

IEEE Standard for Qualification of Class 1E Static Battery Chargers, Inverters, and Uninterruptible Power Supply Systems for Nuclear Power Generating Stations

IEEE Power and Energy Society

Sponsored by the
Nuclear Power Engineering Committee

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IEEE Standard for Qualification of Class 1E Static Battery Chargers, Inverters, and Uninterruptible Power Supply Systems for Nuclear Power Generating Stations

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Abstract: Methods for qualifying static battery chargers, inverters and uninterruptible power supply (UPS) systems for Class 1E installations outside containment in nuclear power generating stations are described in this standard. Similar electronic equipment for use in applications outside containment, where specific standards for such equipment are not available, may also be qualified using these methods. A combination of type testing and analysis, the latter including a justification of methods, theories, and assumptions used, are employed in the qualification methods set forth. Requirements of IEC/IEEE 60780-323 are met by these procedures.

Keywords: battery charger, IEEE 650™, inverter, qualification, uninterruptible power supply (UPS) systems

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Introduction

This introduction is not part of IEEE Std 650-2017, IEEE Standard for Qualification of Class 1E Static Battery Chargers, Inverters, and Uninterruptible Power Supply Systems for Nuclear Power Generating Stations.

This standard provides the methods of qualifying Class 1E static battery chargers, inverters, and uninterruptible power supply (UPS) systems in accordance with IEC/IEEE 60780-323. The static battery chargers, inverters, and UPS systems discussed in this standard are Class 1E. This document, however, addresses this equipment only as a subsystem in the safety-related electrical system.

The techniques and information contained in this standard may be applied to other similar electronic equipment.

The reliability analysis requirements of IEEE Std 577™ and the methods described in IEEE Std 352™ have been used along with statistical data.

The standard was updated to change title to include UPS systems, normative references, definitions, and editorial type changes. A few new clauses were added to address software analysis and transient testing. Figures were modified to be consistent with the added new clauses. Clarification was added to mechanical cycling requirements of connectors and functional monitoring required during environmental and seismic testing and acceptable methods for seismic testing. A new informative annex was added to address design basis transient voltage considerations. The efforts of the working group on this standard and its annexes will continue for the purpose of updating and disseminating more information regarding qualification techniques. The subjects of aging and the use of surveillance/maintenance techniques to address aging will continue to be investigated and will be among the areas considered by the working group in future revisions of this standard.

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IEEE Standard for Qualification of Class 1E Static Battery Chargers, Inverters, and Uninterruptible Power Supply Systems for Nuclear Power Generating Stations

1. Overview

1.1 Scope

This standard describes methods for qualifying static battery chargers, inverters, and uninterruptible power supply (UPS) systems for Class 1E installations outside containment in nuclear power generating stations, and is not intended for qualification under harsh environment (e.g., inside containment) design basis conditions.

1.2 Purpose

The purpose of this standard is to provide specific procedures to meet the equipment qualification requirements of IEC/IEEE 60780-323 for static battery chargers, inverters, UPS systems, and the associated ancillary equipment.¹ This standard is not intended for qualification under harsh environment design basis conditions.

1.3 Applicability and general information

The application of this equipment in the plant's electrical system is not within the scope of this standard as other industry standards, such as IEEE Std 308™ [B7], IEEE Std 603™ [B11], and IEEE Std 946™ [B13], exist for this purpose. IEEE Std 535™ [B9] is applicable for qualification of the battery power sources that are used in the UPS systems. In addition, industry standards exist for equipment performance, such as

¹ Information on references can be found in [Clause 2](#).

ANSI/NEMA PE 5 [B1], ANSI/NEMA PE 1 [B2], IEEE Std 944TM [B12], and IEEE P2405 [B15]. Performance requirements are not specified in this standard.²

The demonstration that an installed static battery charger, inverter, UPS system, or associated ancillary equipment will meet its design specification requires many steps in a program of design, fabrication, quality assurance, qualification, transportation, storage, installation, maintenance, periodic testing, and surveillance. This standard treats only the qualification area of this program. The result of the qualification program may provide a basis for determination of long-term maintenance requirements.

As specified in 1.1 and 1.2, Scope and Purpose, respectively, this standard is not intended for qualification under harsh environment design basis conditions. This standard is applicable for equipment located in a mild environment where the only design basis event (DBE) of consequence is a seismic event [safe shutdown earthquake (SSE)].

Qualification may be accomplished in several ways: type testing, operating experience, or analysis. These methods may be used individually or in combination. The qualification methods in this standard employ a combination of type testing and analysis. Operating experience is of limited use as a sole means of qualification. Operating experience is, however, of great use as a supplement to testing, as the experience may provide an insight into the change in behavior of materials and components through time under actual service and maintenance conditions. Qualification by analysis shall include a justification of the methods, theories, and assumptions used. In general, static battery chargers, inverters, and UPS systems are too complex to be qualified by analysis alone, although analysis is effective in the extrapolation of test data and the determination of the effects of minor design changes to equipment previously tested.

2. Normative references

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

EIA 401-73 (Reaff 90), Paper, Paper/Film, Film Dielectric Capacitors for Power Semiconductor Applications.³

EIA 454-78 (Reaff 90), Fixed Paper and Film-Paper Dielectric Capacitors with Non-PCB Impregnants for Alternating Current Applications.

IEC/IEEE 60780-323, International Standard—Nuclear facilities—Electrical equipment important to safety—Qualification.⁴

IEEE Std 101TM, IEEE Guide for the Statistical Analysis of Thermal Life Test Data.^{5, 6}

IEEE Std 259TM, IEEE Standard Test Procedure for Evaluation of Systems of Insulation for Dry-Type Specialty and General-Purpose Transformers.

IEEE Std 344TM, IEEE Standard for Seismic Qualification of Equipment for Nuclear Power Generating Stations.

² The numbers in brackets correspond to those of the bibliography in Annex G.

³ EIA publications are available from the U.S. Energy Information Administration (<http://www.eia.gov/>).

⁴ IEC publications are available from the International Electrotechnical Commission (<http://www.iec.ch>) and the American National Standards Institute (<http://www.ansi.org/>).

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IEEE Std 383™, IEEE Standard for Qualifying Electric Cables and Splices for Nuclear Facilities.

IEEE Std 384™, IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits.

IEEE Std 577™, IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations.

IEEE Std 7-4.3.2™, IEEE Standard Criteria for Programmable Digital Devices in Safety Systems of Nuclear Power Generating Stations.

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁷

battery charger: Equipment that converts ac power to dc power and is used to recharge and maintain a station battery in a fully charged condition and to supply power to dc loads during normal operation and design basis events.

components: Items from which the equipment is assembled (e.g., resistors, capacitors, wires, connectors, semiconductors, tubes, switches, and electromechanical devices).

equipment: Assembly of components designed and manufactured to perform specific functions.

NOTE—Sensors, cables, electrically operated valves, and I&C cabinet or racks are examples of equipment.⁸

equipment qualification: The generation and maintenance of evidence to ensure that equipment will operate on demand to meet system performance requirements during normal and abnormal service conditions and postulated design basis events.

NOTE—Equipment qualification includes environmental, seismic, and electromagnetic compatibility (EMI/RFI/Surge withstand capability where applicable) qualification.

inverter: Equipment that converts dc power to ac power. It includes auxiliary devices such as transfer switches, alternate source transformers and regulators, input rectifiers (other than battery chargers), and isolation devices (e.g., blocking diodes).

margin: The difference between service conditions and the conditions used for equipment qualification.

operating experience: Accumulation of verifiable service data for conditions equivalent to those for which particular equipment is to be qualified.

qualified life: The period for which an equipment has been demonstrated, through testing, analysis, and/or experience, to be capable of functioning within acceptance criteria during specific operating conditions while retaining the ability to perform its safety functions during design basis events.

⁷ *IEEE Standards Dictionary Online* is available at: <http://dictionary.ieee.org>

⁸ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

NOTE—At the end of the qualified life, the equipment shall be capable of performing the safety function(s) required for the postulated design-basis event and design extension (post-design-basis events) conditions (IEC/IEEE 60780-323). Class 1E equipment may include components that have significant aging mechanisms. The qualification process will include information on when these aging mechanisms start and any replacement/maintenance interval required.

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.

stressor: An agent or stimulus that stems from fabrication or service conditions and can produce degradation of a system, structure, or component (defined in IEEE Std 1205 [B14]).

surge suppressors: A device operative in conformance with the rate of change of current, voltage, power, etc., to prevent the rise of such quantity above a predetermined value.

uninterruptible power supply (UPS) system: A system designed to provide power automatically, without delay or transients during any period when the normal power supply is incapable of performing acceptably. The UPS systems may consist of and not limited to the following modules/sections:

- inverter
- battery charger
- rectifier
- static transfer switch
- maintenance bypass switch
- battery power source
- line regulating transformer

3.2 Acronyms and abbreviations

AVR	automatic voltage regulation
BFP	backup fault protection
DBE	design basis event
EDG	emergency diesel generator
EMC	electromagnetic compatibility
EMI	electromagnetic interference
FCR	field current regulator
FMEA	failure modes and effects analysis
GSU	generator step-up
MTBF	mean time between failure
NPP	nuclear power plant
OBE	operating basis earthquake
RFI	radio frequency interference
SSE	safe shutdown earthquake
UPS	uninterruptible power supply

4. Specifications

4.1 General

This subclause describes the items to be addressed in the owner's specifications for the equipment to be qualified. These items include the equipment identification, the Class 1E performance characteristics, the input power supply, the environmental conditions, and the effect of changes in input power supply and environmental conditions upon the Class 1E performance characteristics. If the equipment specification includes margins, as defined in 3.1, their values shall be identified.

4.2 Class 1E performance characteristics and safety function

The nuclear power generating station owner or its representative shall specify the performance characteristics (including the safety function) of the equipment, including, as a minimum, numerical values and durations for normal, abnormal, DBE, and post-DBE conditions, as indicated in 4.2.1, 4.2.2, and 4.2.3. Stressors shall be addressed in defining the performance characteristics and safety functions.

4.2.1 Class 1E performance characteristics

The following characteristics are suggested conditions, parameters, and performance requirements to be considered in acceptance testing:

- a) Input conditions, such as the following:
 - 1) Voltage (consider voltage from islanding conditions and load rejection)
 - 2) Frequency
 - 3) Phase
 - 4) Current (if limiting conditions exist for installed condition)
- b) Output requirements, such as the following:
 - 1) Voltage and voltage regulation
 - 2) Current (minimum and maximum)
 - 3) Current limit
 - 4) Frequency and frequency regulation (inverters and UPS systems)
 - 5) Load power factor (inverters and UPS systems)
 - 6) Ripple voltage (battery chargers and UPS systems)
 - 7) Harmonic distortion (inverters only)
 - 8) Duration of power interruptions
 - 9) Contact chatter limits for relays and contactors
- c) Surge withstand capability
- d) Reverse dc current flow prevention (chargers only and UPS) (optional feature; user to specify if this feature is required)
- e) Characteristics of auxiliary equipment (if used), including the following:

- 1) Transfer switches (functional operation, e.g., transfer time, high- and low-voltage actuation, and overcurrent actuation)
- 2) Inverter's input rectifier (same input conditions as battery charger)
- 3) Isolating device (blocking and conducting function). IEEE Std 384™ provides specific details related to isolation devices and qualification of isolation devices.
- 4) Alternate source transformer and regulator (input conditions and output requirements)
- 5) External annunciating relays (voltage, load)
- f) Other performance characteristics as required by owner/purchaser specifications

4.2.2 Description of the safety function of Class 1E charger or inverter

The safety function(s) of the equipment (including required operating time) shall be specified for applicable service and DBE conditions expected during its qualified life.

4.2.3 Qualified life objective (where applicable)

The equipment qualified life objective shall be specified along with the set of service conditions under which successful performance must be demonstrated before, during, and after a DBE as applicable.

4.3 Environment

All significant environmental parameters shall be specified in the owner's specification. The range of environmental conditions shall include, as a minimum, normal and abnormal conditions and durations, as well as DBE and post-DBE conditions.

Where applicable, the equipment specification shall include numerical values for the magnitude and duration of the following service conditions:

- a) Minimum and maximum temperature, including profiles if available
- b) Minimum and maximum storage temperature
- c) Maximum relative humidity (operating and storage)
- d) Altitude (static air pressure)
- e) Operational vibration
- f) Seismic requirements
- g) Nuclear radiation type
- h) Irradiation (dose rate and total dose)
- i) Radio frequency interference (RFI) and/or electromagnetic interference (EMI) levels (i.e., the effects of the charger, inverter, or UPS systems on other equipment or vice versa) as defined in NRC Reg. Guide 1.180, Revision 1 [B19]. Regulatory Guide 1.180 recommends using MIL-STD-461E [B18] and IEC Std 61000-4-series to perform electromagnetic compatibility (EMC) testing. Information on EMI/RFI and surge voltages are also given in IEC 62003 [B5], IEC 62040-2 [B6], EPRI 102323 [B3], and IEEE P2425 [B16].

4.4 Other conditions

Where applicable, the equipment specifications shall include the following:

- a) Any significant rate of change or combinations of specified performance and environmental limits listed in 4.2 and 4.3
- b) The expected total number of operating cycles or operating time period for the electromechanical devices (including periodic testing cycles)
- c) Unusual atmospheric contamination (dust, oil, fungus, chemical or water spray, etc.)
- d) Electrical and mechanical interfaces (input and output connections, mounting, voltages, currents, etc.) between the Class 1E equipment to be qualified and other equipment or devices
- e) Dielectric test parameters

5. Qualification

The qualification of Class 1E static battery chargers, inverters, and UPS systems shall be established by analysis and test as outlined in this clause. Figure 1 provides a pictorial overview.

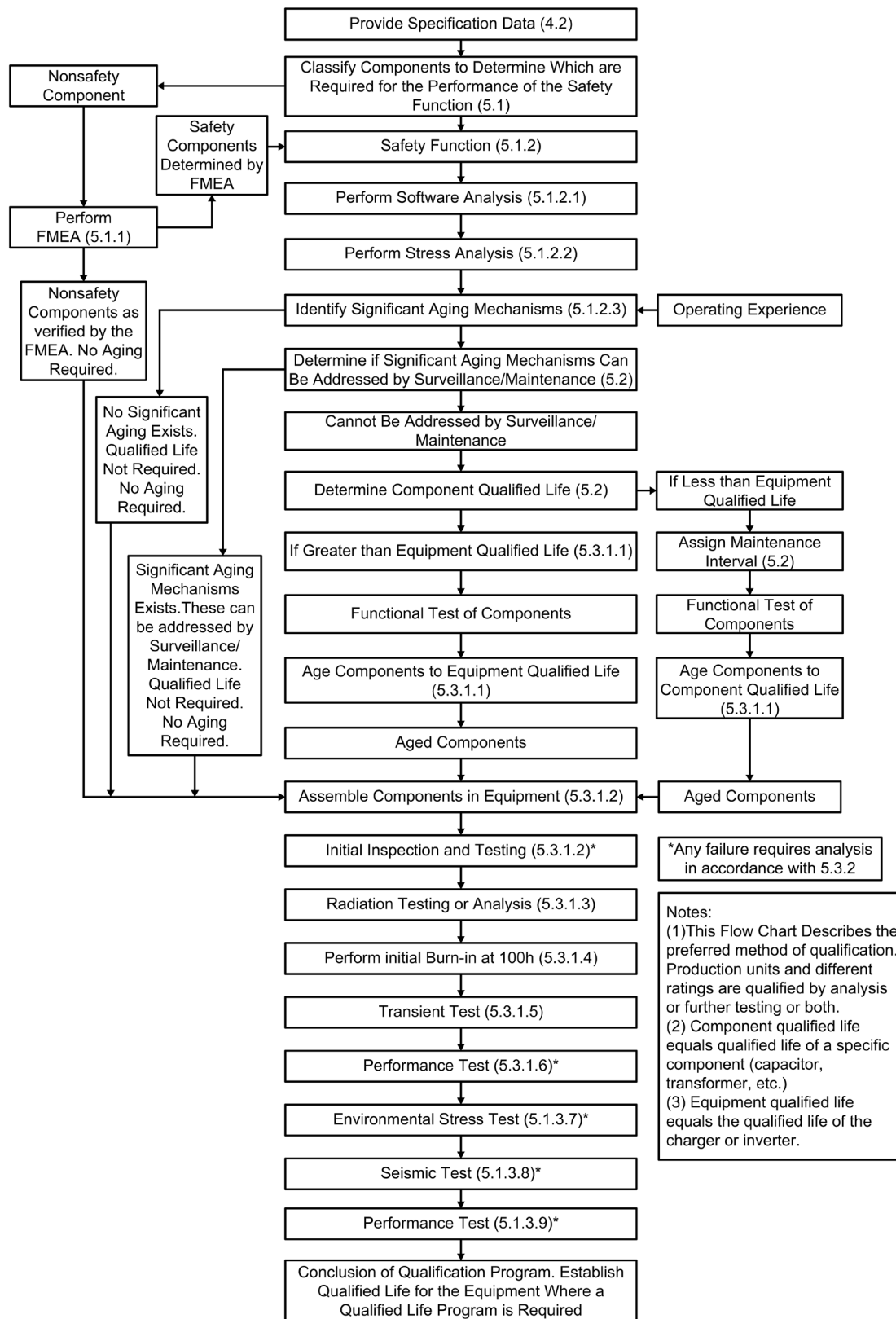


Figure 1—Flowchart for qualification of Class 1E static battery chargers, inverters, and UPS systems