

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear facilities – Electrical power systems – Diesel generator units applied as standby power sources

Installations nucléaires – Systèmes d'alimentation électrique – Unités de générateur diesel utilisées comme sources d'alimentation de secours



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

NUCLEAR FACILITIES – ELECTRICAL POWER SYSTEMS: DIESEL GENERATOR UNITS APPLIED AS STANDBY POWER SOURCES

FOREWORD

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IEC/IEEE 63332-387 was prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation, in cooperation with Nuclear Power Engineering Committee of the IEEE Power and Energy Society, under the IEC/IEEE Dual Logo Agreement between IEC and IEEE.

This document is published as an IEC/IEEE Dual Logo standard.

This new edition supersedes IEEE Std 387-2017 and therefore constitutes a first edition of the standard published under the IEC/IEEE Dual Logo agreement. This document contains the following technical changes with respect to IEEE Std 387-2017:

- This revision incorporates current practices and lessons learned from the implementation of previous versions of this document by the nuclear industry. Additionally, several issues are clarified or changed in this revision.
- This document defines the methods for design and testing of a diesel generator (DG) unit to provide reasonable assurance that in the event it is required to perform its safety functions during a plant emergency condition, it is readily available and capable given the environments to which it can be exposed. This dual logo standard applies to all electrical equipment important to safety in accordance with IAEA terminology including class 1E equipment in accordance with IEEE classification scheme and classes 1, 2 and 3 in accordance with IEC 61226 classification scheme. This document is generally intended for DGs to be utilised as equipment important to safety located in mild environments. The standard may be used in applications where a highly reliable onsite alternating current (AC) power source is required to maintain plant safety following an event with potential loss of offsite power for an extended duration. The documentation and qualification requirements, however, can be less rigorous or different.
- The definitions and terms used in IEC/IAEA standards and guides have been added to support the terminology used in IEEE standards.
- Incorporation of recent industrial experience in the area of DG unit best practices for maintenance and testing.

The text of this International Standard is based on the following IEC documents:

Draft	Report on voting
45A/1536/FDIS	45A/1553/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with the rules given in the ISO/IEC Directives, Part 2, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications/.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

a) Technical background, main issues and organization of the standard

This IEC/IEEE international standard defines the standard criteria for the application and testing of diesel generator (DG) units used as standby power supplies in nuclear facilities. This dual logo standard applies to DG units as relevant for electrical equipment important to safety in accordance with IAEA terminology including all equipment important to safety in accordance with the IEEE classification scheme.

The provisions of this document are divided into the following clauses:

- Clause 5: Principal design criteria,
- Clause 6: Factory production testing,
- Clause 7: Qualification requirements,
- Clause 8: Site testing.

This document harmonizes in a unique standard practice formerly given by IEEE Std 387-2017 on sizing, testing, qualification, and operational requirements of diesel engine-driven onsite power sources. This document also considers the general requirements on electrical power systems provided in IEC 63046 and assesses current practices and operating experience on the current fleet of nuclear facilities with a perspective on safety significance of the performance requirements of DG units during accident mitigation.

This document is applicable to the DG units of new nuclear facilities and upgrading or back-fitting of existing facilities. It is intended that the standard be used by operators of nuclear facilities, design engineers, systems evaluators and by licensors.

b) Situation of the current standard in the structure of the IEC/SC 45A standard series

The entry point for the IEC/SC 45A standard series is the two first-level standards providing general requirements on instrumentation and control (IEC 61513) and electrical power systems (IEC 63046) for nuclear facilities.

IEC/IEEE 63332-387 is a second level IEC/SC 45A document under IEC 63046 which focuses on criteria for the application and testing of DG units used for standby power supplies for electrical equipment important to safety in nuclear facilities.

For more details on the structure of the IEC/SC 45A standard series, see paragraph d) of this introduction.

c) Recommendations and limitations regarding the application of the standard

An important concept is that the current fleet of operating reactors with forced cooling and immediate need for alternating current (AC) powered equipment following an emergency or off-normal condition necessitates safety classified onsite power sources. Designs with passive cooling systems preclude the need for immediate AC driven pumps and motors. However, following the events at Fukushima Daiichi nuclear plant, and requirements for design extension conditions, onsite AC power system(s) are required to make up inventory and perform core cooling functions after the passive systems have performed the immediate safety functions at the onset of an event. Diesel engine driven AC power sources can be used to provide the power necessary to perform the functions important to safety in order to maintain safe state conditions in all types of plant designs.

It is important to note that this document establishes no additional functional requirements for safety systems.

To ensure that the standard will continue to be relevant in future years, the emphasis has been placed on issues of principle, rather than specific technologies.

d) Description of the structure of the IEC/SC 45A standard series and relationships with other IEC documents and other bodies' documents (IAEA, ISO)

The IEC/SC 45A standard series comprises a consistent set of documents organised in a hierarchy of four levels. The top-level documents of the IEC/SC 45A standard series are IEC 61513 and IEC 63046, covering respectively general requirements for instrumentation and control (I&C) systems and general requirements for electrical power systems of NPPs. IEC 61513 and IEC 63046 adopt an overall system life-cycle framework and constitute, along with the relevant second-level standards, the nuclear implementation of the basic safety series IEC 61508.

IEC 61513 and IEC 63046 refer directly to other IEC/SC 45A standards for general requirements for specific topics, such as categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, human factors engineering, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of ageing.

At a third level, IEC/SC 45A standards not directly referenced by IEC 61513 or by IEC 63046 are standards related to specific requirements for specific equipment, technical methods, or activities. Usually, these documents refer to second-level documents for general requirements and can be used on their own.

A fourth level extending the IEC/SC 45A standard series corresponds to the Technical Reports which are not normative.

The IEC/SC 45A standards series consistently implements and details the safety and security principles and basic aspects provided in the relevant IAEA safety standards and in the relevant documents of the IAEA nuclear security series (NSS). In particular this includes the IAEA safety requirements SSR-2/1 (Rev 1), establishing safety requirements related to the design of nuclear power plants (NPPs), the IAEA safety guide SSG-30 dealing with the safety classification of structures, systems and components in NPPs, the IAEA safety guide SSG-39 dealing with the design of instrumentation and control systems for NPPs, the IAEA safety guide SSG-34 dealing with the design of electrical power systems for NPPs, the IAEA safety guide SSG-51 dealing with human factors engineering in the design of NPPs and the implementing guide NSS42-G for computer security at nuclear facilities. The safety and security terminology and definitions used by the SC 45A standards are consistent with those used by the IAEA.

IEC 61513 and IEC 63046 refer to ISO 9001 as well as to IAEA GSR part 2 and IAEA GS-G-3.1 and IAEA GS-G-3.5 for topics related to quality assurance (QA).

At level 2, regarding nuclear security, IEC 62645 is the entry document for the IEC/SC 45A security standards. It builds upon the valid high-level principles and main concepts of the generic security standards, in particular ISO/IEC 27001 and ISO/IEC 27002; it adapts them and completes them to fit the nuclear context and coordinates with the IEC 62443 series. At level 2, IEC 60964 is the entry document for the IEC/SC 45A control rooms standards, IEC 63351 is the entry document for the human factors engineering standards and IEC 62342 is the entry document for the ageing management standards.

NOTE 1 IEC TR 63400 provides a more comprehensive description of the overall structure of the IEC/SC 45A standards series and of its relationship with other standards bodies and standards.

NUCLEAR FACILITIES – ELECTRICAL POWER SYSTEMS: DIESEL GENERATOR UNITS APPLIED AS STANDBY POWER SOURCES

1 Scope

1.1 General

This document defines the criteria for the application and testing of diesel generator (DG) units used as safety class standby power supplies in nuclear facilities. In general, the standard applies to new nuclear facilities as well as for upgrading or back-fitting of existing facilities. Existing facilities can voluntarily adopt the requirements to enhance the performance capabilities and reliability of the installed DG units. The standard can be used in applications where highly reliable onsite alternating current (AC) power source is required to maintain plant safety following an event with potential loss of offsite power for an extended duration.

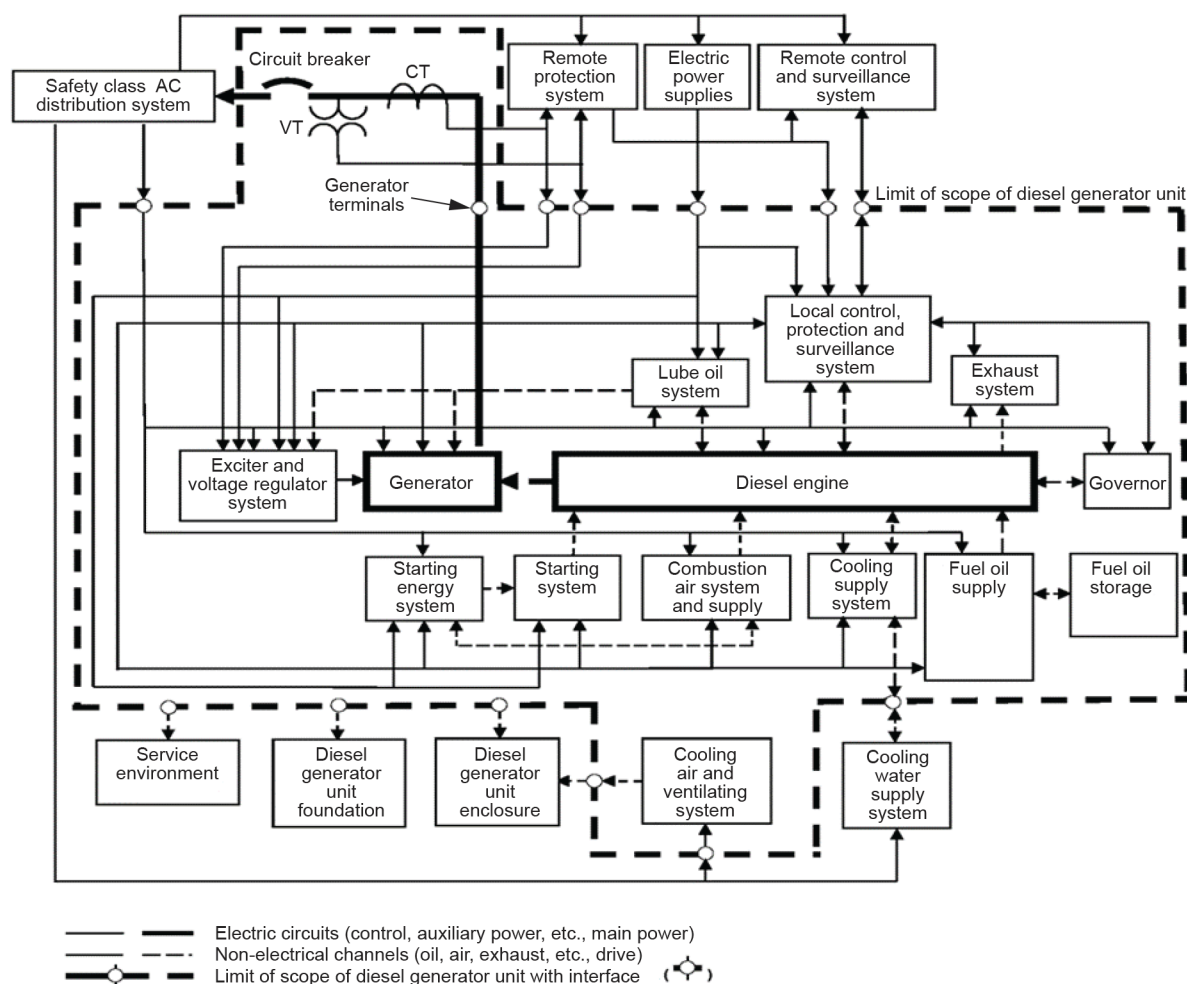
This document provides the principal design criteria, the design features, testing, and qualification requirements for the individual DG units that enable them to meet their functional requirements as a part of the standby power supply under the conditions produced by the design basis events cataloged in the plant safety analysis.

Figure 1 shows the boundaries of systems and equipment included in the scope of this document.

The following items are within the scope of this document:

- a) The diesel engine, which includes the following:
 - 1) the flywheel and coupling (if applicable),
 - 2) the combustion air system and supply,
 - 3) the starting system including storage of energy,
 - 4) the starting energy system,
 - 5) the fuel oil supply system (e.g., including the day tank, filters, piping, pumps, valves and strainers between the day tank and the engine injection pumps),
 - 6) the lubricating oil system including keep-warm system,
 - 7) the cooling system (jacket water), starting at the point where the cooling medium is introduced to the DG unit. (For a closed loop water-cooling system (radiator) supplied as part of the DG unit, the starting point is water/air interface),
 - 8) the exhaust system,
 - 9) the governor system;
- b) The generator, which includes the following:
 - 1) the excitation and voltage regulation system,
 - 2) the diesel generator output breaker at the switchgear,
 - 3) the diesel generator grounding (earthing) system;
- c) The local control, protection, and surveillance systems associated with the diesel engine, the generator, and their auxiliary equipment and systems cited above. The design of control systems is not in the scope of this document. However, the functional criterion is provided;
- d) The AC and direct current (DC) distribution systems associated with the diesel engine including the battery (if supplied with the generator) for starting, field flashing, the generator, and their auxiliary equipment and systems cited above, exclusive of the auxiliary power system beyond the generator output breaker;
- e) Fuel oil storage system (e.g., storage tank, transfer pumps, filters, piping, valves, and strainers between the storage tank and the day tank);

- f) Cooling air and ventilation system;
- g) Those elements that are essential to the safety function of DG units within the scope of this document (see Figure 1);
- h) Evaluation of the characteristics of the service environment relative to performance and qualification.



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Figure 1 – Scope diagram

1.2 Inclusions for site testing

The following items are not in scope of the standard, and in general, the specific requirements might not be applicable. These items or systems are included as they are essential for the performance of the DG unit and also required for accomplishing site testing as described in Clause 8.

- a) The AC and DC power distribution system, which includes the following:
 - 1) circuits for conveying AC power from the generator breaker up to and including the dedicated safety class bus,
 - 2) circuits for conveying AC or DC power to the DG units and associated controls,
 - 3) DC power supplies (batteries and chargers), if dedicated to the DG unit;

- b) The remote and local control, protection (generator, engine, and auxiliaries), and surveillance systems, which include the following:
 - 1) devices for automatic and manual starting,
 - 2) devices for load shedding and sequencing,
 - 3) remote devices for the protection of the DG unit and its auxiliary equipment,
 - 4) synchronizing equipment.

1.3 Exclusions

The following items are not in the scope of this document:

- a) DG unit enclosure and foundations;
- b) External service equipment (e.g., Heating Ventilation and Air Conditioning (HVAC) system) and systems that are a part of, or that are housed in, the DG unit enclosure, other than those identified in 1.2;
- c) The control, protection, and surveillance systems for the following:
 - 1) Protecting the loads energized by the DG unit,
 - 2) Prevention of common-cause failure between the preferred power supply and the standby power supply system;
- d) Determination of the characteristics of the service environment;
- e) Fire protection system.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60034 (all parts), *Rotating electrical machines*

IEC 61226, *Nuclear power plants – Instrumentation, control and electrical power systems important to safety – Categorization of functions and classification of systems*

IEC 62342, *Nuclear power plants – Instrumentation and control systems important to safety – Management of ageing*

IEC 63046, *Nuclear power plants – Electrical power system – General requirements*

IEC/IEEE 60780-323:2016, *Nuclear facilities – Electrical equipment important to safety – Qualification*

IEC/IEEE 60980-344, *Nuclear facilities – Equipment important to safety – Seismic qualification*

IEC/IEEE 62271-37-013:2021, *High-voltage switchgear and controlgear – Part 37-013: Alternating current generator circuit-breakers*

IEEE Std 308-2020, *IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations*

IEEE Std 450, *IEEE Recommended Practice for Maintenance, Testing, and Replacement of Vented Lead-Acid Batteries for Stationary Applications*

IEEE Std 485, *IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications*

IEEE Std 1106, *IEEE Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Nickel-Cadmium Batteries for Stationary Applications*

IEEE Std 1115, *IEEE Recommended Practice for Sizing Nickel-Cadmium Batteries for Stationary Applications*

ASME OM, *Operation and Maintenance of Nuclear Power Plants (Division 2, Part 16, Performance Testing and Monitoring of Standby Diesel Generator Systems in Light-Water Reactor Power Plants)*

NEMA MG 1, *Motors and Generators*, available at <http://www.nema.org/> [viewed 2024-03-11]

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>
- IEEE Standards Dictionary Online: available at <http://dictionary.ieee.org>

3.1

acceptable

demonstrated to be adequate by the safety analysis of the plant

3.2

acceptance criteria

specified bounds on the value of a functional indicator or condition indicator used to assess the ability of a structure, system or component to perform its design function

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.3

accident

any unintended event, including operating errors, equipment failures and other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection and safety

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.4

class 1E

safety classification of the electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or otherwise are essential in preventing significant release of radioactive material to the environment

Note 1 to entry: Users of this document are advised that “Class 1E” is a functional term. Equipment and systems are to be classified Class 1E only if they fulfil the functions listed in the definition. Identification of systems or equipment as Class 1E based on anything other than their function is an improper use of the term. The IAEA has corresponding classes into which *systems* and *components* and other items of equipment are assigned on the basis of their functions and their *safety* significance.

Note 2 to entry: Class 1E and Safety class are considered synonymous for electrical equipment and is a subset of equipment important to safety.

[SOURCE: IEC/IEEE 60780-323:2016, 3.3, modified – The notes to entry have been added.]

3.5

common cause failure

CCF

failures of two or more structures, systems or components due to a single specific event or cause

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.6

continuous rating

electric power output capability that the DG unit can maintain in the service environment for 8 760 hours (h) of operation per year with only scheduled outages for maintenance

3.7

design basis accident

postulated accident leading to accident conditions for which a facility is designed in accordance with established design criteria and conservative methodology, and for which releases of radioactive material are kept within acceptable limits

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.8

design basis events

postulated events used in the design to establish the acceptable performance requirements for the structures, systems, and components

[SOURCE: IEEE Standards Dictionary Online]

3.9

design load

combination of electric load (kilowatt (kW)) and kilovolt-ampere reactive (kvar) having the most severe power demand characteristic, which is provided with electric energy from a DG unit for the operation of engineered safety features and other systems required during and following shutdown of the reactor

Note 1 to entry: Design load can include the term power factor.

3.10

diesel-generator unit

independent source of standby electrical power that consists of a diesel-fuelled 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

3.11

design extension conditions

postulated accident conditions that are not considered for design basis accidents, but that are considered in the design process of the facility in accordance with best estimate methodology, and for which releases of radioactive material are kept within acceptable limits

Note 1 to entry: For nuclear power plants and research reactors, design extension conditions comprise conditions in events without significant fuel degradation and conditions in events with melting of the reactor core

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.12

engine equilibrium temperature

condition at which the jacket water and lube oil temperatures are both within $\pm 5,5\text{ }^{\circ}\text{C}$ ($10\text{ }^{\circ}\text{F}$) of their normal operating temperatures established by the engine manufacturer

3.13

equipment important to safety

equipment that is part of a safety group and/or whose malfunction or failure could lead to undue radiation exposure of the site personnel or members of the public

Note 1 to entry: Equipment important to safety includes:

- those structures, systems and components that prevent anticipated operational occurrences from leading to accident conditions;
- those features that are provided to mitigate the consequences of malfunction or failure of structures, systems and components.

Note 2 to entry:

A) For usage consistent with IEC 61226, equipment important to safety are as follows:

- all I&C equipment performing Category A to Category C functions (in accordance with the IEC 61226 categorisation scheme),
- all electrical equipment needed to ensure emergency energy supply to this equipment in case of a loss of normal power supply,
- all electrical equipment needed to ensure ultimate energy supply in case of total loss of on-site power (if selected as design extension condition to be mitigated).

B) For usage consistent with other IEEE documents and a Class 1E categorization; for equipment important to safety, qualification is essential to the following:

- electric equipment and systems that are essential to emergency reactor shutdown, containment isolation, reactor core cooling, and containment and reactor heat removal, or
- electric equipment that are otherwise essential in preventing significant release of radioactive material to the environment.

Note 3 to entry: Users of this document are advised that Class 1E is a functional term. Equipment and systems are classified Class 1E only if they fulfil the functions listed in the definition. Identification of systems or equipment as Class 1E based on anything other than their function is an improper use of the term.

[SOURCE: IEC/IEEE 60780-323:2016, 3.12, modified – examples of equipment important to safety have been changed to notes.]

3.14

equipment qualification

generation and maintenance of evidence to ensure that equipment will operate on demand, under specified service conditions, to meet system performance requirements

Note 1 to entry: Equipment is qualified for the duration of its operational performance requirement for each applicable DBE condition, including any required post-DBE operation period.

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.15

equipment specification

document identifying all technical and quality assurance requirements for purchasing equipment, material, services and all requirements to meet the safety analysis of the plant

3.16

generator nameplate capacity

maximum amount of electric energy that a generator can produce within specified conditions (e.g., ambient temperature, elevation) as rated by the manufacturer

Note 1 to entry: Generator nameplate capacity is usually expressed in kilovolt-amperes (kVA) and kilowatts (kW), as indicated on a nameplate that is physically attached to the generator.

3.17

interfaces

shared boundary between structures, systems and components that includes physical attachments, mounting, auxiliary components, and connectors (electrical and mechanical) to the equipment

3.18

load-run demand

load-run following a successful start and involving defined acceptance criteria

Note 1 to entry: The applicable criterion may include:

- a load-run of any duration that results from a real (i.e., not a test) automatic or manual signal
- a load-run test to satisfy the plant's load and duration test specifications
- other operations (e.g., special tests) in which the DG unit is planned to run for at least 1 h with at least 50 % of design load

3.19

load-run demand failure

load-run when the DG unit starts but does not pick up the load and run successfully following a valid load-run demand with consideration to exceptions provided in the Note 2

Note 1 to entry: For monthly surveillance tests, the DG unit can be loaded at the rate recommended by the manufacturer or slow-started and reach rated speed on a prescribed schedule to reduce stress and wear on the diesel-generator unit. Any condition identified during maintenance inspections (with the DG unit in the standby mode) that definitely would have resulted in a load-run failure if a demand had occurred shall count as a valid load-run demand failure.

Note 2 to entry: Unsuccessful attempts to start or load-run shall not count as valid demands or failure when they can definitely be attributed to any of the following:

- any operation of a trip that would be bypassed in the emergency operating mode (e.g., high cooling-water temperature trip)
- malfunction of equipment that is not required to operate during the emergency operating mode (e.g., synchronizing circuitry)
- intentional termination of the test because of alarmed or observed abnormal conditions (e.g., small water or oil leaks) that would not have ultimately resulted in significant damage or failure of the DG unit
- component malfunctions or operating errors that did not prevent the DG unit from being restarted and brought to load within 5 min (i.e., without corrective maintenance or significant problem diagnosis)
- a failure to start because a portion of the starting system was disabled for test purposes, if followed by a successful start with the starting system in its normal alignment
- exploratory tests during corrective or preventive maintenance shall not count as demands or failures

3.20

load profile

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

3.21

loss of offsite power

simultaneous loss of electrical power to all unit safety buses, requiring the standby AC power sources to start and supply power to the safety buses

Note 1 to entry: DC systems and uninterruptible AC systems safety buses are not included

[SOURCE: IEC 63046:2020, 3.25]

3.22

margin

difference between service conditions and the conditions used for equipment qualification

[SOURCE: IEEE Standards Dictionary Online]

3.23

mild environment

environment that would at no time be significantly more severe than the environment that would occur during normal plant operation, including anticipated operational occurrences

[SOURCE: IEC/IEEE 60780-323:2016, 3.18]

3.24

preferred power supply

power supply from the transmission system to the Class 1E distribution system that is preferred to furnish electric power under accident and post-accident conditions

Note 1 to entry: Per IAEA SSG-34 Definitions: The preferred power supply is the power supply from the transmission system to the safety classified electrical power system.

[SOURCE: IEEE Standards Dictionary Online]

3.25

power factor

ratio of real (active) power (kW) to apparent power (kVA), expressed as $\cos \phi = \text{kW}/\text{kVA} = \text{kW}/(\text{kW}^2 + \text{kvar}^2)^{1/2}$ where kvar is the reactive power

Note 1 to entry: The design-load power factor is determined by the plant-specific loading analysis and the rated power factor is defined by the OEM and is the capability of the DG unit.

3.26

qualified life

period for which a structure, system or component has been demonstrated, through testing, analysis or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions in accident conditions for a design basis accident or a design basis earthquake

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.27

safety class

for nuclear power plants, the classes into which systems and components and other items of equipment are assigned on the basis of their functions and their safety significance

Note 1 to entry: Class 1E and safety class are considered synonymous for electrical equipment and is a subset of equipment important to safety.

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022, modified – The note to entry has been added.]

3.28

safety system

system important to safety, provided to ensure the safe shutdown of the reactor or the residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022].

3.29

service environment

aggregate of conditions surrounding the DG unit in its enclosure, while serving the design load during normal, accident, and post-accident operation

3.30

service life

period from initial operation to final withdrawal from service of a structure, system or component

Note 1 to entry: The projected service life could be reduced by shelf life for age-sensitive components.

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022, modified – The note to entry has been added.]

3.31

severe accident

accident more severe than a design basis accident and involving significant core degradation

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022].

3.32

short-time rating

<diesel-generator unit> electric power output capability that the DG 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 1 to entry: Operation at this higher rating does not limit the use of the DG unit at its continuous rating.

3.33

single failure criterion

SFC

criterion (or requirement) applied to a system such that it must be capable of performing its task in the presence of any single failure

Note 1 to entry: To ensure that the single failure criterion is met, usually two or more independent (redundant) systems or trains are provided by design to achieve the same safety function

Note 2 to entry: The following exception applies to single failure criterion as used for DG units:

- Any single failure within the DG unit system that prevents the generator from performing the safety function is considered a single failure. Failure of one subsystem installed as part of redundant (or multiple) channels to improve the reliability of a DG unit is not considered a single failure unless the consequences of the failure prevent the DG unit from performing its safety function.

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022, modified – The note 2 to entry has been added].

3.34

standby power supply

power supply that is selected to furnish electric energy when the preferred power supply is not available

[SOURCE: IEEE Standards Dictionary Online]

3.35

start demands

all valid and inadvertent starts, including all starts that are followed by load-runs, whether by automatic or manual initiation, and situations where the DG unit is started, but no attempt is made to load the DG unit

Note 1 to entry: The following conditions may apply to start demand failures:

- Any failure within the DG unit system that prevents the generator from achieving a specified frequency (or speed) and voltage within specified time allowance is classified as a valid start failure. For monthly surveillance tests, the DG unit can be brought to rated speed and voltage in the time recommended by the manufacturer to reduce stress and wear.
- Any condition identified during maintenance inspections (with the DG unit in the standby mode) that would definitely have resulted in a start failure if a demand had occurred shall count as a valid start demand and failure.

3.36

start signal

input signal to the DG unit start logic that initiates a DG unit start sequence

Note 1 to entry: The start signal can be the result of a planned (manual) demand or actual demand such as an automatic/emergency start signal

3.37

start time

elapsed time between receipt of an emergency start signal and achieving voltage and frequency for breaker closure to energize required loads

3.38

surveillance testing

periodic testing to verify that structures, systems and components continue to function or are capable of performing their functions when called upon to do so

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022]

3.39

total integrated dose

total cumulative dose

calculated dose the equipment would be subjected to in its service life (40 years or 60 years) and the bounding dose from the worst-case design basis event for the required period of operation

Note 1 to entry: If qualification in radiation environment is applicable, follow guidance in IEC/IEEE 60780-323.

4 Abbreviated terms

AC	alternating current
DBE	design basis event
DC	direct current
DG	diesel generator
ECCS	emergency core cooling system
FAT	factory acceptance test
HVAC	heating ventilation and air conditioning
LOCA	loss of coolant accident
LOOP	loss of offsite power
MOV	motor-operated valve
NPP	nuclear power plant
OEM	original equipment manufacturer
OPC	open phase condition
RTD	resistance temperature detector
SBO	station blackout
var	volt-ampere reactive power

5 Principal design criteria

5.1 Capability

5.1.1 General

When in service, each DG unit shall have the capability of performing the safety functions of a standby power supply, in accordance with the requirements stated in IEEE Std 308 and IEC 63046.

5.1.2 Mechanical and electrical capabilities

5.1.2.1 General

The variations of voltage, frequency, and waveform (including the effects of harmonic distortion) of the DG unit shall not degrade the performance of any equipment important to safety below an acceptable level (see also Annex F). The DG unit shall also meet each of the following specific capabilities related to the design, application, and qualification requirements of this document.

5.1.2.2 Design conditions

The unit shall be capable of operating during and after any design basis event without support from the preferred power supply system. The following design conditions, including appropriate margins as required by IEC/IEEE 60780-323, shall be specified by those individuals responsible for the system application and, as a minimum, shall include the following:

- a) operational cycles (e.g., 4 000 starts over a period of 40 years or 6 000 starts over a period of 60 years),
- b) operating hours (e.g., 6 000 h over a period of 40 years or 9 000 h over 60 years),
- c) operate continuously for an extended duration when external events impair offsite power sources,
- d) temperature at equipment locations (minimum and maximum with durations and average annual ambient),

- e) the engine equilibrium temperature is within the allowable range,
- f) seismic response spectra,
- g) radiation (specified total integrated dose over a period of 40 years or 60 years depending on the operating period, plus accident if located in harsh environment),
- h) humidity (minimum and maximum with durations),
- i) load profile, including allowable voltage and frequency variations (see Annex A),
- j) absolute barometric pressure (altitude and tornado depressurization/pressurization, duration, and magnitude),
- k) combustion air contaminants (salt, sand, etc.),
- l) fuel type and quality,
- m) auxiliary electrical power supply requirements,
- n) effect of fire protection actuation,
- o) service water quality,
- p) maximum wind speed(s) and direction(s) if radiator cooling is used,
- q) external events such as earthquakes, tornadoes, hurricanes, floods, tsunamis, and seiches,
- r) site specific weather (cold or hot) weather conditions such as ice clogging.

5.1.2.3 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, with respect to the following conditions:

- a) from the normal standby condition,
- b) with cooling not available, for a time equivalent to that required to bring the cooling equipment into service with energy from the DG unit,
- c) achieve voltage and frequency requirements for load sequencing commensurate with assumptions in safety analysis,
- d) on a restart with an initial engine temperature equal to the continuous rating full-load engine temperature.

5.1.2.4 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. Provisions to enable successful light or no-load operation can be provided by the manufacturer.

5.1.2.5 Design load

The unit shall be capable of carrying the design load for the time required by the equipment specification. This includes management of both auto-connect and manual loads.

5.1.2.6 Dynamic load

Facility safety analyses evaluate fluid flow rates in the ECCS (and other important to safety systems) and make assumptions about the steady-state speed of rotating equipment. The ability of the DG to maintain steady-state voltage and frequency within an acceptable band can impact performance capabilities of the ECCS motor loads such as pumps, motor-operated valves, and fans. The voltage and frequency perturbations during load sequencing, coupled with an allowable operating band for DGs during steady-state conditions, should be evaluated for impact on critical parameters, such as flow rates and stroke times, assumed in safety analyses. The function of the DG is to ensure that the safety functions of the systems will be accomplished in accordance with safety analyses (see Annex F). Hence, 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 below their minimum requirements during steady state operation and the duration of transients caused by load application or load removal. During load sequencing, it is important to maintain the DG unit within operational limits defined below to provide reasonable assurance that the sequential motor loads will start, accelerate successfully, and maintain adequate speed, and the diesel engine will not stall or overstress the mechanical systems:

- a) The DG unit shall be designed so that the frequency will not decrease, at any time during the loading sequence, to less than 95 % of nominal and the voltage will not decrease to less than 75 % of nominal. A larger decrease in voltage and frequency may be justified for a DG unit that carries only one large, connected load¹.
- b) Frequency shall be restored to within 2 % of nominal, in less than 60 % of each load-sequence interval, for a step load increase².
- c) Frequency shall be restored to within 2 % of nominal, in less than 80 % of each load-sequence interval, for disconnection of the single largest load³.
- d) Voltage shall be restored to within 10 % of nominal within 60 % of each load-sequence interval⁴.
- e) The acceptance values of the frequency and voltage shall be based on plant-specific analysis (where conservative values of voltage and frequency are measured) to prevent load interruption. A greater percentage of the load-sequence interval may be used if it can be justified by analysis. However, the load-sequence interval shall include sufficient margin for the accuracy and repeatability of the load-sequence timer.
- f) During recovery from transients caused by disconnection of the largest single load, the speed of the DG unit shall not exceed the nominal speed plus 75 % of the difference between nominal speed and the overspeed trip set point, or 115 % of nominal (whichever is lower)⁵.
- g) The transient following a complete loss of load shall not cause the DG unit speed to reach the overspeed trip set point⁶.
- h) The voltage and frequency perturbations can impact the performance of motor driven pumps. The hydraulic perturbations in the associated fluid systems should be evaluated.

¹ Technical basis: This frequency and voltage criteria prevents (1) contactors from dropping out requiring specific engineering analysis and (2) motors from stalling during starting conditions.

² Technical basis: A time limit of 60 % of interval between successive loads provides reasonable assurance that frequency has been restored for successful start of next load.

³ Technical basis: Large load rejection will result in an increase in frequency. A longer time interval (80 %) is acceptable as the increase in speed will not adversely impact the successful start of the next load.

⁴ Technical basis: Limits the amount of time the motors slow down.

⁵ Technical basis: Diesel engine protection from catastrophic mechanical damage and personnel injury.

⁶ Technical basis: Diesel engine protection from catastrophic mechanical damage and personnel injury.

- i) Loads should generally be automatically connected in sequence after restoration of power supplies. The sequencing of loads avoids overloading of standby generators due to motor starting and inrush currents. The capability of the standby system to restore supplies in the defined sequence should be demonstrated by the performance of analytical system studies using commercially available software. Some designs can have process-related start signal in series with the load sequencer signal for specific loads. In such designs, there is a potential for simultaneous sequencing of more than one load per step. Analytical studies should be performed to validate DG unit capability to start and accelerate process related loads concurrent with normally sequenced loads. Baseline analytical studies should be performed during the design and start-up phase of the project and validated with actual tests performed during the operational phase. These studies can be used for evaluating systems modifications implemented throughout the life of the DG unit.

5.1.2.7 Provisions for operator/attendant actions

Each DG unit shall have the capability to start and stop from the main control room. Synchronization capability should be available in the main control room and local panel in the DG unit room. The main control room shall have adequate information for operators to monitor generator voltage, frequency, output power and critical parameters such as steady state engine temperature, lube oil pressure and any parameters recommended by manufacturer. If the plant design requires a remote-control panel (external to the main control room), then adequate control and indication should be provided in the remote-control panel to start, stop and monitor key power output parameters. The unit shall be equipped with provision for:

- a) expected maintenance actions while carrying the design load as defined in 5.1.2.5. Expected maintenance actions include replenishment of fluids and duplex filter changes,
- b) manual/automated synchronization (if manual synchronisation is required by the safety case) with offsite power source (or another running source) for conducting surveillance and recovery from a LOOP/SBO condition,
- c) override emergency mode of operation with interlocks to prevent human errors or spurious switchover.

5.2 Power capabilities

5.2.1 Application

The DG unit shall have continuous and short-time ratings that reflect the output capabilities of the DG unit in accordance with the requirements of 5.1 and the following:

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

5.2.2 Operation

The DG units may be utilized to the limit of their power capabilities, as defined by the continuous and short-time ratings.

Operating a DG unit at load levels less than 30 % of rated output for extended time periods impacts the unit negatively. The most common consequence is engine exhaust sooting or wet stacking. This condition occurs when a diesel engine's unused/unburned fuel, carbon particles, and accumulated moisture gather around the exhaust system components and leak through the exhaust slip joints. This mainly occurs when the engine is operated at light loads for a long period of time due to low heat in the cylinders. No-load or low-load operation of the DG unit for an extended duration can occur following an emergency start with the preferred power source available to the DG unit bus. Unless time and load parameters for light-load and no-load operations 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 has 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 load levels other than those described in 5.2.2 step a) shall be restricted to the manufacturer's recommendations.

5.3 Interactions

Independence between DG units shall not be compromised. Mechanical and electric system interactions between a particular DG unit and other units of the standby power supply, the nuclear side of the plant, the non-nuclear side of the plant, and the safety class electrical system shall be coordinated in such a way that the DG unit's design function and capability requirements of 5.1 can be realized for any design basis event, except failure of that DG unit.

5.4 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-cause failures 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 system
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	Storage of fuel
16	Fuel supply system and equipment
17	Removal of products of combustion
18	Equipment design life
19	Service environment
20	Seismic design

Item	Consideration
21	Design load, including effects of frequency and voltage variations
22	Time available between receipt of start 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 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	DG 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)
31	Electric fault conditions
32	Electric transients, including surge voltages
33	Insulation and temperature rating of electric equipment insulation systems for operating and quiescent conditions
34	Creepage and clearance distances for electric equipment contacts
35	Electrically induced thermal effects
36	Mechanically induced thermal effects
37	Thermal shock
38	Mechanical shock
39	Operating cycles that might cause thermally induced stresses
40	Physical configuration and mechanical support of attached auxiliaries, accessories, hardware, piping, wire and cable, and raceways
41	Handling during manufacture, shipping, storage, and installation
42	Fire protection system: separation between units, and possible damaging effects by actual or inadvertent operation
43	Tornado depressurization's air intake impact
44	Separation criteria between Classes 1, 2 and 3 (IEC 61226 classification) and safety class and non-safety class 1E (IEEE classification) wiring
45	Operational vibration
46	Monitoring DG units during accident and post-accident conditions
47	Design considerations for testability and synchronizing capability
48	Annunciation of protective devices that initiate DG unit trip
49	Communication means between the DG unit room and control room(s)
50	Fire protection interlocks and alarms with regard to personnel safety
51	Data acquisition system

5.5 Design features

5.5.1 Mechanical and electrical design features

5.5.1.1 General

The DG unit is subjected to mechanical stresses associated with the centripetal and centrifugal forces of the moving parts inside it in a specified operational range. In addition, the DG unit is subjected to transients in the electrical system such as mis-synchronised closure of output breaker, electrical faults or sudden load changes. The DG unit shall be designed to mechanically withstand the maximum anticipated vibrations and transients.

The DG unit shall be designed to mechanically withstand the maximum anticipated electrical transients. Typical types of transients include out-of-phase breaker closure and electrical faults.

Manual synchronization of the DG unit can result in out-of-phase breaker closure. The manufacturer should define limits (out of phase closure) and ensure the DG unit can withstand linear and torsional vibrations within the specified limits. The DG output breaker design should preclude out-of-phase closure such as the use of a synchronizing check relay if the allowable limits are exceeded.

When a short circuit is suddenly applied at the end of the generator winding, the electrodynamic force can cause the end of the coil to be deformed or even damage the insulation.

Overvoltage in stator and rotor windings of diesel generators is harmful to generator insulation. Powerful impulse current in stator winding, combined with overvoltage, can lead to breakdown of weak insulation links.

Diesel generators can produce violent vibration, which can cause strong and destructive mechanical stress on some structural components. Some designs can incorporate a coupling that separates the engine from the generator during severe fault conditions to avoid damage to the DG unit.

5.5.1.2 Vibration

Vibration amplitudes shall be limited to be within the design capabilities of the DG unit and auxiliary components. Solenoids, relays, piping, and other devices shall be mounted in such a way as to reduce vibration effects.

Torsional and linear vibrations resulting from unbalance of rotating parts, torque reaction to firing in cylinders, misfiring in cylinders, etc., should be minimized. Resonance condition shall be analysed for all operating modes to ensure that the DG unit can operate safely. The analytical results should be verified during type testing.

5.5.1.3 Torsional vibration

Harmful torsional vibration stresses shall not occur within a range from 10 % above to 10 % below rated idle speed and from 5 % above to 5 % below rated synchronous speed.

5.5.1.4 Overspeed

Moving parts shall be designed to withstand that level of overspeed that results from a short-time rating load rejection. Margin shall be provided to allow the overspeed device to be set sufficiently high so that the unit will not trip on short-time rating load rejection. As a minimum, the generator rotor, exciter rotor (if used), and flywheel shall be designed to withstand an overspeed of 25 % without damage.

5.5.1.5 Governor operation

If the diesel engine is equipped with both the isochronous (non-paralleled) mode and the droop (paralleled) mode, the diesel engine shall operate in both the isochronous mode and the droop mode. Provisions shall be included to automatically place the engine governor in the proper mode of operation when the DG unit is required to operate automatically (see 5.5.2.2). The diesel engine shall be placed in isochronous (emergency) mode when in standby.

5.5.1.6 Voltage regulator operation

If the diesel engine is equipped with both the isochronous (non-paralleled) mode and the droop (paralleled) mode, the voltage regulator shall operate automatically in both the isochronous and the droop modes. Provisions shall be included to automatically place the voltage regulator in the proper mode of operation when the DG unit is required to operate automatically (see 5.5.2.2). The voltage regulator shall be placed in isochronous (emergency) mode when in standby. Annex D provides additional information on the influence of voltage regulating equipment on DG unit surveillance testing.

5.5.1.7 Generator output circuit breaker

The successful operation of the generator output circuit breaker is critical for DG unit for power delivery to the plant loads. The design shall include the following design features, which shall operate automatically and safely when required by plant conditions:

- a) energising the safety class buses to support DG unit loading tests,
- b) energising the isolated bus for LOOP, accident actuation signal concurrent with LOOP, and for routine testing,
- c) restoring the diesel loads back to preferred power supply system without deenergising or tripping loads,
- d) precluding out-of-phase closure that can result in unacceptable engine vibrations. A synchronizing check relay with automatic breaker closure is the preferred method of preventing out-of-phase closure.

Periodic testing of these features in service is defined in 8.4.

Circuit breaker design and testing features should follow the IEEE C37 standards (or applicable clauses of IEC/IEEE common standards such as IEC/IEEE 62271-37-013 where appropriate.

5.5.1.8 Fuel oil storage and supply systems

The fuel oil storage and supply systems are necessary to support the operation and function of the DG unit. System-specific design and component features are included in diesel fuel standards, for example ANS 59.51 and DIN EN 590.

5.5.1.9 Starting energy capacity

5.5.1.9.1 General

The DG unit starting system shall be designed to provide multiple starts/attempts in accordance with the following minimum requirements:

- a) DG unit restart after failing to start in response to LOOP or an accident signal,
- b) DG unit restart attempts are not necessarily required to meet the safety analysis start time requirement,
- c) provide for start and operation of the DG unit in response to LOOP or an accident signal during or immediately following periodic testing of the DG unit.

5.5.1.9.2 Capacity of starting air system

Each DG unit air start system shall consist of two independent sub-systems supplying the engine mounted distribution apparatus. Each sub-system shall have the capability and capacity to meet the following requirements:

- a) The minimum required energy storage capacity for each air start sub-system shall support at least two DG unit restart attempts after failing to start during a LOOP or an accident signal demand. Minimum starts = 1 failed attempt + two subsequent additional attempts = 3 start attempts.

- b) The recommended energy storage capacity for each air start sub-system should provide additional capacity to accommodate possible troubleshooting and subsequent return-to-service testing. The 3 minimum starts requirement above + 2 additional troubleshooting/return-to-service starts means 5 start capacity in each independent sub-system is recommended.

5.5.1.9.3 Capacity of DC starting system

The DC starting system shall be designed to provide multiple starts/attempts in accordance with the following minimum requirements:

- a) The minimum required energy storage capacity shall support at least two DG unit restart attempts after failing to start during a LOOP or an accident signal demand. Minimum starts = 1 failed attempt + two subsequent additional attempts = 3 start attempts.
- b) The DC starting system shall be able to supply DC power to the DG unit immediately following an availability test (i.e., monthly or semi-annual test) and a system operation test. In case of designs that have battery chargers with capacity to support DG unit field flash and nominal DC load, the capacity of the battery might not be required to include considerations of these periodic tests.
- c) The recommended energy storage capacity for the DC starting system should provide additional capacity to accommodate possible troubleshooting and subsequent return-to-service testing. Like the air start system recommendation, a 5-start capacity in each independent starting DC system is recommended when redundant DC systems are used per DG unit.

See Annex E for further information.

5.5.2 Control

5.5.2.1 Control modes and monitoring

The DG unit shall be provided with control systems permitting automatic and manual control from the main control room, the remote-control panel (if panel is required by plant design), and local control panel in the DG unit room. These locations should also have monitoring capability to assure safe and successful operation of the DG unit.

5.5.2.2 Emergency control

Upon receipt of an emergency start signal, the automatic control system shall provide automatic start-up and automatic adjustment of speed and voltage to a ready-to-load condition in the emergency (isochronous) mode according to the following conditions:

- a) During routine surveillance testing performed to demonstrate operability of the DG unit, an emergency start signal shall override all other operating modes and return control of the DG unit to the automatic control system.
- b) An emergency start signal shall not override any manual non-operating modes such as those for repair and maintenance including testing performed post maintenance.

5.5.2.3 Control points

Provisions shall be made for control from the main control room, remote control panel (if applicable) and the DG unit room.

5.5.2.4 Control power

Battery systems for control power, starting, and field flashing shall be sized per IEEE Std 485, or IEEE Std 1115, or equivalent international standards, and according to postulated number of starts over an extended duration without capability to recharge. (See 5.5.1.8 and Annex E for further discussion.)

5.5.3 Status information

5.5.3.1 Indication, annunciation systems and communication

During surveillance activities, the DG unit shall provide indication in the main control room to display DG unit status (i.e., under test, ready-standby, lockout) and annunciate the occurrence of abnormal, pre-trip, or trip conditions.

To facilitate the diagnosis of failure or malfunction, the annunciation system shall indicate which of the DG unit protective trips was activated first.

The local control panel should annunciate the specific parameter or component/system that resulted in the abnormal condition.

A means of communication shall also be provided between DG unit testing locations and the main control room to confirm that the operators know the status of the DG unit under test.

5.5.3.2 Modes to indicate

As a minimum, the following conditions shall be indicated in the main control room and local panel:

- a) unit not running and available,
- b) unit running, not loaded,
- c) unit running, loaded,
- d) unit out of service (e.g., not available due to maintenance or locked out),
- e) unit running, not available (e.g., running post maintenance and not available).

5.5.3.3 Instrumentation

The following systems shall have sufficient mechanical and electrical instrumentation and display of the variables required for successful operation and to generate the abnormal, pre-trip, and trip signals required for indication or alarm of such conditions:

- a) starting system,
- b) lubricating oil system,
- c) fuel systems,
- d) primary cooling system,
- e) secondary cooling system,
- f) combustion air system,
- g) exhaust system,
- h) generator,
- i) excitation system,
- j) voltage regulation system,
- k) governor system.

5.5.4 Protection

DG unit operation is needed to ensure the functions of core cooling, protection of the reactor, and the associated fission product barriers are maintained. During an emergency condition, protecting the plant and the health and safety of the public is the primary objective over the protection of the DG unit. The initial hours of core cooling following a design basis event are critical, and spurious trips of DG units should not compromise nuclear safety. Therefore, the automatic protective features for the DG unit should be prevented from tripping the machine during emergency operation unless the abnormal condition will result in immediate catastrophic failure of the generator or engine. Typically, the main protective features that prevent immediate catastrophic failure include differential current protection for a fault in the generator windings and the engine/generator overspeed protection. Some designs retain overcurrent trip as this trip is also considered critical for prevention of a catastrophic failure.

The remaining electrical and mechanical protective features protect the machine from longer term degradation so that action can be taken to protect the DG unit. The machine can generally operate for an extended period of time with limited degradation in support systems (e.g. leaks in cooling or lube oil systems) and continue to provide power to the emergency loads required to protect the plant. These non-critical protective devices should be prevented from tripping the generator but the actuation should be indicated. The abnormal condition should be annunciated in the Main Control Room and allow the plant operator to determine the relative merits of the continued operation of the DG unit based on plant conditions and the other available AC power sources that can provide power. These protective features typically include:

- generator ground (earth) fault protection for a high impedance grounded generator,
- generator loss of field protection,
- generator over and under frequency protection,
- generator volts/hertz protection,
- generator reverse power protection,
- generator overload protection,
- generator negative sequence current protection.

For the non-critical protection features, the following apply:

- a) They shall be blocked from automatically tripping the DG unit when operating in an emergency mode. The bypassing of non-critical trips shall be indicated in the plant main control room and at the local control panel.
- b) If non-critical protective features are retained during emergency operating mode, then two or more independent measurements of each of these parameters with coincident trip logic shall be provided. The design of the coincident trip logic circuitry shall provide alarm for each individual sensor initiation and shall include the capability to indicate individual sensor trips. All protective devices shall remain effective during the DG unit testing, and during operation in non-emergency conditions. Other periodic tests that demonstrate DG unit's system response under simulated design-basis events shall include protective trip bypass during emergency mode of operation (LOOP, accident, and accident/LOOP).
- c) When protective features are bypassed during emergency operating conditions, the circuitry shall include the capability to perform the following tasks:
 - 1) test the status and operability of the bypass circuits,
 - 2) trigger alarms in the main control room for abnormal values of all bypass parameters (common trouble alarms may be used), and
 - 3) manually reset the trip bypassed function. This action:
 - i) verifies that bypassed trips are not inadvertently re-enabled when the DG unit is in emergency mode,
 - ii) ensures that protective features are active when the DG unit is in the test mode or non-emergency mode.

6 Factory production testing

6.1 General

6.1.1 Implementation

Testing shall be performed in accordance with a written test plan. Factory acceptance test (FAT) of the complete DG unit skid shall be performed.

6.1.2 Documentation

Test documentation shall include the following:

- a) equipment performance specifications,
- b) identification of the specific feature or features to be demonstrated by the test,
- c) test plan,
- d) report of test results. The report shall be available upon customer request and include the following:
 - 1) objective,
 - 2) equipment tested,
 - 3) description of test facility (test setup), instrumentation used, including calibration records reference, and test environment,
 - 4) test procedures, including acceptance/rejection criteria,
 - 5) test data and accuracy (results),
 - 6) test abnormalities and failures, including their disposition and effect on test results,
 - 7) summary, conclusions, and recommendations,
 - 8) supporting data,
 - 9) approval signature and date.

6.1.3 Analyses

Although testing is preferred, analyses may supplement testing or be substituted for test, where testing is not practical, to demonstrate conformance to the criteria stated in Clause 5. Analysis shall include the bases of assumptions used. Report of analysis shall be available upon customer request.

6.1.4 Substitutions

When tests are performed at the manufacturer's or assembler's facilities, and not at the site, the exhaust muffler, intake air filter-silencer, and radiator (if applicable) normally used for shop tests may be substituted in place of the equipment to be provided for a specific site, since it is not practical to utilize the equipment and piping that will exist at the site or future sites for which the DG unit is being qualified. Results of tests shall be corrected to the condition of the service environment and design characteristics, including site exhaust muffler and intake air filter-silencer systems.

6.2 Specific production tests

6.2.1 General

The following tests are minimum requirements for factory production tests.

6.2.2 Engine tests

Each engine shall be tested, utilizing either a water brake dynamometer or a generator to provide accurate means to control power absorption. The following tests shall be performed as a minimum:

- a) Break-in test. Each manufacturer shall develop their own break-in schedule to best suit the engine.
- b) Performance test
 - 1) Test runs. After the engine has satisfactorily completed the break-in test, the following minimum tests with loading and duration recommended in Table 2 shall be run to establish the operating characteristics. These tests may be conducted in any order desired. The results from the test shall be within the design criteria.

Table 2 – Recommended load tests

Load of continuous rating %	Duration Hours
0 to 30	1
30 to 50	1
50	1
75	1
100	2
110	2

- 2) Data logging. Test logs of each of the above tests shall become a part of the records for a particular engine. The test logs shall include at least the following data:
 - i) speed (r/min),
 - ii) brake (hp or kW),
 - iii) brake specific fuel consumption,
 - iv) intake manifold pressure,
 - v) intake manifold temperature,
 - vi) individual cylinder exhaust temperature,
 - vii) turbocharger exhaust temperature,
 - viii) jacket water temperature (engine inlet and outlet),
 - ix) jacket water pressure (engine inlet),
 - x) lube oil temperature (engine inlet and outlet),
 - xi) lube oil header pressure (engine inlet),
 - xii) type of fuel and fuel heat content,
 - xiii) barometric pressure,
 - xiv) intake air temperature,
 - xv) ambient temperature and relative humidity.

6.2.3 Generator tests

As a minimum, generator testing should be in accordance with NEMA MG 1 or equivalent IEC standards such as the IEC 60034 series for rotating electrical machines, or other applicable national standards.

6.2.4 Excitation, control, and other accessories /auxiliaries

All such devices and assemblies shall be tested in accordance with the manufacturer's standard practice.

7 Qualification requirements

7.1 General

The DG units applied as part of the standby power source shall be qualified in accordance with the requirements of this clause⁷. This qualification will provide verification that the unit will meet the requirements of Clause 5 under all expected environmental conditions. Qualification shall be accomplished by performance of type tests on unaged equipment in 7.2, by analysis or testing in 7.3, and by functional testing as required in 7.4 following any ageing or seismic testing. All qualification shall be performed in accordance with a written plan that defines analyses and tests to be performed, parameters to be monitored during tests, test instrumentation, and acceptance criteria for equipment. Additional tests might be necessary to ensure site specific requirements are satisfied.

7.2 Initial type tests

7.2.1 General

DG units not previously type-tested as standby power sources for nuclear facilities shall be subject to a type testing program consisting of load capability, start and load acceptance, and margin tests. It is preferred that these tests be performed at the engine manufacturer's or assembler's factory; however, they may be conducted at the site if certified calibration instrumentation is provided to measure and record the same functions and characteristics normally measured under factory testing conditions. As a minimum, the generator nameplate capacity and overload capacity should be verified as a baseline for future trending.

Type tests may be performed on one or more units, and qualification of one unit will qualify like units of that type for equal or less severe service. If start and load acceptance tests (see 7.2.3) are performed using more than one identical unit, then each of these units shall be tested for load capability (see 7.2.2) and margin (see 7.2.4).

Type tests shall be performed following successful completion of the factory production tests. Following the successful completion of these type tests, the equipment shall be inspected in accordance with the manufacturer's standard procedure, and inspection results shall be documented.

7.2.2 Load capability tests

These tests demonstrate the capability of the DG unit to carry the rated loads at rated power factor for the period of time indicated, and to successfully reject load in accordance with 8.2.2.5. One successful completion of the test sequence shall satisfy this particular requirement. The load capability test sequence shall be as follows:

- a) Load equal to the continuous rating (real and reactive) shall be applied for the time required to reach engine temperature equilibrium.

⁷ The requirements for qualification in this clause are based on IEC/IEEE 60780-323 and IEEE Std 627, as applicable to DG units to ensure that the equipment can perform within its specification requirements.

- b) Immediately following item a) above, the short-time rating load (real and reactive) shall be applied for a period of 2 h and the continuous rated load shall be applied for a period of 22 h.
- c) The short-time rating load rejection test shall be performed. The load rejection test will be acceptable if the increase in speed of the diesel engine does not exceed 75 % of the difference between nominal speed and the overspeed trip set point, or 15 % above nominal, whichever is lower.
- d) Light-load or no-load capability as described in 5.1.2.4 shall be demonstrated by test. Light-load or no-load operation shall be followed by a load application ≥ 50 % of the continuous kilowatt rating for a minimum of 0,5 h or as prescribed by the engine manufacturer.

7.2.3 Start and load acceptance tests

A series of tests shall be conducted to establish the capability of the DG unit to start and accept load within the period of time necessary to satisfy the plant design requirement. An acceptable start and load acceptance test is defined below; however, other methods with proper justification might be found equivalent for the level of reliability to be demonstrated.

A total of 100 valid start and load tests shall be performed with no failures allowed. Failure of the unit to successfully complete this series of tests, as prescribed, will require a review of the system design adequacy, the cause of the failures to be corrected, and the tests continued until 100 valid tests are achieved without any failure. The start and load tests shall be conducted as follows:

- a) Engine cranking shall begin upon receipt of the diesel start signal, and the DG unit shall accelerate to specified frequency and voltage within the required start time.
- b) Immediately following step a), the DG unit shall accept a single-step load ≥ 50 % of the continuous kilowatt rating. Load can be totally resistive or a combination of resistive and inductive loads.
- c) At least 90 of these tests shall be performed with the DG unit initially at warm standby based on jacket water and lube oil temperatures at or below values recommended by the engine manufacturer. After load is applied, the DG unit shall continue to operate until jacket water and lube oil temperatures are within $\pm 5,5$ °C (± 10 °F) of the normal engine operating temperatures for the corresponding load.
- d) At least 10 tests shall be performed with the engine initially at normal operating temperature equilibrium defined as jacket water and lube oil temperatures within $\pm 5,5$ °C (± 10 °F) of normal operating temperatures, as established by the engine manufacturer for the corresponding load.
- e) If the cause for failure to start or accept load in accordance with the preceding sequence falls under any of the categories listed below, that particular test shall be disregarded, and the test sequence shall be resumed without penalty following identification and correction of the cause for the unsuccessful attempt.
 - 1) Unsuccessful start attempts that can definitely be attributed to operator error, including setting of alignment control switches, rheostats, or potentiometers, or other adjustments that might have been changed inadvertently prior to that particular start test.
 - 2) Tests performed for verification of a scheduled maintenance procedure required during this series of tests. This maintenance procedure shall be defined prior to conducting the start and load acceptance tests and will then become a part of the normal maintenance schedule after installation.
 - 3) Tests performed in the process of troubleshooting. Each start attempt performed in the troubleshooting process shall be defined as such before a start attempt is made.
 - 4) Successful start attempts that were terminated intentionally without loading.
 - 5) Failure of any of the temporary service systems such as DC power source, output circuit breaker, load, interconnecting piping and wiring, and any other temporary setup that will not be a part of the permanent installation.

7.2.4 Margin tests

Tests shall be conducted to demonstrate the DG unit capability to start and carry loads that are greater than the magnitude of the most severe step load within the plant design load profile, including step changes above base load. The limiting case step change over base load as defined by the design load profile shall be demonstrated. This is not necessarily the largest step change but can be a smaller step change as the full-load capability of the DG unit is approached. These tests may be combined with the load capability or start and load acceptance tests. At least two margin tests shall be performed using either the same or different load arrangement. A margin test load at least 10 % greater than the magnitude of the most severe single-step load within the load profile is considered sufficient for the margin test. The magnitude and duration of frequency and voltage excursions recorded may exceed those values specified for the plant design load but both should be restored to nominal steady state values. The criteria for margin tests are as follows:

- a) demonstrate the ability of the generator and excitation system to accept the margin test load (usually the low power factor, high inrush, and high starting current of a pump motor) without experiencing instability resulting in generator voltage collapse, or significant evidence of the inability of the voltage to recover,
- b) demonstrate that there is sufficient engine torque available to prevent engine stall, and to permit the engine speed to recover, when experiencing the margin test load.

7.3 Ageing

7.3.1 General

Methods for managing ageing are described in this subclause for the applicable conditions listed in 5.1.2.2, which are determined to be significant. The management of ageing for DGs should be performed in accordance with IEEE 1205, IEC 62342 and IEC/IEEE 60780-323.

7.3.2 Equipment important to safety

Components and assemblies within the scope of this document (see Figure 1) shall be classified into one of the two following categories:

- a) Components and assemblies required to enable the DG unit to meet its capabilities in 5.1 (hereinafter called the safety-related/important to safety function). These components and assemblies require consideration of ageing as a potential cause for common cause failures. Examples can include the governor, generator, cable, excitation system, engine, starting air solenoid valves, and those gaskets and seals that are used to prevent leakage that degrades unit performance.
- b) Components and assemblies not required to perform a safety function. Each of these non-safety/equipment important to safety class components or assemblies require verification that its failure or malfunction will not degrade a safety function. This may be accomplished by testing or analysis. Examples can include generator resistance temperature detectors (RTDs), space heaters, starting air compressors, keep-warm heaters and pumps, and those gaskets and seals whose failure will not degrade unit performance.

7.3.3 Ageing classification

Further classification of the safety-related/important-to-safety components identified in 7.3.2 item a) is required to address the potential for age-related failures. The categories in Table 3 illustrate this classification.

Table 3 – Format for component ageing classification (see Annex B)

Component	Items with age-related failure mechanisms	Method of ageing qualification	Items without age-related failure mechanisms
List specific component (e.g., generator, motor, engine, pump, control panel, tanks, governors, solenoid valves, valves, voltage regulator/excitation systems, circuit breaker)	List all items or materials within that component that have age-related failure mechanisms (e.g., gaskets, insulation, bearings, non-metals, electrical insulation)	List the method used, (e.g., accelerated ageing (IEC/IEEE 60780-323)) Periodic replacement analysis, operating experience seismic (IEC/IEEE 60980-344)	List all items or materials within that component that do not have age-related failure mechanisms (e.g., metal component, ceramic component)

Components without significant age-related failure mechanisms may be excluded. For example, it is recognized that cast iron used in the basic engine block will not represent a potential age-related failure mechanism over normal nuclear service life.

Following classification, those components with potential age-related failures shall be qualified by testing (the preferred method), analysis, or a combination of test and analysis. Components with a resultant identified qualified life less than the overall qualified life objective shall have a maintenance/replacement interval defined. If ageing by test is used, it shall be followed by seismic qualification to meet IEC/IEEE 60980-344. In all cases, the documentation requirements of IEC/IEEE 60780-323:2016, Clause 8 and periodic replacement analysis (Subclause 7.4.1.9) shall be satisfied. An example of this process is given in Annex B.

7.4 Seismic qualification requirements

Seismic qualification in accordance with IEC/IEEE 60980-344 is required for all safety-class and important to safety components. Non-safety class components require analysis or test to show that they will not degrade the safety function of the unit during a seismic event. Seismic testing shall be followed by functional testing to verify the applicable capabilities.

7.5 Ongoing surveillance

7.5.1 General

Ongoing surveillance, including the periodic tests described in 8.4, may be used as a basis for the identification of equipment degradation and validation of the results of the ageing and aged equipment testing described in 7.3.

7.5.2 Preventive maintenance, inspection, testing, and monitoring

A separate preventive maintenance, inspection, testing, and monitoring program (see also 7.5.3) shall be established for the DG unit and all supporting systems based on the manufacturer's recommendations, or other alternative program with sufficient technical basis for DG units used in nuclear standby applications. These preventive maintenance, inspection, testing, and monitoring recommendations may be based on condition, operating hours, fixed time intervals, industry operating experience, or a combination of any of these. Programs shall include, as a minimum, specific procedures for each portion of the unit as follows:

a) Maintenance, inspection, and testing, shall include the following:

- 1) The engine, including the governor, overspeed trip device, internal components to the maximum extent practical, turbocharger, lube oil components, fuel oil components, jacket water components, starting components, cleaning, adequate lubrication, and water chemistry.
- 2) The generator and rotating exciter (if used), including insulation condition, bearings, cooling system, lubricating oil system, and space heaters (if applicable).
- 3) Electrical auxiliary equipment, including local engine and generator control, exciter and voltage regulator, and protection and surveillance components.

4) Subsystems, to include the following:

- i) Starting energy, typically consisting of air receiver tanks, compressors, piping, valves, and associated instrument and control devices, and reliable power supply.
- ii) Fuel oil, typically consisting of pumps, filters (two loops to conduct in-service filter replacement), strainers, piping, valves, and associated instrument and control devices.
- iii) Lube oil, typically consisting of pumps, filters, duplex strainers, keep-warm heaters and pumps, coolers, sump tanks, piping, valves, and associated instrument and control devices.
- iv) Cooling water, typically consisting of expansion tanks, heat exchangers, pumps, keep-warm heaters and pumps, piping, valves, and associated instrument and control devices.

b) Monitoring shall include the following:

- 1) DG unit monitoring practices shall follow those similar to ASME OM, Operation and Maintenance of Nuclear Power Plants (Part 16, Performance Testing and Monitoring of Standby Diesel Generator Systems in Light-Water Reactor Power Plants), or other equivalent standards.

Electrical cabinets and/or enclosures should also be provided with thermography observation ports.

7.5.3 Records and analyses

Records shall be maintained for each DG unit to provide a basis for an analysis of the unit's overall performance. These records also provide a basis for verifying any assumptions made concerning age-related failure mechanisms. The documentation may also be used to shorten or extend the replacement intervals based on a comprehensive condition monitoring concept and maintenance strategies.

7.6 Modifications

Modifications to a previously qualified DG unit, such as governor, generator, overall system fly-wheel effect, excitation system characteristics, cooling media, or other accessories/auxiliaries that can change the capability or performance of a previously qualified DG unit shall be analysed to determine if the degree of change is major or minor.

- a) Major changes to a qualified engine, such as changes in stroke or bore, brake mean effective pressure, speed, or DG unit's arrangement in unique or different configuration shall be requalified in accordance with 7.6.
- b) Minor changes to a previously qualified DG unit, such as component parts substitution, or addition shall be qualified by analysis or testing, or both.

7.7 Documentation

Qualification documentation shall be in accordance with IEC/IEEE 60780-323 and shall include the following:

- a) service and environment (see 5.1.2.2),
- b) classification table of all components at different safety classes as described in IEEE and IEC safety classification systems,
- c) analysis/justification for non-safety class/important to safety components,
- d) classification table of different safety and non-safety classes of components with or without age-related failure mechanisms,
- e) justification of ageing methods for various components,
- f) test data for control panels, exciter/regulator (including seismic),
- g) test data for insulation systems testing,

- h) test data for seismic testing of smaller mechanical components,
- i) analytical data for seismic analysis of generator, engine, and major mechanical components,
- j) historical data/justification for items requiring periodic replacement,
- k) correlation of qualification program to instruction book information for periodic replacement, etc.

8 Site testing

8.1 Testing

Site testing shall consist of site acceptance testing, pre-operational testing, and periodic testing. Individual tests shall be as shown in Table 4.

Table 4 – Site testing

Reference	Tests	Site acceptance tests (8.2)	Pre-operational tests (8.3)	Availability tests (8.4.2.2)		System operation tests- refuelling/ two-year (8.4.2.3)	Independence tests 10 years (8.4.2.4)
				Monthly	Semi-annual		
8.2.2.2	Starting	X	—	—	—	—	—
8.2.2.3	Load acceptance	X	—	—	—	—	—
8.2.2.4	Rated load	X	—	—	—	—	—
8.2.2.5	Load rejection	X	—	—	—	—	—
8.2.2.6	Electrical	X	—	—	—	—	—
8.2.2.7	Subsystem	X	—	—	—	—	—
8.3.2	Reliability	—	X	—	—	—	—
8.5.2	Slow start	—	—	X	—	—	—
8.5.3	Load run	—	—	X	X	—	—
8.5.4	Fast start	—	—	—	X	—	—
8.5.5	LOOP	—	X	—	—	X	—
8.5.6	Accident signal	—	X	—	—	X	—
8.5.7	Combined accident and LOOP Signal	—	X	—	—	X	—
8.5.8	Largest load rejection	—	X	—	—	X	—
8.5.9	Design load rejection	—	X	—	—	X	—
8.5.10	Endurance and load	—	X	—	—	X	—
8.5.11	Hot restart	—	X	—	—	X	—
8.5.12	Synchronizing	—	X	—	—	X	—
8.5.13	Protective trip bypass	—	X	—	—	X	—
8.5.14	Protective trip verification	—	X	—	—	X	—
8.5.15	Test mode override	—	X	—	—	X	—
8.5.16	Independence	—	X	—	—	—	X

8.2 Site acceptance testing

8.2.1 General

After final assembly and preliminary start-up testing, each DG unit shall be tested at the site to demonstrate the capability of the unit to perform its intended function.

8.2.2 Tests

8.2.2.1 General

Tests to be applied to the DG unit are shown in Table 4 and are described in 8.2.2.2 to 8.2.2.7:

8.2.2.2 Starting test

Starting tests shall demonstrate the capability to attain and stabilize frequency and voltage within the limits and time defined in the equipment specification. The acceptance criteria for frequency and voltage shall be equal to or higher than the minimum required voltage and frequency within specified time allowance for the safety-related/important to safety loads.

8.2.2.3 Load acceptance test

Load acceptance tests shall demonstrate the capability to accept the individual loads that make up the design load, as described in Clause 5 and 7.2.3, in the desired sequence and time duration and to maintain the voltage and frequency within the acceptable limits. If the DG unit has a light-load or no-load operation capability, the load acceptance test sequence shall include consideration of the potential effects on load acceptance following such operation (also see 5.2.2).

8.2.2.4 Rated load test

Rated load tests shall demonstrate the capability of carrying the following loads for the indicated times without exceeding the manufacturer's design limits:

- a) A load equal to the continuous rating with consideration for power factor for the time required to reach engine temperature equilibrium plus 1 h.
- b) Immediately following the load in item a), the short-time rating load shall be applied for a period of 2 h.

8.2.2.5 Load rejection test

Load rejection tests shall demonstrate the capability of rejecting short-time rating load without exceeding speed or voltage that will cause tripping or component damage.

8.2.2.6 Electrical test

Electrical tests shall functionally demonstrate that the electrical properties of the generator, excitation system, voltage regulation system, engine governor system, and the control and surveillance systems are acceptable for the intended application and meet the steady state and dynamic design requirements for frequency, voltage, and power output.

8.2.2.7 Subsystem test

Tests shall demonstrate the capability of the control, protection, and instrumentation systems to function in accordance with the requirements of the intended application.

8.2.3 Test loads

Loads to be applied, carried, and rejected during site testing shall be the design load auxiliaries located at the station. Equivalent loads may be used if these auxiliaries cannot be operated for testing.

8.3 Pre-operational testing

8.3.1 General

Following completion of the site acceptance testing, pre-operational tests shall be performed to demonstrate starting and operational adequacy of the DG units and the system. Tests are discussed in 8.3.2 and 8.3.3.

8.3.2 Reliability test

Reliability tests shall demonstrate that an acceptable level of reliability has been achieved to place the new DG unit into operation. This shall be achieved by a minimum of 25 valid starts (e.g., 20 slow starts (8.5.2) to reduce wear and tear and 5 fast starts (8.5.4) and load-run tests (8.5.3) without failure on each installed DG unit. Annex C provides further information on DG unit reliability program elements.

8.3.3 Individual pre-operational tests

The individual pre-operational tests shall be as indicated in Table 4 and as described in 8.4.2.

8.4 Operational testing

8.4.1 General

After being placed in service, the DG unit shall be tested periodically to demonstrate that the continued capability and availability of the unit to perform its intended function is acceptable. Records and analysis described in 8.6 shall be maintained for all periodic tests. It is recognized that some of these tests may be combined and not necessarily performed individually. The periodicity of the testing is recommended based on operating experience. However, plant specific requirements or DG unit manufacturer provided guidance or plant safety case with a supporting technical basis shall be applied to override the frequency or periodicity of the tests provided in Table 4. The functional tests of redundant DG units shall be distributed evenly over the test interval (e.g., one test run of one train per week). It is not necessary to begin the periodic tests in 8.4.2 from standby conditions unless otherwise specified:

- a) Test equipment shall not cause a loss of independence between redundant DG units or between DG unit load groups.
- b) Periodic testing of a DG unit shall not impair the capability of the unit to supply emergency power in the required start time in response to start signals.
- c) All DG unit protective trips and alarms shall be operative and in calibration during applicable periodic testing.
- d) Written procedures for testing shall be prepared and utilized. The procedures shall include the manufacturer's applicable test recommendations, identify all special arrangements or changes in the normal plant system configuration required to perform the test and consider plant safety evaluation. The procedures shall be used to verify that the system is restored to its normal configuration after completion of the tests. All tests shall be in general accordance with the manufacturer's recommendations for reducing engine wear, including cool-down operation at reduced power followed by post-operation lubrication. Test procedures that involve starting and stopping the DG unit shall include the following steps that are pertinent to each specific test:
 - 1) Observe and record the pre-start data listed in Table 5.
 - 2) Initiate the start signal and measure and record the start time to voltage and frequency for all fast starts.
 - 3) Confirm that the generator voltage and frequency are maintained within the prescribed limits for the particular circumstances of each test.
 - 4) Record the parameters listed in Table 5 at the beginning of any load-carrying test and at the end of any load-carrying test and at 1 h intervals during the test, if applicable. The data shall be recorded under similar conditions for use in trending analyses.

- 5) Observe and record the post-test data listed in Table 5 after completion of the test.
- e) Communication shall be established between the DG unit testing location and the Main Control Room so that operators are cognizant of the status of the DG unit undergoing the test.
- f) During system operational tests, problems can arise with individual components that do not detract from the overall test purpose. These components shall be repaired and their interface with the system shall be retested; however, the total test need not be repeated unless necessary due to the critical function of the component involved.

Abnormal conditions discovered during any test shall be evaluated to determine if either of the following applies:

- the condition would prevent the DG unit from performing its intended function,
- the test is a valid test.

For the purposes of periodic testing, the DG unit shall not be operated greater than the OEM's established continuous ratings, other than for the provisions regarding loading to the short-term ratings in the endurance and load test (see 8.5.10).

8.4.2 Periodic tests

8.4.2.1 General

Periodic tests shall consist of availability, system operation, and independence verification tests.

Table 5 – Test parameters

Parameter ^a	Pre-start	During test	Post-test
<u>Pressures</u>			
Lube oil: engine – inlet	X	X	—
Lube oil: turbo – inlet	X	X	—
Lube oil: engine – filter differential	—	X	—
Lube oil: turbo – filter differential	—	X	—
Combustion air manifold	—	X	—
Jacket water	—	X	—
Crankcase	—	X	—
Starting air	X	X	X
Fuel oil manifold	X	X	
<u>Temperatures</u>			
Lube oil: engine – inlet and outlet	X	X	—
Jacket water: engine – inlet and outlet	X	X	—
Exhaust: each power cylinder	—	X	—
Exhaust: turbo outlet	—	X	—
Exhaust: exhaust manifold (if applicable)	—	X	—
Stator winding		X	
<u>Electrical</u>			
Frequency	—	X	—
Power	—	X	—
Reactive	—	X	—
Current: generator – all phases	—	X	—
Voltage: generator – all phases	—	X	—
Current: field	—	X	—
Voltage: field		X	
<u>Level</u>			
Lube oil: engine generator crankcase	X	X	X
Lube oil: generator bearing	X	X	X
Jacket water: standpipe or expansion tank	X	X	X
^a These parameters are considered the minimum requirements for this document (where applicable for the design of the DG unit). Additional parameters may be added for performance measurements.			

8.4.2.2 Availability tests

These tests demonstrate the continued capability of the DG to start and accept load. A frequency of once in 31 days (slow-start and load-run test) is recommended. The recommended test intervals are based on the need for lubrication (of bearings and cylinders), checks for potential leaks and other identified degradation mechanisms, in order to ensure that the DG is ready for operation.

Each DG unit shall be started as described in 8.5.2 and loaded as described in 8.5.3. In lieu of the above slow start test, once every six months a fast-start as described in 8.5.4 and load-run test as described in 8.5.3 shall be performed. It is permissible to extend the test intervals, provided the extension is documented in the safety case and based on operating experience and validated by reliable operation of the DG unit over a period of several years.

8.4.2.3 System operation tests

This series of tests demonstrates the ability of the DG unit to perform its intended function under simulated emergency conditions. These tests shall be performed at shutdown/refuelling outages or at a frequency of not more than every 24 months by performing the tests identified in Table 4. Certain tests may be conducted during the operating mode if the tests can be evaluated to be safely performed without increasing the probability of plant trip, loss of power to the safety buses, or LOOP.

8.4.2.4 Independence verification test

This testing involves demonstrating that the trains of standby electric power are independent at a frequency of once every 10 years (during a plant shutdown), or, subsequent to any modifications where DG unit independence might have been affected (whichever is shorter), by starting all redundant units simultaneously to identify certain common-cause failures undetected in single DG unit tests (see also Table 4).

8.5 Test description

8.5.1 General

The following descriptions apply to the tests listed in Table 4. These tests shall be preceded by a pre-lube period and shall be in general accordance with the manufacturer's recommendations for reducing engine wear, including cool-down operation at reduced power followed by post-operation lubrication. Unless otherwise noted, these tests shall be performed at a power factor as close as practicable to the design load power factor as plant voltage conditions permit.

8.5.2 Slow-start test

Demonstrate proper start-up from standby conditions and verify that the required design voltage and frequency are attained. The unit can be slow-started and reach rated speed on a prescribed schedule to reduce stress and wear on the DG unit.

8.5.3 Load-run test

Demonstrate load-carrying capability, with load equivalent to 90 % to 100 % of the continuous rating of the DG unit, for an interval of not less than 1 h and until attainment of temperature equilibrium has been attained. This test may be accomplished by synchronizing the generator with offsite power. Testing may be performed at unity power factor or at a lagging power factor within the DG unit capability. The loading and unloading of a DG unit during this test shall be gradual and based on a prescribed schedule that is selected to reduce stress and wear on the DG unit.

8.5.4 Fast-start test

Demonstrate that each DG unit starts from standby condition (if a plant has normally operating pre-warm systems, this would constitute its standby condition) and verify that the DG unit reaches required voltage and frequency within acceptable limits and time, as defined in the plant technical specifications or operating procedures.

8.5.5 Loss of offsite power (LOOP) test

Demonstrate by simulating a loss of offsite power that accomplishes the following:

- a) The safety class buses are de-energized and the loads are shed from these buses.
- b) The DG unit starts on the emergency start signal from its standby conditions, attains the required voltage and frequency, and energizes permanently connected loads within acceptable limits and time, energizes all auto-connected shutdown loads through the load sequencer, and operates for greater than or equal to 5 min. If the required safety loads are not available, the applicable circuit for breaker open/close signal should be verified and one or more equivalent load(s) may be used to make up the load for DG unit testing.