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TECHNICAL REPORT

colour inside

Nuclear Power plants – Instrumentation and control systems – Use of formal security models for I&C security architecture design and assessment

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NUCLEAR POWER PLANTS – INSTRUMENTATION AND CONTROL SYSTEMS – USE OF FORMAL SECURITY MODELS FOR I&C SECURITY ARCHITECTURE DESIGN AND ASSESSMENT

FOREWORD

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IEC TR 63415 has been prepared by subcommittee 45A: Instrumentation, control and electrical power systems of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
45A/1465/DTR	45A/1476/RVDTR

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 Technical Report 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- withdrawn,
- replaced by a revised edition, or
- amended.

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INTRODUCTION

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

Over the last twenty years, Instrumentation and Control (I&C) systems for nuclear facilities and Nuclear Power Plants (NPP) have progressed from using hard-wired, mostly analogue components to the versatile mostly digital systems. This progression to digital systems have enhanced design flexibility, and provides for increased acquisition of system performance data but also introduces susceptibility to cyber-attacks for the system itself and nuclear facility as a whole. The generally recognized solution of the I&C NPP security provision problem is to define security requirements as early as possible during the life cycle of the I&C system. These requirements are mapped into the appropriate system's architecture and security measures (controls) during the design stage. However, in practice, security controls are often introduced only at the final stages of system development. It may lead to a "disagreement" between system architecture and security controls that presumably make the application of implemented measures ineffective.

On a technical view, the problem may be represented as a set of particular issues, such as asset classification, selection, and assignment of security controls providing protective barrier measures against cyber-attacks, arrangement of information links between assets, etc. Current I&C NPPs security development practice addresses these issues. The work [1][1] deals with assets classification issue. The technical level IEC 63096 standard [6] deals with selection of the security controls. However, in general, the cybersecurity provision of the I&C system is still an unresolved issue, especially at the stage of system design and approval of functional requirements and cybersecurity measures. It is intended that this Technical Report is used by operators of NPPs (utilities), systems evaluators and by licensors.

b) Situation of the current Standard in the structure of the IEC SC45A standard series

IEC 63415 is a 4th level IEC/SC45A document covering the use.

For more details on the structure of the IEC SC45A standard series, see item d) of this introduction.

c) Recommendations and limitations regarding the application of the Standard

To ensure that the document 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 SC45A 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 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 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.

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[1] Numbers in square brackets refer to the Bibliography.

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 64000 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 – INSTRUMENTATION AND CONTROL SYSTEMS – USE OF FORMAL SECURITY MODELS FOR I&C SECURITY ARCHITECTURE DESIGN AND ASSESSMENT

1 Scope

The TR provides an overview over the formalized modelling and designing of cybersecure architectures to apply for I&C system cybersecurity enforcement at NPPs. The plant-specific risk assessment can use the techniques covered by this TR.

The formal security models are often used in the analysis and design of I&C security architectures. A formal security model is a mathematical notation such as algebra and set theory or logical expression that defines the security properties of a system and the relationships between different components. It provides a rigorous way to reason about the security of a system and to identify potential vulnerabilities and threats.

This document considers the complex problem of NPP I&C architecture synthesis to address particular issues:

- asset classification,
- barrier measures assignment,
- the information transfer and links conformity with security requirements.

This document provides guidance on creating a comprehensive security model applicable to NPP I&C systems that describes NPP I&C cybersecurity architecture and aids in accomplishing the main tasks of I&C system secure design, which are:

- specification of system designs with increased determinism that enhance security,
- mapping of the security requirements into the security architecture of the I&C system,
- definition of the security requirements for information exchange between components within the I&C system, operators and other systems,
- assistance in the determination of the security degree assignment with a model-based technique considering asset properties and formal grouping of the assets,
- design and establishment of security zones boundaries.

These tasks are closely related with the I&C NPP security framework established by IEC 62645 [2] and implement the Secure by Design principle (SeBD) [3].

This document presents the following limitations. The presented methods of the security modelling rely on the following properties of the I&C system:

a) The system is built upon the hierarchical principle, the hierarchy exists both at the level of functional system architecture (subsystems, software and hardware components etc.) and at the security architecture level (degrees and zones);

b) The focus is on preserving integrity, which prevails over the principle of maintaining confidentiality.

c) The availability property and any time related behaviour are out of the scope of this document;

d) The notion of a “secure” communication or a “secure” barrier in the document generally does not define the exact mechanism (controls) of how the secure property is achieved. It just assumes that an appropriate set of the security controls is implemented in situ;

e) The approach takes into account the existing nuclear safety classification scheme [7].

In addition to a general consideration of the I&C system security, several assumptions about properties of the I&C system have been made to facilitate the analysis, namely:

- the set of the assets is fixed and stable over a long period of time;
- peer-to-peer relations between assets are fixed and known;
- technological/functional requirements are determined.

The users of the presented methods are supposed to be familiar with basics of graph theory, discretionary access models, and documents listed in Clause 2.

Specific software tools implementing the presented methods eases the requirements to the users' mathematical background.

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

IEC 62645, *Nuclear power plants – Instrumentation, control and electrical power systems – Cybersecurity* requirements

IEC 62859, *Nuclear power plants – Instrumentation and control systems – Requirements for coordinating safety and cybersecurity*

IEC 63096, *Nuclear power plants – Instrumentation, control and electrical power systems – Security controls*

NTERNATIONAL ATOMIC ENERGY AGENCY, Computer Security Techniques for Nuclear Facilities, IAEA Nuclear Security Series No. 17-T (Rev. 1), IAEA, Vienna (2021)

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
asset
physical or logical object owned by or under custodial duties organization, having either a perceived or actual value for organization

[SOURCE: IEC TS 62443-1-1 2009, 3.2.6]

3.2
I&C system
system, based on electrical and/or electronic and/or programmable electronic technology, performing I&C functions as well as service and monitoring functions related to the operation of the system itself.

The term is used as a general term which encompasses all elements of the system such as internal power supplies, sensors and other input devices, data highways and other communication paths, interfaces to actuators and other output devices. The different functions within a system may use dedicated or shared resources

Note 1 to entry: See also “I&C function”.

Note 2 to entry: Any network is either a part of an I&C system or an I&C system by itself.

[SOURCE: IEC 61513:2011, 3.29]

3.3
I&C function
function to control, operate and/or monitor a defined part of the process

[SOURCE: IEC 61513:2011, 3.28]

3.4
data model
information exchange model

model that describes access relations between assets in I&C system during their functioning

3.5
digital twin
a digital twin is a formal digital representation of some asset, process or system that captures attributes and behaviours of that entity suitable for communication, storage, interpretation or processing within a certain context

3.6
integrity level
property of the asset which solely depends on the connectivity property

3.7
security architecture
plan and set of principals describing the security services that a system is required to provide to meet the needs of its users, the system elements required to implement the service and the performance level required in the elements to deal with the threat environment

[SOURCE: IEC TS 62443-1-1:2009, 3.2.100]

Note 1 to entry: The security architecture defines the security structure of the I&C system as a system of systems, including the main functions, degrees, zones and boundaries of each system, the interconnection or independence of critical digital assets (CDAs), the priority of the goals of simultaneously operating in the system and the order of interaction between the personal and the machine in the I&C system.

Note 2 to entry: In narrower context the system architecture is a partitioning of the I&C system into a number of interconnected subsystems and components and the arrangement of system subsystems using zone approach to comply with security requirements related to the overall security degree of the system.

3.8
security controls
means of managing security which can be administrative, technical, or management

[SOURCE: IEC 62645:2019, 3.18, modified – “technical, physical, or administrative” replaced by “administrative, technical, or management]

3.9
security degrees
gradation of security protection with associated sets of requirements, assigned to a system according to the maximum consequences of a successful cyberattack on this system in terms of plant safety and performance

Note 1 to entry: We assume that security degrees are ordered. The order from smaller to bigger number corresponds to the sequence from highest security to less strict security.

[SOURCE: IEC 62645:2019, 3.19]

3.10
security measure
abstract barrier that enables secure data transfer between assets

3.11
security policy
set of rules that specify or regulate how a system or an organization provides security services to protect its assets

Note 1 to entry: the term “security policy” used in the content of the document corresponds to “I&C digital programmable system policy” in IEC 62645 context.

Note 2 to entry: I&C programmable digital system security policy should be translated into requirements, which will be used to derive essential properties of the security models.

Note 3 to entry: Requirements may be expressed mathematically or in a natural non-formal language.

[SOURCE: IEC TS 62443-1-1:2009, 3.2.112]

3.12
security model
security requirements model

model that defines collection of classes (degrees of cybersecurity) and relations between them, and rules governing asset attribution to a degree

3.13
security zone

A computer security zone is a logical and/or physical grouping of digital assets that are assigned to the same computer security level and that share common computer security requirements owing to inherent properties of the systems or their connections to other systems (and, if necessary, additional criteria).

[SOURCE: IAEA Nuclear Security Series No. 17-T: 2021, 2.9]

3.14
security architecture synthesis
process of bringing the information exchange model into accordance with the security requirements model

4 Abbreviated terms

CDA Critical Digital Asset

CPS Cyber Physical System

DAC Discretionary Access Control

MAC Mandatory Access Control

DM Data Model
ICM Integrated Cybersecurity Model
I&C Instrumentation and Control
LAN Local Area Network
NPP Nuclear Power Plant
OS Operation System
SeBD Secure by Design
SLM Security Level Model
TR Technical Report
WS Workstation

5 I&C system security life cycle and security modelling activities

The overall life cycle of the I&C programmable digital security system security forms the basis for the understanding how various components of a secure I&C system are related to each other. Development of the I&C system commonly includes the security related activities which are spread on life cycle stages defined by IEC 62645. The security policy ought to cover all life cycle stages. Omission of any stage in the security policy makes it very difficult to achieve cybersecurity in the next stages. Table 1 shows how security modelling is used on each security life cycle stages to strengthen the security of the I&C architecture.

Table 1 – I&C life cycle stages and corresponding scenarios for the use of security modelling

N	Life cycle stage (as per IEC 61513:2011)	Security tasks (as per IEC 62645:2019)	Application of security models
1.	System requirements specification		
2.	NA	Describe system using a top-down approach, considering the global I&C architecture	Top-down structural view of the system architecture. The mathematical models are used to model relations between I&C system components. See 9.6.
3.	NA	Security degree assignment	To facilitate the security degree assignment using mathematical methods. See Annex E.
4.	System specification	System architecture	The system architecture is partitioned into a number of interconnected subsystems and components which are combined to logical zones. That arrangement complies with security degree assigned to subsystems. The mathematical models are used to model relations between I&C subsystem and components. See 9.7.