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Nuclear power plants — Control rooms — Application of visual display units (VDUs)

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee NCE/8, Reactor instrumentation.

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Nuclear power plants -
Control rooms -
Application of visual display units (VDUs)
(IEC 61772:2009)

Centrales nucléaires de puissance -
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Utilisation des unités de visualisation
(CEI 61772:2009)

Kernkraftwerke -
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Anwendung von Sichtgeräten
(IEC 61772:2009)

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Foreword

This document (EN 61772:2013) consists of the text of IEC 61772:2009 prepared by SC 45A "Instrumentation and control of nuclear facilities" of IEC/TC 45 "Nuclear instrumentation".

The following dates are fixed:

• latest date by which this document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2014-01-14
• latest date by which the national standards conflicting with this document have to be withdrawn	(dow)	2016-01-14

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The text of the International Standard IEC 61772:2009 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60964	2009	Nuclear power plants - Control rooms - Design	EN 60964	2010
IEC 61226	2005 [1)]	Nuclear power plants - Instrumentation and control systems important to safety - Classification of instrumentation and control functions	-	-
IEC 61227	2008	Nuclear power plants - Control rooms - Operator controls	-	-
IEC 61513	-	Nuclear power plants - Instrumentation and control important to safety - General requirement for systems	EN 61513	-
IEC 61771	-	Nuclear power plants - Main control-room - Verification and validation of design	-	-
IEC 61839	2000	Nuclear power plants - Design of control rooms - Functional analysis and assignment	-	-
IEC 62241	2004	Nuclear power plants - Main control room - Alarm functions and presentation	-	-
ISO 11064	Series	Ergonomic design of control centres	EN ISO 11064	Series
IAEA Safety Guide NS-G-1.3	2002	Instrumentation and control systems important to safety in nuclear power plants	-	-

[1)] IEC 61226 is superseded by IEC 61226:2009, which is harmonised as EN 61226:2010.

CONTENTS

INTRODUCTION

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

During the work to create a standard for the design of control rooms of nuclear power plants, it became obvious that the volume of such a standard would become very large. Therefore the standard was split into one main standard (IEC 60964 with an annex) and some supplementary standards. This standard is one of the supplementary standards.

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

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

IEC 61772 is the third level IEC SC 45A document tackling the generic issue of use of VDUs in NPPs Main Control Room.

IEC 61772 is to be read in conjunction with IEC 60964 which is the appropriate IEC SC 45A document which provides general requirements concerning the design of Nuclear Power Plants main control rooms. IEC 61227, IEC 61771, IEC 62241 and IEC 61839 should also be read with this standard.

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

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

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 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 45 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 GS-R-3) 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 – APPLICATION OF VISUAL DISPLAY UNITS (VDUs)

1 Scope and object

This International Standard supplements IEC 60964. It presents design requirements for the application of VDUs in main control rooms of nuclear power plants.

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. IEC 61227, IEC 61771, IEC 62241 and IEC 61839 should also be read with this standard.

This standard assists the designer in specifying VDU applications (including displays on individual workstations and larger displays for group-working or distant viewing) together with or instead of conventional (panel) displays by:

– stating principles to take advantage of VDU capability;
– giving examples of good practice and guiding the designer to avoid deficiencies of design.

This standard contains:

a) requirements for information needs:
   – according to information goals e.g. operation, maintenance, protection,
   – allowing for the necessary amount of space, e.g. location, arrangement,
   – using a hierarchy and/or relationships,
   – avoiding unnecessary information,
   – ensuring that information is relevant,
b) requirements for good presentation such as:
   – clear and flicker-free display with suitable updating frequency,
   – enough display space and an optimal arrangement,
   – adequate format and symbol sizes,
   – pictorial, symbolic display in addition to alpha-numeric capacity,
   – standardized, common symbols and names,
   – arrangements oriented to human factor needs, e.g. population stereotypes,
   – use of grouping and coding methods,
   – use of consistent flow directions,
   – appropriate abstraction levels according to the needs of the different presumed users,
c) methods for easy and quick access to the specific information of current interest:
   – by simple selection of single formats or format-sets according to information goals,
   – by using different kinds of menus (icons of neighbouring information) or other access techniques (last display, selection on screen, etc.) by soft keys on or off the VDU screens or cursors,
   – by using programmed presentation (triggered by any binary signal, such as an alarm),
d) design criteria to obtain appropriate reliability of all functions necessary to achieve the specified information goals.

This standard is intended for application to the design of new main control rooms in nuclear power plants designed to IEC 60964 and where this is initiated after the publication of this standard. If it is to be applied to existing control rooms or control areas designs, care should be taken as some assumptions made (such as automation level) may not apply.

Where a deviation from this standard is necessary in a back-fitting application the reasons should be documented.

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 60964:2009, *Nuclear power plants – Control rooms - Design*

IEC 61226:2005, *Nuclear power plants – Instrumentation and control systems important to safety – Classification of instrumentation and control functions*

IEC 61227:2008, *Nuclear power plants – Control rooms – Operator controls*

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

IEC 61771, *Nuclear power plants – Main control room – Verification and validation of design*

IEC 61839:2000, *Nuclear power plants – Design of control rooms – Functional analysis and assignment*

IEC 62241:2004, *Nuclear power plants – Main control room – Alarm functions and presentation*

ISO 11064 (all parts), *Ergonomic design of control centres*

IAEA Safety Guide NS-G-1.3:2002, *Instrumentation and control systems important to safety in Nuclear Power Plants*

3 Terms, definitions and abbreviations

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

3.1
associated information
additional, or helpful information complementary to the main display content of a single format or a format-set. The existence of this additional capability of display may be indicated by certain icons (navigation targets, as integrated parts of the displayed information) and their selection will lead to the display of single formats or pictorial menus or, where suitable, alpha-numeric menus

3.2
Large Screen Display (LSD)
any form of larger display intended for group viewing, shared tasks, monitoring at a distance, etc.

3.3
navigation targets
areas on the display screens that provide access to other displays, when a cursor or pointer is placed on the area and a suitable control action is taken

3.4
primary display
VDU display intended as the main (or one of the main) displays to facilitate the operator's main monitoring and control tasks. Primary displays need to be located more restrictively so that the operator is able to use them effectively from the working position

3.5
secondary display
VDU display filling a supportive role, such as to promote general situation awareness, group cooperation, casual monitoring when moving around the MCR, overall monitoring when not occupied with more specific tasks

3.6
touch panel
soft control which uses a position detector to detect the operator's finger pointing at the label on the VDU. 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.

3.7
Visual Display Unit (VDU)
type of display incorporating a screen for presenting computer-driven images

[IEC 60964]

3.8 Abbreviations

CRT: cathode ray tube

DLP: digital light processing

LCD: liquid crystal display

LSD: large-screen display

MCR: main control room

NPP: nuclear power plant

V&V: verification and validation

VDU: visual display unit

4 Design requirements

4.1 Intended purpose and application

4.1.1 General

The design process of the VDU system shall reflect the requirements of IEC 60964.

The design process shall identify the goals of the display system, e.g. safety, availability, operability.

Where a system is back-fitted to an existing plant, the extent of application of the requirements of IEC 60964 and of this standard shall be identified.

The availability requirements shall be determined from the classification of the system in accordance with IEC 61226 and IEC 61513.

The VDU system shall be designed so that operators can perform their tasks correctly and promptly. Account should be taken of the relationship between the information to be presented and any associated controls.

Consideration shall be given to control/display integration and the type of operating procedure (event based, symptom-based or state-based).

The presentation of the relevant information shall be taken into account in the choice of the kind of display to be used.

The design shall be based on ergonomic principles to ensure ease of operation and to minimize operator errors, both of intention and execution.

As the information displayed on VDUs is a major information source and contributes to the total operator workload, the display design shall minimize the workload contribution from monitoring, operation and problem solving to avoid information overload.

The design of the VDU system shall develop and document a clear definition of the intended purpose of the displays, their safety role and their basic performance requirements.

The following factors have great influence on the necessary extent, structure and capabilities of the entire system:

– new design or back-fitting application,
– safety, non-safety or legal licensing relevance,
– extent of plant automation,
– capabilities and needs of the main users,
– display only, or integrated soft controls.

The system may be provided in one step or in several steps according to funding, time limits, increased experience or changes in the state of the art of hardware and software, and changes in philosophies which might affect the role of the operators.

Some aspects of enhanced VDU-based displays are given in Annex A of this standard.

This standard offers broad guidance, but when the project needs to go into more detail, a set of specific design and style guides shall be established. To do so, this standard also provides directions to ensure that the project specific guidance can provide a consistent design across displays, systems and old/new equipment.

4.1.2 Number and location of displays

Typically, one of the first design decisions is the overall control-room configuration, i.e.:

– number and location of computer workstations and their hardware such as VDUs, keyboards,
– number and location of other hardware items such as alarms and controls.

In order to minimize late changes of the design, an early analysis of operator tasks should include the following tasks:

– analysing the information to be presented to the operators,
– obtaining input from operating crews.

For new plant designs the following should be included in the design team:

– staff with operating experience from previous plants,
– staff with operating experience from similar designs,
– representative future operators.

Determining the appropriate amount of display area should include consideration of:

– the information that will be needed at one time by the operators,
– the arrangement of information within display pages,
– the arrangement of pages within the display network,
– the means used to access the information.

The coordination of activities among crew members should be taken into account.

4.1.3 Placement to avoid daylight and lighting problems

The overall requirements and guidance given in the general control room design basis are relevant.

The major lighting problem is to supply enough light to illuminate printed and written material without illuminating the display screens (and LSDs) and undesirably reducing screen contrast.

In general, the overall lighting in the control room should be indirect and somewhat diffuse.

The room décor and colours of furnishing are important in determining the overall appearance of the workspace.

Architectural-surface reflectance should support diffuse lighting while not creating too much reduction of contrast on VDUs and LSDs.

The lighting scheme and choice of luminaires should be integrated with the rest of the design process.

The lighting scheme and choice of luminaires should not be handled piecemeal or in isolation.

Each new light-source or bright surface that is added into a control-room can potentially cause a variety of problems. For example:

– unplanned supplementary illumination can cause glare or reflections from VDU screens;
– unplanned general lighting can cast “waste light” or scattered light onto LSDs, reducing:
  – contrast,
  – colour-saturation,
  – readability.

Note that projection-screens with lower gain are more prone to cause the above problems than screens with higher gain.

Windows that admit daylight are especially problematic for LSDs.

Light distribution may need to be carefully controlled.

Front-projectors should be positioned so that they do not cause glare or reflections on operator workstation displays.

Care should be taken with colours in relation to room lighting conditions. Note that:

– unsaturated colours are difficult to discriminate in bright room light,
– similar colours are hard to distinguish in dim room-lighting.

Luminaires should have neutral colour rendering.

Coloured ambient illumination should not be used if colour-coding is used in the control-room.

Lamp-types with poor colour-rendering should not be used.

If the control-room has emergency lighting that may be used while operators continue to use displays, then this also should have good colour-rendering

4.2 Principal users

The principal users of each group of VDUs shall be identified as part of the definition of design requirements. These may be the reactor or other plant operators, the operation supervisor, maintenance staff or management. In the case of LSDs, there may be different users or groups of users situated in different areas of the MCR.

The level of understanding of the displayed information shall be primarily related to main control room operators’ mental capabilities and the formats shall be produced with their fullest co-operation from the outset. This is because operators in the main control room normally are the principal users of the information system at NPPs in normal, disturbed and accident situations. They are the only personnel always present and in charge.

In addition to the basic information, a more concentrated and abstract display of information shall be given to shift leaders, safety engineers and, according to utility practice, other on-site and off-site advisors to the control room staff. These may be concerned with the analysis and strategic decision-making in longer lasting, complex situations. Such a display format is also a suitable candidate for LSD when one of its identified functions is to maintain situation awareness and promote group cooperation.

The design targets should be to enhance the operators' role towards that of a safety and performance optimizer, by exploiting and supporting the mental capacity and expert knowledge of the operator.

Experience of display use on nuclear plants shows that operating and maintenance staff need access to all plant information, both direct and derived, within the workstation’s VDU display system, and that this should include specific facilities to allow display of information on:

– logic control algorithms,
– trip setpoints,
– alarm thresholds,
– signal scale factors,
– input assignment,

and other characteristics of the system used to define the performance of the display application. This facility is of specific value during plant commissioning and for the confirmation of modifications.

4.3 Failure criteria

The reliability requirements and failure criteria should be identified from the safety categorization process of IEC 61226 and from plant safety requirements, emerged from, among others, regulatory bodies. A failure of an information system means that the information is degraded and not sufficient and precise enough to understand or perform a safety task properly. A single failure within a system is any failure of a component, e.g., a sensor, a processor or a display unit.

Applications of VDUs may include:

a) Individual screens and LSDs with no safety relevance and other instruments, used to enhance the understanding of certain situations or to facilitate early detection of abnormalities such as those which inform about actions of automatic systems, energy or fluid flows and balances and small radioactivity releases or leakage.
b) LSDs and screens for information and control which may have safety relevance such as those necessary to perform actions according to safety-related procedures for plant conditions within and beyond the design bases.
c) Screens for safety such as those of a dedicated safety panel.
d) Soft controls in an integrated information and control system.

Such applications may be used for new designs or back-fitting of control rooms.

For case a),

– Redundancy is generally not essential and an occasional failure of the information function may be acceptable.

For case b),

– Redundancy shall be provided to ensure that a single component failure in the system does not prevent operation of its general function.
– Display functions (consisting of already concentrated information) should have an availability which meets the relevant documented safety needs.

For case c),

– A failure of a single display shall not prevent operator actions required for safety. Redundancy and diversity of information and control means may be used for this.
– Information necessary for handling accidents shall rely only on safety qualified measurements of sufficient redundancy but may be supplemented by other information.
– The probability of a failure of the information function shall be considered in relation to the relevant and documented safety needs.

For case d),

– A failure of a single display shall be considered according to the safety and availability criteria of a), b) or c), for which the control actions concerned are taken.

4.4 System requirements

Subclauses 4.1 to 4.3 enable the designer to determine requirements for the VDUs. This document states the high level requirements.

A style guide should give detailed guidance on specific response time, viewing angle limits etc.

The following areas shall have detailed requirements developed:

- the amount and structure of computing and storage capability,
- the necessary redundancy, diversity and complexity of information,
- the environmental conditions and requirements for the VDU or LSD.

Requirements intended primarily for workstation VDU-system design shall be established for the following:

- the character and symbol sizes provided by the VDU equipment,
- the number of sufficient pixels to differentiate the symbols employed where a character matrix is used,
- specific requirements for the maximum viewing angle for a primary or a secondary display (between the line of sight and the perpendicular to the plane of the display),
- specific requirements for the contrast of characters and symbols to background with possible control of luminance,
- the update frequency of information in digital form.

In addition the following requirements are fixed for workstation VDU-system design:

- The call-up time of any element of a format (set) shall meet the needs for display presentation arising from task analysis.
- The call-up time of any element of a format (set) shall meet the operator's human factor needs for display.
- The update frequency of information in digital form should be one that ensures that data is easily and accurately read by the operator, whether the plant is at steady-state or in a transient, and without rapidly changing lowest digits being displayed.
- The character and symbol sizes provided by the VDU equipment should be sufficient for human factors recommendations on legibility.

Requirements for the VDUs themselves shall be established and include:

- the colours used to code information,
- the screens refresh frequency,
- the spectrum of installed room lighting,
- the phosphor persistence of CRT-type VDUs. Special considerations may apply for other technologies, such as LCD, DLP.

In addition the following requirements are fixed for the VDUs themselves:

- Flashing of text or variables shall be avoided.
- Suitable measures shall be provided to ensure the reflection of other light sources on the screens are kept to a level that does not interfere with task performance or cause discomfort.
- Soft controls shall have a feedback mechanism providing information on whether the action called for has been executed or not. Critical actions shall be protected from accidental activation.

Further details about soft controls are given in IEC 61227.

4.5 Information needs and application procedures

4.5.1 General

The information to be displayed shall be defined in principle and then in detail by analysis of the operators' and other users' needs for information in different operating conditions.

The design process should include review and comment by experienced operators.

Screen formats should "use the user's model". The industry and even sub-populations in it will have their own associations and well-learnt meanings for e.g.:

- piping,
- fluids,
- alarm status.

User's models may also depend on the plant's and operators history with previous equipment and traditional panels. There is therefore no automatic need to completely redesign displays from effective conventional panels simply because the displays will now be realised with LSD technology.

The user's "model" is built up from:

- education,
- training, and
- operational experience.

The user's "model" includes knowledge of:

- the connections between plant systems, allowing deductions of how fluids can get from one system to another;
- mass and energy changes in a system, allowing the prediction of the effect on a second system.

4.5.2 Back-fitting applications

The addition of VDUs or substitution of conventional instrumentation by VDUs may enable information to be presented that cannot easily and simply be displayed by conventional instruments, particularly where flexibility is required in a display, for example:

- the output of computer calculations and comparisons,
- overview displays based on derived values, grouped alarms, trends, synthesized variables to summarise plant state, etc.,
- x-y diagrams (graphs of a value against another value), e.g. safety parameters or critical functions display,
- x-t diagrams (graphs of value against time),
- trend logs with flexible scaling (also for long-term history),
- system mimic diagrams with real time status information,
- combinations of different information, e.g. a core map on four screens,
- operating procedures with real time status information.

4.5.3 New MCR design

An iterative procedure should be followed that encompasses:

a) investigation and specification of the main objectives (top-down approach), such as:
   - information goals for monitoring of the plant and the automatic actions,
   - information for decision-making (for manual actions),
b) collation of display requirements for status and trend information of plant conditions and automatic control systems including protection systems (bottom-up approach);
c) determination of the relationship between display formats.

   This should take into account:
   - associated formats,

  – related information,
  – different views formats;

d) refinement of the design by repeating these design steps and adding more details.

Examples of different formats, their typical use and some of their characteristics are given in Annex B.

5 Design and implementation of VDU formats

5.1 Design

A system based approach to functional design of the control room shall be used to determine the information and control needs of the assumed users (see IEC 60964, clause 6 and IEC 61839).

A new design for a general control suite arrangement should identify:

– a list of system functions in the MCR,
– information on work-tasks in the MCR,
– information on the tasks to be undertaken by those outside the MCR who can easily see into the MCR,
– a preliminary description of the equipment to be installed in the MCR.

In the case of a retrofit, redesign, or upgrade a review of current work-tasks and an analysis of the constraints to be observed shall be done when proposing changes to the way work is done.

The requirements for a display-unit or suite of displays shall be determined with a thorough and systematic analysis of the proposed use of the data being displayed.

For each proposed item of information the designer shall take into account the following attributes:

– for how many users the display is required;
– for what purpose or purposes (e.g. monitoring, control action or maintenance) the data are required and how reliable they should be;
– whether comparisons with other data on VDU formats or other displays are required;
– when and how often and how quickly the data is required, e. g. relevance to operator actions;
– the accuracy with which the data shall be read (e.g., from a distance for overall monitoring, close up for accurate and detailed tasks);
– the characteristics of the data in terms of rate of change, noise, etc.;
– errors of interpretation by the operator:
  - Are elementary items of information or information calculated from several values adequate for the operator tasks?
  - Is analogue or binary information more adequate?
  - Is unambiguous interpretation of the proposed information ensured?
– the degree of detail or abstraction which is required (e.g., overview display, individual workstation display);
– the time of an event which causes an important transient.

Data that is relevant to the operator should not be mixed with data primarily for other users; only data needed by the operator for monitoring, decision-making or execution shall be provided in the main hierarchy of displays. Examples are:

– overview, status and ongoing control actions of systems and controls,
– prime cause and transient status of incidents,
– operator guide information.

Other data which is specific to maintenance or analysis should be available through the display system, but may be accessed outside the display hierarchy using special facilities. Examples are:

– active or passive malfunctions noted during automatic actions,
– fatigue monitoring data,
– number and duration of operation of components,
– data related to computer-maintenance, e.g., detailed error messages from a computerized display system.

The location of data display facilities should take into account the intended operational staffing levels, the assignment of operational responsibilities and functions and the need to optimize the number of VDUs consistent with the manning of each operator work-station. The latter consideration shall be dependent on anthropometrical factors such as:

– viewing angle,
– viewing distance,
– proximity to associated controls and indications,
– the amount of data to be referred to.

The determination of the number of workstations shall take account of task sharing and repair, breakdown and equipment faults, to ensure an acceptable number is available at all times.

5.2 General requirements

5.2.1 Presentation

Displays should be as simple, clear and comprehensible as possible.

Where complex or highly detailed displays are necessary, good organization and structure are required.

Where safety criteria require raw, unprocessed or safety quality data to be presented in addition to the processed information, the display organization and identification shall differentiate between these types of information.

5.2.2 Availability

Necessary information shall be displayed to the operator whenever it is required and with necessary redundancy, e.g., alarms may be shown on mimic formats in addition to other forms of display (see IEC 62241). For specific failure criteria, see 4.3.

5.2.3 Legibility

Information shown on VDUs shall be clearly understood in any operating condition. Appropriate use should be made of text and graphical items.

To obtain the necessary legibility of the VDU, the format specification shall be based on a human factor data base such as that shown in 7.2 of IEC 60964.

5.3 Accuracy

5.3.1 Understandability

The display shall communicate the intended information to the operator without ambiguity or loss of meaning.

The scaling of graphs and histograms shall enable the operator to read and understand adequately indications, and the maximum or current value should be annotated with the numerical value.

For digital displays, the resolution of the presentation of measurements should be chosen so that sufficient accuracy is achieved whilst ensuring that the number of digits which change at each update under steady-state conditions is small.

Digits of changing values shall not be updated faster than at three-tenths of a second interval.

5.3.2 Compatibility of VDU-formats with other man-machine interfaces

See 4.4.8 of IEC 61227.

Compatibility shall be provided between VDU formats at individual workstations and any displays on LSDs.

5.3.3 Consistency between VDU formats

Standardization of displays can be beneficial but it shall not take precedence over more important criteria given herein.

If consistency of information presentation is not preserved, the rationale for variation shall be documented.

All items within a suite of displays which represent the same information should be similarly named.

When using the same items on different displays they should be, where appropriate, in consistent positions for each display.

Grouping techniques should be consistently applied with standardized headings and style.

There should be consistency between VDU formats at individual workstations and any displays on LSDs.

Presentation and interaction of LSDs should not conflict with individual workstations and other design aspects. This is to reduce interference with things previously learnt, and to make it easier to find information quickly.

Note that consistency and compatibility of LSD formats with other systems:

– will help with learning and acceptance;
– does not preclude the development of special additional features for overview purposes, such as abstract overview graphs, special overview symbols, overall alarm cues, etc.

5.4 Form of presentation

5.4.1 Principles

5.4.1.1 General

Human beings are capable of visually comparing information and detecting contradictions. Therefore, displays shall be designed so as to benefit from this ability. It may be beneficial to display a certain information goal as a set on several screens at the same time or different views of the same information on different screens.

In selecting the form of a display, due account shall be taken of the advantages of a particular presentation in relation to the information being displayed. Analogue coding such as bar graphs, trends and symbols in addition to numerical representation should be used preferably.

The need for text-labels is reduced if graphical means such as mimics and symbols are used.

5.4.1.2 Colours

Where colour is used with safety significance, other kinds of coding, e.g. position, symbol shape or text shall be used (“redundant” coding) to ensure that safety significance can be clearly noticed by the operators without sole or unsupported reliance on colour.

A neutral background colour should be used if colour-coded objects are used.

The decision to use colour-coding should be based on an understanding of what the user wants to do.

Objects can also be coded by other methods than colour-coding, such as:

– shape,
– position,
– intensity,
– blinking,
– etc.,

The choice of colour should be conscious.

The choice of colour should not be the default coding method even though it is easiest to implement.

Aesthetic use of colour should come secondary to, and should complement, the colour-coding or formatting. Note that:

– it is possible to make displays look unattractive and garish with just a handful of unsuitably chosen colours;
– unsuitably chosen colours can detract from the functional effectiveness of other colours (colour pollution) used, even if the display looks more attractive to casual visitors;
– one argument for using colour displays is to encourage long-term user-acceptance.

Saturated colours should be used to indicate the important, categorical nature of information if the overview display is to contain important qualitative information.

Smaller differences in hue, saturation or intensity can code ordered or quantified information.

Less important information that is constantly present or not dynamic, such as flow lines and types of fluid, may still be coloured but should not be as saturated. This is to preserve the usefulness of layering and the effectiveness of colours for really important categories or status changes.

5.4.2 Use of symbols and graphics

Symbols should be standardized.

The risk of interpreting a symbol in more ways than only one must be zero, unless the new interpretation is due to the use of the symbol in combination with other specific symbols, where this use is uniquely addressed in the display requirements.

The range of symbol sizes should be limited to a progression which allows easy recognition of the various sizes.

5.4.3 Schematic and mimic displays

Related items of the power plant should be organized in such a way that reflects their relationships with an appropriate degree of abstraction to avoid complication of the display.

Process flow paths and the sequence of events should generally progress:

- from left-to-right, or
- from top-to-bottom, or
- in accordance with population stereotypes.

Additional guidance for layout of mimic diagrams is given in 4.4.5 of IEC 61227.

5.4.4 Formatting of information

Sentence and message construction should present good syntax.

Sentence and message construction should not be worded cryptically.

Where possible a standardized hierarchical message structure should be employed.

The layout of information should reflect the sequence, if any, in which it is used.

Rows of tabular information should normally be divided into groups of not more than five.

The presentation should be compatible with other related forms of information display within the same location.

Grouping and coding techniques shall be used for enhancement of the perceptions of displayed information. These grouping and coding criteria are shown in 7.5 of IEC 60964.

All information stored in and processed by the information system shall be able to be displayed in the appropriate manner, arrangement, and time.

Most information should be requested and arranged by the operating staff.

Some information may be automatically displayed or may be recommended by automatically displayed menu proposals.

It shall be clearly stated in the design documentation and may require optimized format selection mechanisms (e.g. dedicated access push buttons) if there are individual formats, or information of event- or symptom-oriented format-sets that are requested to be displayed a very short time after being selected.

Depending on the variety of information needs and the diagnosis strategies, multiple accesses to the relevant displays and their flexible handling shall be provided.

Displays shall be designed to minimise the number of moves to access the information.

Some examples of access methods are shown in Annex D.

6 Design and implementation of large screen displays

6.1 Purpose of LSD systems

The most common purpose of LSDs is to support joint situation awareness and interaction through facilitating simultaneous viewing of the same information by several individuals. With regard to control room design at NPPs, the main purpose of LSDs is therefore to increase team performance. A secondary advantage of LSDs is that they provide overall plant knowledge to cleared individuals other than the control room operators, so that the operators do not have to be disturbed. The LSDs might also contribute to increasing individual performance, although they are not intended to replace the operators' primary display (which is taken care of by individual workstation design).

Large screens can also be used to compensate for some of the drawbacks of VDUs compared with the older but larger wall panels. Some of the disadvantages of individual VDUs without wall panel or complementary LSDs, which retro-fitted LSDs can resolve, include:

– difficulty in maintaining awareness of overall plant status,
– difficulty and time-delay in accessing computer-based controls and displays,
– difficulty in maintaining awareness of the actions of other team members,
– difficulty in communicating.

VDUs and LSDs should of course be designed according to ergonomic principles, which in many cases will need adapting. The overall goals and requirements for the LSDs shall be identified by the designer.

Typical goals of the display design are:

– The display should enhance situation awareness and overall understanding of the status of the plant.
– LSD formats should be interpretable at a distance, at least at an overall level, without having to read detailed text.
– LSDs should be suitable for one operator alone to use.
– LSDs should support situation awareness, for the MCR crew as a whole.
– LSDs should also function as a “walk-up” display for briefing or group-work purposes.
– Presentation of information and status-changes should have negligible processing delays.
– Unnecessary information should be omitted; operators are expected to use their personal workstation for detailed actions.
– The LSD should effectively display current status to multiple team members simultaneously.
– The LSD should allow team members to see the effects of their actions on the tasks of other operators.
– The LSD should make monitoring easier for the team-leader or supervisor.

If it is decided that LSDs are appropriate by the plant or an upgrade project, then the most critical issues to resolve before implementation are:

– the number of displays, configuration and placement of LSDs,

– the information presented on the LSDs,
– the control of the information content on the screens,
– the control or adaptation of lighting in relation to display type. (This issue is more dependent on the particular technologies chosen than others.)

These aspects are addressed inclusively in 6.2 to 6.5.

6.2 Overview of LSD design issues

For display management and control of LDSs it shall be decided:

– Who has authority to change the information being displayed ? and
– How those changes should be implemented (manually or automatically) ?

The design of the LSD format should address particular problems that have been identified, for example, from:

– operating experience, or
– a situation analysis of an existing installation.

In each project it should be identified which specific problems the designer should address.

Typical problems found in control room review could include:

– unplanned stoppages due to untimely intervention by control room staff,
– difficulty in maintaining awareness of plant states,
– human errors due to inadequate control room design for monitoring, situation awareness and detection,
– safety-related situations, for example, due to mutually conflicting situation interpretations by the operators,
– difficulty in integrating and accessing information speedily from existing systems,
– wishes from operating staff for improvements on ways of staff communication.

The LSD system should include an on-screen display pointer under operator control. This is to facilitate group work, discussion and collaboration.

Operators should be able to control the display pointer from their normal seated positions.

LSDs should be used when their presence has a concrete positive contribution to joint situation awareness and interaction among control room operators or cleared individuals using the overall information presented by the LSDs.

In all cases, the application of LSDs should be validated with regard to cost-benefit factors and in comparison with other available solutions.

6.3 Placement of LSDs in the MCR

6.3.1 General

Before starting detailed design of information presentation the project should consider:

– the number of LSDs, and
– the configuration of LSDs.

Human factors issues such as visibility and the reaction of the operators should be considered before deciding on the configuration.

The designers should consider what kind of detailed information that users need to see. Therefore, the design should consider:

- Do the users need to resolve all details ?
- Will some or all of the LSD information also be available on other displays ?

Users should be able to resolve all detail that is important to them at their maximum viewing distance.

6.3.2 Placement relative to operators viewing areas

The designer should decide which areas of the control-room are included in the LSDs intended viewing area so that guidelines for maximum viewing distance are not exceeded.

The determination of the maximum viewing distance can be based on:

- Who the user is ?
- What the user's information requirements are ?
- What type of information is displayed ?
- In what way the users use the information ?

The viewing angle for the LSD relative to an operator's normal position in a control room should not be too large.

The normal work area for any principal user of an LSD should be within the acceptable off-centre viewing area of that LSD.

LSDs should be located relative to critical users so that they are not obscured by other people.

LSDs should be located so that the need for frequent head rotation in order to look at the LSDs is avoided.

Guidelines on placement of LSDs relative to operators should not be too rigid, since operators occasionally move around and sit casually.

If it is difficult to find a suitable placement of LSDs, this may indicate that a better solution could be established through other options, such as:

- display of less information,
- use of larger or more LSDs,
- replication of display-units, or
- multiple copies of display-formats.

For assessment of visual angles for secondary displays, a range of horizontal placements within ±80º of the normal line of sight is acceptable.

For assessment of visual angles for secondary displays, a range of vertical placements should be within ±45º of the normal line.

If two users' normal working positions are offset to either side of a LSD, then information important to both of them may need to be placed in or near the overlap between the visual zones of the operators to be seen and understood by both of them. The designer should consider the combined effects of:

- off-centre viewing,

– loss of brightness due to non-uniform screen reflectance, and
– any loss of off-centre colour rendition, brightness or contrast due to the display-type.

The display for a particular user should not be closer than half the display's width or height, whichever is greater. This criterion sets the minimum viewing distance.

Visibility assessment of LSDs should take into account the capabilities and limitations of the operators. This includes issues such as:

– head rotation,
– viewing angle,
– obstruction,
– shared use, and
– character height.

Shared displays should be visible when looking over workstation equipment.

The upper limit of the shared display is determined by the line of sight of a small person at the position closest to the display.

The closer users should be able to see the whole picture and should not be able to see the construction of the picture (dots, lines, inter-pixel gap on LCD projectors).

Refer to ISO 11064 for more detailed requirements.

6.4 Information content of LSD formats

6.4.1 General

The LSD pictures should be specially developed to be complementary to primary workstation pictures.

The LSD pictures should not be copies of primary workstation pictures even if these workstations already have overview pictures available on them, tailored to individual operators.

Displays for standard VDUs should not be copied to LSD systems without there first being an evaluation for acceptability.

When LSDs are introduced operators should continue to have access to all information necessary to complete their tasks in their immediate work area, because LSDs should be supplementing rather than replacing individual computer displays.

The information on the LSDs should largely be for the benefit of multiple users of the space simultaneously.

The maximum viewing distance is permitted to be different for different types of information in the display. For example, high-level status indications may be intended for viewing from larger distances, across the control-room.

The determination of acceptable text size should consider the type of information and the context in which the information will be used. The minimum size criteria does not necessarily need to be applied to all areas of the display in the same way.

Users should be able to resolve all important display details at maximum viewing distance.

6.4.2 Screen and display performance

The LSD should appear continuous. Users should not be able to distinguish:

- scan lines,
- pixel boundaries,
- character-matrices,
- boundaries between multiple projection surfaces, or
- areas of overlap between projectors.

The screen designer should "anti-alias" curved or sloping edges with colour-scales or grey-scales. Depending on the viewing distance, this may make certain older projectors and projector technologies less suitable (e.g., "screen-door effect ", lower-resolution projectors).

The displayed image should not have appreciable geometric distortion.

The size of a symbol of unit area projected anywhere on the LSD should not vary by more than 10 % in height or width, from ergonomics criteria. (Aesthetic standards may be higher still.)

6.4.3 Screen format design for LSDs

The main elements of overview displays should as far as possible avoid the need for mental calculations and processing of numerical data. Information that cannot be taken in at a glance should be avoided.

Secondary numerical data may be present on the main elements of overview displays if it does not clash with other guidance, but these data should not be the primary means by which the overview works.

The display should not primarily allow quantitative overview.

The display should allow rapid comparative overview, i.e. visual comparisons with:

- normal,
- presets,
- alarm limits,
- components that should have similar values.

Information detail should be avoided on LSDs.

Detail should be left to individual operator displays.

Clutter and patterning in display elements that do not carry information should be minimised. Clutter and garishness can be reduced by using less saturated colours and by removing unnecessary lines around format areas.

The LSD should give clear and quickly usable links to where further information can be found, e.g., a picture number or link.

Different groups and classes of information should be separated, and put into separate layers of presentation, where adequate. In this way the most important task information is visually prominent, whereas features and objects that indicate less important information are placed on perceptually more distant or 'lower' levels.

Layering can be used where there is a map-like basis for the information being presented, such as an overview mimic diagram of a plant. Layering can be achieved with:

– spatial separation,
– graphical border elements,
– intensity differences,
– contrast, and
– colour.

For example:

– saturated colours only for alerts such as alarms,
– operating systems in semi-saturated, natural looking colours, and
– shut down systems in a totally unsaturated colour (shade of grey).

Layering lets people find what they want faster on an overview display, as opposed to the older principle of using a set of maximally discriminable colours.

Text labels for graphical or symbolic elements tend to clutter LSD formats and are less necessary than with detailed formats on individual workstations.

The need for text labels is reduced using LSDs, because LSD formats tend to be always present and therefore very well learnt.

The use of text labels which are to be read at a distance should be minimised. However, there may be less salient labels for displayed quantities that are designed to be read from closer range. A key or other control operation to show or hide detail may be used with advantage.

Note that:

– lighter backgrounds are less prone to having their contrast reduced by scattered light;
– unsaturated colours at longer viewing distances can create problems on the wrong background.

All luminance that is supposed to be the same should appear the same. This means that:

– luminance towards the edges of a LSD should not be less than 50 % of the centre luminance of the line of projection. That is not usually a problem for modern projectors;
– the luminance of the screen centre at maximum viewing angle should be at least half the maximum luminance. This should be true from the operating position of all staff intended to use the LSD regularly or constantly.

The above places restrictions on the amount of positive gain the projection screen material can have.

6.4.4 Special colour issues for LSD formats

Colour may be used if it is necessary to:

– emphasize a specific target in an overview (saturated colours),
– provide warning signals that are attention-getting on an overview,
– imply physical states of components or trains summarised on the LSD,
– segment broad areas of a LSD format (unsaturated colours),
– group and bring together information within the overall information presentation area of the LSD,

– be aesthetically pleasing, and easy on the eye, for prolonged viewing and even for casual users of the control-room's LSDs.

Colour codes should be as few as possible to meet the needs of the LSD-related task.

The design should avoid the need to discriminate any categorical difference in meaning of colours close in hue if they will be far apart on the LSD.

In the context of LSDs, the user is not expecting to make a quantitative reading of a quantity from the colour or saturation. (The workstation is used to investigate instead.)

Colours far apart in the spectrum that fall in the centre of vision provoke continuous refocusing, and this can lead to visual fatigue with a constant display like an LSD.

The design should be especially cautious when using colour for emphasis on LSD formats. If too much salient colour is used, then this detracts from the effectiveness of the LSD as a rapid overview and users begin to complain of clutter or garishness. No one colour is better than another for attracting attention in peripheral vision—contrast is at least as important. Note that:

– for small targets, colours away from the pure blue part of colour-space should be used;
– small targets are more easily detected using "warm" colours than "cool" colours;
– coloured symbols and icons on a background of similar brightness (e.g., blue or green on a red background) will be very problematic;
– when shape discrimination is important, foreground and background should have different brightness. (The eye distinguishes shapes by brightness contours rather than colour alone.);
– poor colour choices that lack contrast may lead to errors;
– luminance contrast for text is very important, over and above colour;
– broadly speaking, the hue and saturation of text foreground and background can be ignored (with a few qualifications);
– there should be a luminance contrast of at least 3:1 between text and background as the standard suggests. (A luminance difference is needed to detect edges; colour difference is not enough.)

6.5 Control of change of display-content on LSDs

The project should define the degree to which selection of an appropriate large screen display is automated (if several will be provided) based on:

– task analysis, and
– requirements.

During the task described above the designer shall be aware of the following:

– automatic control can reduce personnel response time and "interface workload",
– operators are not so enthusiastic if the choice of display by the system is not correct,
– full manual control gives operators their choice, but it increases workload and may distract operators from their primary displays (those on their workstations).

One solution might be to have automatic selection with manual over-ride, the decision being allocated to the team leader. Multiple presets depending on situation or plant state could also be implemented. Note that:

– any critical information that is shown on the LSD should not be modifiable or erasable,
– control of changes to the display should be allocated to chosen users who operate according to established procedures or in accordance with a supervisor,

– if a user wants to make changes that are of interest primarily only to that user, a separate display, e.g., the user's workstation, should be used. (This does not preclude workstation-based LSD from functioning as a secondary display for other users.)

7 Verification

The verification of a VDU-based information system shall be carried out for a well-specified set of operational state data including abnormal states and fault conditions.

Tests to be performed in a stand alone test environment or in the context of the I&C integration testing should be included.

Tests in the integration phase of the full scope training simulator should be considered.

The verification process and the general verification criteria shall follow the relevant requirements given in 6.4 and Clause 8 of IEC 60964, and in IEC 61771.

Special attention shall be given to ensure consistency in situations where variables are displayed at several locations at the same time.

Time delays caused by different scanning or considerable pre-processing shall be reviewed and assessed with respect to consequences and clearly documented.

It may be beneficial to use special tools for the verification process. A practical example of verification is given in Annex E of this standard.

Experience has shown that some information or even some display formats are most helpful in any situation. Such information and display formats may be displayed continuously, for example, on overview displays or LSDs, or included as constituents of the most important format sets.

The key formats and key format sets shall be verified and validated carefully, since they by definition contain only summarising information that an operator may come to rely on for initial alerting in a plant disturbance.

8 Validation

The validation of a VDU-based information system shall be carried out defining representative scenarios of operation, disturbed situations or accident conditions and information goals for different users of the system.

Possible test environments include:

– paper drafts,
– stand alone work stations,
– part scope simulation,
– full scope simulation.

The validation process and the general validation criteria shall follow the relevant requirements given in 6.5 and Clause 8 of IEC 60964 and in IEC 61771 (see also Annex E of this standard).

Annex A
(informative)

Advantages and disadvantages of VDU-based display

A.1 Advantages

a) VDU application enables new types of information display to be used. It leads to new possibilities for information condensation and abstraction which could not be achieved with the conventional instrumentation of the past.

b) The relatively small size of VDUs allows for easy situation dependent presentation of information. Accordingly, the size of a modern MCR can be minimized (normal operation, disturbed situations, refuelling, tests, etc.).

c) For a complete display of all information of a certain information goal, one screen only may be sufficient, but arrangements of multiple VDUs enable more sophisticated information to be assembled together with an optimal overview and the possibility of showing the same situation from different viewpoints.

d) The tailored composition of the entity of primary information for one information goal enables the display of unnecessary information to be avoided.

e) A VDU system of adequate capabilities enables fruitful dialogue activities which may be performed from one working position (no need to move around in the MCR).

f) Multiple VDU-formats can be related to each other in an optimal way according to the specific situation; all arrangements can be rearranged at any time by easy shifting capability. Also that of most interest can be brought to the centre.

g) An arrangement of well-designed formats on multiple screens can be monitored by several users at the same time so that they can all think and discuss on the basis of the same information (and can be guided by cursor).

h) The content of one format may be presented in several layers. Using the approach of a background and some foreground layers, the higher levels of information concentration and abstraction can easily be applied.

i) Not all information which can be displayed in one format needs to be displayed at any one time. This may be triggered manually by means of hard or soft keys or according to well-specified conditions.

j) Trend logs of different scaling and diagrams with a history display assist the review of the past for diagnosis. Reverse reading of histories in trend curves and in diagrams may lead to the prime cause of a disturbance. Extrapolation of history information may serve as a simple method of assessing the future behaviour of the process.

k) Repeating the display of a transient in slow motion (at once or after stabilizing the plant's behaviour) may enable the operating crew and advising and supporting personnel to get a better understanding of its development.

l) The great flexibility and capability of a VDU-based system enables an operator to both obtain an overall view of the present situation and browse through different views of the plant (from the operators (fixed) location) which in turn leads to early detection of even small deviations of variables. This may also apply in cases of time or load or situation-dependent variables.

m) These advantages can be used especially to implement enhanced operator support systems (see 7.7 of IEC 60964).

   In order to enhance plant safety, availability and operability, operator support functions such as safety parameter display and surveillance functions, plant diagnosis functions, symptom-based or event-based operator guide functions, functions for automatic on power-test should be provided. As far as practicable such functions should be fully integrated into the overall design of the control room.

They may be based on the knowledge of experts in the fields of nuclear engineering and computer techniques and may range from:

– signal validation and pre-processing (filtering, comparison, computation);
– intelligent picture design:
  - main goal and advice for relevant additions;
  - sequenced display of the operation manual; other diagram versions;
  - display of all possible, graded countermeasures;
  - division into foreground, main and background information;

to simple, easy and flexible access and recording.

n) The use of VDUs allows for efficient integration with soft controls (see IEC 61227 for further details).

A.2 Disadvantages

a) All information will not always be presented at the same location. “Key hole” effect.
b) Understanding of VDU-based intelligent information needs a certain level of training and a reasonable knowledge base (e.g. formats designed for trained shift operators may not be suitable for visitors).
c) VDU-based information does not support the human capabilities of spatial information coding and “information catching” to the same extent as conventional panels.
d) The lifetime of a screen is more limited than that of conventional instrumentation.

Annex B
(informative)

Examples of formats, typical use and some characteristics

Applications ***Advantages/disadvantages***

B.1 Alpha-numerical displays

Alarm displays	Require only little interpretation
Messages for guidance	Give rather complete information
Text of procedures	Need extended space for the display and long time to read and comprehend
Operation information	
Maintenance information	Valuable for signal validation and testing

B.2 Bar-graphs

Normalized indications for comparison	Enable standardized scaling to be used
Indication of actual values together with limit values (colour changes at limit)	Simplifies comparisons; good for easy and quick limit recognition

B.3 Trend curves

With different standardized time scales (s - min - h - d - w - m the last ones with long history display in time steps)	Good for assessment of time dependence (especially of correlated variables; slow and fast time scale; high resolution; repetitive; stable)
With per cent of units scaling	
With windowing and zooming capability	
Similar trend curves for comparison Correlated variables together (e.g. flow in/level/ flow out)	Easy comparison of similar behaviours and early detection of deviations (comparison of actual curves to reference)
Predetermined groups directly accessible for the user	Permit looking at the past and prediction of future behaviour
Free composition arrangements	Permit comparison with pre-computed or experienced behaviour

Applications	*Advantages/disadvantages*

B.4 Logic displays

Preferable as overviews (overview of simple labelled boxes)	Good for understanding: what initiation has caused what actuation Good for detailed detection of failures Exceptional for detail display

B.5 Mimic diagrams: structure and status displays of systems

Structure and all components of process systems	Good plant overview
Actual status of systems and plant components (open/closed-on/off-running/standing) (ready, disturbed, in/out operation, in/out of service, removed) Status of control systems (including protective functions)	Good for showing "success paths"
Indication of variables/diagrams	Detailed information such as margins, thresholds and boundaries
Results of automatic or manual actuations	Fast feed-back information

B.6 X – Y Diagrams

Two-dimensional dependencies Multi-dimensional dependencies	Good for understanding of functional dependencies in depth: e.g. margins, thresholds and boundaries, anticipation of evolution of variables; which causes what, why at what time, and how long and often

Multiple plane compositions:

– in the main plane: actual values of variables (some with history),

– in the background plane: diagrams with design areas and lines,

– in the foreground: balance indications
(e.g. horizontal/vertical, flashing, bar-graphs, etc.).

Dynamic area as: functional status of controls.

B.7 Overview displays (LSDs)

Status of process and control systems	Good for maintaining common situation awareness, high level information and early problem detection

B.8 Screen selection

As menus, preferably with icon tables	Good for quick special access to different formats or format-sets; may be tailored to each special information goal, situation or special formats

Annex C
(informative)

Format design and implementation basis

The design of a format should be based on the operators' needs and should take account of:

– the design description of the plant systems;
– all plant operational states, such as normal operation, disturbances, refuelling, maintenance, accidents and emergency conditions;
– simulation experience for normal operation and disturbances;
– the feed-back from commissioning and operation of similar plants already in operation (both with stored data, e.g. on tapes).

The implementation basis should include:

– a short description of the purpose of the formats (text);
– a proposal for its layout (picture);
– a specification of necessary signals (listing);
– a specification of signal pre-processing, functions of indications and the relevant time dependencies (functional diagram), refreshing time;
– a specification of the up-date rate of each signal;
– a specification of tests.

Annex D
(informative)

Examples of access methods

Some examples of access methods are the following:

D.1 Access to single formats

Single formats can be selected in different ways:

a) by pressing a dedicated push-button;
b) by dialling a certain number;
c) by calling an alpha-numeric menu and marking a certain line by tracker-ball, or paging forward and backward by push-buttons;
d) by selecting in any format a special navigation target, which leads to associated information on a single format or by selecting in special formats, showing icons of all those formats which together form a complete set of information about a certain "information goal";
e) by asking for one format from the list of the previous formats on the screen;
f) by selecting an "associated format" to a special format just displayed:
   – diagram to system;
   – curve to diagram;
   – logic to schemes or system.

D.2 Access to format-sets

Format-sets may be selected by pressing one push-button identifying the set and another marking the VDU for the display in the upper left format of the format-set.

The sets may be compositions of single formats according to:

– operation, maintenance, disturbance or accident goals;
– overview formats of the main plant, auxiliary systems or situations of all kinds of operation;
– mixed information and text of all kinds of procedures for event and symptom oriented behaviour.

D.3 Access to information for transient analysis

Information about transients may be displayed by using:

– back and forth tracking of trend curves with different time scales;
– alarm lists (and paging);
– diagram display which also shows changes with time and the course of movement of operating points of variables.

D.4 Other possibilities of access

These may be windowing or zooming, but care shall be taken to ensure legibility.

Annex E
(informative)

Verification and validation of VDU

E.1 Verification

E.1.1 General

A VDU-based information system differs in principle from a conventional system in system structure as well as in information processing and display. Therefore, the verification procedures also need to be quite different. V&V of VDU systems by definition includes any LSD systems whether integral to or supplementary to workstation VDU systems.

Verification of a VDU-based system where stationary and transient information display is brought close together in any format, and especially in the highly sophisticated ones, needs both aspects to be monitored and checked with respect to suitable relationships between different sets of information, particularly bearing in mind the great variability of process dynamics and the effects of scan intervals on processing time delays.

Each advanced VDU-based system which has been developed on the basis of extended computer-based, experimental or operational knowledge, offers supplementary associated information to the main topic of a format. This is done inside the frame of the same format or on neighbouring VDUs. This enables the designers to provide complete information for a goal-oriented display but needs special additional assessment.

Repeated tests should preferably be carried out over a full range of conditions on a full scope simulator during the construction stage if available, but it may be necessary to defer some tests until the commissioning stage.

E.1.2 A proven verification of VDU formats

The verification of a highly sophisticated format may consist of several sequential tests (see Figure E.1).

a) In a computer centre:
   - specified test sequences during implementation;
   - knowledge-based laboratory tests by the designer;
   - the use of a full-scope simulator.
b) On-site:
   - tests of all signal lines to the system, for both single signals and "integral signals" for redundant or combined display (with different signal values);
   - supervising tests by the commissioning engineers of the plant and/or by the designer;
   - documentation of commissioning tests such as:
     - load changes, load rejections;
     - failures of plant items and trips;
     - loss of power supplies to systems;

   using:
     - computer storage on discs (for long-term transients);
     - hard copies (at certain stationary conditions);
     - screen capture or photo series (for transients);

- computed additions (to assess non-measurable variables).

E.2 Validation

The proposed design shall be validated according to the general evaluation criteria for validation (see 6.5.3 of IEC 60964 and IEC 61771). A validation procedure shall be concentrated on well-specified goals of the partial process of top-down design and to the key formats of highest information and concentration abstraction.

This validation shall take into account the results of the verification, especially assessing the completeness of required functions, signals, formats and format-sets.

This shall be done with respect to the main and also to the associated information of a format. Attention shall especially be given to detect unacceptable contradictions.

It may also be of great benefit to use a full-scope simulator for the relevant plant as the main validation tool.

Running the formats dynamically by use of recordings with data produced on a simulator or even stored during commissioning of a similar plant can lead to the same quality.

The final validation shall be done during the plant commissioning by:

– testing the key-displays during some/all main transient tests;
– checking all displays at several stationary conditions.

In case of back-fitting, only a relevant set of formats and format-sets may be applied, for example, to:

– one goal .... a format-set
– one sub-goal .... one format

The above mentioned requirements shall therefore be applied with restrictions.

Definition of information goals (Manufacturers) (Users)	– Central format – Associated information
Format - specification (Designer) – format proposal + description – signals + functional diagrams – test sequences	– Icons – Single formats
Programming (Programmers) Verification, tests	Test centre (with plant data)
Single format verification (Designers) (Knowledge-based tests)	
Input signal, checks (Instrumentation & Control commissioning engineers) (Computer system + single formats)	On-site or, partially on a simulator
Program operability and selection checks (Computer system commissioning engineers)	
Different test effort according to complexity (Changing crews) – comparison of hard copies with conventional indications for different stationary conditions (all formats); – numerous additional signal inputs: integral test (single, redundant and sequential) hard copies (photos) of relevant diagrams; – transients of plant commissioning tests for single formats, format-sets of distinct information goals: hard copies and photographs; – documentation (storage of all tapes about plant tests).	

Figure E.1 – Format creation and verification

Annex F
(informative)

Method of VDU format design presenting information on plant conditions and equipment state

VDU displays are used widely for presenting information on plant conditions and equipment state. Often a mimic layout of the plant or equipment is shown, with inserted values and states, time-based graphs, alarm markers and titles.

The following guidelines are offered for this special display design.

Make a hierarchy comprising: overview - main plant - detail plant - signal details.

Put in navigation guides to get from one display to the next at its level, and up and down the hierarchy.

Workstation-based VDUs show a "keyhole" view of plant (relative to panel meters on traditional panels or LSDs); design the display formats knowing this.

Have at least two methods of selecting each picture, e.g. mouse and keyboard, keys and navigation targets - operators' tastes differ, and one method may fail.

Include soft navigation targets, think the navigation tree through.

Match the mimic layouts the operator will be used to, consistently.

Design the displays in relation to the operating instructions if possible.

Identify the signals for each display before trying to design the display layouts in detail.

Include in any format only the information necessary for users' needs.

Write a guidance document for display designers, to ensure consistent titles, formatting, character sizes, colours, symbols. Use it, and then update it.

Use standard large, medium and small character size consistently for main titles, captions and details.

Centred titles are read quicker than left or right justified titles.

Do not use CAPITALS, use lower case letters, which are easier to read.

Use colour for clarity, and use it consistently. Moreover, in order to make the user aware of a display colour failure, the three main colours (red, green, blue) should be continuously displayed in a dedicated area of the VDU.

Ensure that colour vision impaired people can still get all the necessary information.

Do not use a colour code alone, use symbols, shape, position, strings of characters.

It has been proved unsafe to use mirrored left-handed and right-handed layouts - stick to one orientation.

Keep to a consistent naming scheme for plant items - do not say "Boilers A, B, C" in one place and "Steam generators 1, 2, 3" in another.

Define standard dynamic symbols for valve states, pump on/off, etc., and standard layouts for digit strings for measurements, with standard positions for alarm symbols, alarm reset, etc.

A detail/declutter toggle for signal tag identification can be valuable.

Operators may only want an overview and one or two main items most of the time; do them really well.

Operators like time-based graphs of process variables.

The operators and commissioning staff need the full detail on signals, somewhere, so provide it.

Show titles and values of measurements, plant unit scaling, alarm settings, etc., with their instrument tag identification, in full, at a lowest display level.

Show titles and states of contacts and alarms, with tag identification, in full, at the lowest display level.

Prepare the picture designs on a magnetic medium or computer aided design (CAD) tool, put all the signal identification and dynamic information on it too and not only on paper.

Get the picture design magnetic information translated automatically to make the data for the on-line computer to use.

Use a version management scheme.

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