

IEEE Standard Requirements for Secondary Network Protectors

Sponsor

**Transformers Committee
of the
IEEE Power Engineering Society**

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Abstract: The performance, electrical and mechanical interchangeability as well as the safety of the equipment are covered. The proper selection of such equipment is established as a basis for use in this standard. Certain electrical, dimensional, and mechanical characteristics are described, and certain safety features of three-phase, 60 Hz, low-voltage 600 V and below network protectors are taken into consideration. They are used for automatically connecting and disconnecting a network transformer from a secondary spot or grid network.

Keywords: grid network, network, protector, spot network

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Introduction

(This introduction is not a part of IEEE Std C57.12.44-1994, IEEE Standard for Secondary Network Protectors.)

A survey of the Edison Electric Institute (EEI) and the National Electrical Manufacturers Association (NEMA) in 1987 indicated a need for standards on requirements for secondary network protectors. The first working group meeting was held February 24, 1988, in Washington, D. C.

This new standard was developed by a task force working group consisting of EEI, NEMA, and Institute of Electrical and Electronics Engineers (IEEE)/Power Engineering Society (PES) delegates now under the Underground Transformers and Network Protectors Subcommittee of the IEEE/PES Transformers Committee.

The applicable rules and procedures of ANSI and IEEE for preparation and approval of voluntary consensus standards were followed.

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IEEE Standard Requirements for Secondary Network Protectors

1. Overview

1.1 Scope

This standard describes certain electrical, dimensional, and mechanical characteristics and takes into consideration certain safety features of three-phase, 60-Hz, low-voltage (600 V and below) network protectors. They are used for automatically connecting and disconnecting a network transformer from a secondary spot or grid network.

1.2 Purpose

This standard is intended for use as a basis for establishing the performance, electrical and mechanical interchangeability, and safety of the equipment covered and to assist in the proper selection of such equipment.

1.3 Word usage

As used in this standard, the word “shall” indicates mandatory requirements. The words “should” and “may” refer to matters that are recommended and permissive, respectively, but not mandatory.

NOTE—The introduction of this standard describes the circumstances under which the document may be used on a mandatory basis.

2. References

All characteristics, definitions, tests, and voltage designations, except as specifically covered in this standard, shall be in accordance with the standards listed below.

When a standard referred to in this document is superseded by a revision approved by the American National Standards Institute, Inc., the revision shall *not* apply. The referenced standard and the specific referenced edition shall be the applicable referenced standard until the new version of the referenced document is incorporated by formal action or appropriate revision of the citing standard.

ANSI B1.1-1989, Standard for Unified Inch Screw Threads (UN and UNR Thread Forms).¹

¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

ANSI B1.20.1-1983, Standard for Pipe Threads, General Purpose (Inch).

ANSI C57.12.28-1988, Standard for Switchgear and Transformers-Pad-Mounted Equipment—Enclosure Integrity.

ANSI C57.12.40-1990, Standard Requirements for Secondary Network Transformers, Subway and Vault Types (Liquid Immersed).

ANSI C57.12.57-1987, Standard Requirements for Ventilated Dry-Type Network Transformers 2500 kVA and below, three-phase with high-voltage 34 500 volts and below, low-voltage 216Y/125 and 480Y/277 volts.

ANSI C57.12.70-1978 (R 1987), Standard Terminal Markings and Connections for Distribution and Power Transformers.

ANSI C84.1-1989, Standard Voltage Ratings (60 Hz) for Electric Power Systems and Equipment.

IEEE Std 1-1986 (Reaff 1992), IEEE Standard General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation (ANSI).²

IEEE Std 100-1988, IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).

IEEE Std C37.09-1979 (Reaff 1988), IEEE Standard Test Procedure For AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis (ANSI).

IEEE Std C57.12.00-1987, IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers (ANSI).

IEEE Std C57.12.80-1978 (Reaff 1992), IEEE Standard Terminology for Power and Distribution Transformers (ANSI).

IEEE Std C57.91-1981 (Reaff 1991), IEEE Guide for Loading Mineral-Oil-Immersed Overhead and Pad-mounted Distribution Transformers Rated 500 kVA and Less with 65 °C or 55 °C Average Winding Rise (ANSI).

IEEE Std C57.92-1981 (Reaff 1991), IEEE Guide for Loading Mineral Oil-Immersed Power Transformers Up to and Including 100 MVA with 55 °C or 65 °C Winding Rise (ANSI).

3. Definitions

An asterisk (*) following a definition indicates that the definition is identical to that which appears in IEEE Std 100-1988.³

3.1 arcing contacts: The contacts of a switching device on which the arc is drawn after the main (and intermediate, where used) contacts have parted.*

3.2 desensitizing relay: A relay that prevents tripping of a network protector on transient power reversals, which neither exceed a predetermined value nor persist for a predetermined time.

3.3 intermediate contacts: Contacts in the main circuit which part after the main contacts and before the arcing contacts have parted.*

²IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

³Information on references can be found in clause 2.

3.4 main contacts: Contacts which carry all or most of the current of the main current.*

3.5 mechanically trip-free: A term indicating that the release can open the device even though 1) in a manually operated switching device the operating lever is being moved toward the closed position; or 2) in a power-operated switching device, such as solenoid- or spring-actuated types, the operating mechanism is being moved toward the closed position either by continued application of closing power or by means of a maintenance closing lever.*

3.6 network limiter: An enclosed fuse for disconnecting a faulted cable from a low-voltage network distribution system and for protecting the unfaulted portions of that cable against serious thermal damage.*

3.7 network master relay: A relay that functions as a protective relay by opening a network protector, when power is back-fed into the supply system and as a programming relay by closing the protector in conjunction with the network phasing relay when polyphase voltage phasers are within prescribed limits.*

3.8 network phasing relay: A monitoring relay which has as its function to limit the operation of a network master relay so that the network protector may close only when the voltages on the two sides of the protector are in a predetermined phaser relationship.*

3.9 network protector: An assembly comprising a circuit breaker and its complete control equipment for automatically disconnecting a transformer from a secondary network in response to predetermined electrical conditions on the primary feeder or transformer, and for connecting a transformer to a secondary network either through manual control or automatic control responsive to predetermined electrical conditions on the feeder and the secondary network. *Note:* The network protector is usually arranged to connect automatically its associated transformer to the network when conditions are such that the transformer, when connected, will supply power to the network and to automatically disconnect the transformer from the network when power flows from the network to the transformer.*

3.10 network protector fuse: A back-up device for the network protector.

3.11 network secondary distribution system: A system of alternating-current distribution in which the secondaries of the distribution transformers are connected to a common network for supplying light and power directly to consumers' services.*

3.12 phasing voltage: The voltage across the open contacts of selected phase. *Note:* This voltage is equal to the phasor difference between the transformer voltage and the corresponding network voltage.*

3.13 pumping: The unintentional cyclical tripping and closing of a network protector.

3.14 removable breaker: The removable breaker consists of the circuit breaker, disconnecting provisions, network relays, auxiliary panels, current transformers, control devices, other attachments, and all interconnecting wiring, which can be rolled out of the network protector enclosure on rails for maintenance or removal.

3.15 shunt tripping: A release energized by a source of voltage. *Note:* The voltage may be derived either from the main circuit or from an independent source.*

3.16 solid state network relay: A solid state relay which performs the combined functions of the master and phasing relays.

3.17 spot network: A small network, usually at one location, consisting of two or more primary feeders, with network units and one or more load service connections.

3.18 short-time current: The current carried by a device, an assembly, or a bus for a specified short time interval.*

4. Service conditions

4.1 Usual service conditions

4.1.1 General

Network protectors conforming to this standard shall be suitable for operation at rated current under the following conditions.

4.1.2 Temperature

The ambient temperature shall be between -20°C and 40°C .

4.1.3 Altitude

The altitude shall not exceed 3300 ft (1000 m).

4.2 Unusual service conditions

4.2.1 General

Conditions other than those described in 4.1.1 are considered unusual service, and when prevalent, shall be brought to the attention of those responsible for the design and application of the apparatus. Examples of some of these conditions are listed in 4.2.2 through 4.2.3.

4.2.2 Unusual temperature and altitude conditions

Network protectors may be used at higher or lower ambient temperatures or at higher altitudes than those specified in 4.1 but special consideration must be given to these applications. IEEE Std C57.91-1981 and IEEE Std C57.92-1981 provide information on recommended practices for the accompanying transformer.

4.2.3 Insulation at high altitude

The dielectric strength of network protectors, which depend primarily on air for insulation, decreases as the altitude increases due to the effect of decreased air density. Network protectors design voltage shall be derated using the correction factors of table 1 shown on page 5.

The insulation level at 3300 ft (1000 m) multiplied by the correction factor from table 1 must not be less than the required insulation level at the required altitude.

Table 1—Dielectric-strength correction factors for altitudes greater than 3300 ft (1000 m)

Altitude		Altitude correction factor for dielectric strength
(feet)	(meters)	
3300	1000	1.00
4000	1200	0.98
5000	1500	0.95
6000	1800	0.92
7000	2100	0.89
8000	2400	0.86
9000	2700	0.83
10 000	3000	0.80
12 000	3600	0.75
14 000	4200	0.70
15 000	4500	0.67

5. Design tests

The design tests shall be divided into three separate categories designated as continuous current thermal, electrical, and mechanical endurance.

5.1 Continuous current thermal test

The continuous current test shall be performed to demonstrate that the network protector can carry its rated continuous current at its rated frequency in an ambient temperature range between 10 °C and 40 °C without attaining a temperature rise in excess of those listed in table 2 shown on page 6. (See annex A for more information.) The network protector shall be tested with the highest loss fuse that would normally be applied with that network protector rating.

5.1.1 Test conditions

The network protector in its enclosure, with fuses, shall be connected to a three-phase current source at the transformer side of the network protector with copper bus bar whose ampacity is rated to carry the full rated current. This bus bar shall extend a minimum of 4 ft (1.219 m) from the network protector. This bus bar shall have a current density range of 800 A to 1500 A per square inch. The transformer throat openings shall be suitably enclosed with an insulating panel permitting the transformer extension bus to exit, but to seal all openings at the throat area. The network side terminals shall be short circuited with the same size bus bar as used on the transformer side connection and shall extend a minimum of 4 ft (1.219 m) from the network side terminal(s).

Thermocouples shall be used to measure the temperature. Thermocouples used for measuring the temperatures of insulation shall be located on the current carrying member or other metal part at a point as close as

Table 2—Temperature rise

Material temperature class	Temperature rise °C
90	50
105	65
130	90
155	115
180	140
200	160
220	180

practical to the accessible junction of the insulation and the current carrying member or other metal part. Thermocouples used for measuring the temperature of the transformer or network side terminal connections and other conducting joints shall be located approximately 0.5 in (12.7 mm) from the terminal or other conducting joints on the current carrying member. Thermocouples shall be held in intimate contact with the conductor surface by such methods as welding, drilling and peening, or cementing. Thermocouples may be used to determine the internal air temperature within the network protector enclosure by suspending the unmounted thermocouple bulbs in air.

The bus entering or leaving the network protector shall not be used to add or remove heat during the continuous current thermal test. To determine this, three thermocouples shall be placed one foot apart along the bus attached to the network protector. The bus is then shielded from air convection flow such that the three thermocouples along the bus bar are within 5 °C of the adjacent thermocouple on the bus bar. These readings are only applicable to the final three readings taken at 30 min intervals, and are not subject to the temperature variation criteria of the internal parts of the network protector. Refer to figure 1 on page 7 for the minimum number of thermocouples required.

5.1.2 Test duration

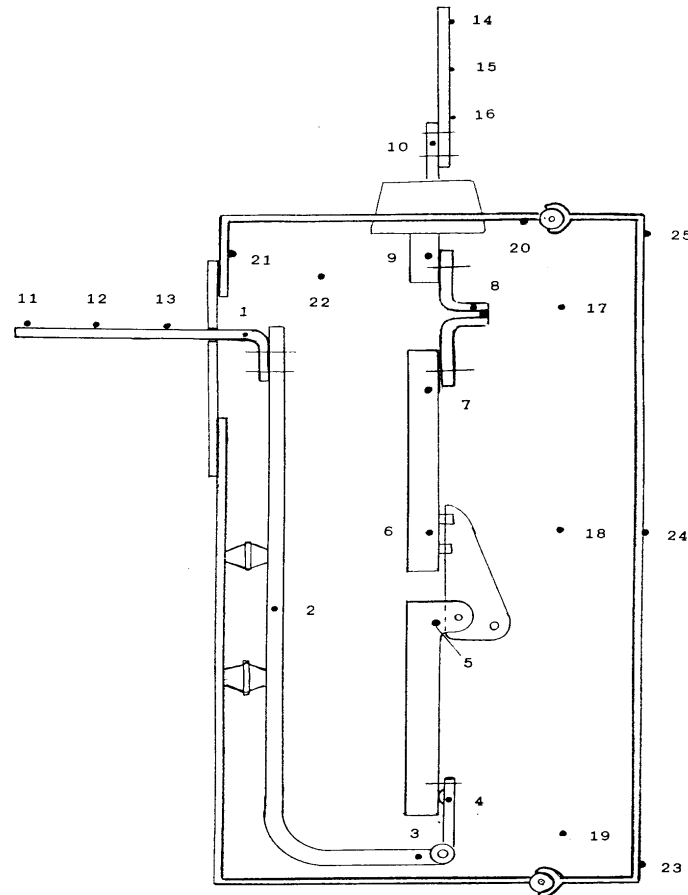
The rated continuous current of the network protector at rated frequency shall be applied continuously until the temperature rise stabilizes. The temperature rise shall be considered stable when three successive readings taken at 30 min intervals vary no more than ± 1.0 °C. If the temperature rise at the end of the second interval is equal to the established limit (see table 2) and if the temperature rise has increased since the previous reading, the test shall be continued one more interval.

5.1.3 Ambient temperature

The network protector shall be tested at an ambient temperature between 10 °C and 40 °C. No correction factors need be applied. The temperature rise shall, in no case, exceed those specified in table 2. The ambient temperature shall be determined by taking the average of the readings of the three thermocouples placed horizontally 12 in (30 cm) from the projected periphery of the network protector enclosure and approximately on a vertical line as follows:

- One approximately 12 in (30 cm) above the network protector or enclosure (including bushings)
- One approximately 12 in (30 cm) below the network protector enclosure. In the case of a floor mounted network protector enclosure, it shall be 12 in (30 cm) above the floor or mounting base
- One approximately midway between the above two positions

All reasonable precautions shall be taken to reduce errors caused by the time lag between the temperature rise of large apparatus and variations in the ambient temperature. Therefore, the ambient sensing thermocouples shall be immersed in a suitable liquid, such as oil, in a suitable metal cup. The size of the metal cup should be determined by the size of the apparatus being tested, but in no case shall the cup be any smaller than 1.0 in (2.5 cm) in diameter and 2.0 in (5.1 cm) high.



NOTE—Thermocouples 1 through 16 shall be duplicated on all three phases.

Figure 1—Thermocouple locations

5.1.4 Performance

Network protectors shall be considered to have passed this test if the limits of observable temperature rise for every point measured as specified in table 2 are not exceeded. The resistance of the conductors shall be measured on the network protector and its enclosure, either as one unit or separately. The resistance values recorded should be representative of the values recorded after the continuous current thermal test and serve as a basis for quality control monitoring of production of the individual designs and establishing the maximum acceptable limits of the individual designs and configurations.

5.2 Electrical tests

5.2.1 Interrupting rating test

The interrupting rating of the network protector, without fuses, shall be expressed in rms symmetrical amperes at the maximum design voltage of the network protector.

5.2.1.1 Test conditions

The symmetrical amperes shall be determined by measuring the current flow in the test circuit by short circuiting the supply side of the test circuit at the network protector. The ac current measured shall be the rms symmetrical current and shall be measured in the first half cycle after the short circuit is initiated. This current shall be calculated in accordance with clause 7 of IEEE Std C37.09-1979. The symmetrical current value shall be the average of the phase currents. The test circuit shall be such that the X/R ratio is between 6.6 and 8 with the X and R in series connection. Any reactor used in the test circuit shall be an air-core reactor. All interrupting testing must be three-phase with the removable breaker installed in its enclosure. The enclosure shall be insulated from ground and shall be connected to ground through a 30 A, current limiting fuse having an interrupting capacity of 200 000 symmetrical amperes.

5.2.1.2 Circuit characteristics

The transient characteristics of the test circuit shall be such that the rms total current of the maximum phase at the end of 60 cycles (based on a 60 Hz frequency) is not less than the interrupting rating of the circuit breaker.

The test circuit impedance shall be such that the currents at the end of 60 cycles are essentially equal in the three-phases.

Two separate tests shall be performed. One test shall energize from the transformer side with the network side shorted. The other test shall energize from the network side with the transformer side shorted.

5.2.1.3 Operating duty cycle

The operating duty cycle of a network protector shall consist of an opening operation followed by a 2 min interval and another opening operation (duty cycle is 0–2 min–0). For each opening operation, the network protector shall carry its rated interrupting current for 1 s before opening.

The 30 A fuse to ground shall be inspected after each duty cycle to insure that the fuse is intact. If the fuse has interrupted, the test was failed and shall be terminated.

NOTE—Any changes made to the network protector shall be reviewed with respect to its effect on the thermal test.

5.2.1.4 Performance

At the end of this test the network protector shall be in the following condition:

- a) *Mechanical.* The network protector shall be in substantially the same mechanical condition as before the test.
- b) *Electrical.* The network protector shall be capable of withstanding rated voltage in the OPEN position and of carrying rated current at rated voltage.

After this test, the network protector may be inspected and maintained.

5.2.2 Short-time current test

A network protector without fuses shall be given a short-time current rating, expressed in rms symmetrical amperes at the maximum design voltage of the network protector.

5.2.2.1 Test conditions

The symmetrical amperes shall be determined by measuring the current flow in the test circuit by short circuiting the supply side of the test circuit at the network protector.

The ac current measured shall be the rms symmetrical three-phase current and shall be measured in the first half cycle after the short circuit is initiated. This current shall be calculated in accordance with clause 7 in IEEE Std C37.09-1979. The symmetrical current value shall be the average of the phase currents. The test circuit shall be such that the X/R ratio is between 6.6 and 8 with the X and R in series connection. Any reactor used in the test shall be an air-core reactor.

The transient characteristics of the test circuit shall be such that the rms total current of the maximum phase at the end of 60 cycle (based on a 60 Hz frequency) is not less than the short-time rating. The rms total current of the first half-cycle shall be at least 1.25 times the short-time rating.

5.2.2.2 Operating duty

The rated short-time current shall be maintained for a period of 60 cycles without the network protector breaker's contacts parting. The test circuit is to be de-energized at the end of 60 cycles by its supply breaker and not the network protector breaker.

5.2.2.3 Performance

At the end of this test the network protector shall be capable of carrying rated continuous current without exceeding its temperature rise and shall be capable of meeting its interrupting rating. The main contacts shall be free of excessive burning or pitting.

5.2.3 Fault close test

For network protectors having either spring close mechanisms or stored-energy mechanisms, fault close levels shall be tested to verify the network protectors ability, less the fuses, to close and latch its contacts.

5.2.3.1 Test conditions

The symmetrical amperes shall be determined by measuring the current flow in the test circuit by short circuiting the supply side of the test circuit at the network protector. The ac current measured shall be the rms symmetrical current and shall be measured in the first half cycle after the short circuit is initiated. This current shall be calculated in accordance with clause 7 in IEEE Std C37.09-1979. The symmetrical current value shall be the average of the phase currents.

Maximum allowable fault close and latch current shall not exceed the network protector's interrupting rating. The test circuit shall be such that the X/R ratio is between 6.6 and 8 with the X and R in series connection. Any reactor used in the test circuit shall be an air-core reactor. The characteristics of the test circuit shall be such that the rms total current of the maximum phase of the first half cycle (based on a 60 Hz frequency) is not less than the fault close and latch rating of the circuit breaker. The transient characteristics of the test circuit shall be such that the dc component of the test current will decay to zero within 10 cycles.