



# IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations

**IEEE Power Engineering Society**

Sponsored by the  
Nuclear Power Engineering Committee



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# **IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations**

Sponsor

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

Approved 27 September 2007

**IEEE-SA Standards Board**

**Abstract:** Criteria that establish protection requirements for Class 1E power systems and equipment are prescribed in this standard. The purpose of and the means for obtaining protection from electrical and mechanical damage, or failures that can occur within a time period that is shorter than that required for operator action, are described. Testing and surveillance requirements are included. Plant physical design requirements to protect against events such as pipe whip, fire, dropped load, etc., are not included.

**Keywords:** Class 1E, electrical equipment, nuclear power generating stations, power systems, protection

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## Introduction

This introduction is not part of IEEE Std 741-2007, IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations.

The IEEE Power Engineering Society has developed this standard to provide the principal design criteria, design features, and testing requirements for the protection of Class 1E power systems and equipment supplied from those systems. It is of particular use in identifying the need for special protection features where the requirements of nuclear power generating stations necessitate supplementing accepted industry practices.

Wherever possible, this standard identifies other standards or documents that provide more explicit guidance for specific protection requirements. By definition, the protection shall be adequate to sense and to determine the presence of an unacceptable condition and to execute the operations required in order to limit degradation effects. In this role, this standard pays special attention to the requirements for design verification documentation to support the protection performance.

This standard also addresses the electrical penetration assemblies installed as part of the containment structure that may require special considerations for protection. Also included are the criteria used to establish the necessity for special considerations and the resulting protection requirements.

The revision of this standard included the following principal changes:

- Updating the standard in terms of additional protection considerations regarding motor service factor
- Updating the standard in regard to additional considerations when selecting digital protective devices (e.g., EMI/RFI)
- Updating normative references, including the addition of several new standards
- Deleting definitions from Clause 3 that are given in *The Authoritative Dictionary of IEEE Standards Terms* [B6].<sup>a</sup>
- Updating Annex D in regard to short circuit considerations when setting breaker instantaneous trip settings used in combination with contactors/starters to preclude contactor/starter damage
- Adding a bibliography (see Annex E)

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<sup>a</sup> The numbers in brackets correspond to those of the bibliography in Annex E.

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# IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations

## 1. Scope

This standard provides the principal design criteria, design features, and testing requirements for the protection of Class 1E power systems and equipment supplied from those systems. It identifies special protection features that are needed where the requirements of nuclear power generating stations necessitate supplementing accepted industry practices.

~~This standard prescribes that establish protection describes the purpose of and the means for obtaining from electrical and mechanical damage, or failures that can occur within a time period that is shorter than that required for operator action. It includes testing and surveillance. It does not include plant physical design requirements to protect against events such as pipe whip, fire, dropped load, etc~~

## 2. Normative references

~~This standard shall be used in conjunction with the publications. When following standards are superseded by an approved revision, revision shall apply.~~

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

~~ANSI/ISA S67.04 Part 1-1994, Setpoints for Nuclear Safety-Related Instrumentation.<sup>+</sup>~~

IEEE Std 141<sup>TM</sup>1993, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (~~ANSI~~) IEEE Red Book<sup>TM</sup>.<sup>1, 2</sup>

IEEE Std 142<sup>TM</sup>1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (~~ANSI~~) IEEE Green Book<sup>TM</sup>.

IEEE Std 242<sup>TM</sup>2001 242-1986, (~~Reaff~~ 1991) IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (~~ANSI~~) IEEE Buff Book<sup>TM</sup>.

<sup>1</sup> IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA. Std ~~741-1997~~ 08854, USA (<http://standards.ieee.org/>).

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

<sup>2</sup> The IEEE standards or products referred to in this clause are trademarks of the Institute of Electrical and Electronics Engineers, Inc.

IEEE Std 308™ ~~2001~~ ~~1991~~, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations. ~~(ANSI)~~.

IEEE Std 317™1983 (Reaff ~~2003~~~~1996~~), IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations ~~(ANSI)~~.

IEEE Std 336 ~~2005~~~~1985~~ (Reaff ~~1991~~),™, IEEE Standard Installation, Inspection, and Testing Requirements for Power, Instrumentation, and Control Equipment at Nuclear Facilities ~~(ANSI)~~.

IEEE Std 338™1987 (Reaff ~~2000~~~~1993~~), IEEE Standard Criteria for the Periodic Surveillance Testing of [Nuclear](#) Power Generating Station Safety Systems ~~(ANSI)~~.

IEEE Std 384™1992 ([Reaff 1998](#)), IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits ~~(ANSI)~~.

IEEE Std 415™1986 (Reaff 1992), IEEE Guide for Planning of Preoperational Testing Programs for Class 1E Power Systems for Nuclear Power Generating Stations ~~(ANSI)~~.<sup>3</sup>

IEEE Std 446™1995, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (~~ANSI~~ [IEEE Orange Book™](#)).

IEEE Std 487~~1992~~™ [2000](#), IEEE Recommended Practice for the Protection of WireLine Communication Facilities Serving Electric ~~Power Stations~~ ~~(ANSI)~~[Supply Locations](#).

IEEE Std 518™1982 (Reaff [1997](#) ~~1996~~), IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources ~~(ANSI)~~.<sup>4</sup>

IEEE Std 603 ~~1991~~™[1998](#), IEEE Standard Criteria for ~~Digital Computers in~~ Safety Systems for Nuclear Power Generating Stations ~~(ANSI)~~.

IEEE Std 666™1991 (~~Reaff 1996~~), IEEE Design Guide for Electric Power Service Systems for Generating Stations ~~(ANSI)~~.

~~IEEE Std 765~~1995, ~~IEEE Standard for Preferred Power Supply (PPS) for Nuclear Power Generating Stations~~ ~~(ANSI)~~.

IEEE Std 944™1986 (Reaff 1996), IEEE Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations ~~(ANSI)~~.

IEEE Std 946 [2004](#) ~~1992~~™, IEEE Recommended Practice for the Design of DC Auxiliary Power Systems for Generating Stations ~~(ANSI)~~.

[IEEE Std 1050](#)™2004, [IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations](#).

[IEEE Std 1290](#)™1996, [IEEE Guide for Motor Operated Valve \(MOV\) Motor Application, Protection, Control, and Testing in Nuclear Power Generating Stations](#).

[IEEE Std 1375](#)™1998, [IEEE Guide for the Protection of Stationary Battery Systems](#).

IEEE Std C37.91™ ~~2000~~~~1985~~ (Reaff ~~1990~~), IEEE Guide for Protective Relay Applications to Power Transformers ~~(ANSI)~~.

IEEE Std C37.96™ ~~2000~~~~1988~~, IEEE Guide for AC Motor Protection.

IEEE Std C62.2™[1987](#) ~~1989~~ (Reaff 1994), IEEE Guide for the Application of Gapped Silicon Carbide Surge Arresters for Alternating Current Systems ~~(ANSI)~~.

IEEE Std ~~415-1986~~ ~~C37.96-1988~~ (Reaff 1992) has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood CO 801125704, USA, tel. (303) 7922181 (<http://global.ihs.com>).  
<sup>4</sup> IEEE Std 518-1982 (Reaff 1997) has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood CO 801125704, USA, tel. (303) 7922181 (<http://global.ihs.com>).  
<sup>5</sup> IEEE Std 944-1986 (Reaff 1996) has been withdrawn; however, copies can be obtained from Global Engineering, 15 Inverness Way East, Englewood CO 801125704, USA, tel. (303) 7922181 (<http://global.ihs.com>).

[IEEE Std C62.23™1995 \(Reaff 2001\)](#), [IEEE Application Guide for Surge Protection of Electric Generating Plants](#).

IEEE Std C62.41™1991 (Reaff 1995), IEEE Recommended Practice on Surge Voltages in LowVoltage AC Power Circuits.

IEEE Std C62.45™2002-~~1992~~, IEEE Guide on Surge Testing for Equipment Connected to LowVoltage AC Power Circuits.

IEEE Std C62.92.3™1993 ([Reaff 2005](#)), IEEE Guide for the Neutral Grounding in Electrical Utility Systems, Part III—Generator Auxiliary Systems (~~ANSI~~).

NEMA ICS 2-~~1993~~ [2000](#), Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated ~~Not More than 2000~~ [600](#) Volts ~~AC or 750 Volts DC~~.<sup>6</sup>

[NEMA MG 12003, Motors and Generators](#).

### 3. Definitions

[Clause B.2, The Authoritative Dictionary of IEEE Standards Terms \[B6\]](#),<sup>7</sup> and [IEEE Std C37.100™ \[B10\]](#) should be referenced for terms used in this standard.

**3.1 degraded voltage condition:** A voltage deviation, above or below normal, to a level that, if sustained, could result in unacceptable performance of, or damage to, the connected loads and/or their control circuitry.

**3.2 loss of voltage condition:** A voltage reduction to a level that results in the immediate loss of equipment capability to perform an intended function.

**3.3 pump runoff:** A pump flow condition in which the pump is operating beyond its design point due to a reduction in the system head. As a result, the pump motor's brakehorsepower and full load current demand may be increased.

**3.4 service factor (generalpurpose alternatingcurrent motor):** A multiplier that, when applied to the rated power, indicates a permissible power loading that may be carried under the conditions specified for the service factor.

### 4. General design criteria

As used in this standard, protection refers to the sense, command, and execute features with their associated interconnections (see IEEE Std 603-~~1991~~ [1998](#)<sup>8</sup>) that are provided to minimize equipment damage and any interruption of electrical service resulting from mechanical or electrical failures or other unacceptable conditions. Protection includes equipment required to support the Class 1E power system in the performance of its safety function, and components whose function is to increase the availability and reliability of the safety related equipment. The protection shall be capable of the following:

- a) Preventing failures in safety systems and equipment from disabling safety functions to below an acceptable level. The protective actions of each load group shall be independent of the protective

actions provided by redundant load groups (see IEEE Std 308~~1991~~[2001](#)).

- b) Operating the required devices upon detection of unacceptable conditions to reduce the severity and extent of electrical system disturbances, equipment damage, and potential personnel and property hazards.
- c) Monitoring the connected preferred power supply and, where an alternate preferred power supply is provided by the design, of automatically initiating a transfer or alerting the operator to manually transfer to the preferred alternate power supply.
- d) Providing indication and identification of the protective operations.
- e) Periodic testing to verify logic schemes and protective functions.
- f) Being designed in such a way that the availability of protection control power is monitored.
- g) Periodic testing to verify set points. This requirement is not applicable to fuses.

<sup>6</sup> NEMA publications are available from ~~the National Electrical Manufacturers Association, 4300 N. 17th St., Ste. 1847, Rosslyn, VA 22209~~ Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, USA (<http://global.ihs.com/>).

<sup>7</sup> The numbers in brackets correspond to those of the bibliography in Annex E.

<sup>8</sup> For information on references, see Clause 2.

Those parts of the protection that have a safety function shall meet the requirements of IEEE Std 6031998 and IEEE Std 3082001. Documentation requirements for the protection of Class 1E power systems and equipment are found in IEEE Std 3082001. Those parts of the protection whose function is nonsafety related shall be designed such that their failure does not degrade the Class 1E power system below an acceptable level.

## 5. Principal design criteria and requirements

### 5.1 AC power distribution systems

#### 5.1.1 Switchgear and bus protection

For recommended practices in application of overcurrent relays, directional relays, differential relays for bus protection, and ground fault relaying, refer to IEEE Std 1411993, IEEE Std 242~~1986~~[2001](#), and IEEE Std 6661991. The protection systems for the ac distribution system should be coordinated in accordance with IEEE Std 2422001. For supplementary information on ground protection practices, refer to IEEE Std 1421991.

If the power distribution system design cannot accommodate paralleling of bus supplies, or if paralleling can be allowed only under certain conditions, interlocks or procedural restrictions shall be provided to restrict such paralleling. Consideration shall be given to the higher fault current that could exist during parallel operation when selecting protective devices.

If the power distribution design allows for automatic bus transfers, consideration shall be given to the impact of the bus transfer on the coordination of protection devices (see Annex C).

#### 5.1.2 Bus voltage monitoring schemes

Bus voltage monitoring schemes that are used for disconnecting the preferred power source, load shedding, and starting the standby power sources are part of the protection and shall meet the criteria that follow. Voltage monitoring schemes, which are used only for alarms, do not have to meet these criteria.

- a) Bus voltage shall be detected directly from the Class 1E bus to which the standby power source is

connected.

- b) Upon sensing preferred power supply degradation, the condition shall be alarmed in the main control room. On sensing preferred power supply degradation to an unacceptable low voltage condition, the affected preferred power supply shall be automatically disconnected from the Class 1E buses.
- c) Each division shall have an independent scheme of detection of degraded voltage and loss of voltage conditions. Within each division, common equipment may be used for the detection of both conditions (see Annex A).
- d) Each scheme shall monitor all three phases. The protection system design shall be such that a blown fuse in the voltage transformer circuit or other single phasing condition does not cause incorrect operation, nor prevent correct operation, of the scheme. Means shall be provided to detect and identify these failures.
- e) The design shall minimize unwanted operation of the standby power sources and disconnection of the preferred power supply. The use of coincident logic and time delay to override transient conditions is a way to accomplish this.
- f) Capability for test and calibration during power operation shall be provided.
- g) The selection of undervoltage and time delay set points shall be determined from an analysis of the voltage requirements of the Class 1E loads at all onsite distribution levels (see Annex A).
- h) Indication shall be provided in the control room for any bypass incorporated in the design.

### 5.1.3 Feeder circuits

For recommended practice on motor protection, refer to IEEE Std C37.96 ~~1988~~2000, IEEE Std 242 2001, and IEEE Std 6661991. See 5.5 for additional requirements associated with valve actuator motors (VAMs). The feeder circuit protection shall consider any expected operating conditions of the motor that could require ~~electrical system~~ current demands above the motor's nameplate rating such as operation into the ~~following~~:

- a) motor service factor
- b) ~~Pump runout conditions~~;
- c) ~~Operation~~

(see NEMA MG 12003), or operation at other than rated voltage.

For recommended practice on power transformer protection, refer to IEEE Std C37.91~~1985~~ 2000 and IEEE Std 6661991. For recommended practice on feeder circuit to power distribution panel protection, refer to IEEE Std 1411993 and IEEE Std 2422001. For criteria for isolation and separation of nonClass 1E circuits from Class 1E circuits, refer to IEEE Std 3841992.

For use of highspeed magnetic circuit breakers in special applications, refer to Annex D.

### 5.1.4 Standby power supply protection

For diesel generator protection recommended practice, refer to IEEE Std 2422001.

In the manual control mode, synchronizing interlocks should be provided to prevent incorrect synchronization whenever a standby power source is required to operate in parallel with the preferred power supply.

When a standby power supply is being operated in parallel with the preferred power supply, protection shall be provided to separate the two supplies if either becomes degraded to an unacceptable level. This protection shall not lock out or prevent the availability of the power supply that is not degraded.

### 5.1.5 Load shedding and sequential loading

An automatic load shedding and sequential loading scheme may be included to ensure that the preferred or standby power sources can be loaded while maintaining voltage and frequency within acceptable limits.

The Class 1E bus load shedding scheme shall automatically prevent shedding during sequencing of the emergency loads to the bus when connected to the standby power source.

If the preferred or standby power source breaker is tripped during [loading](#) or subsequent to loading, the load shedding and sequential loading scheme shall be arranged to be automatically reset to perform its function in the event that the loads are to be reapplied.

### 5.1.6 Surge protection

For surge protection of equipment and systems, refer to IEEE Std 1411993 or IEEE Std ~~2421986~~[C62.231995 for electric generating plants](#). For surge protection of induction motors, refer to IEEE Std C37.96~~1988~~ [2000](#). For guidance on protection of wire line facilities used for protective relaying and data transfer circuits, refer to IEEE Std 487~~1992~~ [2000](#).

For recommendations in design and installation of lowenergy, lowvoltage signal circuits associated with solidstate electronic equipment, refer to IEEE Std 5181982.

Surge protection shall be provided to protect the shunt field of dc VAMs. This surge protection may take the form of a resistor in the motor control center, wired in parallel with the shunt field to provide a discharge path for the shunt field's inductive voltage surges.

For guidance in the application of surge arresters to all types of power circuits and equipment, refer to IEEE Std C62.21987. Refer to IEEE Std C62.411991 for guidance in determining the surge voltage for lowvoltage equipment, and to IEEE Std C62.45~~1992~~ [2002](#) to provide guidance for tests that should be used to determine the surge withstand capability of the equipment used on lowvoltage circuits.

## 5.2 DC power system

~~For recommended practice on protection for batteries, refer to IEEE Std 9461992.~~

The dc power distribution system shall be provided with coordinated [protection](#). Refer to [IEEE Std 9462004 for dc system design](#) and [IEEE Std 13751998 for station battery](#) protection. Coordination for dc power system circuits shall include the main bus protective devices and the protective devices used in branch circuits, in switchgear control circuits, in relay and process control panels, [and in battery chargers](#). Care shall be taken to use appropriate correction factors or dc trip characteristic curves for protection devices. [The current limiting characteristics of battery chargers shall be considered](#).

For criteria for isolation and separation of nonClass 1E circuits from Class 1E circuits, refer to IEEE Std 3841992.

Ground detection monitoring shall be provided for ungrounded systems.

Battery chargers shall be provided with current limiting features or overload protection, reverse current protection, output undervoltage, and overvoltage alarms and/or trips. For additional guidance on the protection of battery chargers, refer to IEEE Std 446~~1987~~ [1995](#).

## 5.3 Instrumentation and control power system

For guidance on protection for inverters, refer to IEEE Std 446~~1987~~ [1995](#). For information on ground