

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
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Abstract: IEEE Std 741-1990, *IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations*, prescribes criteria that establish protection requirements for Class 1E power systems and equipment. It describes 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. It includes both design and documentation requirements. It does *not* include plant physical design requirements to protect against certain events.

Keywords: Criteria for the protection of class 1E power systems and equipment, nuclear power generating stations, design requirements, valve actuator motor, surveillance.

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Foreword

(This Foreword is not a part of IEEE Std 741-1990, IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations.)

The IEEE has developed this document 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, the standard identifies other standards or documents which 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 execute the operations required in order to limit degradation effects. In this role, the standard pays special attention to the requirements for design verification documentation to support the protection performance.

Of particular interest are the electrical penetration assemblies installed as part of the containment structure which may require special considerations for their protection. Included are the criteria used to establish the necessity for special considerations and the resulting protection requirements where this is needed.

At the time IEEE Std 741-1986 was approved for issuance by the IEEE Standards Board, Working Group SC 4.7 undertook a commitment to consider the following in the future revision of the standard:

- (1) Review IEEE Std 946-1985, *IEEE Recommended Practice for the Design of Safety Related DC Auxiliary Power Systems for Nuclear Power Generating Stations*, for possible reference.
- (2) Inclusion of the Criteria for Protection of Valve Actuator Motors.

This revision incorporates the criteria for protection of the valve actuator motors to provide for safe operation and to minimize their spurious trips. In addition, the Working Group incorporated the references to IEEE Standards 946 and 944 as part of this revision in Sections 5.2 and 5.3, respectively.

Adherence to the criteria set out in this standard may not in itself suffice for assuring public health and safety because it is the integrated performance of structures, fluid systems, instrumentation, and electrical systems that limit the consequence of accidents. Applicants have the responsibility to assure that their integrated performance is adequate.

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

1. Scope and Purpose

This document prescribes criteria that establish protection requirements for Class 1E power systems and equipment. It describes 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. It includes both design and documentation requirements. It does not include plant physical design requirements to protect against events such as pipe whip, fire, dropped load, etc.

2. Definitions

These definitions apply to words as used in the context of this document.

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

loss of voltage condition. A voltage reduction to a level which results in the immediate loss of equipment capability to perform its intended function.

3. References and Documents in Preparation

3.1 References

[1] ANSI C50.41-1982, Polyphase Induction Motors for Power Generating Stations.¹

¹ANSI publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018.

[2] ANSI/ASME NQA-1-1983, Quality Assurance Program Requirements for Nuclear Power Facilities.²

[3] ANSI/NEMA ICS 2-1983, Industrial Control Devices Controllers, and Assemblies.³

[4] IEEE Std 141-1986, IEEE Recommended Practice for Electric Power Distribution for Industrial Plants (ANSI).⁴

[5] IEEE Std 142-1982, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (ANSI).

[6] IEEE Std 242-1986, IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (ANSI).

[7] IEEE Std 308-1980, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations (ANSI).

[8] IEEE Std 317-1983 (R 1988), IEEE Standard for Electric Penetration Assemblies in Containment Structures for Nuclear Power Generating Stations (ANSI).

[9] IEEE Std 336-1985, IEEE Standard Installation, Inspection, and Testing Requirements for Power, Instrumentation, and Control Equipment at Nuclear Facilities (ANSI).

[10] IEEE Std 338-1987, IEEE Standard for Periodic Testing of Nuclear Power Generating Station Safety Systems (ANSI).

²ANSI/ASME publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the American Society of Mechanical Engineers, Order Department, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300.

³ANSI/NEMA publications are available from the Sales Department, American National Standards Institute, 1430 Broadway, New York, NY 10018, or from the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.

⁴IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, Piscataway, NJ 08854.

[11] IEEE Std 384-1981, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits (ANSI).

[12] IEEE Std 387-1984, IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations (ANSI).

[13] IEEE Std 415-1986, IEEE Guide for Planning of Preoperational Testing Programs for Class 1E Power Systems for Nuclear Power Generating Stations (ANSI).

[14] IEEE Std 446-1987, IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (ANSI).

[15] IEEE Std 487-1980, IEEE Guide for the Protection of Wire Line Communication Facilities Serving Electric Power Stations (ANSI).

[16] IEEE Std 498-1985, IEEE Standard Requirements for the Calibration and Control of Measuring and Test Equipment Used in Nuclear Facilities (ANSI).

[17] IEEE Std 518-1982, IEEE Guide for the Installation of Electrical Equipment to Minimize Electrical Noise Inputs to Controllers from External Sources (ANSI).

[18] IEEE Std 603-1980, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations (ANSI).

[19] IEEE Std 944-1986, IEEE Recommended Practice for the Application and Testing of Uninterruptible Power Supplies for Power Generating Stations (ANSI).

[20] IEEE Std 946-1985, IEEE Recommended Practice for the Design of Safety-Related DC Auxiliary Power Systems for Nuclear Power Generating Stations (ANSI).

[21] IEEE C37.91-1985, IEEE Guide for Protective Relay Applications to Power Transformers (ANSI).

[22] IEEE C37.96-1988, IEEE Guide for AC Motor Protection (ANSI).

[23] IEEE C62.2-1987, IEEE Guide for Application of Gapped Silicon-Carbide Surge Arresters for Alternating-Current Systems (ANSI).

[24] IEEE C62.41-1980, IEEE Guide for Surge Voltages in Low-Voltage AC Power Circuits (ANSI).

[25] IEEE C62.45-1987, IEEE Guide on Surge

Testing for Equipment Connected to Low-Voltage AC Power Circuits (ANSI).

[26] NEMA MG 1-1987, Motors and Generators.⁵

3.2 Documents in Preparation⁶

4. General Design Criteria

4.1 As used in this document, protection refers to the sense, command, and execute features with their associated interconnections (IEEE Std 603-1980 [18]⁷) provided to minimize equipment damage and any interruption of electrical service resulting from mechanical or electrical failures or other unacceptable conditions. It 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:

4.1.1 Be capable of preventing failures in safety systems and equipment from disabling safety functions to below an acceptable level. Protection in one load group shall not respond to disturbances in a redundant load group.

4.1.2 Be capable of 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.

4.1.3 Be capable of monitoring the connected power supply and, where an alternate supply is provided by the design, of automatically initiating a transfer or alerting the operator to manually transfer to the alternate power supply.

4.1.4 Be capable of providing indication and identification of the protective operations.

4.1.5 Be capable of being periodically tested to verify logic schemes and protective functions.

⁵NEMA publications are available from the American Society of Mechanical Engineers, Order Department, 22 Law Drive, Box 2300, Fairfield, NJ 07007-2300.

⁶(a) The Power Engineering Society Surge Protective Devices Committee Working Group 3.4.13 is presently preparing IEEE P1041, Application Guide for Surge Protection of Electric Generating Plants. At the time of its publication, this document is expected to provide the requirements for surge protection devices used in nuclear power generating stations.

(b) The Neutral Grounding Devices Subcommittee Working Group 3.5.3 of the Power Engineering Society Surge Protective Devices Committee is presently preparing IEEE PC62.92, Part III, Application Guide for Neutral Grounding of Generating Station Auxiliary Power Systems. This document is expected to cover grounding for auxiliary systems.

⁷The numbers in brackets correspond to those of the references listed in 3.1.

4.1.6 Be designed such that the availability of protection control power is monitored.

4.1.7 Be capable of being periodically tested to verify setpoints. This requirement is not applicable to fuses.

4.2 Those parts of the protection that have a safety function shall meet the requirements of IEEE Std 603-1980 [18] and IEEE Std 308-1980 [7]. 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.

4.3 Unless specifically identified in Section 5 of this document, redundant or coincident logic protection schemes within a division of the Class 1E power system are not required.

5. Principal Design Criteria and Requirements

5.1 AC Power Distribution Systems

5.1.1 Switchgear and Bus Protection

5.1.1.1 Refer to IEEE Std 141-1986 [4] and IEEE Std 242-1986 [6] for recommended practices in application of overcurrent relays, directional relays, differential relays for bus protection, and ground fault relaying. The protection systems for the ac distribution system should be coordinated in accordance with IEEE Std 242-1986 [6]. Refer to IEEE Std 142-1982 [5] for supplementary information on ground protection practices.

5.1.1.2 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 may exist during parallel operation when selecting protective devices.

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 outlined below. Voltage monitoring schemes that are used only for alarms do not have to meet these criteria.

5.1.2.1 Bus voltage shall be detected directly from the Class 1E bus to which the standby power source is connected. Class 1E bus voltage monitoring shall not be derived from a non-Class 1E bus.

5.1.2.2 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 Appendix A.

5.1.2.3 Each scheme shall monitor all three phases. The design shall be such that a blown fuse in the voltage transformer circuit or other single phasing condition will not cause incorrect operation, nor prevent correct operation, of the scheme. Means shall be provided to detect and identify these failures.

5.1.2.4 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.

5.1.2.5 Capability for test and calibration during power operation shall be provided.

5.1.2.6 The selection of undervoltage and time delay setpoints shall be determined from an analysis of the voltage requirements of the Class 1E loads at all on-site distribution levels.

5.1.2.7 Indication shall be provided in the control room for any bypass incorporated in the design.

5.1.3 Feeder Circuits

5.1.3.1 Refer to IEEE C37.96-1988 [22] for motor protection recommended practice. See 5.5 for additional requirements associated with valve actuator motors.

5.1.3.2 Refer to IEEE C37.91-1985 [21] for power transformer protection recommended practice.

5.1.3.3 Refer to IEEE Std 141-1986 [4] and IEEE Std 242-1986 [6] for feeder circuit to power distribution panel protection recommended practice.

5.1.3.4 Refer to IEEE Std 384-1981 [11] for criteria for isolation of non-Class 1E loads from Class 1E power systems.

5.1.4 Standby Power Supply Protection

5.1.4.1 Refer to IEEE Std 242-1986 [6] and IEEE Std 387-1984 [12] for diesel generator protection recommended practice.

5.1.4.2 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.

5.1.4.3 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 which is not degraded.

5.1.5 Load Shedding and Sequential Loading

5.1.5.1 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.

5.1.5.2 If bus voltage transients could reinitiate load shedding, the load shedding feature shall be disabled when the source-breaker is closed.

5.1.5.3 If the preferred or standby power-source breaker is tripped during 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. See 3.2, footnote 6 (a).

5.1.6.1 Refer to IEEE Std 141-1986 [4] and IEEE Std 242-1986 [6] for surge protection of equipment and systems.

5.1.6.2 Refer to IEEE C37.96-1988 [22] for surge protection of induction motors.

5.1.6.3 Refer to IEEE Std 487-1980 [15] for guidance on protection of wire line facilities used for protective relaying and data transfer circuits.

5.1.6.4 Refer to IEEE Std 518-1982 [17] for recommendations in design and installation of low-energy low-voltage signal circuits associated with solid-state electronic equipment.

5.1.6.5 Surge protection shall be provided to protect the shunt field of dc valve actuator motors. 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.

5.1.6.6 Refer to IEEE C62.2-1987 [23] for guidance in the application of surge arresters to all types of power circuit and equipment.

5.1.6.7 Refer to IEEE C62.41-1980 [24] for guidance in determining the surge environment for low-voltage equipment.

5.1.6.8 Refer to IEEE C62.45-1987 [25] to provide guidance for tests that should be used to determine the surge withstand capability of the equipment used on low-voltage circuits.

5.2 DC Power System

5.2.1 Refer to IEEE Std 946-1985 [20] for recommended protection for batteries.

5.2.2 The direct current power distribution system should be provided with coordinated protection. Coordination for dc power system circuits should include the main bus protective devices

and the protective devices used in branch circuits, in switchgear control circuits, and in relay and process control panels. Care shall be taken to use appropriate correction factors or dc trip characteristic curves for protection devices.

5.2.3 Ground detection monitoring shall be provided for ungrounded systems.

5.2.4 Protective devices should be provided to isolate the battery from a bus fault.

5.2.5 Battery chargers shall be provided with current limiting features or overload protection, reverse current protection, output undervoltage, and overvoltage alarms and/or trips. Refer to IEEE Std 446-1987 [14] for additional guidance on the protection of battery chargers.

5.3 Vital Instrumentation and Control Power System

5.3.1 Refer to IEEE Std 446-1987 [14] for guidance on protection for inverters. Refer to IEEE Std 142-1982 [5] for information on ground protection practices. See 3.2, footnote 6 (b).

5.3.2 Where a rectifier type power supply is used as a source for an inverter, it shall be provided with reverse current protection, current limiting features or overload protection, and output undervoltage and overvoltage protection.

5.3.3 The vital instrumentation and control power distribution system should be provided with coordinated protection. Since inverters and motor generator sets are output limited, special attention must be given to integrating protective device sensitivity and system available fault current. Coordination should include the protective devices in the alternate supply, inverters, static switches, distribution panels, instrumentation panels and racks, and other equipment powered from the system.

5.3.4 Where a vital instrumentation and control power bus is supplied by an inverter with current limiting characteristics and an automatic transfer has been provided to an alternate source with higher available current, this alternate source may be used in order to achieve the coordinated protection in 5.3.3 above.

5.3.5 Ground detection monitoring shall be provided for ungrounded systems.

5.3.6 The vital instrumentation and control power system should be provided with undervoltage, overvoltage, and underfrequency protection. Where its power is supplied from a static inverter, overfrequency protection should also be provided. Refer to IEEE Std 944-1986 [19] for recommended practice on alarms and indication.