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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Nuclear power plants – Control rooms – Operator controls

Centrales nucléaires de puissance – Salles de commande – Commandes opérateurs

IEC 61227:2008

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NUCLEAR POWER PLANTS – CONTROL ROOMS – OPERATOR CONTROLS

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 61227 has been prepared by subcommittee 45A: Instrumentation and control of nuclear facilities, of IEC technical committee 45: Nuclear instrumentation.

This second edition cancels and replaces the first edition published in 1993 and constitutes a technical revision. This edition includes the following significant technical changes with respect to the previous edition:

a) account has been taken of the fact that computer design engineering techniques have advanced significantly in the intervening years;
b) alignment of the standard with the new revisions of IAEA documents NS-R-1 and NS-G-1.3, which includes as far as possible an adaptation of the definitions;
c) replacement, as far as possible, of the requirements associated with standards published since the first edition, especially, IEC 60964 (edition 2) and IEC 61772 (edition 2);
d) review of the existing requirements and updating of the terminology and definitions.

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

FDIS	Report on voting
45A/694/FDIS	45A/702/RVD

Full information on the voting for the approval of this standard 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 maintenance result 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.

INTRODUCTION

a) Technical background, main issues and organisation of this standard

This IEC standard specifically focuses on operator controls.

It is intended that this standard be used by operators of NPPs (utilities), systems evaluators and by licensors.

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

IEC 61227 is the third level IEC SC 45A document tackling the generic issue of operator controls.

IEC 61227 is to be read in association with IEC 60964 and IEC 61772. IEC 60964 is the appropriate IEC SC 45A chapeau document for control rooms which provides guidance on control room design and which references IEC 61227. IEC 61772 establishes requirements for the application of VDU (Visual Display Units).

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

c) Recommendations and limitations regarding the application of this standard

It is important to note that this standard establishes no additional functional requirements for safety systems.

To ensure that this 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 document of the IEC SC 45A standard series is IEC 61513. It provides general requirements for I&C systems and equipment that are used to perform functions important to safety in NPPs. IEC 61513 structures the IEC SC 45A standard series.

IEC 61513 refers directly to other IEC SC 45A standards for general topics related to categorization of functions and classification of systems, qualification, separation of systems, defence against common cause failure, software aspects of computer-based systems, hardware aspects of computer-based systems, and control room design. The standards referenced directly at this second level should be considered together with IEC 61513 as a consistent document set.

At a third level, IEC SC 45A standards not directly referenced by IEC 61513 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 45A standard series, corresponds to the Technical Reports which are not normative.

IEC 61513 has adopted a presentation format similar to the basic safety publication IEC 61508 with an overall safety life-cycle framework and a system life-cycle framework and provides an interpretation of the general requirements of IEC 61508-1, IEC 61508-2 and IEC 61508-4, for the nuclear application sector. Compliance with IEC 61513 will facilitate consistency with the requirements of IEC 61508 as they have been interpreted for the nuclear

industry. In this framework IEC 60880 and IEC 62138 correspond to IEC 61508-3 for the nuclear application sector.

IEC 61513 refers to ISO as well as to IAEA 50-C-QA (now replaced by IAEA 50-C/SG-Q) for topics related to quality assurance (QA).

The IEC SC 45A standards series consistently implements and details the principles and basic safety aspects provided in the IAEA code on the safety of NPPs and in the IAEA safety series, in particular the Requirements NS-R-1, establishing safety requirements related to the design of Nuclear Power Plants, and the Safety Guide NS-G-1.3 dealing with instrumentation and control systems important to safety in Nuclear Power Plants. The terminology and definitions used by SC 45A standards are consistent with those used by the IAEA.

NUCLEAR POWER PLANTS – CONTROL ROOMS – OPERATOR CONTROLS

1 Scope

This International Standard supplements IEC 60964 which applies to the design for control rooms of nuclear power plants. It identifies the Human-Machine Interface (HMI) requirements for discrete controls, multiplexed conventional systems, and soft control systems. For the main control room of a nuclear power plant, IEC 60964 includes general requirements for layout, user needs and verification and validation methods, and these aspects are not repeated in this standard. However, IEC 61772 on Visual Displays Unit (VDU) also provides some guidance on displays and indications where necessary for the correct application of the control requirements.

This standard is intended for application to the design of new main control rooms in nuclear power plants designed to IEC 60964 where this is initiated after the publication of this standard. If it is desired to apply it to supplementary control points or local control positions, or to existing control rooms or designs, special caution shall be exercised as it makes assumptions such as the automation level that may not apply.

2 Normative references

The following referenced documents are indispensable for the application 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 60073, *Basic and safety principles for man-machine interface, marking and identification – Coding principles for indicators and actuators*

IEC 60964, *Nuclear power plants – Control rooms – Design of main control room*

IEC 61771, *Nuclear power plants – Control rooms – Verification and validation of design*

IEC 61772, *Nuclear power plants – Control rooms – Application of visual display units (VDU)*

IAEA Safety guide NS-G-1.3:2002, *Instrumentation and Control Systems Important to Safety in Nuclear Power Plants*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60964 and the following definitions apply:

3.1
discrepancy control and indication
binary control with state and discrepancy indication using a single control switch

3.2
discrete (individual) controls
devices to support operator control of plant components, such as pumps, valves, controllers, with one control being assigned to a single plant component or function

3.3
multiplexed
used for several purposes at different times. For example, a start-stop switch may be selected by another device associated to a number of plant items and used to start or stop the item to which it is connected at the time

3.4
operator controls
devices which the operator uses to send demand signals to control systems and plant items

3.5
semaphore
electrically driven mechanical device which displays the plant condition (e.g. open or closed switch position) by the angular position of the visible surface

3.6
soft control
control device for input of operator commands, that has connections with the control system that are mediated by software rather then direct physical connections. As a result, the functions of a soft control may be variable and context dependent rather than statically defined.

NOTE Typically, soft control devices use VDUs for displaying the input options, and pointing devices such as track ball, mouse, touch capability, or light pen for the selection of the choice.

3.7
touch panel
soft control which uses a position detector to detect the operator's finger pointing at the label on the VDU (Visual Display Unit). Alternatively, a light pen may be used or a cursor may be moved over the VDU format to identify a label. The label may describe an item of plant or a control action.

4 Design principles

4.1 Basic concepts

An overall systems design approach is required for the design of the HMI. IEC 60964 states the requirements for overall design of the control room system and the establishment of the principles required for safety, availability and user considerations, and the functional design of the system as a whole. The designer shall consider his goals, and the relative importance of the various design factors for his particular application.

Operator controls shall be designed so that operators can perform their tasks easily and correctly. Consideration shall be given to control-display integration and the type of operating procedure and its presentation shall be taken into account in the choice of controls to be used. Particular attention shall be given to the needs of the operator for simple error-proof systems that will optimize the operator's performance under all conditions. Their design shall be based on ergonomic principles to ensure ease of operation and to minimize operators' errors, both of omission and execution. Where conventional systems are used, mechanical characteristics of control elements, such as size, operating pressure or force, tactile feedback, etc., shall meet human capabilities and characteristics specified in the anthropometric data base.

The design of the control panels and controls shall be consistent with the overall system design and shall comply with the requirements specified in IEC 60964 and, in particular, with the following subclauses of that standard:

a) Panel layout

b) Location aids

c) Information and control systems

d) Control-display integration

e) Communication system

f) Other requirements

Any system shall give immediate feedback to the operator that it has received a control command, for example, by lighting a device or a mark on a VDU. Appropriate plant feedback shall indicate when the command has been implemented, for example the valve has closed.

4.2 Types of HMI

The types of operator interface available for control may be classified into two groups,

a) discrete controls comprising dedicated systems / multiplexed conventional systems;

b) soft controls.

The groups have the following characteristics, and the task analysis described in 4.3 is used to determine the most appropriate type to use.

4.2.1 Discrete controls

Dedicated controls have the disadvantage of being present even when not wanted, thus increasing the size of the whole control desk and providing "clutter" when other controls are in use.

Dedicated controls are particularly suitable for controls in constant use, for example electrical output, or those whose immediate accessibility and reliability are of prime importance, for example an emergency trip button. Requirements for their layout are described in 5.1.1.

Multiplexed controls, a sub-set of discrete controls, use a single control for the same function on several equipments, thus reducing the number of controls on the desk or panel so that they can be made smaller and the controls can be brought closer to the operator. However, the operator has to make a selection, so the number of operations is increased and the chances of error and the operator response time may be increased.

Multiplexed controls shall be designed with good feedback to the operator for the function selected, to permit error recovery. They are particularly suitable for the control of seldom-used systems that are not required in a hurry, for example, tank filling, and for systems where the consequences of error are not serious and where time is available for correction in the event of error.

4.2.2 Soft controls

These controls are a type of multiplexed system where they can have different functions at different times. Typically, soft controls are implemented using one (or two) VDUs together with a pointing device (such as mouse, track ball light pen or touch capability), or a combination of a VDU with a set of dedicated controls. Control actions are performed in the following way:

– selection of the object to be controlled using the pointing device;

– presentation of the command options on the VDU as menu items or icons, e.g. in a pop-up-window or on a separate VDU;

– selection and activation of the command option to be executed, again using the pointing device.

These systems have many of the characteristics of conventional multiplexed systems, but make it possible to assemble controls related to specific tasks and not offer the operator controls that are invalid or inappropriate to that task, so guiding the operator to correct

actions. All information required by the operator to perform the correct control action shall be presented to him when required, either on the touch screen or on a related adjacent format.

Selection error rates could be high if the system is not well-designed and, as a hierarchical selection of several formats may be required to recall the control set required, the process of selection of a control not already on display may be relatively lengthy. However, it may be possible to use a single format with changed windows for several control actions.

It is often difficult to optimise the position of the VDU for both monitoring and touching and two screens may be required. Off-screen pointing devices (e.g. track ball and light pen) are an alternative solution.

Soft controls can be particularly useful where the task is under the control of the operator.

For using soft controls, suitable consideration shall be needed to satisfy HMI requirements. For example: software switch selection time, human error rate in selecting the switches, or system response time. The VDU can display the mimic diagram of the system with the information required by the operator, who will identify the concerned item in the computer, and use a touch panel, soft control switch, or pointing device to achieve the desired effect.

For more information on the requirements for soft controls interfaces, see 5.2.

4.3 Selection of control system

The process to select and specify a control system should start from the consideration of the available technologies on the market and of the available feed-back from the plants.

This process shall clearly distinguish between the selection of the “main control system” and the selection of the proper control type for every plant component / plant function.

It is also to be considered that, for common cause failure reasons, two different control systems could be selected to perform the same function.

A task analysis is required as a fundamental part of the control room design and this shall be documented in a manner that indicates the requirements for the controls in terms of:

a) frequency of use;

b) grouping, and relationship with other controls;

c) speed of access required (when not already in use);

d) reliability;

e) acceptability of common cause faults;

f) importance of consequences of erroneous selection;

g) complexity of system controlled;

h) type of information display proposed (VDU or dedicated instruments);

i) type of control equipment proposed;

j) categorization of control functions by their importance to safety;

k) operating procedures (e.g., normal, testing, emergency).

Bearing in mind the characteristics of the types of control system identified in 4.2, the designer shall select the most appropriate interface for each control and develop the design following the requirements of 5.1. The proposed design shall then be validated in accordance with the method given in IEC 60964 and detailed in IEC 61771. In the design and validation, it is important that all relevant inputs to the HMI design are taken into account. These will include contributions from the:

a) plant designer;
b) control system equipment designer;
c) information system designer;
d) safety and reliability specialist;
e) topic specialist (e.g. radiation protection specialist, chemist, etc.);
f) operations staff; maintenance staff;
g) existing design criteria (in the case of refits or extension);
h) human factors specialist.

In practice, detailed interface design depends upon thorough task analysis.

Representative operators should be consulted in the selection and development of formats and control actions. It is highly recommended that live tests are conducted using a simulator.

Post-commissioning operations will also provide much valuable information on design adequacy. However, the adaptability of the user population and the constraints generated by operating factors will restrict such feedback to those items which create significant operating or maintenance problems rather than subjective detail.

5 Design requirements

5.1 Individual controls and indicators

There are three main types of displays and control element combinations to be considered:

a) individual indicators and controls;
b) VDU and individual controls, and
c) VDU only.

Individual indicators and controls shall be laid out as described below, and they shall be positioned close to VDU giving related information. VDU layout is covered in IEC 61772 (see also 5.1.8).

5.1.1 Control board layout

Formal rules for the layout of control and indication devices on desk and panel surfaces are described in IEC 60964 as a distributed set of requirements associated with components. Layout of control panels and desks with individual controls and individual indicators shall follow a consistent design concept.

It is not possible to postulate unique design rules which will meet every possible design and operational circumstance. Certain rules will require conditional application depending on the exact balance of objectives for any given part of the operator interface. The priority given to the various principles will be situation dependent. The order given below has been found to cope with the majority of applications.

The primary classification of control and indication devices on a desk or panel is based on who has responsibility for use of the device. (Where more than one user requires a piece of information, consideration shall be given to duplication of displays.) Considered in conjunction with function and frequency of use, this will determine the general location for a device.

Control room layout will determine the controls and indication functions allocated to the desk or panel. The layout of devices shall follow a logical sequence. The most general sequence is that of the plant, i.e. mimic diagram of the plant, but other sequences such as sequence of use should be considered.