

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

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Abstract: Methods for qualifying static battery chargers and inverters for Class 1E installations in a mild environment outside containment in nuclear power generating stations are described. The qualification methods set forth employ a combination of type testing and analysis, the latter including a justification of methods, theories, and assumptions used. These procedures meet the requirements of IEEE Std 323-1983, *IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations*.

Keywords: battery charger, inverter, qualification.

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Foreword

(This Foreword is not a part of IEEE Std 650-1990, IEEE Standard for Qualification of Class 1E Static Battery Chargers and Inverters for Nuclear Power Generating Stations.)

This standard provides the methods of qualifying class 1E static battery chargers and inverters in accordance with IEEE Std 323-1983, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations. The static battery chargers and inverters 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 guidelines of IEEE Std 381-1977, IEEE Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations, have been utilized for aging complex electronic equipment. The reliability analysis requirements of IEEE Std 577-1976, IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations, and the methods described in IEEE Std 352-1987, IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems, have also been utilized along with statistical data.

The efforts of the working group on this standard and its appendixes 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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1. Scope and Purpose

1.1 Scope

This standard describes methods for qualifying static battery chargers and inverters for Class 1E installations in a mild environment outside containment in nuclear power generating stations. 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 308–1980 [9]¹, IEEE Std 603–1980 [18], and IEEE Std 946–1985 [19], exist for this purpose. In addition, industry standards exist for equipment performance, such as ANSI/NEMA PE 5–1985 [3]. Performance requirements are not specified in this standard.

1.2 Purpose

The purpose of this standard is to provide specific procedures to meet the requirements of IEEE Std 323–1983 [10]. For the purpose of this standard, battery chargers and inverters must perform their safety function under specified service conditions.

The demonstration that an installed battery charger or inverter 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.

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, battery chargers and inverters

¹The numbers in brackets correspond to those of the references in Section 2

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. References

- [1] ANSI/EIA 401–73 (R 79) (R 83), Paper, Paper/Film, Film Dielectric Capacitors for Power Semiconductor Applications.²
- [2] ANSI/EIA 454–78, Fixed Paper and Film-Paper Dielectric Capacitors with Non-PCB Impregnants for Alternating Current Applications.
- [3] ANSI/NEMA PE 5–1985, Utility Battery Chargers.³
- [4] EPRI NP-3326, Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components—Phase 1, December 1983.⁴
- [5] EPRI NP-5024, Correlation Between Aging and Seismic Qualification for Nuclear Plant Electrical Components—Phase 2, January 1987
- [6] IEEE Std 100–1984, IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).⁵
- [7] IEEE Std 101–1987, IEEE Guide for the Statistical Analysis of Thermal Life Test Data (ANSI).
- [8] IEEE Std 259–1974 (Reaf 1980), IEEE Standard Test Procedures for Evaluation of Systems of Insulation for Specialty Transformers.
- [9] IEEE Std 308–1980, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations (ANSI).
- [10] IEEE Std 323–1983, IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations (ANSI).
- [11] IEEE Std 338–1987, IEEE Standard Criteria for the Periodic Testing of Nuclear Power Generating Station Safety Systems (ANSI).
- [12] IEEE Std 344–1987, IEEE Recommended Practices for Seismic Qualification of Class 1E Equipment for Nuclear Generating Stations (ANSI).
- [13] IEEE Std 352–1987, IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Protection Systems (ANSI).
- [14] IEEE Std 381–1977 (Reaf 1984), IEEE Standard Criteria for Type Tests of Class 1E Modules Used in Nuclear Power Generating Stations (ANSI).
- [15] IEEE Std 382–1985, IEEE Standard for Qualification for Actuators for Power Operated Valve Assemblies with Safety-Related Functions for Nuclear Power Generating Stations (ANSI).

²EIA publications are available from the Electronic Industries Association, Engineering Department, 2001 Eye Street NW, Washington, DC 20006, USA.

³NEMA publications are available from the National Electrical Manufacturers Association, 2101 L Street NW, Washington, DC 20037, USA.

⁴EPRI reports are available from the Research Reports Center (RRC), P.O. Box 50490, Palo Alto, CA 94303, USA.

⁵IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[16] IEEE Std 383–1974 (Reaf 1980), IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations (ANSI).

[17] IEEE Std 577–1976 (Reaf 1986), IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Power Generating Stations (ANSI).

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

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

3. Definitions

All definitions, except as specifically covered in this section, shall be in accordance with IEEE Std 100–1984 [6].

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

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

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

inverter: Equipment that converts dc power to ac power. 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.

mild environment: An environment expected as a result of normal service conditions and extremes (abnormal) in service conditions where seismic is the only design-basis event (DBE) of consequence.

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

qualification: The generation and maintenance of evidence to ensure that the equipment can operate on demand to meet the system performance requirements.

qualified life: The period of time, prior to the start of a design-basis event, for which equipment was demonstrated to meet the design requirements for the specified service conditions.

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 and post-design-basis events (IEEE Std 323–1983 [10]). In mild environments, 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.

4. Specifications

4.1 General

This section 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 Section 3, their values shall be identified.

4.2 Class 1E Performance Characteristics and Safety Function

The required Class 1E performance characteristics and the safety function shall be specified by those responsible for the design application of the equipment, and shall include, as a minimum, numerical values and durations for normal, abnormal, design-basis event (DBE), and post-design-basis event conditions, as indicated in 4.2.1–4.2.3.

4.2.1 Class 1E Performance Characteristics

- 1) Input conditions, such as
 - a) Voltage
 - b) Frequency
 - c) Phase
- 2) Output requirements, such as
 - a) Voltage and voltage regulation
 - b) Current (minimum and maximum)
 - c) Current limit
 - d) Frequency and frequency regulation (inverters only)
 - e) Load power factor (inverters only)
 - f) Ripple voltage (battery chargers only)
 - g) Harmonic distortion (inverters only)
- 3) Surge withstand capability
- 4) Reverse dc current flow prevention (chargers only)
- 5) Characteristics of auxiliary equipment (if used), including
 - a) Transfer switches (functional operation, e.g., transfer time, high and low voltage actuation, and overcurrent actuation)
 - b) Inverter's input rectifier (same input conditions as battery charger)
 - c) Isolating device (blocking and conducting function)
 - d) Alternate source transformer and regulator (input conditions and output requirements)

4.2.2 Description of the Safety Function of Class 1E Charger or Inverter

4.2.3 Qualified Life Objective

(where 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 design-basis event and post-design-basis event conditions.

4.3.1

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

- 1) Minimum, maximum, and annual average ambient temperature
- 2) Minimum and maximum storage temperature
- 3) Maximum relative humidity (operating and storage)
- 4) Altitude

- 5) Operational vibration
- 6) Seismic requirements
- 7) Nuclear radiation type
- 8) Irradiation (dose rate and total dose)
- 9) Radio frequency interference (RFI) or electromagnetic interference (EMI) levels (i.e., the effects of the charger or inverter on other equipment, or vice versa)

4.4 Other Conditions

Where applicable, the equipment specifications shall include

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

5. Qualification Methods

The qualification of Class 1E static battery chargers and inverters shall be determined by the qualification program outlined in this section. See Fig 1 for flow chart.

5.1 Analytical Requirements

An analysis shall be performed on all components within the charger or inverter to determine which components are required for the performance of its safety function and which components are not.

5.1.1 Nonsafety Component Analysis

A failure modes and effects analysis (FMEA) shall be performed, in accordance with Section 4.2 of IEEE Std 577–1976 [17]⁶, on all components presumed to be nonsafety components. The FMEA shall demonstrate that the failure of these components, as used in the circuit throughout the qualified life of the equipment, does not affect the ability of the charger or inverter to perform its safety function (see 4.2.2) or, by way of interfaces, does not affect the safety functions of other equipment. The nonsafety components shall be assembled into the sample equipment without additional analysis or testing. Any component whose failure is determined to affect the ability of the charger or inverter to perform its safety function by the FMEA shall be considered a safety component, and is addressed in 5.1.2.

5.1.2 Safety Component Analysis

Components designated as safety components are those whose failure affects the ability of the charger or inverter to perform its safety function or, by way of interfaces, affects the safety function of other equipment. They shall be analyzed in accordance with the requirements of this section.

⁶For guidance in performing an FMEA, consult IEEE Std 352–1987 [13].

5.1.2.1 Stress Analysis

An essential part of the qualification of this equipment is to verify the integrity of its design. Thus, as part of the qualification process, a stress analysis of the equipment shall be performed to assure that no electrical component is stressed to a point where its aging is accelerated beyond that expected in operation. Should any components be overstressed, a redesign shall be performed to correct this condition. Appendix A provides background information on this topic, as well as an example of a stress analysis.

5.1.2.2 Component Classification

All safety components within the charger or inverter shall be classified as either components for which aging is not a significant failure mechanism or components for which aging is a significant failure mechanism. An aging mechanism is significant if, in the normal and abnormal service environment, it causes degradation during the installed life of the equipment that progressively and appreciably renders the equipment vulnerable to failure to perform its safety function(s) under DBE conditions (see Section 6.2.1 of IEEE Std 323–1983 [10]). Operating experience, testing, and analysis may be utilized in this classification process.