltage Criteria (See Note 2)		
Column 1	Column 2	Column 3	Column 4
Class	BIL	kV	kV
1.2	45	1.2	1.2
2.5	60	2.5	2.5
5.0	75	5.0	5.0
8.7	95	8.7	8.7
15.0	110	8.7	8.7
23.0	150	15.0	8.7
34.5	200	25.0	8.7
46.0	250	34.5	15.0
69.0	350	46.0	15.0
92.0	450	69.0	15.0
115.0	550	69.0	15.0
138.0	650	92.0	15.0
161.0	750	92.0	15.0
180.0	825	115.0	15.0
196.0	900	115.0	15.0
230.0	1050	138.0	15.0

NOTES:

- 1 — Where the insulation class for the terminal of a device is specified to be the system insulation class, the nominal system insulation level shall apply except that reduced BIL may be used where appropriate.
- 2 — When the fault voltage criterion applies, the maximum rms voltage that may exist between the terminal and ground, under fault conditions, is determined. If this fault voltage falls between the values in columns 3 and 4 corresponding to the system insulation class in column 1, the system insulation class at the terminal in question shall be the value in column 3 which equals or is next higher than the maximum fault voltage. If the fault voltage is less than the value in column 4, the system insulation class at the terminal in question shall be the value in column 4. If the fault voltage exceeds the value in column 3 the system insulation class at the terminal in question shall be the value in column 1.

Specific instructions for selecting the BIL and insulation class, and associated dielectric tests for a particular device, are covered in the section of the standard which is set aside for the device in question.

Reactors	Section 7.
Ground-Fault Neutralizers	Section 8.
Grounding Transformers	Section 9.
Resistors	Section 10.
Capacitors	Section 11.
Combination Devices	Section 12.

Basic impulse insulation levels and insulation class designations used with grounding devices are given in Table 4.

The two ends of the winding of a neutral device may be assigned different insulation levels.

3.2 Dielectric Withstand Test Levels

Applied-potential, induced-potential, and impulse test withstand levels are those given in Table 5. For duration and frequency of test, see 14.2.2.

3.3 Protective Devices

Suitable protective devices shall be provided whenever necessary to hold transient overvoltages at the terminals of a device to values within the limits set by the selected insulation levels.

4. Temperature Limitations

4.1 Limits

Steady-state and rated-time temperature rises for current-carrying parts, determined under standard operating conditions, shall not exceed the limits established in Table 6.

Top oil temperature rises determined under standard operating conditions shall not exceed the limits established in Table 8.

Parts, other than current-carrying parts, in contact with or adjacent to insulation or oil, shall not attain temperature rises in excess of those allowed for current-carrying parts. Other parts shall not attain temperatures that will be injurious to structures, or personnel, or produce excessive smoke or toxic fumes.

4.2 Steady-State Temperature Rises (see definition in Section 3)

The steady-state average winding temperature rise shall be determined by routine test (see Section 5.1).

The steady-state hot-spot winding temperature rise T_{HS} shall be determined by design test.

4.3 Rated-Time Temperature Rises (see definition in Section 13)

4.3.1 Ten-Second and One-Minute Ratings.

The rated-time temperature rise of 10-second and 1-minute devices is an average winding rise (except resistors, for which it is a hot-spot rise).

The rated-time temperature rise of 10-second and 1-minute devices shall be taken as the sum of the steady-state rise determined as in 4.2 and the additional rise caused by the flow of rated thermal current (or, for certain resistors, the application of rated voltage) for rated time, determined by calculation, using Eq 11 (for resistors, Eq 17).

4.3.2 Ten-Minute Ratings.

The rated-time temperature rise of 10-minute devices is an average winding rise (except resistors, for which it is a hot-spot rise).

The rated-time temperature rise of 10-minute devices shall be taken as the winding rise above ambient resulting from the flow of rated thermal current (or, for certain resistors, the application of rated voltage) for 10 minutes starting with an initial temperature rise equal to the steady-state rise of the device.

The rated-time temperature rise of 10-minute devices shall be determined by routine test (Section 5.1).

4.3.3 Extended-Time Ratings (see definition in Section 13)

The rated-time temperature rise of extended-time devices is an average winding rise (except resistors, for which it is a hot-spot rise).

The rated-time temperature rise of extended-time devices shall be taken as the ultimate rise above ambient resulting from the continued flow of rated thermal current (or, for certain resistors, the continued application of rated voltage).

The rated-time temperature rise of extended-time devices shall be determined by routine test (Section 5.1).

5. Tests

Unless otherwise specified, tests shall be made at the manufacturer's facilities.

5.1 Routine Tests (see definitions in Section 13)

The following routine tests shall be made on all devices where feasible, except as covered in the section of the standard which is set aside for the device in question. The numbers shown do not necessarily indicate the sequence in which the tests shall be made. All tests shall be made in accordance with Section 14., Test Code.

- 1) Resistance measurements of all windings on the rated voltage connection and taps or sections of each device
- 2) Voltage measurements on the rated voltage connection and on all tap connections
- 3) Polarity and phase relation tests on the rated voltage connection
- 4) Excitation loss at rated voltage on the rated voltage connection
- 5) Excitation current at rated voltage on the rated voltage connection
- 6) Impedance voltage and power at rated current on rated connection of each device and the tap connections of one unit only of a given design
- 7) Temperature test or tests shall be made on a device only if no record of a temperature test, made in accordance with these standards, on a duplicate or essentially duplicate design, is available
NOTE — This standard provides for using values calculated from tests at reduced currents.
- 8) Dielectric tests

Table 5— Dielectric Test Voltage and Time to Test-Gap Flashover

Insulation Class	Grounding Transformers, Ground-Fault Neutralizers & Reactors*														Resistors†	Capacitors		
	Impulse Tests							Applied Potential			Induced Potential					Applied Potential	Applied Potential	
	Chopped Wave				Full Wave													
	Oil	Dry	Mini- mum Time to Flashover		Oil	Dry (Exclud- ing Reactors)	Dry Reactors	Oil	Dry (Exclud- ing Reactors)	Dry Reactors	Excluding Reactors	Reactors						
												Oil	Dry		Out- door		In- door	
kV rms	kV crest		Micro- seconds		kV crest			kVrms			kV rms	kV crest	kV rms			kV rms		kV rms
Col. 1	Column 2				Column 3			Column 4			Column 5				Column 6	Column 7		Column 8
1.2	54	10	1.5	1.0	45	10	45	10	4	10	Two Times Rated Voltage	45	13	10	5	10	5	Two
2.5	69	20	1.5	1.0	60	20	60	15	10	19		60	25	19	7.5	15	10	Times
5.0	88	25	1.6	1.0	75	25	75	19	12	26		75	35	26	13.5	19	15	Rated
8.7	110	35	1.8	1.0	95	35	95	26	19	36		95	48	36	22	26	22	Voltage
15	130	50	2.0	1.25	110	50	110	34	31	50		110	67	50	36	34	28	
18	145	-	2.25		125	-	125	40	40	-		125	-	-	-	40		
25	175	75	3		150	75	150	50	50	70		150	93	70	60	50		
34.5	230	105	3		200	105	200	70	70	95		200	127	95	80	70		
46	290	140	3		250	140	250	95	95			250				95		
60	345	-	3		300	-	300	120	120			300				120		
69	400	215	3		350	215	350	140	140			350				140		
92	520		3		450		450	185				450				185		
115	630		3		550		550	230				550				230		
138	750		3		650		650	275				650				275		
161	865		3		750		750	325				750				325		
180	950		3		825		825	360				825				360		
196	1035		3		900		900	395				900				395		
215	1120		3		975		975	430				975				430		
230	1210		3		1050		1050	460				1050				460		

*Dry-type reactors do not receive chopped-wave impulse test.

†For resistors made in sections, see 10.3.2.

Table 6— Limiting Temperature Rises Above 30° C Ambient for Current Carrying Parts—Neutral Devices * †

Column 1	Column 2	Column 3		Column 4		Column 5		Column 6		Column 7	
		55°C Oil-Immersed		55 °C Dry-Type		80 °C Dry-Type		150°C Dry-Type		Resistors	
		Temperature Rise °C	Time Factor [‡] seconds	Temperature Rise °C	Time Factor [‡] seconds	Temperature Rise °C	Time Factor [‡] seconds	Temperature Rise °C	Time Factor [‡] seconds	Stainless Steel ^{**}	Cast Grid #
<i>Steady State</i> for Continu- ous Current Ratings	Steady State (Hot-Spot) Section 4.2	65		65		110		180		385	385
	Steady State (Average) Section 4.2	55		55		80		150		-	-
<i>Rated Time</i> for Thermal Current Rat- ings (rated voltage for certain resistors)	Extended-Time (Average) Section 4.3.3	75		75		110		200		610	385
	Ten-Minute (Average) Section 4.3.2	125		125		185		275		610	460
	Less than 10 Minutes (Average) Section 4.3.1	120	22 500	120	103 000	160	143 000	250	98 400	760	510
		125	15 000	130	53 300	170	86 700	260	63 000		
		130	9 000	140	30 000	180	53 700	270	41 000		
		135	6 700	150	16 700	190	33 300	280	26 600		
		140	4 300	160	9 330	200	21 000	290	18 000		
		145	3 000	170	5 330	210	13 700	300	12 000		
		150	2 100	180	3 330	220	9 170	310	8 340		
		155	1 500	190	2 000	230	6 170	320	5 670		
		160	1 030	200	1 270	240	4 170	330	4 000		
		165	733	210	767	250	2 830	340	2 800		
		170	517	220	500	260	1 970	350	1 968		