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Nuclear power plants - Instrumentation, control and electrical power systems - Requirements for static uninterruptible DC and AC power supply systems

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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Nuclear power plants - Instrumentation, control and electrical power systems - Requirements for static uninterruptible DC and AC power supply systems

FOREWORD

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IEC 61225 has been prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation. It is an International Standard.

This fourth edition cancels and replaces the third edition published in 2019. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) expansion and clarification of the requirements for static uninterruptible DC and AC power supply systems to ease the application in SMRs and passive designs.

This International Standard is to be used in conjunction with IEC 61513:2011, IEC 60709:2018, IEC 60880:2006, IEC 62138:2018, IEC 62855:2016 and IEC 63046:2020.

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

Draft	Report on voting
45A/1591/FDIS	45A/1610/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 ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, 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 committee has 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- withdrawn, or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

The 1993 issue of IEC 61225 was developed for specifying the requirements relevant to the design of electrical supplies for I&C systems in nuclear power plants. Considering the experience gathered worldwide on this subject, in 2003 working group A2 recommended a revision to this document to allow a new revision, IEC 61225 Ed. 2 (2005), to be consistently integrated into the SC 45A standard series. In 2015, working group A11 recommended a revision to this document following the publication of the revision of IAEA SSG-34 and that the scope of the standard should cover static uninterruptible power supplies for all types of connected equipment. In 2022, working group A11 recommended a revision to this document to ease the application to SMRs and passive designs.

International operating experience with electrical supply systems in nuclear power plants has highlighted a number of supply voltage variations and malfunctions, such as:

- voltage perturbations due to disturbances on the internal AC distribution system (with origin off-site or on-site).
- voltage overshoot on loss of grid.
- open phase conditions (one or two phases).
- asymmetrical faults.

These types of perturbations can degrade the performance of static uninterruptible power supplies and ultimately result in failure of connected equipment.

One of the objectives of the uninterruptible power supplies is to protect connected equipment from voltage variations on the on-site AC interruptible distribution system (the immunity concept). The power supplies also guarantee an output voltage with specified magnitude and waveform (in case of AC) to connected loads. The power supplies have the capacity to supply the relevant loads during a specified time regardless of any voltage variations on the on-site AC interruptible distribution system.

Examples of voltage and frequency variations in the incoming feeder to the supplies can be found in informative Annex A. Examples of specifications for static uninterruptible power supplies can be found in informative Annex B. Requirements for SMRs and passive designs are given in Annex C.

This document is applicable to the design of static uninterruptible electrical power supplies in new nuclear power plants (including SMRs and passive designs) when design work is initiated after the publication of this document and in general for nuclear facilities. It also serves as a reference for upgrading and modernizing existing nuclear power plants and facilities.

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

IEC 61225 is a second level document specifically addressing the particular topic of requirements for electrical supplies.

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

c) Recommendations and limitations regarding the application of this document

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 top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046. IEC 61513 provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 63046 provides general requirements for electrical power systems of NPPs; it covers power supply systems including the supply systems of the I&C systems. IEC 61513 and IEC 63046 are to be considered in conjunction and at the same level. IEC 61513 and IEC 63046 structure the IEC SC 45A standard series and shape a complete framework establishing general requirements for instrumentation, control and electrical systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general topics related to the categorization of functions and the classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, cybersecurity, software and hardware aspects for programmable digital systems, coordination of safety and security requirements and management of ageing. The standards referenced directly at this second level should be considered together with IEC 61513 and IEC 63046 as a consistent document set.

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

A fourth level extending the IEC SC 45 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 requirements SSR-2/1, 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 and the implementing guide NSS17 for computer security at nuclear facilities. The safety and security terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

IEC 61513 and IEC 63046 have adopted a presentation format similar to the basic safety publication IEC 61508 with an overall life-cycle framework and a system life-cycle framework. Regarding nuclear safety, IEC 61513 and IEC 63046 provide the interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. In this framework IEC 60880, IEC 62138 and IEC 62566 correspond to IEC 61508-3 for the nuclear application sector. IEC 61513 and IEC 63046 refer to ISO as well as to IAEA GS-R 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 and IEC 62342 is the entry document for the ageing management standards.

NOTE It is assumed that for the design of I&C systems in NPPs that implement conventional safety functions (e.g. to address worker safety, asset protection, chemical hazards, and process energy hazards) international or national standards are applied.

1 Scope

This document specifies the performance and the functional characteristics of the low voltage static uninterruptible power supply (SUPS) systems in a nuclear power plant (NPP) and, when applicable, in nuclear facilities in general. An uninterruptible power supply (UPS) is an electrical equipment which draws electrical energy from a source, stores it, and maintains the supply in a specified form by means inside the equipment to output terminals. A SUPS has no rotating parts to perform its functions.

The specific design requirements for the components of the power supply system are covered by IEC standards and other standards listed in the normative references. Otherwise, specific component-level design requirements are outside the scope of this document.

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 60038, *IEC standard voltages*

IEC 60146-1-1, *Semiconductor converters – General requirements and line commutated converters – Part 1-1: Specification of basic requirements*

IEC 60146-2, *Semiconductor converters – Part 2: Self-commutated semiconductor converters including direct d.c. converters*

IEC 60364-4-41, *Low voltage electrical installations – Part 4-41: Protection for safety – Protection against electric shock*

IEC 60709, *Nuclear power plants – Instrumentation, control and electrical power systems important to safety – Separation*

IEC 61000 (all parts), *Electromagnetic compatibility (EMC)*

IEC 61513, *Nuclear power plants – Instrumentation and control important to safety – General requirements for systems*

IEC 62003, *Nuclear power plants – Instrumentation, control and electrical power systems – Requirements for electromagnetic compatibility testing*

IEC 62040 (all parts), *Uninterruptible power systems (UPS)*

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

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

3 Terms and definitions

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

NOTE Other terms not defined below are defined in IAEA Safety Guides SSG-34 and SSG-39.

ISO and IEC maintain terminological 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

3.1
anticipated operational occurrence
AOO
deviation of an operational process from normal operation that is expected to occur at least once during the operating lifetime of a facility but which, in view of appropriate design provisions, does not cause any significant damage to items important to safety or lead to accident conditions

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.2
battery charger
electrical item used to convert AC into DC to charge batteries and to supply power to DC loads during normal operation

Note 1 to entry: The battery charger provides transformer isolation of the DC output from the AC input and is equipped with regulation and monitoring.

[SOURCE: IEEE 946, 2004]

3.3
common cause failure
CCF
failure of two or more structures, systems or components due to a single specific event or cause

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.4
common mode failure
CMF
failure of two or more structures, systems or components in the same manner or mode due to a single specific event or cause

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.5
diversity
presence of two or more independent (redundant) systems or components to perform an identified function, where the different systems or components have different attributes so as to reduce the possibility of common cause failure, including common mode failure

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.6
division
collection of items, including their interconnections, that form one redundancy of a redundant system or safety group

Note 1 to entry: Divisions can include multiple channels.

Note 2 to entry: Designation that enables the establishment and maintenance of physical, electrical, and functional independence from other redundant sets of items.

[SOURCE: IAEA SSG-39, 2016]

3.7
item important to safety
item that is part of a safety group and/or whose malfunction or failure could lead to radiation exposure of the site personnel or members of the public

Note 1 to entry: Items important to safety include those structures, systems and components whose malfunction or failure could lead to undue radiation exposure of site personnel or members of the public;

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.8
plant states

<table>
<tr><th colspan="2">Operational states</th><th colspan="3">Accident conditions</th></tr>
<tr><td rowspan="2">Normal operation</td><td rowspan="2">Anticipated operational occurrences</td><td rowspan="2">Design basis accidents</td><td colspan="2">Design extension conditions</td></tr>
<tr><td>Without significant fuel degradation</td><td>With core melting</td></tr>
</table>

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.9
redundancy
provision of alternative (identical or diverse) structures, systems and components, so that any single structure, system or component can perform the required function regardless of the state of operation or failure of any other

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.10
single failure
failure which results in the loss of capability of a single system or component to perform its intended safety function(s), and any consequential failure(s) which result from it

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

3.11
single failure criterion
criterion (or requirement) applied to a system such that it must be capable of performing its task in the presence of any single failure

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 (Interim) Edition]

4 Abbreviated terms

AC	alternating current
CCF	common cause failure
CMF	common mode failure
DC	direct current
EMC	electromagnetic compatibility
EMP	electromagnetic pulse
I&C	instrumentation and control
IGBT	insulated-gate bipolar transistor
NPP	nuclear power plant
SMR	small modular reactor
SUPS	static uninterruptible power supply
UPS	uninterruptible power supply

5 System requirements

5.1 General

This document defines requirements for reliable and robust SUPS systems in nuclear facilities including NPPs. In general, more stringent criteria are applied to items important to safety, such as power supplies, requiring additional verifications. However, the entire on-site and off-site power systems contribute to the reliability and robustness of the nuclear facilities power system. The same requirements should be applied to SUPS systems regardless of their importance to safety with a graded approach to verification and validation.

For SMRs and power plants with passive designs, the term "(highly) reliable power supply" is often used instead of "power supply important to safety". Provisions for power supplies important to safety apply in general for a reliable power system. These supplies are required for monitoring and actuation (if necessary) of systems important to safety.

Robust power supply systems shall have sufficient margins and built-in conservatism to ensure that:

- equipment ratings, capabilities and capacities required to meet intended goals are not exceeded during all postulated conditions considered in the safety case;
- equipment protection set points are selected to accommodate anticipated perturbations in the nuclear facility's electrical distribution system during all modes of operation and plant states;
- the equipment has the capacity and capability to support emergency operations.

The design of the power supplies shall include analysis of:

- transient, dynamic, and quasi-stationary variations in voltage and frequency (in case of AC power source);
- power interruptions on the incoming feeder (see 5.2.2) (or voltage or frequency dips exceeding the allowed dynamic variation range) lasting from milliseconds up to extended loss of all AC interruptible power supplies;
- asymmetrical conditions;
- independence of redundant parts of the power supply system and resilience against common cause failures (CCFs).