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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Nuclear power plants – Electrical power systems – Electrical power systems analysis

Centrales nucléaires de puissance – Systèmes d'alimentation électrique – Analyse des systèmes d'alimentation électrique

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Nuclear power plants – Electrical power systems – Electrical power systems analysis

Centrales nucléaires de puissance – Systèmes d'alimentation électrique – Analyse des systèmes d'alimentation électrique

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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NUCLEAR POWER PLANTS – ELECTRICAL POWER SYSTEMS – ELECTRICAL POWER SYSTEMS ANALYSIS

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 62855 has been prepared by subcommittee 45A: Instrumentation, control and electrical systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

The text of this document is based on the following documents:

FDIS	Report on voting
45A/1094/FDIS	45A/1100/RVD

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

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

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

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

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INTRODUCTION

a) Technical background, main issues and organisation of the Standard

The principal function of the electrical power system is to support the safe operation of a nuclear power plant (NPP) in all modes of operation. A subset of the electrical power system is essential for supporting nuclear safety functions at various voltage levels. This subset is critical for all plant states and events requiring plant cool-down in a controlled manner. A reliable power system is critical for maintaining control to power, control and monitor plant safety functions. This is required to support the barriers that prevent radiological releases during design basis accidents and design extension conditions.

International Standards and National safety codes provide guidance on acceptable requirements for safe and reliable operation of electrical distribution systems. Compliance with these safety codes and standards generally provides reasonable assurance for the correct electrical functionality and capability of these systems in the nuclear power plant (NPP).

The design basis of the electrical power systems in a NPP should be established by consideration of the following elements:

- nuclear design criteria, defence in depth approach, safety classification, design basis conditions (DBC) and design extension conditions (DEC);
- requirements for transmission system operating limits, grid safety, grid code, plant performance and operating limits;
- architecture and specification of the electrical power systems;
- sizing of main components and systems such as unit auxiliary and standby transformers, switchgear, cables, motors and standby alternating current (AC) and direct current (DC) power sources;
- load allocations and load power balance;
- load flow calculations;
- coordination of characteristics (voltage, current and short circuit current);
- support system requirements during postulated DBCs;
- design verification including verification analyses.

An example of design bases considerations for electrical power systems is provided in informative Annex A.

Guidelines and an example of analytical methods are detailed in informative Annex B. The relationship between analyses and verification of design bases and equipment specification is given in informative Annex C. An example of plant specific acceptance criteria (see 5.8) is given in informative Annex D.

It is intended that the Standard will be used by operators of NPPs (utilities), systems evaluators and by licensors.

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

IEC 62855 is a third level IEC SC 45A document covering the topic of electrical power systems analysis.

This standard supports the guidance provided in the IAEA Safety Guide SSG-34 related to the design of electrical power systems for nuclear power plants.

This standard is related to

- IAEA Nuclear Energy Series NG-T-3.8 dealing with electric grid reliability and interface with nuclear power plants, and
- IEC 61513 establishing general requirement for I&C systems important to safety used in nuclear power plants..

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

c) Recommendations and limitations regarding the application of this standard

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[1]. 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 NPP; 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 (NPP), the IAEA safety guide SSG-30 dealing with the safety classification of structures, systems and components in NPP, the IAEA safety guide SSG-39 dealing with the design of instrumentation and control systems for NPP, the IAEA safety guide SSG-34 dealing with the design of electrical power systems for NPP and the implementing guide NSS 17 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.

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1 Under preparation. Stage at the time of publication: IEC ANW 63046:2016.

IEC 61513 and IEC 63046 have adopted a presentation format similar to the basic safety publication IEC 61508 (all parts) 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-3 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 IEC 62443 (all parts). At level 2, regarding control rooms, IEC 60964 is the entry document for the IEC SC 45A control rooms standards, and IEC 62342 is the entry document for the IEC SC 45A 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 requirement 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 will be published this NOTE 2 of the introduction of IEC SC 45A standards will no longer be valid.

NUCLEAR POWER PLANTS – ELECTRICAL POWER SYSTEMS – ELECTRICAL POWER SYSTEMS ANALYSIS

1 Scope

IEC 62855 provides the electrotechnical engineering guidelines for analysis of AC and DC electrical power systems in nuclear power plants (NPPs) in order to demonstrate that the power sources and the distribution systems have the capability for safe operation and shut down of the NPP, bringing it to a controlled state after an anticipated operational occurrence or accident conditions and finally reaching a safe state.

The analytical studies discussed in this document provide assurance that the design bases are satisfied to meet their functional requirements under the conditions produced by the applicable design basis events. The studies provide assurance that the electrical power system is capable of supporting safety functions during all required plant conditions.

NOTE The safety functions are described in IAEA Specific Safety Requirements SSR-2/1 related to the design of the nuclear power plants..

Analytical studies validate the robustness and adequacy of design margins and demonstrate the capability of electrical power systems to support plant operation for normal, abnormal, degraded and accident conditions.

The analyses are used to verify that the electrical power system can withstand minor disturbances and that the consequences of major disturbances or failures do not degrade the capability of the electrical power systems to support safe shutdown of the plant and maintain the plant in shutdown condition.

The analyses are performed with one or more of

- simulation tools (software and hardware) that have been verified and validated,
- hand calculations, and
- tests.

This document provides guidance on the types of analyses required to demonstrate that the plant's auxiliary power system can perform the required safety functions. This document does not provide specific details on how the analysis should be conducted.

This document does not cover digital controllers (such as controllers for rectifiers, inverters, sequencers and electrical protection devices) used in electrical power systems. IEC 61513 gives recommendations that apply to the electronic controls and protective elements of the electrical power systems.

This document does not include environmental conditions (i.e. temperature, humidity, etc.) or external events (seismic, flooding, fire, high energy electromagnetic pulse, etc.) that may impact equipment sizing or protection requirements. The external events lightning and geomagnetic storms are included.

This document does not cover additional or unique requirements for stand-alone power system, such as power supplies for security measures in NPPs. Pertinent clauses of this document may be used as a guideline for such systems.

Redundancy in the power system design can increase the availability of electrical power to critical plant equipment. Performing a probabilistic risk assessment (PRA) is a method of assessing system availability and optimizing design for high reliability. This document does not cover improving the reliability of NPP electrical power systems using statistical or diverse and redundant schemes.

Requirements for safeguards of personnel involved with installation, maintenance and operation of electrical systems and general personal safety are outside the scope of this document. General guidance for lightning protection of equipment is provided in relevant clauses of this document.

This document is intended to be used:

- for verification of the design of new nuclear power plants,
- for demonstrating the adequacy and impact of major modifications of electrical power systems in operating nuclear power plants, and
- where there is a requirement to assess and establish operating limits and constraints for existing plants.

Pertinent parts of this document can be used as guidance for decommissioning stages.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

There are no normative references in this document.

3 Terms and definitions

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

3.1
alternate AC source
power source reserved for the use for the power supply to the plant during total loss of all non-battery power in the safety power systems (station blackout) and other design extension conditions

Note 1 to entry: Figure A.2 gives a graphical representation.

3.2
house load operation
operation of a nuclear power plant to supply power only to its own electrical loads

3.3
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.

Design extension conditions include conditions in events without significant fuel degradation and conditions with core melting

[SOURCE: IAEA SSR-2/1:2012, definitions revised as DS462]

3.4
loss of off-site 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.

3.5
power balance
steady state active and reactive power required by the electrical power system

Note 1 to entry: This document provides the basis for sizing electrical equipment (switchboards, cables, power sources, transformers, batteries, rectifiers/inverters, etc.).

3.6
preferred power supply
power supply from the transmission system to the safety classified electrical power system, comprising transmission system, switchyard, main generator, distribution system up to the safety classified electrical power system

Note 1 to entry: Some portions of the preferred power supply are not part of the safety classification.

3.7
standby AC power source
power source, capable of supplying the necessary power in anticipated operational occurrences and accident conditions, in the event of the loss of off-site power and main generator

3.8
station blackout
plant condition with complete loss of all AC power from off-site sources, from the main generator and from standby AC power sources important to safety to the essential and non-essential switchgear buses

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

Note 2 to entry: Alternate AC supplies are available.

3.9
total harmonic distortion
ratio of the rms value of the harmonic content of an alternating quantity to the rms value of the fundamental component of the quantity

[SOURCE: 60050-551:1998, 17-06]

3.10
transmission system operator
party responsible for providing and operating networks for long-distance transmission of electricity as well as regional distribution and responsible to ensure the system security with a high level of reliability and quality

4 Symbols and abbreviations

AC	alternating current
AOO	anticipated operational occurrences
CCF	common cause failure
CMF	common mode failure
DBA	design basis accident

DBC	design basis conditions
DC	direct current
DEC	design extension conditions
EMC	electromagnetic compatibility
LOOP	loss of off-site power
NPP	nuclear power plant
PPS	preferred power supply
PRA	probabilistic risk assessment
QA	quality assurance
SSC	structures, systems and components
THD	total harmonic distortion.
TSO	transmission system operator
UPS	uninterruptible power supply
V&V	verification and validation

5 Electrical power system analyses

5.1 Overview of typical studies

5.1.1 Transient stability analyses

Grid disturbances, such as a short circuit on a transmission line, sudden loss of generation, or the loss of a large load, may cause instability. If such disturbances are not cleared rapidly, instability may ultimately lead to loss of parts or total loss of the preferred power supply.

Transient stability studies investigate the transient behaviour of the NPP generator after a disturbance on the electrical network in the vicinity of the plant. The study determines the capability of the generator to remain connected to the grid and studies the effects of the transient on the unit electrical power supply system.

5.1.2 Load flow studies

The different power balances are input data for the load flow studies. Load flow studies are performed to determine the steady-state operation of an electric power system. The study is used to establish

- the voltage drop on each feeder,
- the bus voltage,
- the load terminal voltage, and
- the power flow in all branch and feeder circuits.

The study is used to determine if system voltages remain within specified limits under all defined conditions.

5.1.3 Transient and dynamic studies

Transient studies determine the voltage, current, power and frequency in a power system when a fault or a disturbance occurs in an interconnected network. This may result from events such as starting and loading of standby power sources, starting and running of large motors and failures of voltage regulation for generators.

During and after such a disturbance, these dynamic studies