Nuclear power plants — Control rooms — Operator controls

ICS 27.120.20

British Standards

National foreword

This British Standard is the UK implementation of IEC 61227:2008. It supersedes BS 7517:1995 which is withdrawn.

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

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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CONTENTS

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.

Within a given structure (either desk or panel), control devices shall be arranged to form functional groups irrespective of the nature of the information presented. A functional group should be specified in terms of the achievement of a given function or process operation. For certain plant items, for example pumps, the "functional" grouping may equate to a group of mechanical plant components. The groupings shall take account of "systems" as a series of plant components which are linked in some functional way e.g. a piped or ducted fluid system, electrically connected system, or a set of components which are installed to achieve or maintain a defined plant function, for example, primary and secondary shut-down devices. (These two sets of plant devices may be functionally independent but are provided to achieve the same end result, i.e. subcritically.)

Panel layout of one group shall be done consistent with the layout of adjacent functional groups.

The groups of controls and indications so formed shall normally be laid out logically in the sequence of use, but if superimposed on a mimic, should be placed in appropriate positions in relation to the mimic.

5.1.2 Positioning of groups

The position of a group within a desk or panel shall be optimized taking into account the following factors:

a) the order of use should follow some simple principle, such as left to right in start-up or power raise, or following the order of energy flow from source on the left to sink on the right. It should accord with accepted population stereotypes;

b) the order should not be biased in favour of infrequent operating conditions;

c) the devices required for safety and normal minute-to-minute operation should be close to the operator's monitoring position, and this factor may be an exception to the overall pattern derived from a);

d) there may be displays which shall be visible from a number of operating positions, such as an overview, or which require to be easily and reliably located in a fault situation. If desk mounted they should be located in the near-vertical surface in preference to the near-horizontal;

e) where more than one functional group contains similar plant items, for example the main boilers, the groups should be identically laid out and follow in an apha-numeric order.

5.1.3 Device layout

Within a group there shall be a detailed analysis of the relationships between devices and the sequences of use, and the layout shall be optimized for the following factors:

a) for those groups where there is a unique sequence of use the devices should be arranged left to right in sequence of use, taking into account the general requirements for safety and visibility referred to in 5.1.2;

b) controls should be placed below indications, or where not practicable, on the right of the indication. This does not apply to a control common to many devices, such as "lamp test";

c) where there is no unique sequence of use, devices should be arranged left to right in order of plant identification or energy flow.

Component layouts shall not be "mirror-imaged" ('handed') unless this is justified by HFE (Human Factors Engineering) specialist. Also the layout should not be compromised simply to save space.

A mimic layout may not permit the application of all these requirements.

5.1.4 Uniformity of orientation

Similar looking control elements or arrangements shall be operated in a similar manner and provide similar choice selection. Control movements shall conform with population stereotypes, but typical examples are given in Annex A.

5.1.5 Mimic diagrams

In cases where indication and control devices are arranged in a diagrammatic or schematic display (commonly referred to as a mimic diagram), the above layout principles apply to the functional clusters of controls and displays, but there are a number of additional considerations.

The schematic should conform to a representational model of the plant that can be used by an operator. This will have been conditioned by the physical appearance and layout of the plant, by the layout of controls and indications in the control room and local panels, and by the drawings most frequently used. All three factors shall be considered. As an example, if only the physical layout of quadrantized plant around a reactor were taken into account, it would result in a diagram of these quadrants containing mirror-imaged elements. As a general rule, mirror imaging is undesirable and should be avoided. Controls and indications should be positioned to relate to the physical position of the related plant item.

Corresponding information should be placed in the same relative position in all similar instances. This is the approach taken on control desks, and so the elements showing the quadrants would be designed identically, being differentiated by titles and labelling or colour. This standardized layout, for example for a pump set, facilitates recognition by the operator.

Flow paths should be arranged to be as simple as possible and generally should be left-to-right, and top-to-bottom. In the case of a closed system, the designer shall judge whether a clockwise or anti- clockwise flow is appropriate, although the former is recommended. Direction of flow shall be consistent between diagrams. Usually, the most involved part or the most significant part of the flow path should be arranged to be left-to-right. Flow direction should be maintained within functional plant areas.

Certain physical aspects of a system shall be taken into account. For instance, in a system where gravity plays a significant part, for example a low-pressure water system, the diagram should reflect this in the position of vessels and pumps, etc. Similarly, large physical objects such as boilers and turbo-generators should be represented in a way which is consistent with their physical appearance.

The normal rules of graphic design apply, in that the display should lead the user's eye around the mimic in a continuous manner. Angled lines can lead the user's eye to a particular point on the display, but in general mimics should be based on a rectilinear framework as used for single-line flow diagrams. Junctions should be reduced to show flow direction and cross-overs should be minimized. If flow lines do not join, they shall not touch; the minor flow line should be broken to give a small separation from the major line. If both are of equal significance, the vertical line should be broken to give the separation.

The organization of the diagram as a whole should enable the user to identify with the plant and quickly relate the data on the diagram to give him a clear understanding of what is happening on the plant and the location of touch panels and controlled items. Where several plant items operate in parallel, for example a set of boilers or pumps, comparison of their performance is facilitated if key variables from each are displayed in adjacent positions in lines or columns.

5.1.5.1 Mimic panels for electrical systems

All circuit-breaker representations should be placed in vertical representations of circuits and the control or indication device should be placed close to the relevant switchboard symbol.

Feeders into switchboards should enter into the top of the switchboard representation.

Circuits fed from a switchboard should descend from the switchboard symbol.

Switchboard inter-connectors should form horizontal lines, broken as necessary to give precedence to vertical representations. Inter-connector circuit breakers should obey the general rule for breakers. The order of breakers on a mimic panel need not follow the physical arrangements in the electrical rooms. Precedence should be given to considerations of diagram clarity. However, it should be noted that this rule cannot be applied for representations within the same room as the actual switchboard. Adequate inter-circuit spacing is required and this will depend upon the physical size of the largest component used. This could be a control switch or an in-line current display for example. Adequate space is required between adjacent switchboards to provide the necessary degree of visual discrimination between non-related circuits.

5.1.6 Coding

Coding techniques shall be applied to the design of controls and shall be consistent for all related systems and equipment.

The forms of visual coding used in the control room interface include (in order of significance to the designer):

a) Text

   Device functions are marked either on the device or adjacent to it (the relative position of the text being standardized) using coded forms of text. The formation and application of nomenclature and abbreviations lies outside the scope of this standard but the consequent positioning rules are discussed below.

b) Position

   Control desk and panel designs may be based on the "dark-board" philosophy, where normal running conditions produce a completely dark panel. Plant states are indicated by the position of devices such as the discrepancy indicator and semaphore indicator.

c) Illumination

   The need to achieve greater throughput of information across the interface and the need to enhance the operator's monitoring capacity have led to the use of lit-board systems. Generally lit-board and dark-board techniques shall not be mixed on the same panel or desk. Lit-board systems and the use of increased automation have led to increased use of illuminated push-button systems rather than rotary switch devices.

   Abnormal conditions may be indicated by steady lights, for example a change to manual by illuminating the manual push-button, and flashing lights may be used to denote the need for operator attention to an alarm or change of plant state.

d) Shape coding

   For dedicated rotary controls, shape coding should be specified to take advantage of feedback to the operator that he has identified the correct control. Selectors could have an arrow-shaped handle clearly pointing to the item selected, whereas raise-lower controls could use a T-shaped handle and circuit breakers a "pistol grip".

e) Colour coding

   This is a useful technique, but the use of colour as a sole coding medium is fraught with problems due to colour modified vision, subjective interpretation and the plethora of "standards" relating to colour. Colour coding should be used only in a redundant mode. This is almost always achieved by the additional use of such coding techniques as shape, pattern, or size or the addition of text. Code shall be applied consistently to all controls throughout a particular NPP.

   For current practice on VDU, see IEC 61772 and, for hand controls, IEC 60073 may be consulted.

Special attention shall be paid to the use of red and green colour for coding purposes, especially when red/green is used for coding switch-gear status, it shall not be used for coding other information such as equipment availability/failure.

f) Size coding

Size may be used to draw attention to frequently required items or safety items needed quickly. However, for general use, size coding is not as effective as other methods.

5.1.7 Protection against mal-operation of control devices

To prevent a human-induced event, erroneous activation of controls shall be minimized. Techniques used to guard against accidental selection or mal-operation of control devices include device positioning, device protection and inherent device features, and shall be achieved using the following methods.

a) Proper location: controls shall be located so that the operator is not likely to strike them or move them accidentally in any sequence of control movements. Devices such as reactor trip, turbine trip, or protection vetoes which have an immediate and significant effect on plant state should be placed at the upper part of a control desk to reduce the risk of inadvertent operation.

   Control devices which can have a major effect on plant operation, such as important valve controls or control rod controls, should, unless positioned to prevent inadvertent operation, be fitted with flap guards (hinged covers) which have to be lifted before the device can be accessed. Other controls should be recessed, shielded or otherwise surrounded by physical barriers. For unguarded push-buttons, to improve their resistance to inadvertent operation, raised sleeve guards should be used.

b) Priority of actuation: safety system actuation signals shall have priority over manual actuation signals. Any exceptions shall be clearly specified.

c) Interlocking controls: controls may be provided with interlocks, for example double action, permissive logics, or simultaneous use of two separate buttons. If one of the buttons is common for several separate controls, as a general control action release button, the contact action of this button should not be sustained but should be of the impulse type, thereby preventing unauthorized control action procedures.

   Appropriate choice of device torque or force is necessary to avoid unintended operation and to provide adequate tactile feedback. The use of two-action devices or combination of devices or in critical cases keylock devices is often argued to reduce erroneous operations. Devices such as the discrepancy switch with its turn-push-turn action do reduce the chance of accidental operation, but they can do little to combat the problem of incorrect control identification.

   Where there are similar controls for different systems or trains, they should be well separated or coded, for example by colour.

d) Manual back-up: upon failure of complicated automatic systems responsibility for control may be transferred to the operator. Even with the presentation of the appropriate controls and information, human error may occur unless the required operations are simple and easily understood, and the operator has been appropriately trained. Automatic back-up or alternative systems giving appropriate indications may then be required to bring the task within the operator's abilities.

e) Individual failures of the operator: system hardware, or software should not cause operation of a device controlled by a soft control. One way of accomplishing this is to require the operator and the controller to send two separate and valid messages (e.g., component select and component operate) to effect operation of a device by a soft control.

5.1.8 Compatibility with VDU formats

When designing a human-system interface which includes both computer-based and discrete displays, it is essential that the interface be considered as a whole. Consistency between VDU displays and discrete displays can be considered under four headings:

a) Layout: the relationship between controls and indications both on the desk and panel surfaces and the VDU display shall be considered. Generally, the VDU will host indications rather than active control devices as such, but in systems containing touch-sensitive displays, it may contain controls usually directly associated with one or more items of information.

   The detailed layout of information on VDU screens lies outside the scope of this standard and reference should be made to IEC 61772 on VDU format design. In general, the positional rules of this standard are valid for both discrete components, and VDU display elements.

   In the case of discrete components, physical and anthropometric constraints prevail, whereas in a VDU display, details of text positioning, etc., can be a limiting factor. Emphasis should be placed on the use of schematic and tabular presentation displays in computer-based information systems, but the use of touch screen controls requires increased consideration given to the layout of control elements within a display (see also 5.2 on soft controls).

b) Notation: similar use shall be made of agreed plant nomenclature and abbreviations, etc., on both discrete displays and VDU displays. The space limitations often apparent in VDU display systems may result in the need to use more concise forms in addition to those used in the discrete portions of the interface.

c) Symbology: where diagrammatic representations are used, the symbology used to represent plant components should be similar. It cannot be guaranteed that identical forms will be used, due to the differing nature of the two display media, the discrete presentation being usually a reflective display whilst the VDU display is emissive. These factors will affect certain symbol shapes and line thickness ratios, etc.

d) Colour: use shall be made of similar codes in both forms of the interface. The nature of display phosphors can mean that certain colours are more visible than others (e.g. orange can be more visible than red) and this may dictate a relaxation of absolute standards. The colours which can be used in a discrete component interface will be determined by considerations of colour contrast and visibility. The background colour for desks and panels shall be chosen to provide adequate colour contrast with all commonly used colours, and a light grey has often been used. Additional contrast enhancement, such as outlining, may sometimes be found necessary.

5.2 Soft controls

Soft controls provide HMIs that are mediated by software as opposed to direct physical connections. While design requirements mentioned in 5.1.5 and 5.1.8 apply also to the design of soft controls, they have unique characteristics that make them different from conventional controls. For instance, conventional controls have a dedicated spatial location while soft controls have a virtual location. All conventional controls exist in the same location at the same time. Soft controls are displayed on VDUs and often cannot be viewed all at once. The same set of soft controls may also be used for different modes, each performing different functions. Finally, soft control interfaces are flexible and reconfigurable, given that they are mediated by computer software. All these unique characteristics represent explicit design challenges, requiring specific design guidance. This guidance is provided in subclauses 5.2.1 to 5.2.5.

5.2.1 Display devices

All visual displays units have size limitations and therefore, not all components of a control system may be visible to the operator at once. Nonetheless, soft control shall allow the operator to access individual components where required, and information should be provided on the status of each component and its control relationship to other components. Sufficient display area shall be provided to ensure that short-term control tasks can be performed without interfering with longer-term ones. Otherwise, a set of several display devices can be used to support different control tasks. More information on the design requirements for display design can be found in IEC 61772.

5.2.2 Selection displays

A selection display shows a set of components or variables that may be chosen for a control task. Components and variables presented on a selection display shall be visually distinct to ensure the selection of the correct item. One common format for presentation is to use a mimic diagram (see section 5.1.5). Selection displays shall be clearly laid out and labelled to ensure operators can differentiate between components. The guidance on layout and labelling presented in this standard and in IEC 61772 should be applied in order to ensure that components and variables within selection displays are visually distinct and support operators correctly select items.

Concurrent access of operators to the same plant component has to be analysed and regulated. If the same selection display is used at several work stations, the design shall enable one operator to follow on the activities of the others.

5.2.3 Input fields

Fields for providing a control input shall be designed and labelled to ensure operators are able to determine which plant component is being controlled. In the case of input errors, an error message shall be displayed to the operator. Input may be entered through a designated function on operating dialog or through an alphanumeric code (+/– keys, arrow keys, dedicated keys, etc.).

5.2.4 Input formats

There are several types of input formats to be considered when designing soft controls, and these are described below. For all of them, the interface shall clearly indicate which setting or value has been selected.

a) Discrete-adjustment interfaces shall be used when selecting from a set of individual settings or values. Each selection option shall be clearly labelled.

b) Continuous-adjustment interfaces shall be used when selecting adjustments along a continuum or when a very large range of discrete values are present. Each selection option shall be clearly labelled.

c) Soft “slider” interfaces can be used when the range of possible values and the ratio of a value to that range need to be displayed. The range of values shall be indicated on the slider in accordance with the labelling conventions described in this standard. The numerical value representing the current setting of a soft slider shall be indicated numerically on the slider.

d) Arrow buttons can be used when settings or values can be incrementally increased or decreased. The numerical value representing the current setting shall be indicated numerically. Each press of an arrow button shall change the setting or value in an easily predictable way. Appropriate salient feedback shall be presented when arrow buttons are actuated. Each arrow button shall be clearly labelled.

e) Boxes selection can be used by combining a checklist style page and alphanumeric codes for direct command entry (e.g., entering the Subject Index (SI) for a pump directly without navigating through a page). When selection is accomplished by command entry, a standard command entry area (window) should be provided where users enter the selected code.

NOTE Operator interfaces requiring input of alphanumeric codes should be avoided as basis solution, and only included as a complementary solution for specific cases.

5.2.5 User-system interaction

Multiple modes occur in soft control when a display or input device is designed for more than one function. Multiple modes are prone to operator errors. This happens when an operator interacts with a soft control believing that the interface is in one mode, when it is in fact in another mode. Reducing the number of control modes can reduce errors. The excessive use of multiple modes in soft control shall be avoided. When multiple modes are unavoidable, they shall be clearly indicated, so that the operator can easily determine the current mode.

Cursors are often used to interact with soft controls. Cursors shall have distinctive visual features to ensure they are easily detectable by operators. In the case of a multi-screen workstation, the system shall indicate on which screen the selection cursor is active. The cursor shall be stable and have the possibility to move from one VDU to another in the case of a multi-screens workstation. Control actions applied on a control device (e.g., mouse) shall be compatible with cursor movements observed on the VDU. The use of multiple cursors on a single display shall be avoided.

Prompting operators for entries should be done with clear and specific information or input window. This information may include when and where to provide input as well as permissives and consequences associated with the entry. Standard symbols shall be used for input prompting.

The HMI shall give operators feedback for all selected actions. It may also allow actions to be cancelled before they are executed. The HMI shall also indicate the status of actions in progress. More information on feedback and system response time can be found in IEC 61772. Warning messages shall allow operators to obtain detailed information describing what action was performed, how it was performed, and why it was inappropriate.

Self-correcting features detect and automatically correct errors that operators make when providing input. Self-corrective actions impose additional mental burdens on operators. Therefore, automated, self-correcting features should not be employed for plant-control actions.

When dealing with sequential actions, HMIs shall allow operators to rapidly assess the status of sequential actions in progress. Confirmation steps shall require the operator to respond to a warning or advisory message (e.g., “Do you want to proceed?”). When used, confirmation steps should give details on the goal of an action, not just the action. For example, confirming a deletion action on a specific file, rather than a deletion action alone. Undo features shall be consistently available for all plant-control actions on soft control interfaces.

To avoid erroneous or spurious control (e.g., slips and mistakes) when sending a command, the following general sequence of control may be followed:

a) selection of the control,
b) selection of the command,
c) validation of the command.

Commands that do not directly act on the process do not require a validation step. Some controls may also need to be addressed quickly (e.g., silencing alarm horn).

5.3 Special requirements for touch panels

Touch panels may be used where the selection delay is acceptable. They shall be located so that the ergonomic requirements for both monitoring and control are met. Where appropriate multiple screens, or the use of off-screen devices (track ball or joystick) may be considered.

The VDU formats and touch panels shall cover a work area which is complete for the intended task and guides the operator to suitable actions. There shall also be simple means to move on to other work areas likely to be required or to select new formats. Although the visible areas of touch pads may appear to cover the whole screen, the actual active areas and the space between active areas shall be so chosen that the active areas are easy to select and the risk of touching an incorrect area is very low, particularly for critical actions. There shall be suitable arrangements for setting up the positions of the finger detected by the location matrix and the pads identified on the VDU format.

The equipment shall respond reliably and consistently, and inform the operator immediately of each touch detected by a change of colour or a symbol or message, or an audible tone. Alarms and indications of invalid operations (e.g. raising a parameter to an excessive level) shall be integrated into the format system in a helpful way (e.g. giving current value/alarm level or the reason for an action being invalid). For important irrecoverable plant operations, two touch actions should be required within a specified time. Also see 5.2 for additional requirements for soft controls.

Annex A
(informative)

Examples for the arrangement of discrete controls

a) Rotary control switches*:* OFF/ON selections are arranged with the OFF position at 12 o'clock and the ON position at 3 o'clock. Clockwise rotation causes the device to start.

b) Discrepancy control switches*:* where these switches are not mounted as part of a schematic diagram, the normal OFF/ON positional rule applies. Where they are mounted in a diagram, the OFF position is placed at right-angles to the relevant diagram line and the ON position in line with it. Similar arrangements apply to discrepancy indicators whether of the automatic semaphore type or manually dressed.

c) Selector switches*:* bi-state selections other than OFF/ON are equally disposed about a vertical centre-line. Where a superior state can be identified, that is one in which the system is more active or more automated, this is placed to the right of the pair:

   For example: Lower – Raise

   Low-range – High-range

   Tri-state selections are equally disposed about a vertical centre-line. Where a superior state can be identified, this is placed to the right of the centre-line:

   For example: Down – Off – Up

   Slow – Off – Fast

   Multi-position selector switches are arranged with the positions equally disposed around the 12 o'clock position. Unless there is a definable “home" or "normal" position, other arrangements should be avoided.

d) Push-button and push-button/indicators: bi-state control selections or indicators are arranged to form a horizontal pair. The superior state is placed to the right of the pair:

   For example: Open – Close (circuit breaker)

   Close – Open (valve)

   OFF – ON

   Reset – Normal

   Hold – Engage

   Manual – Auto

   Failed – Complete

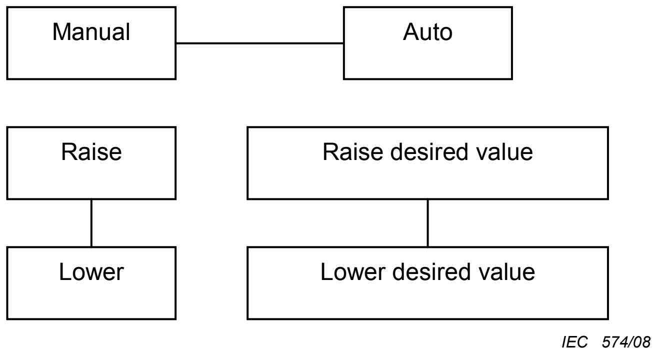
   Tri-state selections or indications are occasionally required and these form an extension of the above rule. In such cases, the three devices should be aligned in relation to associated components.

e) Regulating functions which, for example, achieve damper or valve inching are arranged to form a vertical pair with the superior state above:

For example:	Raise	Open	Raise desired value
	Lower	Close	Lower desired value

   Where a regulating device is latched in the operating position following operation of a push-button, and a stop function is provided, the vertical pair arrangement above is used and the stop push-button is placed to the left of the pair and on the horizontal centre-line between them.

f) Where push-buttons are arranged in arrays of four, five or six, the stated principles of superior state and plant identification are employed to derive the layout. Selection and indication of "manual" and "automatic" control states occupy the top horizontal pair of positions. Below these there are two vertical pairs of devices. The left-hand pair is assigned to manual control while the right-hand pair is reserved for manual adjustment of the control loop desired value. In both of these cases the superior state is placed at the top of the pair (see figure below for example).



g) In cases where plant provisions require additional actuators to be controlled or where cascade control loops are provided, these concepts are retained and additional devices are provided in consistent positions. Space constraints should not be allowed to corrupt the arrangement described. Single isolated indication or control devices are placed on an appropriate centre-line of an associated component or group of components. Where one or more devices are omitted from an array, the standard positioning is retained and the space vacated is not used. This is to maintain the position coding which is inherent in the above rules.

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BSI Group Headquarters
389 Chiswick High Road,
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Tel +44 (0)20 8996 9001
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