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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Mobile remotely controlled systems for nuclear and radiological applications – General requirements

Systèmes télécommandés mobiles pour applications nucléaires et radiologiques – Exigences générales

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Mobile remotely controlled systems for nuclear and radiological applications – General requirements

Systèmes télécommandés mobiles pour applications nucléaires et radiologiques – Exigences générales

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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CONTENTS

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MOBILE REMOTELY CONTROLLED SYSTEMS FOR NUCLEAR AND RADIOLOGICAL APPLICATIONS – GENERAL REQUIREMENTS

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Draft	Report on voting
45/904/FDIS	45/907/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/standardsdev/publications.

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- withdrawn,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

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INTRODUCTION

Mobile remotely controlled systems are used in areas that are difficult to access by human workers, such as high-radiation, high-temperature, high-pressure, and submerged environments.

International standards for applications other than nuclear applications, such as individual protective equipment and industrial, service-related, and medical applications, are developed within ISO TC 299.

There are a variety of mobile remotely controlled systems [14][1] intended for application in various environmental conditions, namely: multifunctional mobile robot systems for the inspection and maintenance of the primary cooling water system of a nuclear power plant; shape-changing robots that serve as a remotely controlled inspection system in the primary containment vessel of a nuclear power plant; robots that inspect the reactor head and floor, underwater mobile robots that detect and remove loose parts within the reactor vessel; underwater crawling and swimming robots that serve as a remotely controlled system for feeder pipe inspection and maintenance of steam generators in an underwater environment; operation control systems for non-destructive inspections, mobile robots intended for radiation and chemicals reconnaissance and monitoring, as well as local distribution of gamma-radiation sources located in inaccessible areas; and double-arm or heavy duty robots that are used to dismantle nuclear power plants.

In this regard, it is necessary to develop technical standards that govern the design, manufacturing, interoperability, and use of mobile remotely controlled systems for nuclear applications that are suitable for various works such as the integrity inspection of nuclear components, repair of nuclear components, on-site monitoring when any abnormality or accident occurs in a nuclear facility, and nuclear decontamination and dismantling.

These technical standards concern the design, establishment, and performance of mobile remotely controlled systems and can be used to implement various important tasks and follow-up measures, such as monitoring nuclear-related activities.

To this end, general requirements for mobile remotely controlled systems have been provided for nuclear and radiological applications.

Detailed specifications of these general requirements need to be designated by manufacturers to provide support to the users of their products.

1 Numbers in square brackets refer to the Bibliography.

MOBILE REMOTELY CONTROLLED SYSTEMS FOR NUCLEAR AND RADIOLOGICAL APPLICATIONS – GENERAL REQUIREMENTS

1 Scope

This document defines the general requirements for Mobile Remotely Controlled Systems (MRCSs) for nuclear and radiological applications such as integrity inspections, repair of components, handling of radioactive materials, and monitoring of physical conditions and radiation dose intensity in specific areas. (Refer to Annex A for more information regarding the main purposes of the MRCS.)

MRCS is used in the concerned area where human access is difficult or impossible during normal operation, transient and accidents, and recovery from an accident in nuclear facilities.

This document applies to MRCSs that are used to support nuclear and radiological facilities.

These general requirements encompass high-level performance requirements regarding sensors, monitoring devices, control devices, interfacing mechanisms, simulation methods, and verification methods thereof in a normal environment or extreme environmental conditions, such as high radiation, high temperature, and high humidity environments.

In this document, the term "MRCS" used hereinafter refers to a mobile remotely controlled system used for nuclear and radiological applications.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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
built-in control/diagnostics system
BCDS
specialized circuit of the on-board control system intended to check the state of MRCS permanently

3.2
hazard
event having the potential to cause injury to plant personnel, damage to components, equipment, structures or MRCSs. Hazards are divided into internal hazards and external hazards

Note 1 to entry: Internal hazards are, for example, controller fail or power loss.

Note 2 to entry: External hazards are, for example, fire, flooding, earthquake and lightning.

Note 3 to entry: Damage to MRCSs is added to the source.

[SOURCE: IEC 61513:2011, 3.25, modified, – Note 3 to entry has been added.]

3.3
mission
objective description of the fundamental task performed by a system

3.4
mobile remotely controlled system
MRCS
robotics in nuclear instrumentation that are mobile, remotely controlled by an operator, and consisting of sub-systems, modules or assemblies

EXAMPLE 1 Subsystems, modules or assemblies are, for example, mechanical and electrical/electronical controls, communications (between the operator and the robotic, and some robotic subsystems, modules or assemblies), lighting and possibly audio subsystems, modules or assemblies, sampling and monitoring subsystems, modules or assemblies, used for photographing the environment with video or still photos, sampling or monitoring the contacted air or surfaces for radioactive materials, noxious gases and particulates such as asbestos, and performing other designed activities, all controlled by the operator.

3.5
operator
person designated to start, monitor, and stop the intended operation of the MRCS

[SOURCE: ISO 8373:2012, 2.17, modified, – Robotic system has been replaced with MRCS.]

3.6
remote control
control of a device from a distant point

3.7
risk
potential that a given threat will exploit vulnerabilities of an asset or group of assets and thereby cause harm to the organization

Note 1 to entry: It is measured in terms of a combination of the severity of impact from the environment, probability of the exposure time to the radiation and the controllability for MRCS.

[SOURCE: IAEA Nuclear Security Series No. 17:2011, modified, – The second sentence in the definition has been removed, and Note 1 to entry has been added.]

3.8
risk assessment
overall process of systematically identifying, estimating, analysing and evaluating risk

[SOURCE: IAEA Nuclear Security Series No. 17:2011]

3.9
robot
actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks

[SOURCE: ISO 8373:2012, 2.6, modified – The notes have been removed.]

3.10
safety
protection of people and the environment against radiation risks, and the safety of facilities and activities that give rise to radiation risks

Note 1 to entry: 'Safety' as used in the IAEA glossary and safety standards includes the safety of nuclear installations, radiation safety, the safety of radioactive waste management and safety in the transport of radioactive material; it does not include non-radiation-related aspects of safety.

[SOURCE: IAEA Safety Glossary: 2018, 3.1, modified, – The second sentence in the definition has been removed, and Note 1 to entry has been added.]

3.11
scenario
possible sequence of interactions

[SOURCE: SG-CG/M490/E:2012-12, 3.10]

4 Abbreviated terms

BCDS	Built-in Control/Diagnostics System
HMI	Human-Machine Interface
MRCS	Mobile Remotely Controlled System

5 General descriptions

5.1 Working environment

5.1.1 General

MRCSs shall be used to implement tasks in nuclear facilities where human access is difficult or impossible. Working environments in nuclear facilities are identified according to operating conditions and working areas, including, but not limited to, the following factors.

5.1.2 Atmospheric environment

- Radiation and radioactivity
- High temperature and high humidity
- Toxic and explosive gases
- Underwater or submerged environment

5.1.3 Structural environment

- Narrow and confine spaces limited to human access
- Areas of high altitude with a risk of falling
- Presence of obstacles with a risk of collision
- Sloped areas such as stairs
- Uneven paths, including gratings
- Areas where humanlike manipulations are needed, such as operations of doors and valves

These environmental factors should be applied to the mission of the MRCS, as described in Annex A.

MRCSs shall perform given missions in various working environments with or without human intervention.

The safety of the human operators, nuclear facilities and MRCSs should be confirmed for their working environment.

5.2 Structure of MRCS

The MRCS or a human operator is a subject who conducts a given task, while a nuclear facility is an object on which the task is performed.

As a subject, the MRCS performs a given task related to an object either autonomously or in cooperation with a human operator.

Any problems that may occur while performing the task should be addressed by the MRCS and the human operator, and the final decision shall be made by the human operator.

Accordingly, when planning given tasks, a human operator should minimize the occurrence of any unexpected problems, including by simulations.

The MRCS, as a subject which performs a given task, is structured as follows.

The MRCS is composed of two subsystems, as shown in Figure 1, the slave subsystem and the master subsystem.

The slave subsystem is intended to operate in an area inaccessible to a human operator, or a dangerous area, as shown in Figure 1.

The master subsystem is located in a safe area and used to supervise the slave subsystem by human operator.

The two subsystems are located away from each other, and thus necessary information needs to be exchanged between them through communications.

Figure 1 – MRCS structure

The functions of the slave subsystem, as shown in Figure 2, are as follows.

- The sensing function is to collect information necessary to perform a given task.
- The mobility function is to place the slave subsystem in the target area where the given task is located.
- The manipulation function is to move a tool to the target position and place it in the desired pose so as to handle the object.
- The local control function is to control the sensing, manipulation, and mobility functions and exchange information with the master subsystem.
- The slave communication function is to receive control commands from the master subsystem and transmit sensor information and the status of the slave subsystem to the master subsystem.
- The slave power supply function is to provide power or energy sources to the slave subsystem.

The functions of the master subsystem, as shown in Figure 2, are as follows.

- The human-machine interface (HMI) is to receive command inputs from the human operator and provide the human operator with multimodal information regarding the environmental conditions and status of the slave subsystem.

- The remote control function is to convert a command input from the human operator to an appropriate form of control command suitable for the slave subsystem.
- The communication function is to transmit control commands to the slave subsystem and receive data from the slave subsystem.
- The master power supply function is to provide power or energy sources to the master subsystem.

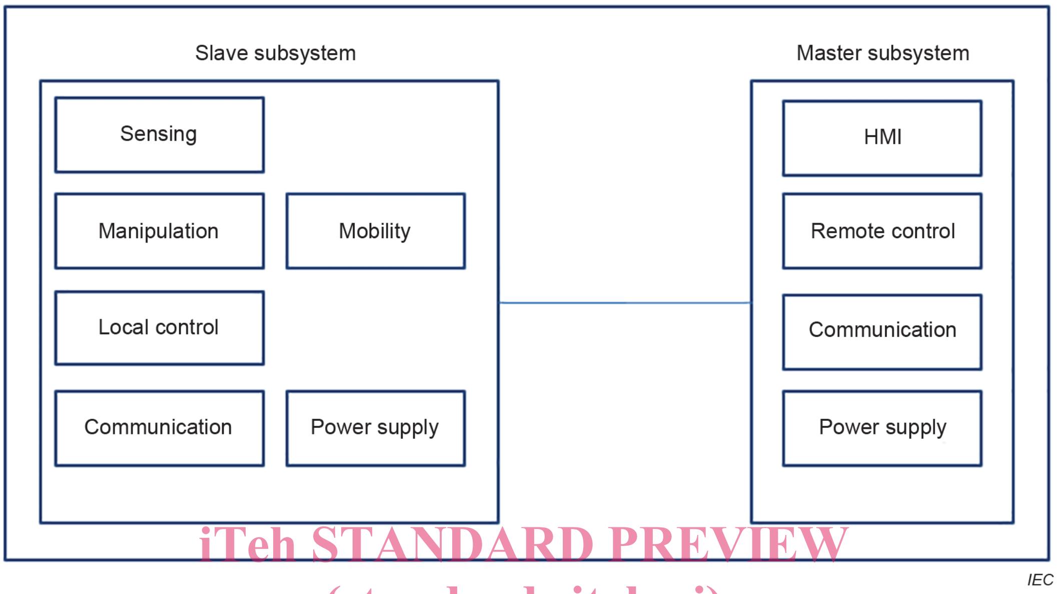

Figure 2 – MRCS functions

5.3 Risk analysis and safety measures

To prevent or mitigate risks, necessary safety measures shall be prepared.

These risks may occur due to various factors, including but not limited to:

- Atmospheric environment, as mentioned in 5.1.2
- Structural environment, as mentioned in 5.1.3 (e.g., falling or rollover)
- Incorrect manipulation by the operator
- Defects or damaged electronic equipment that may cause an electric shock or fire
- Defects or malfunction of a control circuit that may cause machine malfunction
- Defects or failure of an electric circuit that may cause machine malfunction and power disturbances
- Loss of circuit continuity due to a sliding contact or rolling contact that may cause a failure of safety function or mechanical defects
- Electrical disturbances, such as interferences by electromagnetic fields, static electricity, and radio frequencies, which may occur externally or internally causing equipment malfunction

Here, safety measures refer to a combination of measures taken to address those risks, as well as protection measures that need to be taken by the user.

These safety measures are considered in the system design and development phases to mitigate the risks.

Appropriate safety measures shall be prepared based on the results of risk assessment.

Safety protection and working procedures also need to be considered.

Safety protection includes the use of safety devices and recognition measures.

6 General requirements

6.1 General

The MRCS shall be designed and manufactured to meet the requirements for given missions taking into consideration the environmental factors specified in 5.1.

These requirements consist of the safety, functional, operational and test requirements;

- Safety requirements (6.2)
- Functional requirements (6.3)
- Operational requirements (6.4)
- Test requirements (6.5)

6.2 Safety requirements

6.2.1 General

The MRCS shall be designed to safely complete the mission in the working environment mentioned in 5.1. The safety of MRCS should be verified in three different aspects.

- MRCS should be designed to limit the level of risk that may cause health damage to humans while all the time using MRCS, including the pre-processes (e.g., preparation, installing, master and setting up the master station), the main processes (e.g., remote operation of mobile base, remote controlling of manipulator), and the post-processes (e.g., retrieving, decontaminating, maintaining, and repairing the MRCS).
- MRCS should be designed to limit the level of risk to cause damage to the external environment. MRCS should be safely returned without causing damage to the environment during the mission.
- MRCS should be designed to protect itself from the dangers of the external environment. MRCS should be safely returned without failure during the mission.

Depending on the working environment, the specific safety requirements should be considered. Annex B provides a safety verification tool to ensure that the MRCS concerned can be applied in a specific mission environment. The manufacturer shall provide performance specifications and relevant information.

6.2.2 Requirements for preventing damage to humans

The MRCS shall be designed in such a way as to guarantee safety of humans all the time while utilizing it. The level of risk imposed on humans while working on the MRCS shall be reduced to a level below the allowable limit. If applicable, it is necessary to consider issues that include, but are not limited to, the following items.

- MRCS should be designed to mitigate all possible risks, as identified in 5.1, to a level below the allowable limit, if they have reached the level where humans could be harmed.
- MRCS should be designed to warn of the risks to humans, while preparing, installing, operating, retrieving, decontaminating, inspecting, maintaining, repairing, or utilizing the MRCS for other purposes.
- MRCS operating procedures should be clearly defined and documented. The possible risks in each procedure and the way to mitigate those should be described.

- MRCS should be designed not to harm humans in case of collision or contact with it, due to its physical properties (speed and force) or electrical properties.
- MRCSs should be designed to guarantee the safety in repairing or maintenance. A modular design that allows the user to simply replace the failed module is desirable to reduce the risk.
- MRCSs should be designed in such a way that they are not easily contaminated.
- The MRCS should be decontaminated after finishing a mission so that humans can access the MRCS in order to maintain or repair it after the decontamination.
- MRCS should be designed to firmly fix all parts to prevent the separated parts which harm humans.

6.2.3 Requirements for preventing damage to the nuclear and radiological facility

The level of potential risk to the nuclear and radiological facility while working on the MRCS shall be reduced to a level below the allowable limit. If applicable, issues should be considered, including but not limited to the following.

- The entire task should be performed so as not to damage the structures in case of unexpected falling or rollover of the MRCS.
- The entire task should be performed so as not to damage the structures in case of unexpected collision with the structures. The operating speed shall be limited enough to reduce the possible risk.
- The entire task should be performed so as not to damage the structures in case of intended contact. The contact stress exerted on the structure should be kept below the allowable stress limit.
  - The entire task should be performed so as not to generate foreign substance in order to prevent damage to the structure or disturbing normal operation of nuclear facility. Manipulation should be carefully done not to drop the handling object.
  - Inspection should be conducted to find foreign objects.
  - The foreign objects may be removed, if detected.

6.2.4 Requirements for preventing damage of MRCSs

The MRCS should complete the given mission safely without causing any damage until returning to a pre-defined position. Its mission should be terminated if a failure occurs. The MRCS should return to a pre-defined position for repairing, or it should halt safely at the position in case it is impossible to return. The MRCS should be designed so as to provide appropriate safety measures and to minimize degradation of performance, in consideration of the working environment as specified in 5.1.

The level of risk to MRCS shall be reduced to a level below the allowable limit. The MRCS shall be designed, manufactured, and operated while taking into consideration, but not limited to, the following requirements.

- MRCS should be designed so as to provide redundancy and diversity to reduce the risk in case of malfunction, performance degradation, and failure of the device.
- MRCS should be radiation tolerant or hardened, if necessary.
- Subsystem, module or assembly in MRCS should be waterproofed, if necessary.
- Subsystem, module or assembly in MRCS should be designed so as to prevent the degradation due to dust, if necessary.
- Subsystem, module or assembly in MRCS should be designed so as to minimize inducing vibration, and anti-vibration measures should be applied, if necessary.
- Subsystem, module or assembly in MRCS should be designed so as to guarantee the mechanical strength and to reduce friction, if necessary.