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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Electrical power systems – Coordination and interaction with electric grid

Centrales nucléaires – Systèmes d'alimentation électrique – Coordination et interaction avec le réseau électrique

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NUCLEAR POWER PLANTS – ELECTRICAL POWER SYSTEMS – COORDINATION AND INTERACTION WITH ELECTRIC GRID

FOREWORD

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IEC 63298 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.

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

Draft	Report on voting
45A/1529/FDIS	45A/1545/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- withdrawn, or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

Nuclear power plants (NPPs) need an electric grid for the dual purpose of exporting produced energy and for a reliable power source for start-up, operation, shutdown and emergency conditions.

Owing to the electrical size of the NPP compared to the electrical size of the electric grid, it may be a challenge to safely integrate the NPP into the electric grid.

Coordination between the electric grid and the NPP is becoming increasingly important as more countries adopt a liberal energy market and responsibilities are held by multiple stakeholders (e.g., production, transmission, distribution, and trading organizations).

The purpose of this document is to define the high-level requirements and recommendations for the coordination of NPPs and electric grids to ensure the appropriate interactions between the two entities.

The specific features of the NPP and electric grid that are in scope for this document are described in Annex A.

The requirement for coordination between the electric grid operators and NPP operators is described in WANO SOER 1999-1 which focusses on significant operating experience relating to the loss of connection to the electric grid at NPPs (this event being one of the major contributors to NPP core damage frequency).

IAEA Nuclear Energy Series, NG-T-3.8, *Electric Grid Reliability And Interface With Nuclear Power Plants* describes the characteristics of the electric grid that are required for the connection and successful operation of an NPP, as well as the characteristics of an NPP that are significant for the design and operation of the electric grid.

This document focuses on technical requirements, such as the data exchange between the NPP operators and the electric grid operators, the analyses carried out by both sides and the acceptance criteria.

This document also defines the coordination requirements to ensure that operating instructions for the electric grid and the NPP are developed to provide a means of safe and reliable operation.

This document also defines the requirements for the development of a framework for any specific tests that may be deemed necessary for the electric grid and the NPP, such as testing of NPP regulation capabilities and load rejection to house load operation tests.

Finally, this document provides guidance on the need for continuous coordination between the electric grid and NPP during the NPP's design life, on topics such as operation and maintenance, design modifications and changes to grid conditions.

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

This document is a second level document specifically addressing the topic of coordination between the NPP and electric grid.

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

This document is used in conjunction with IEC 61513, IEC 62855 and IEC 63046.

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 IEC SC 45A standard series comprises a hierarchy of four levels. The top-level documents of the IEC SC 45A standard series are IEC 61513 and IEC 63046.

IEC 61513 provides general requirements for instrumentation and control (I&C) systems and equipment that are used to perform functions important to safety in nuclear power plants (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 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 power systems for nuclear power plants.

IEC 61513 and IEC 63046 refer directly to other IEC SC 45A standards for general requirements for specific topics, such as categorization of functions and classification of systems, qualification, separation, defence against common cause failure, control room design, electromagnetic compatibility, human factors engineering, 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 requirements for specific equipment, technical methods, or activities. Usually these documents, which make reference to second-level documents for general requirements, 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, the IAEA safety guide SSG-51 dealing with human factors engineering in the design of NPPs and the implementing guide NSS42-G for computer security at nuclear facilities. The safety and security terminology and definitions used by the 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 9001 as well as to IAEA GSR 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, IEC 63351 is the entry document for the human factors engineering 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 TR 63400 provides a more comprehensive description of the overall structure of the IEC SC 45A standards series and of its relationship with other standards bodies and standards.

NUCLEAR POWER PLANTS – ELECTRICAL POWER SYSTEMS – COORDINATION AND INTERACTION WITH ELECTRIC GRID

1 Scope

1.1 General

The scope of this document is to provide high level requirements and recommendations for the coordination of NPPs and the electric grid; see also item a) of the Introduction.

The specific design requirements for components and equipment are covered by other specific IEC standards outside the scope of this document.

1.2 Use of this document

This document is intended to be used:

- for the design of new NPPs (including small modular reactors (SMRs), where applicable);
- for considering the adequacy and impact of major modifications to the electric grid for operating NPPs;
- for periodic design reviews of operating NPPs.

Pertinent parts of this document can be used as guidance for NPP operation and in general for nuclear facilities.

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 62855:2016*, Nuclear power plants – Electrical power systems – Electrical power systems analysis*

IEC 63046:2020*, Nuclear power plants – Electrical power system – General requirements*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
defence in depth
hierarchical deployment of different levels of diverse equipment and procedures to prevent the escalation of anticipated operational occurrences and to maintain the effectiveness of physical barriers placed between a radiation source or radioactive material and workers, members of the public or the environment, in operational states and, for some barriers, in accident conditions

Note 1 to entry: Five levels of defence in depth are discussed in IAEA SSR-2/1:2016:

a) The purpose of the first level of defence is to prevent deviations from normal operation and the failure of items important to safety.

b) The purpose of the second level of defence is to detect and control deviations from normal operation in order to prevent anticipated operational occurrences from escalating to accident conditions.

c) The purpose of the third level of defence is to prevent damage to the reactor core and releases of radioactive material requiring off-site protective actions and to return the plant to a safe state by means of inherent and/or engineered safety features, safety systems and procedures.

d) The purpose of the fourth level of defence is to prevent the progress of, and to mitigate the consequences of, accidents that result from failure of the third level of defence by preventing accident sequences that lead to large release of radioactive material or early release of radioactive material from occurring.

e) The purpose of the fifth and final level of defence is to mitigate radiological consequences of a large release of radioactive material or an early release of radioactive material that could potentially result from an accident.

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 edition]

3.2
distribution system operator
DSO
party responsible for providing and operating networks for distribution of electricity and responsible for ensuring system security with a high level of reliability and quality

3.3
electric grid
network of synchronized electrical generators and consumers that are connected by electric lines and operated by dedicated control center(s)

Note 1 to entry: The electric grid is composed of the national transmission system(s) and distribution system(s) to which the NPP is connected; within the scope of this document this term mostly refers to the part of electric grid that has "functional relevance to the NPP itself".

3.4
electric grid operator
organization operating the electric grid, which could be either the transmission system operator or distribution system operator depending on the relevant part of the electric grid

3.5
fault-ride-through
ability of generating units to ride through transmission system faults and stay connected to electric grid

3.6
frequency control
method of operating a generating unit at less than full output, under automatic control, so that its output increases automatically if the system frequency falls, and decreases automatically if the system frequency rises

[SOURCE: IAEA NP-T-3.23, 2018 edition, modified – The term "automatic frequency control/automatic frequency responsive operation" is replaced with "frequency control".]

3.7
grid code
document that describes the required technical characteristics, performance and operation of the transmission system and generating units, as defined by the TSO or government agency

[SOURCE: IAEA NG-T-3.8, 2012 edition]

3.8
house load operation
operation of a nuclear power plant to supply power only to its own electrical loads

[SOURCE: IEC 62855:2016, 3.2]

3.9
island operation
independent operation of a part of the electric grid after being disconnected from the rest of the electric grid having at least one generator supplying power and controlling the frequency and voltage

Note 1 to entry: The terms "house load operation" and "island operation" for an NPP are similar from a functional and control point of view, where house load operation is the smaller of the electric loads.

3.10
loss of off-site power
LOOP
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.

[SOURCE: IEC 62855:2016, 3.4, modified – The abbreviated term has been added.]

3.11
NPP operator
company or organization that is the operator of an NPP and which has the primary responsibility for the safe operation of the plant and will have to satisfy the requirements of the nuclear regulatory body in the country where the NPP is located

Note 1 to entry: For the scope of this document, NPP operator also includes an organization that has a license for the design and construction of an NPP that is not yet constructed or operating

[SOURCE: IAEA NP-T-3.23, modified – The term "nuclear power plant owner/operating organization" has been replaced with "NPP operator", the definition has been modified to form a single phrase, "nuclear power plant" has been replaced with "NPP" and the Note to entry added.]

3.12
probabilistic safety assessment
PSA
comprehensive, structured approach to identifying failure scenarios, constituting a conceptual and mathematical tool for deriving numerical estimates of risk

Note 1 to entry: Three levels of probabilistic safety assessment are generally recognized:

Level 1 comprises the assessment of failures leading to determination of the frequency of fuel damage.

Level 2 includes the assessment of containment response, leading, together with Level 1 results, to the determination of frequencies of failure of the containment and release to the environment of a given percentage of the reactor core's inventory of radionuclides.

Level 3 includes the assessment of off-site consequences, leading, together with the results of Level 2 analysis, to estimates of public risks.

[SOURCE: IAEA Nuclear Safety and Security Glossary, 2022 edition]

3.13
transmission system operator
TSO
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

[SOURCE: IEC 63046:2020, 3.51, modified – The abbreviated term has been added.]

4 Abbreviated terms

AC	Alternating current
CDF	Core damage frequency
DiD	Defence in depth
DSO	Distribution system operator
FCT	Fault clearance time
FMEA	Failure mode effect analysis
GIC	Geomagnetic induced currents
HV	High voltage
IAEA	International Atomic Energy Agency
LOOP	Loss of off-site power
NPP	Nuclear power plant
OPC	Open phase condition
PSA	Probabilistic safety assessment
SBO	Station black out
SMR	Small modular reactors
TSO	Transmission system operator

5 Contractual coordination

The first step in developing coordination between an NPP and electric grid operator is to set up an appropriate contractual framework or, in the initial phases, develop cooperation agreements.

The method chosen to achieve this will depend upon the rules of a specific country but generally there should be a contract for different levels of cooperation: preliminary joint studies, grid analyses and finally, a contract for the connection of the NPP to the electric grid and subsequent operation of the NPP.

Contractual arrangements shall clearly define, as a minimum:

– boundaries between the NPP and the electric grid;
– mutual responsibilities;
– technical conditions for connection of the NPP;
– references to valid operating procedures.

NOTE Boundaries between the NPP and the electric grid can include physical, operating, maintenance, etc.

6 Technical coordination

6.1 General

Technical coordination should take place between the NPP operator and the electric grid operators at all stages of operation including design, construction, operation and maintenance.

Technical coordination, based on agreed input data and analyses, should take place to check and verify that the mutual requirements of the NPP and electric grid are satisfied in accordance with agreed acceptance criteria.

The objective is to ensure that:

– the NPP will remain connected to the grid after disturbances, if the grid is within defined limits;
– the functionality of the NPP electrical system should not be impacted by the electric grid.

6.2 Conceptual design of the interface of the NPP with the electric grid

The NPP and electric grid operators, from first phases of conceptual design, shall:

a) Plan the new NPP generating units according to the planned demands of electric grid consumption and flexible operation requirements;
b) Check the electrical size of a new NPP in comparison with the available electric grid to be confident it will be possible to dispatch the produced energy;
c) Provide an assessment of the electric grid reliability based on electric grid operator data;
d) Run a preliminary version of the power system analysis relevant to the new NPP connection, based on electric grid operator data (power system analyses are specified in 6.5);
e) Design the scheme for connecting the NPP to the electric grid;
f) Carry out an initial assessment of the NPP compliance with electric grid parameters with regards to frequency/voltage ranges, regulation, and load rejection capabilities. This assessment should confirm that compliance with the electric grid requirements does not create nuclear safety constraints.