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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Centrales nucléaires de puissance – Systèmes d'instrumentation, de contrôle-commande et d'alimentation électrique – Exigences pour les systèmes d'alimentation en courant alternatif et en courant continu statiques sans interruption

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

NUCLEAR POWER PLANTS – INSTRUMENTATION, CONTROL AND ELECTRICAL POWER SYSTEMS – REQUIREMENTS FOR STATIC UNINTERRUPTIBLE DC AND AC POWER SUPPLY SYSTEMS

FOREWORD

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

This third edition cancels and replaces the second edition published in 2005. This edition constitutes a technical revision.

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

a) the principal objective of this edition is to address the requirements on the static uninterruptible power supplies in nuclear power plants;
b) in addition to Instrumentation and Control (I&C) power supplies include all static uninterruptible power supplies;

c) emphasize that the static uninterruptible power supplies shall protect the connected equipment (loads) from transients on the on-site AC distribution system (the immunity concept);

d) in accordance with the defence-in-depth concept, this standard applies to static uninterruptible power supplies for all equipment, not only for equipment important to safety, with a graded approach to verification and validation;

e) addition of the requirement that, when batteries are connected in parallel under abnormal operating conditions, they shall be properly protected with isolation devices to avoid any failure that may impair more than one division of the uninterruptible power supply.

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

FDIS	Report on voting
45A/1235/FDIS	45A/1250/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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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 standard so that a new revision, IEC 61225 Ed. 2 (2005), could be consistently integrated into the SC 45A standard series. In 2015, working group A11 recommended a revision to this standard 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.

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

This standard is applicable to the design of static uninterruptible electrical power supplies in new nuclear power plants, when design work is initiated after the publication of this standard. It also serves as a reference for upgrading and modernizing existing nuclear power plants.

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 standard

This standard is to be applied in conjunction with IEC 61513, IEC 60709, IEC 60880, IEC 62138, IEC 62855 and IEC 63046 (to be published).

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 categorization of functions and 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 1 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, process energy hazards) international or national standards would be applied.

NOTE 2 IEC/SC 45A domain was extended in 2013 to cover electrical systems. In 2014 and 2015 discussions were held in IEC/SC 45A to decide how and where general requirements for the design of electrical systems were to be considered. IEC/SC 45A experts recommended that an independent standard be developed at the same level as IEC 61513 to establish general requirements for electrical systems. Project IEC 63046 is now launched to cover this objective. When IEC 63046 is published, this NOTE 2 of the introduction of IEC/SC 45A standards will be suppressed.

NUCLEAR POWER PLANTS – INSTRUMENTATION, CONTROL AND ELECTRICAL POWER SYSTEMS – REQUIREMENTS FOR STATIC UNINTERRUPTIBLE DC AND AC POWER SUPPLY SYSTEMS

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 and, for applicable parts, in general for nuclear facilities. An uninterruptible power supply is an electrical equipment which draws electrical energy from a source, stores it and maintains supply in a specified form by means inside the equipment to output terminals. A static uninterruptible power supply (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 standards listed in the normative references and are otherwise 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/IEEE 60780-323, *Nuclear power plants – Electrical equipment important to safety – Qualification*

IEC 60880, *Nuclear power plants – Instrumentation and control systems important to safety – Software aspects for computer-based systems performing category A functions*

IEC 60980, *Recommended practices for seismic qualification of electrical equipment of the safety system for nuclear generating stations*

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

IEC 61508 (all parts), *Functional safety of electrical/electronic/programmable electronic safety-related systems*

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

IEC 62003, *Nuclear power plants – Instrumentation and control important to safety – Requirements for electromagnetic compatibility testing*

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

IEC 62138, *Nuclear power plants – Instrumentation and control systems important to safety – Software aspects for computer-based systems performing category B or C functions*

IEC 62566, *Nuclear power plants – Instrumentation and control important to safety – Development of HDL-programmed integrated circuits for systems performing category A functions*

IEC 62566-2, *Nuclear power plants – Instrumentation and control important to safety – Development of HDL-programmed integrated circuits – Part 2: HDL-programmed integrated circuits for systems performing category B or C functions* (to be published)

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: Source IAEA Safety Glossary, 2016 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
failures of two or more structures, systems and components due to a single specific event or cause

[SOURCE: IAEA Safety Glossary, 2016 edition]

3.4
diversity
the 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 Safety Glossary, 2016 edition]

3.5
division
collection of items, including their interconnections, that form one redundancy of a redundant system or safety group

Note 1 to entry: Divisions may 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]

3.6
plant states

Operational states		Accident conditions		
Normal operation	Anticipated operational occurrences	Design basis accidents	Design extension conditions	
			Without significant fuel degradation	With core melting

[SOURCE: IAEA Safety Glossary, 2016 edition]

3.7
redundancy
provision of alternative (identical or diverse) structures, systems and components, so that any one can perform the required function regardless of the state of operation or failure of any other

[SOURCE: IAEA Safety Glossary, 2016 edition]

3.8
safety related system
system important to safety that is not part of a safety system

[SOURCE: IAEA Safety Glossary, 2016 edition]

3.9
safety system
system important to safety, provided to ensure the safe shutdown of the reactor or residual heat removal from the core, or to limit the consequences of anticipated operational occurrences and design basis accidents

[SOURCE: IAEA Safety Glossary, 2016 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 Safety Glossary, 2016 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 Safety Glossary, 2016 edition]

3.12
station blackout
SBO
plant condition with complete loss of all AC power from off-site sources, from the main generator and from standby AC power sources

Note 1 to entry: Uninterruptible DC and AC power supplies may be available as long as batteries can supply the loads.é

Note 2 to entry: Alternate AC supplies according to IAEA SSG-34 are available.

[SOURCE: IAEA SSG-34, 2016]

4 Abbreviated terms

AC	Alternating current
AOO	Anticipated operational occurrence
CCF	Common cause failure
DC	Direct current
EMC	Electromagnetic compatibility
I&C	Instrumentation and control
IGBT	Insulated-Gate Bipolar Transistor
NPP	Nuclear Power Plant
SBO	Station blackout
SSC	Structures, systems and components
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 power plants (NPPs). Even though more stringent criteria are applied to safety power supplies and more verification is necessary, the entire onsite and off-site power systems contribute to the reliability and robustness of the NPP power systems. It is recommended that the same requirements are applied to SUPS systems regardless of safety classification with a graded approach to verification and validation.

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;

- equipment protection set points are selected to accommodate anticipated perturbations in the NPP electrical distribution system during all modes of operation;
- 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 (or voltage / frequency dips exceeding the allowed dynamic variation range) lasting from milliseconds up to SBO conditions;
- asymmetrical conditions.

5.2 Function and description

5.2.1 Preamble

The SUPS system shall provide a continuous uninterruptible supply to each connected load within the specified tolerances of voltage, and (for AC systems) waveform and frequency for all input conditions.

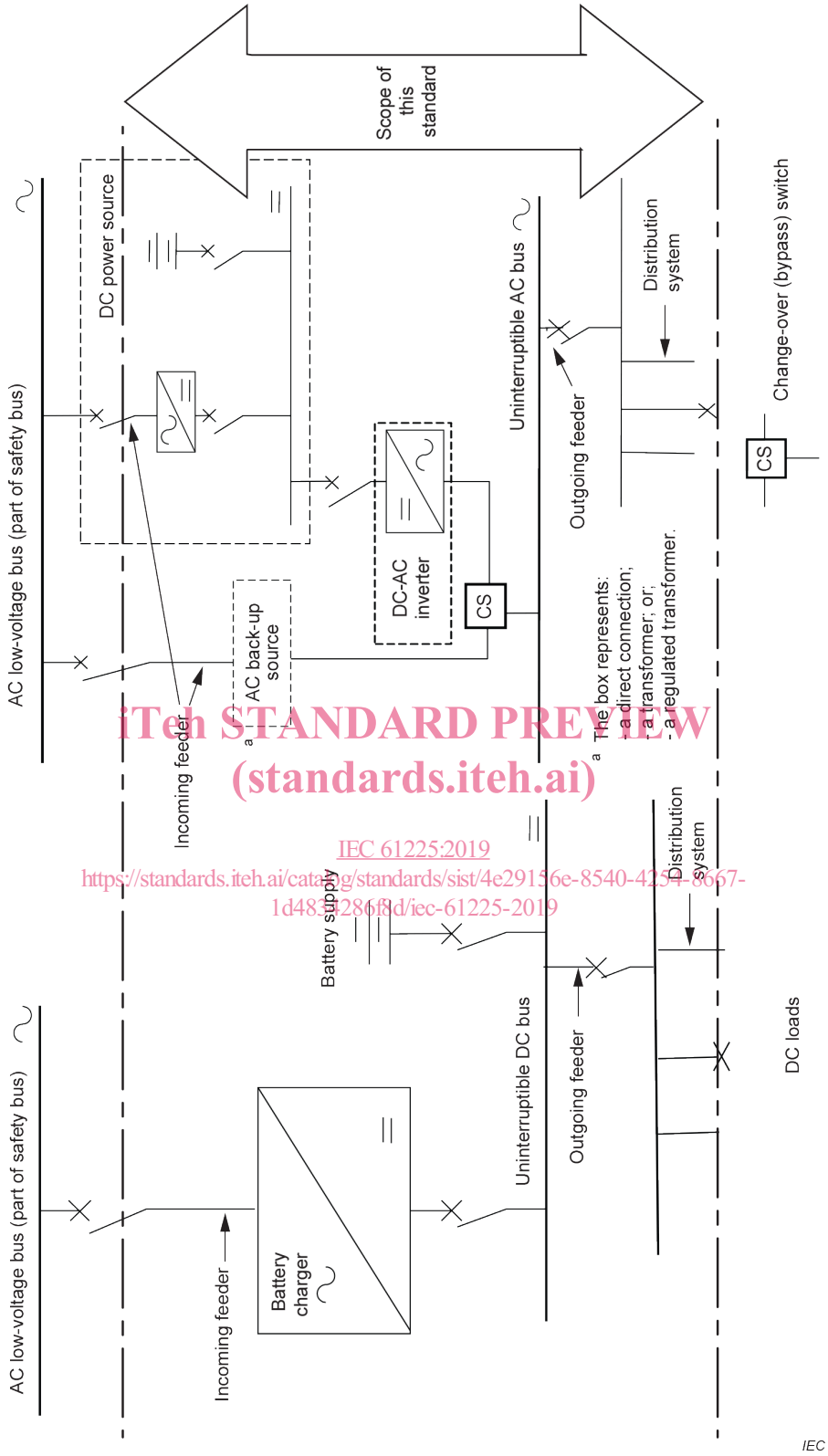
SUPS generally consists of one or both of the following systems (see Figure 1):

- a DC power system with battery chargers and batteries, supplying DC loads;
- an AC power system with battery chargers, back-up batteries, static switches and inverters, supplying AC loads.

In certain designs the battery chargers and batteries could be common to both the DC and AC power system.

The functions and the classification of the power supplies should be designated according to the safety classification scheme of the NPP. In general, the classification should be based on the highest classification of the load supplied by the power supply as discussed in 7.2.

The constraints on connecting loads with different classifications are discussed in 8.5.



DC/DC converters, AC/DC converters and converters for voltage stabilization are not shown. Uninterruptible AC power supply can also be provided by an UPS. An UPS is normally an integrated assembly of battery charger, battery and inverter as shown on the right-hand side of the figure.

Figure 1 – System boundary