

IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations

Sponsor

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Abstract: The criteria for the application and testing of diesel-generator units as Class 1E standby power supplies in nuclear power generating stations is described.

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Introduction

(This introduction is not part of IEEE Std 387-1995, IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations.)

This standard supplements IEEE Std 308-1991, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations, in that it amplifies subclause 6.2.4 of that standard (Standby power supplies) concerning requirements for diesel-generator units.

The IEEE has developed this standard to provide the principal design criteria, design features, qualification considerations, and testing requirements for individual diesel-generator units, including auxiliary equipment and controls within the scope of this standard used in the standby power supply of a nuclear facility, which comply with the Nuclear Regulatory Commission's Code of Federal Regulations (10 CFR 50).

This standard presents specific procedures and criteria applicable to qualifying the diesel-generator unit and supplements the criteria described in IEEE Std 323-1983, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations, and IEEE Std 627-1980, IEEE Standard for Design Qualification of Safety System Equipment Used in Nuclear Power Generating Stations.

This revision of the standard provides additional detail in the following areas:

- a) Defining specific qualification requirements
- b) Clarifying scope and scope diagram
- c) Providing requirements for no-load and light-load operation, since extended operation under these conditions may be detrimental to unit performance
- d) Expanding factory production testing and site testing criteria
- e) Updating specific surveillance requirements
- f) Providing guidance for test parameters (annex C)
- g) Providing guidance for reliability program elements (annex D)

This revision of the standard incorporates periodic testing requirements described in IEEE Std 749-1983, IEEE Standard for Periodic Testing of Diesel-Generator Units Applied as Standby Power Supplies in Nuclear Power Generating Stations, which has been withdrawn.

Industry practice is focusing toward monitoring and trending to facilitate aging and reliability determinations. This standard provides guidance for recommended test parameters and reliability program elements as described in annexes C and D. These guidelines reflect industry practices and are in agreement with guidelines developed by the Nuclear Management and Resources Council (NUMARC), now known as the Nuclear Energy Institute (NEI).

The qualification requirements delineated in this standard consider aging considerations as potential common mode failure mechanisms. Operating experience is generally available on diesel-generator units similar to those covered by this standard, and is useful in establishing the effect of aging mechanisms for those components where the technical state-of-the-art does not allow for techniques such as accelerated aging. The basis for allowing operating experience is supplemented by noting that the application of these diesel-generator units for nuclear service is such that the actual operating time under loaded conditions is expected to be less than one year continuous service in the 40-year life expectancy of the plant. For areas where the state-of-the-art is not as limited, accelerated aging techniques should be used.

Components or assemblies that have been used for testing should not be placed into in-service use unless they have been analyzed to demonstrate their adequacy for in-service use.

Other industry standards exist or are being developed to cover topics related to this standard, including the American Nuclear Society series standards^a describing design requirements for diesel-generator unit auxiliary systems.

Adherence to these criteria may not suffice for ensuring public health and safety because it is the integrated performance of the structures, the fluid systems, the instrumentation systems, and the electrical systems of the station that establishes the consequences of accidents. Each applicant has the responsibility to ensure that this integrated performance is adequate.

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IEEE Standard Criteria for Diesel-Generator Units Applied as Standby Power Supplies for Nuclear Power Generating Stations

1. Overview

1.1 Scope

This standard describes the criteria for the application and testing of diesel-generator units as Class 1E standby power supplies in nuclear power generating stations.

Figure 1 shows the boundaries of systems and equipment included in the scope of this standard. Site testing is covered in clause 7, and the boundaries for site testing are given in 1.1.2.

1.1.1 Inclusions

The following items are within the scope of this standard:

- a) The diesel engine, including
 - 1) The flywheel and coupling (if applicable)
 - 2) The combustion air system, starting at the engine air intake connection, including the effects of any remote air intake filter or silencer, or both
 - 3) The starting system
 - 4) The starting energy system
 - 5) The fuel oil system, including the day tank and the filters and strainers between the day tank and the engine
 - 6) The lubricating oil system
 - 7) The cooling system, starting at the point where the cooling medium is introduced to the diesel-generator unit
 - 8) The exhaust system, including the exhaust silencer, but excluding piping from the engine exhaust connection to the inlet of the silencer and silencer tail pipe
 - 9) The governor system

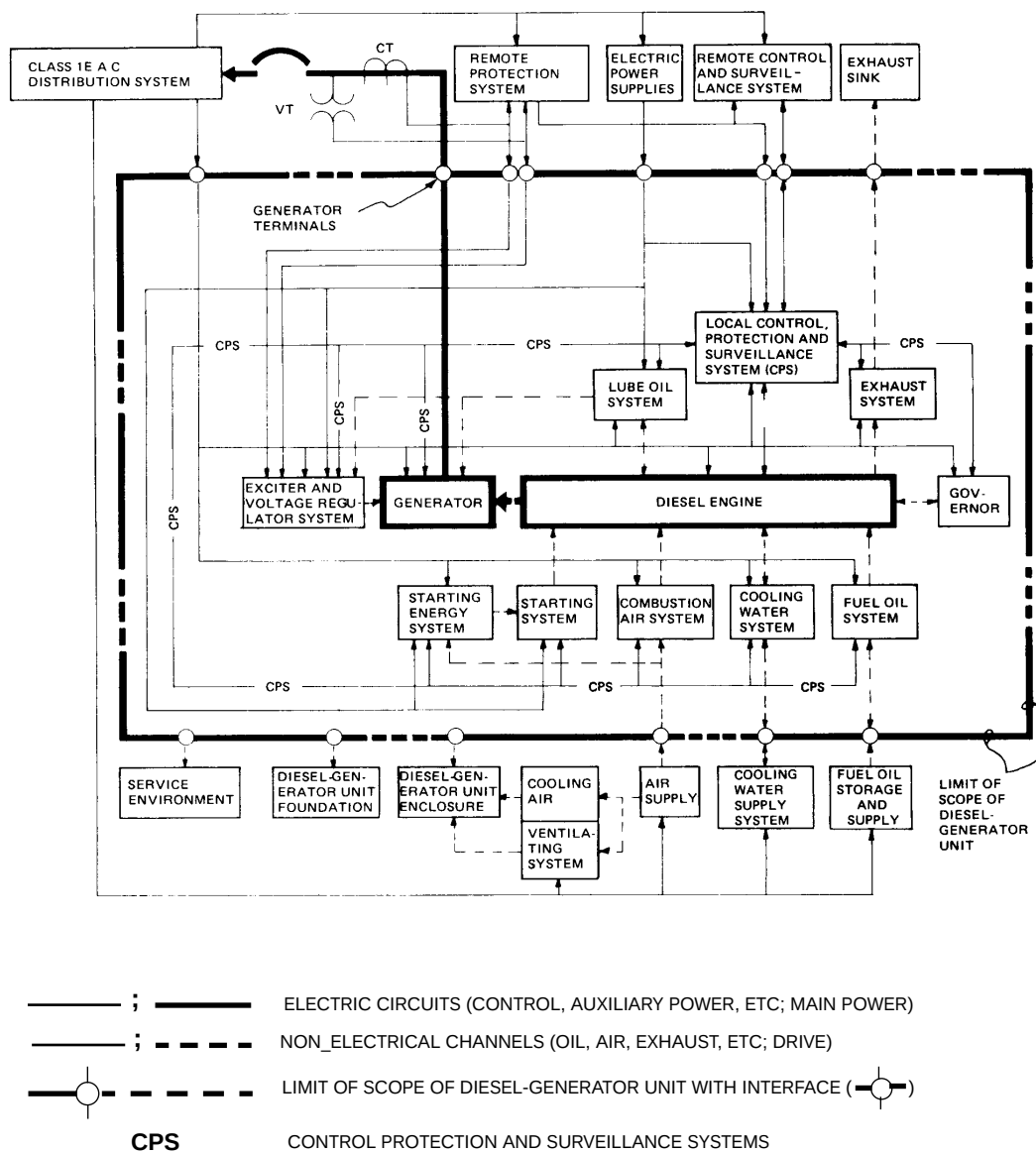


Figure 1—Scope diagram

- b) The generator, including
 - 1) The main leads terminating at the generator terminals
 - 2) The excitation and voltage regulation systems
- c) The local control, protection, and surveillance systems associated with the diesel engine, the generator, and their auxiliary equipment and systems cited above
- d) The ac and dc distribution systems associated with the diesel engine, the generator, and their auxiliary equipment and systems cited above, exclusive of the auxiliary power system beyond the generator terminals
- e) Those elements that are essential to the safety function of diesel-generator units within the scope of this standard (see figure 1)
- f) Evaluation of the characteristics of the service environment relative to performance and qualification

1.1.2 Inclusions for site testing

The following items are included for site testing purposes only, as described in clause 7.

- a) The ac and dc power distribution system, which includes
 - 1) Circuits for conveying ac power from the diesel-generator terminals up to and including the main disconnect device
 - 2) Circuits for conveying ac or dc power to the diesel-generator units and associated controls
 - 3) DC power supplies, if dedicated to the diesel-generator unit
- b) The remote and local control, protection, and surveillance systems, which include
 - 1) Devices for automatic and manual starting
 - 2) Devices for load shedding and sequencing
 - 3) Remote devices for the protection of the diesel-generator unit and its auxiliary equipment
 - 4) Synchronizing equipment
 - 5) Field flashing devices

1.1.3 Exclusions

The following items are outside of the scope of this standard:

- a) Diesel-generator unit enclosure and foundations
- b) External service equipment and systems that are a part of, or that are housed in, the diesel-generator unit enclosure, other than those tabulated in 1.1.1, such as equipment for providing and conveying combustion air, ventilating air, etc., to the vicinity of the diesel-generator unit
- c) Fuel oil storage system (day tank, storage tank, transfer pumps and filters, and strainers between the storage tank and the day tank)
- d) The control, protection, and surveillance systems for
 - 1) Protecting the loads energized by the diesel-generator unit
 - 2) Prevention of common-mode failure between the preferred power supply and the standby power supply
- e) Determination of the characteristics of the service environment
- f) Fire protection system

1.2 Purpose

The purpose of this standard is to provide the principal design criteria, the design features, testing, and qualification requirements for the individual diesel-generator units that enable them to meet their functional requirements as a part of the standby power supply under the conditions produced by the design basis events cataloged in the Plant Safety Analysis.

2. References

This standard shall be used in conjunction with the following standards.

ANS 59.51-1989, Fuel Oil Systems for Emergency Diesel Generators.¹

ANSI C50.10-1977, American National Standard General Requirements for Synchronous Machines.²

ANSI/ASME 1995 Boiler and Pressure Vessel Code.³

ANSI/NFPA 37-1994, Stationary Combustion Engines and Gas Turbines.

IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).⁴

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

IEEE Std 323-1983 (Reaff 1990), IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations (ANSI).

IEEE Std 338-1987 (Reaff 1993), IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems (ANSI).

IEEE Std 344-1987 (Reaff 1993), IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations (ANSI).

IEEE Std 384-1992, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits (ANSI).

IEEE Std 603-1991, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations (ANSI).

IEEE Std 627-1980 (Reaff 1991), IEEE Standard for Design Qualification of Safety Equipment Used in Nuclear Power Generating Stations (ANSI).

IEEE Std 741-1990, IEEE Standard Criteria for the Protection of Class 1E Power Systems and Equipment in Nuclear Power Generating Stations (ANSI).

NEMA MG 1-1993, Motors and Generators.⁵

¹ANS publications are available from the American Nuclear Society, 555 North Kensington Avenue, La Grange Park, IL 60525, USA.

²ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

³This publication is available from the American Society of Mechanical Engineers, 22 Law Drive, Fairfield, NJ 07007, USA.

⁴IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁵NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Suite 300, Washington, DC 20037, USA.

3. Definitions

3.1 acceptable: Demonstrated to be adequate by the safety analysis of the plant.

3.2 continuous rating (of diesel-generator unit): The electric power output capability that the diesel-generator unit can maintain in the service environment for 8760 h of operation per year with only scheduled outages for maintenance.

3.3 design basis events: Postulated events used in the design to establish the performance requirements of the structures and systems.

3.4 design load: That combination of electric loads (kW and kvar), having the most severe power demand characteristic, which is provided with electric energy from a diesel-generator unit for the operation of engineered safety features and other systems required during and following shutdown of the reactor.

3.5 diesel-generator unit: An independent source of standby electrical power that consists of a diesel-fueled internal combustion engine (or engines) coupled directly to an electrical generator (or generators); the associated mechanical and electrical auxiliary systems; and the control, protection, and surveillance systems.

3.6 engine equilibrium temperature: The condition at which the jacket water and lube oil temperatures are both within ± 5.5 °C (10 °F) of their normal operating temperatures established by the engine manufacturer.

3.7 load profile: The magnitude and duration of loads (kW and kvar) applied in a prescribed time sequence, including the transient and steady-state characteristics of the individual loads.

3.8 qualified diesel-generator unit: A diesel-generator unit that meets the qualification requirements of this standard.

3.9 redundant equipment or system: An equipment or system that duplicates the essential function of another equipment or system to the extent that either may perform the required function regardless of the state of operation or failure of the other.

3.10 service environment: The aggregate of conditions surrounding the diesel-generator unit in its enclosure, while serving the design load during normal, accident, and post-accident operation.

3.11 short-time rating (of diesel-generator unit): The electric power output capability that the diesel-generator unit can maintain in the service environment for 2 h in any 24 h period, without exceeding the manufacturer's design limits and without reducing the maintenance interval established for the continuous rating.

NOTE—Operation at this higher rating does not limit the use of the diesel-generator unit at its continuous rating.

3.12 standby power supply: The power supply that is selected to furnish electric energy when the preferred power supply is not available.

3.13 start-diesel signal: That input signal to the diesel-generator unit start logic that initiates a diesel-generator unit start sequence.

3.14 surveillance: The determination of the state or condition of a system or subsystem.

4. Principal design criteria

4.1 Capability

4.1.1 General

When in service, each diesel-generator unit shall have the capability of performing as a redundant unit of a standby power supply, in accordance with the requirements stated in IEEE Std 308-1991.⁶

4.1.2 Mechanical and electrical capabilities

The diesel-generator unit shall also have each of the following specific capabilities to meet the design, application, and qualification requirements of this standard:

- a) *Design conditions.* The unit shall be capable of operating during and after any design basis event without support from the preferred power supply. The following design conditions, including appropriate margins as required by subclause 6.3.1.5 of IEEE Std 323-1983, shall be specified by those individuals responsible for the system application and, as a minimum, shall include
 - 1) Operational cycles (4000 starts⁷ over a period of 40 years, unless otherwise specified)
 - 2) Operating hours (6000 h⁸ over a period of 40 years, unless otherwise specified)
 - 3) Temperature at equipment locations (minimum and maximum with durations and average annual ambient)
 - 4) Seismic response spectra
 - 5) Radiation (1×10^4 rd of gamma integrated dose over a period of 40 years, unless otherwise specified)
 - 6) Humidity (minimum and maximum with durations)
 - 7) Load profile, including allowable voltage and frequency variations (see 3.7 and annex A)
 - 8) Absolute barometric pressure (altitude and tornado depressurization, duration, and magnitude)
 - 9) Combustion air contaminants (salt, sand, etc.)
 - 10) Fuel type and quality
 - 11) Auxiliary electrical power supply requirements
 - 12) Effect of fire protection actuation
 - 13) Service water quality
- b) *Starting and loading.* The unit shall be capable of starting, accelerating, and being loaded with the design load within the time required by the equipment specification
 - 1) From the normal standby condition.
 - 2) With cooling not available, for a time equivalent to that required to bring the cooling equipment into service with energy from the diesel-generator unit.
 - 3) On a restart with an initial engine temperature equal to the continuous rating full-load engine temperature.

⁶Information on references can be found in clause 2.

⁷These figures already include margins.

⁸See footnote 7.

- c) *Light-load or no-load operation.* The unit shall be capable of accepting design load following operation at light load or no load for the time required by the equipment specification.
- d) *Design load.* The unit shall be capable of carrying the design load for the time required by the equipment specification.
- e) *Quality of power.* The unit shall be capable of maintaining voltage and frequency at the generator terminals within limits that will not degrade the performance of any of the loads comprising the design load below their minimum requirements, including the duration of transients caused by load application or load removal.

4.2 Ratings

4.2.1 Application

The diesel-generator unit shall have continuous and short-time ratings that reflect the output capabilities of the diesel-generator unit in accordance with the requirements of 4.1 and the following:

- a) Inspections and scheduled maintenance shall be performed periodically using the manufacturer's recommendations and procedures.
- b) Unscheduled maintenance shall be performed in accordance with the need as indicated by the periodic inspections and operating experience.

4.2.2 Operation

The diesel-generator units may be utilized to the limit of their power capabilities, as defined by the continuous and short-time ratings. Unless time and load parameters for light-load and no-load operation are established by tests and documentation, the following precautions shall be taken:

- a) When 4 h operation at 30% or less of the continuous rating have been accumulated (without at least 0.5 h operation above 50% of the continuous rating), the unit shall be operated at a load of at least 50% of the continuous rating for a minimum of 0.5 h.
- b) Operating at 30% or greater of the continuous rating shall be restricted to the manufacturer's recommendations.

4.3 Interactions

Independence between units shall not be compromised. Mechanical and electric system interactions between a particular diesel-generator unit and other units of the standby power supply, the nuclear plant, the conventional plant, and the Class 1E electric system shall be coordinated in such a way that the diesel-generator unit's design function, and capability requirements of 4.1, may be realized for any design basis event, except failure of that diesel-generator unit.

4.4 Design and application considerations

Design and application considerations shall include, but not necessarily be limited to, the considerations listed in table 1.

Table 1—Design and application considerations

Item	Consideration
1	Avoidance of common failure mode between units of the standby power supply
2	Single failure criterion as applied to the standby power supply
3	Matching of the diesel engine, generator, excitation system, voltage regulator, and governor
4	Energy for operation of the control, protection, and surveillance systems
5	Control, protection, and surveillance systems
6	Lubrication system and equipment
7	Selection of air, water, or other means of cooling
8	Supply of cooling medium and ambient air temperature
9	Cooling system and equipment
10	Selection of electric, pneumatic, or other means of starting
11	Supply of starting energy
12	Starting system and equipment
13	Supply, temperature, and quality of combustion air
14	Combustion air system and equipment
15	Supply of fuel
16	Fuel supply system and equipment
17	Removal of products of combustion
18	Equipment design life
19	Service environment
20	Seismic design
21	Design load
22	Time available between receipt of start-diesel signal and initiation of load sequence
23	Description of loading sequence with time durations of application of individual loads
24	Maximum time available between receipt of start-diesel signal and acceptance of design load
25	Accommodation of loading sequence and time duration for application of individual loads
26	Load performance characteristics (transient and steady-state)
27	Continuous rating
28	Short-time rating
29	Light-load or no-load operation
30	Diesel-generator unit performance characteristics, including transient characteristics (cold/hot engine kW and generator step-change kVA) and any applicable engine derating due to service environment (see item 19)