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| Document ID | : | GA91-9101-0101-21000 |
| Document Number | : | 3E-GD-A0060 |
| Revision Number | : | B |

# UK ABWR Generic Design Assessment

## Generic PCSR Chapter 21 : Human-Machine Interface


**Hitachi-GE Nuclear Energy, Ltd.**

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# Table of Contents

## 21.1 Introduction

The Human-Machine Interface (HMI) is the interface between UK ABWR users and plant systems, through the Control and Instrumentation (C&I). HMIs are the principal mechanism through which personnel interact with and control the plant and processes. The HMIs provide information and facilities in the form of displays, indicators, alarms and controls. The HMIs support the monitoring or delivery of plant functions (including safety functions) through observation, analysis, decision-making, action and confirmation.

This chapter describes the HMIs for the UK ABWR. The HMIs grouped by systems are distributed plant wide, from the Main Control Room (MCR) to the various backup and local control locations.

This chapter includes safety case information not only for HMIs in control rooms such as MCR, but also local control locations, including HMIs in the Remote Shutdown System (RSS) Panel Room, in the Back-up Building (B/B) Control Panel Room and in the Radwaste Building Main Control Room (Rw/B MCR).

An overview of the HMIs that are installed in control locations is described below:

(1) Main Control Room
The MCR is the place where operators conduct operation and related monitoring in assumed plant conditions, except in a time of evacuation of the MCR due to hazardous situations (i.e. un-inhabitability) and other fault and accident scenarios where the MCR can no longer be used.

(2) Remote Shutdown System Panel Rooms
The RSS panel rooms are the place where the operators conduct monitoring and operation at the time of evacuation of the MCR due to un-inhabitability of the MCR and other similar events.

(3) Back-up Building Control Panel Room
The B/B control panel room is the place where the operators conduct monitoring and operation during fault conditions, in particular, Severe Accident (SA) conditions when the MCR and RSS panel rooms do not provide the required functionality and when it is not feasible for personnel to remain in the Reactor Building (R/B).

(4) Radwaste Building Main Control Room
The C&I and HMIs for the Radioactive Waste (RW) are not directly related to power generation or emergency action; however, they are required to perform functions with impact on nuclear, personnel and environmental safety. The HMIs in the Rw/B MCR are used to monitor and control the C&I systems and plant associated with the RW facility. Some information and alarms associated with the RW facility are repeated to the HMIs in the MCR.

(5) Local Control Locations
The HMIs for the Structures, Systems and Components (SSCs) controlled and monitored locally are implemented in a local panel. However the SSCs required for the Safety System Logic and Control (SSLC) system are also controlled and monitored from the HMIs in the MCR.

The HMIs for the UK ABWR are designed to provide the users (both operators and maintenance personnel, as applicable) with adequate information to be able to perform the required tasks, in an appropriate location under assumed plant conditions.

In general, each HMI design aims to:

- Provide indicators and controls required for functionality of C&I systems.
- Minimise the likelihood of user misinterpretation, errors and omissions.
- Provide ease of operation, in terms of the usability and maintainability.
- Take into account experience from existing plants to improve the design to support improved task performance by users.

Each HMI has been assigned functionality and the use of any particular HMI for monitoring and operation depends on the tasks to be performed and the plant status. The general overarching assignment of HMIs is shown in Table 21.1-1.

**Table 21.1-1: Assigned Functionality of HMI in each Plant Status**

| HMI Location | Plant status | | | | | |
|---|---|---|---|---|---|---|
| | | | | Fault Condition | | |
| | Normal Operation | Startup and Shutdown | Outage and Refuelling Outage | DBA | BDBA | SA |
| MCR | X | X | X | X | X | (X) |
| RSS Panel Rooms | - | - | - | X (*Note1) | (X) (*Note2) | - |
| B/B Control Panel Room | - | - | - | (X) | (X) | X (*Note1) |
| Rw/B MCR | X | X | X | (X) | - | - |
| Local | X | X | X | (X) | (X) | (X) |

* DBA = Design Basis Accident
BDBA = Beyond Design Basis Accident

"X" in the table 21.1-1 indicates that the HMIs in each location are available in each plant status. This does NOT indicate that each HMI should be used in each plant status.
"(X)" indicates that the HMI is not always used in a certain plant status but is used according to a particular condition. In other words, these HMIs are used if those are available in each plant status, including fault conditions.
For example, the HMIs in the RSS panel rooms are used in the case of event coupled with a loss of MCR habitability. These are not always used in a DBA or BDBA.

In order to construct effective HMI designs, Hitachi-GE has addressed the requirements and claims stated in section 21.2.

*Note 1: Including the case of fault condition coupled with a loss of MCR habitability.
*Note 2: The HMIs in the RSS panel rooms are available depending on the initiating event.

**NOTE**
**The assignment of HMIs during the Fault Conditions, including DBA, BDBA, and SA, will be updated later where appropriate.**

## 21.2 Requirements and Claims for HMIs

### 21.2.1 Requirements for HMIs

The requirements for the HMIs have arisen from;

- HMI requirements related to normal or routine plant and process operating requirements have been derived from the plant and process documentation [generally captured in the relevant System Design Description (SDD) documents], from the Allocation of Function (AoF) Report [Ref-13] and from the Human Factors (HF) Concept of Operations Report (COR) [Ref-14].

- HMI requirements related to DBA or SA have been derived from the Fault Schedule work documented in the Topic Report (TR) on Fault Assessment [Ref-11] and the Human Reliability Analysis (HRA) Report [Ref-9].

- In particular where Human Based Safety Claims (HBSCs) have been made in the Safety Case, HMIs related to operator action have been identified and are documented in the HRA Report [Ref-9] and HBSCs Report [Ref-10]. These claims are underpinned and substantiated by suitable HF assessment, including human error analysis, as reported in the PCSR Chapter 27 Human Factors, and its supporting documents.

- Similarly, of the HBSCs where probabilistic claims have been made in the Probabilistic Safety Analysis (PSA) on any safety function involving the operator and the HMI, the Human Error Probability (HEP) of failure of that claimed human action has been derived and is documented in the HRA Report [Ref-9]. The probabilistic requirements for the HMI equipment are derived from the PSA work.

- The HMIs are required to meet the requirements arising from good HF engineering practice that account for human cognitive and physical capabilities and limitations. These requirements are documented in the Human Factors Engineering (HFE) Specification [Ref-7].

- The HMIs are required to reflect many of the design features associated with the C&I architecture. These are documented in the Basis of Safety Cases (BSCs) on C&I Architecture [Ref-6].

### 21.2.2 Safety Functional Claim (SFC)

The Fundamental Safety Functions (FSFs) which the HMIs support are identified in the list of category and class in the PCSR Sub-chapter 5.4 Categorisation and Classification of SSCs, and described below;
FSF1 - Control of reactivity
FSF2 - Fuel cooling
FSF3 - Long term heat removal
FSF4 - Confinement/Containment of radioactive materials
FSF5 - Others

These are supported by a set of High Level Safety Functions (HLSFs) that are applied to each C&I system. These HLSFs are listed in Table 5.4-1 of the PCSR Sub-chapter 5.4 and are applied accordingly to each system, including the Human-Machine Interface System (HMIS) (i.e. the total group of HMIs).

The list of claims in this chapter and the linkage to corresponding HLSFs is shown in Appendix A1. A short description on the application of HLSFs in the development of the claims, arguments and evidence is provided in the PCSR Chapter 1 Introduction.

Additionally each HMI is considered against a generic HMI claim;

> The design, development and assessment of all HMIs address the SFCs made for the system that the HMI is part of and any HBSCs associated with the HMI.

Detailed safety case claims and assumptions are described in the BSC on Overall HMI [Ref-1].

### 21.2.3 Safety Property Claim (SPC)

To underpin and achieve the identified SFCs of the HMIS (see Section 21.2.2), some considerations are taken into account in the HMIs design. These are the Safety Property Claims (SPCs).

The SFCs have been identified for the C&I systems by the UK ABWR Safety Case Working Group (SCWG). The latest list of C&I SPCs provided in the PCSR Chapter 14 C&I has been used to structure this section, since the HMIS forms in inherent link to and part of the C&I. A description of how the HMIS relates to and supports each of the C&I SPCs is provided below.

**SPC C&I 1:** *The requirement of the classification, independence, redundancy and diversity applied to the C&Is and its support systems are compliant with those of Structures Systems and Components.*

The design, equipment selection, architecture and implementation of the HMI equipment meet this claim.

This is primarily covered within the PCSR Chapter 14 C&I.

**SPC C&I 2:** *Category A safety functions required for frequent faults are implemented by 2 independent and diverse provisions. The Category A safety function first line provision is a Class 1 system. The second line provision is Class 1, 2 or 3 as required; e.g. from reliability and risk reduction consideration.*

This is primarily an issue for the C&I controller and field equipment. This is covered in the PCSR Chapter 14 C&I.

Where the systems and equipment controlled by HMIs are relevant to this claim the design, equipment selection, architecture and implementation of the HMI equipment meet this claim.

**SPC C&I 3:** *The safety systems and the safety related systems are both diverse from and independent of each other to protect against CCF.*

The HMIs attached to the safety system and the safety related system are designed and implemented to minimise the risk of Common Cause Failure (CCF) of the HMIs functionality. This is achieved through:

- The use of different technology for the HMIs associated with the safety systems and the HMIs associated with the safety related systems. As for the HMI technology for the Class 1 system (SSLC), Hitachi-GE is proposing to design an HMI architecture based on the new Class 1 FPGA platform which is currently under development for the SSLC. Further information of HMI technology is shown in the related BSCs [Ref-1, 2].
- The HMI equipment for the safety and safety related systems being independent of each other.

**SPC C&I 4:** *The C&I is designed, quality assured, manufactured and installed to withstand internal hazards.*

In the MCR, the segregation of equipment associated with separate systems is more limited than with the controller. These issues are addressed through having secondary HMIs available in the RSS and in the B/B.

**SPC C&I 5:** *The C&I is designed, quality assured, manufactured and installed to withstand external hazards.*

In the MCR the segregation of equipment associated with separate systems is more limited than with the controller. This issue is addressed through having secondary HMIs available in the RSS and in the B/B.

**SPC C&I 6:** *The C&I continues to meet its functional safety requirements throughout its operational life.*

The systems and equipment controlled by HMIs are designed for an operational life similar to that of the C&I controller and systems. This is considered against a proposed C&I lifecycle approach for the power plant.

**SPC C&I 7:** *The C&I has additional equipment and measures for mitigating severe accidents as an application of defence in depth.*

The design, equipment selection, architecture and implementation of the HMI equipment meet this claim.

This is primarily covered within the PCSR Chapter 14 C&I.

**SPC C&I 8:** *C&I systems are designed to achieve the adequate performance in accordance with the safety requirements; including reliability, testability, accuracy, response time, and range.*

The HMIs are designed in accordance with the deterministic and probabilistic requirements associated with safety functions involving operator monitoring or actions.

The design of the HMIs is based on the requirements of tasks that arise from safety measures with operator actions. The human actions related to the delivery of safety functions are identified by fault analysis [Ref-11] and form part of the HBSCs [Ref-10]. SSCs which are used to achieve safety functions are also identified through fault analysis and the results are shown in the list of category and class of SSCs [Ref-12]. HMIs which are used to monitor and control these safety measures are designed to meet reliability requirements to the same level as the associated SSCs and C&I systems.

Safety case and assumptions are described in the BSC on Overall HMI [Ref-1], requirements on equipment are described in the PCSR Chapter 14 C&I and related safety case documents [Ref-6]. HF considerations related to the HMI which underpin task performance of the HBSC are described in the PCSR Chapter 27 Human Factors and its supporting documents;
- General HF considerations are stated in the HFE specification which comply with international standards and guidance related to HFs.
- Information of specific HBSC and related HMIs is shown in the support documents of the HRA and HBSCs [Ref-9, 10].

**SPC C&I 9:** *The design, development and implementation processes of the C&I systems comply with standards and good practice set by their classification and the systems' role in the architecture.*

The HMIs are designed, developed, and implemented to support C&I system, which complies with international standards and guidance set by their category and class defined under IEC 61226.

**SPC C&I 10**: *The divisions of the safety systems are physically and electrically separated from each other thus ensuring independence of the divisions.*

The SSLC Class 1 HMI in the MCR matches the divisional segregation and independence applied to the SSLC as a whole.

The Hardwired Backup System (HWBS) Class 2 HMI is designed to maintain the electrical separation of the two divisions and, where appropriate, the physical separation of the two divisions.

### 21.2.4 Reference Standards

The reference standards that have been considered as part of the design of the HMI are listed in the table below. Further information and standards are listed as part of the HFE Specification [Ref-7].

| No. | Reference Standards | |
|---|---|---|
| 1 | IEC | IEC61513 “Nuclear power plants-Instrumentation and Control important to safety – General requirements for systems” Ed 2.0, Aug 2011 |
| 2 | IEC | IEC61226 "Nuclear power plants – instrumentation and control systems important for safety – classification of instrumentation and control functions" Ed 3.0, Jul 2009 |
| 3 | IEC | IEC60964 “Nuclear power plants - Control rooms - Design” Ed 2.0, Feb 2009 |
| 4 | IEC | IEC60965 “Nuclear power plants - Control rooms - Supplementary control points for reactor shutdown without access to the main control room” Ed 2.0, Jul 2009 |
| 5 | IEC | IEC 61508 “Functional safety of electrical / electronic / programmable safety-related systems” Ed 2.0 Apr 2010 |
| 6 | ISO | ISO 11064-1 “Ergonomic design of control centres - Principles for the design of control centres” |
| 7 | EEMUA | EEMUA 191 “Alarm Systems - A Guide to Design, Management and Procurement” |
| 8 | IAEA | DS-431 “Design of Instrumentation and Control Systems for Nuclear Power Plants” |
| 9 | WENRA | Issue E (Design Basis Envelope for Existing Reactors) “Instrumentation and Control systems and control room” |
| 10 | WENRA | Issue F (Design Extension of Existing Reactors) “Instrumentation for the management of beyond design basis accident conditions” |
| 11 | NRC | NUREG/CR-6635 "Soft Controls: Technical Basis and Human Factors Review Guidance" 2000 |
| 12 | NRC | NUREG/CR-6636 "Maintainability of Digital Systems: Technical Basis and Human Factors Review Guidance" 2000 |
| 13 | NRC | NUREG-0700 "Human-System Interface Design Review Guidelines" Rev.2 2002 |

# 21.3 HMIs in the Main Control Room

## 21.3.1 Introduction

This section outlines the HMIs in the MCR.
The details are described in the BSC on MCR HMI [Ref-2].

The main HMI of the nuclear reactor and power generation systems is established in the MCR. This is in order to allow the main human actions required for monitoring, and controlling the plant to occur in one appropriately-designed facility.

The MCR contains HMIs related to the following C&I systems;

- SSLC
- HWBS
- Safety Auxiliary Control System (SACS)
- Plant Control System (PCntlS)
- Reactor/Turbine Auxiliary Control System (ACS)
- Plant Computer System (PCS)

The operators in the MCR monitor and control the plant and processes during a plant startup, shutdown, normal operation, fault conditions, and during outage and refuelling outage periods. (See Table 21.1-1 in section 21.1)

Note that many of the refuelling activities are controlled locally, including through the Fuel Handling Machine (FHM) remote control room. Other plant processes are also supported by HMIs in other control room or local control panels, as described in the remaining sections in this chapter.

The MCR is designed to enable the required complement of operational and support personnel (see the PCSR Chapter 30 Operation regarding minimum MCR crew complement) to remain in the room, performing necessary tasks, even in the event of foreseeable accidents. The layout of the HMIs in the MCR supports the workflows and communication needs of the crew for required operations during assumed plant states, including maintenance, as ensured by the HF support and analysis conducted as part of the UK ABWR integrated HF programme (see Section 21.3.3.2 and the PCSR Chapter 27 Human Factors).

In addition, the HMIs in the MCR are designed with suitable and sufficient features to support the required tasks in assumed plant conditions required and help reduce the risk of operator errors to as low as reasonably practicable (ALARP).

## 21.3.2 Design of HMIs in the MCR

### 21.3.2.1 Structure

The basic layout of the MCR is shown in Figure 21.3-1.
Further information regarding the layout of the MCR is shown in the BSC on MCR HMI [Ref-2].

The Main Control Console (MCC), the Wide Display Panel (WDP), the Safety Auxiliary Panels (SAuxPs), an operator desk, and the Main Control Room Supervisor (MCRS) / Control Room Operator (CRO) Desk are installed in the MCR.

(1) MCC
The MCC provides operators with HMIs required for the operation and monitoring functions that are necessary in plant normal operation (including power control), startup/shutdown, outage and refuelling outage and during plant fault conditions.

(2) WDP
The WDP is intended to provide a display of the key plant parameters in a form that can be easily assimilated and, hence, provide an effective overview of the plant status to a wide number of people in the MCR.

(3)SAuxPs
In order to overcome a loss of safety function or HMI for the SSLC, two types of auxiliary control panels are installed in the MCR.

(a) SAuxP for Class 1
SAuxP (for Class 1) provides an alternative HMI linked to the SSLC.

(b) SAuxP for Class 2
SAuxP (for Class 2) provides an alternative HMI linked to the A2 C&I systems in case of failure of the A1 SSCs.

These SAuxPs provide the minimum required manual controls and relevant indicators.
The required indicators and controls for these SAuxPs is based on the results of fault studies and other safety analysis, plus the related HF analysis (i.e. HRA), as described in the PCSR Chapter 27 Human Factors and its supporting documents.
Further information of SAuxPs is shown in the BSC on MCR HMI [Ref-2].

(4) Desks
A MCRS desk is provided, with a MCRS workstation, to allow for oversight and monitoring of activities within the MCR, as well as enough room to perform the various paperwork and referencing duties falling to the MCRS.
Desks are provided taking the following factors into consideration:

- Writing and laying down of documents and procedures
- Communication between operators (including CRO and MCRS)

The above workstations and desks are appropriately divided and arranged in accordance with their functions. This is to improve operational effectiveness and to reduce the probability of operator error, through separation and grouping of HMIs related to safety versus plant control, and grouping of the most important displays and controls to safety in order to focus operator attention accordingly.

The arrangement is designed to enable the CRO and MCRS to adequately communicate with each other. The design also provides all of the MCR personnel with good visibility and usability of the WDP, and further provides MCRS with a clear overview of the MCC activity as well.

The allocation of HMI by C&I system is as follows:

(1) SSLC

The HMIs for SSLC (Divisions 1, 2 and 3), containing indicators and controls, are included on the MCC and WDP. Alarms and indications from the SSLC are included on the WDP and repeated on alarms lists on the MCC. Some specific SSLC indicators and controls are included on the part of the SAuxP for Class 1.

(2) HWBS

The HWBS consists of various indicators, controls and alarms required for important manual backup actions in the case of postulated events with concurrent loss of the Class 1 (SSLC) functionality. These are contained on the SAuxP for Class 2.

(3) SACS

Class 2/3 SACS HMIs, including indicators and controls, are included on the MCC and WDP.
These HMIs are display screen based.

(4) PCntlS

Class 2 PCntlS HMIs, including indicators and controls, are included on the MCC.
These HMIs are display screen based.

(5) ACS

Class 3 ACS HMIs, including indicators and controls, are included on the MCC and WDP.
These HMIs are display screen based.

(6) PCS

Class 3 PCS HMIs, including indicators, are included on the MCC.
These HMIs are functionality-rich display screen based.

Further information of allocation of HMI in the MCR by the above C&I systems is provided in the BSC on MCR HMI [Ref-2].

HF support to the development of the HMIs for the UK ABWR and preliminary HF analysis have been conducted during Steps 2 and 3 of the GDA. The HFE Specification [Ref-7] details basic generic HF requirements to meet modern standards and good practice guidance in HMI design.

The HF assessment and analysis for the operability of the HMIs are planned to be undertaken during Step 4. The results of this support and analysis are reflected to the HMI design, including use of consistency, suitable colour coding and labelling, where appropriate. These design considerations relevant to the HF analysis are applied to not only the design of the HMIs in the MCR, but also the design of other control rooms, including RSS panel rooms, B/B control panel room and Rw/B MCR. This is also relevant to the consideration for user task performance.

Further details on the analysis and design support, and the arguments and evidence relating to the HBSCs linked to these HMIs are given in the relevant BSCs for the particular HMI location (see [Ref-2, 3, 4, 5]) and the PCSR Chapter 27 Human Factors including its supporting documents.

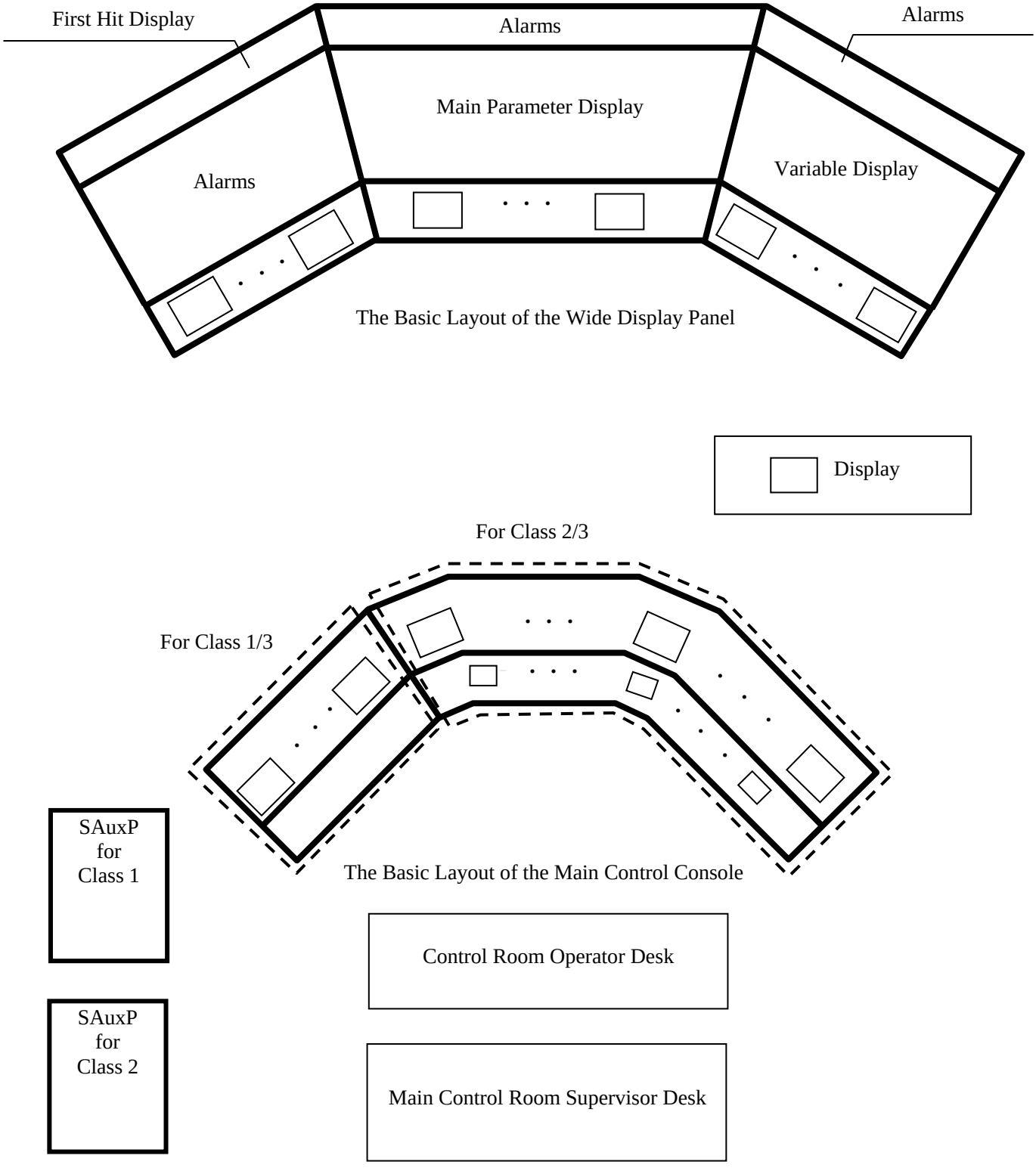



**Figure 21.3-1: The Basic Layout of the MCR**

### 21.3.2.2 Function

The HMIs in the MCR allow the operators to monitor operating conditions and important parameters in the reactor and other plant, processes and facilities. In addition, the MCC is designed to allow the operators to respond quickly and accurately to undertake manual operations required to secure the safety of the reactor.

The HMIs in the MCR support achieving the FSFs identified in section 21.2.2.
The FSFs which are associated with the HMIs in the MCR are described below;

FSF1 - Control of reactivity
FSF2 - Fuel cooling
FSF3 - Long term heat removal
FSF4 - Confinement/Containment of radioactive materials
FSF5 - Others (including the monitoring of key plant parameters)

In order to achieve the safety functions mentioned above, adequate HMIs associated with operations and monitoring of systems/equipment are installed in the MCR. This is demonstrated through the HF analysis and substantiation work given in the PCSR Chapter 27 Human Factors, with arguments and evidence to support the HBSCs related to the HMIs given in the supporting documents to that chapter.

Details of C&I systems relevant to the FSFs mentioned above are shown in the PCSR Chapter 14 C&I. Further descriptions of the functionality which HMIs in the MCR deliver are shown in the BSC on MCR HMI [Ref-2].

## 21.3.3 Consideration for User Task Performance

The HMIs in the MCR are designed to enable comfortable, logical and effective task performance for all users. This includes taking the environmental conditions, layout and workspace into consideration for both operators and maintenance personnel.

In order to provide effective and reliable plant and process monitoring and control, the layout of the indicators and controls on the MCC has been designed by taking good-practice human interface design principles into consideration. For example, the display devices and operational equipment are grouped by system within the panel layout to make related system tasks easier to complete in a logical manner.

Since UK ABWR is a highly-automated plant and most operator manual actions within the MCR relate to providing additional backup to safety systems, the alarm system is a key to ensuring expected user task performance. The alarm system in the MCR includes an effective design based on HF good practice and modern standards provided in the HFE Specification [Ref-7]. The system is designed such that it:

- focuses operator attention on key important alarms;
- minimises alarm flooding;
- groups SSC-specific alarms by system;
- allows operator management of alarm display and audible features;
- prioritises alarms in a logical and consistent manner; and
- gives essential information on large tiles on the WDP to be visible by the whole crew, with repeated alarms that give further detailed information on the displays located on the MCC.

In order to minimise various types of errors (misinterpretation, omission, selection errors, etc.) by the operators, the design of the HMIs:

- has enabled the group monitoring of key plant parameters;
- follows HF good practice standards for labelling of indicators and controls; and
- has sorted the displays according to relationship with the equipment and controls.

In order to further minimise commission errors by the operators, including inadvertent operation, the HMIs have been designed with protection on certain controls, for example by utilising protective covers or key-operated switches, where appropriate. In addition, such equipment is also designed for its easy identification by colour, shape and labelling.

Further descriptions of the HF requirements and assessments that have been used to support the optimal HMI design can be found in the PCSR Chapter 27 Human Factors and supporting documents. The remainder of this section provides a summary of these considerations.

### 21.3.3.1 Environmental Conditions in the MCR

(1) In order for the operators to comfortably operate in the MCR, environmental factors such as temperature, lighting, and noise have been taken into consideration and the room and supporting systems have been designed accordingly.
(2) Lighting is particularly important for safe, effective use of the HMIs. For UK ABWR, not only have overall normal and emergency light levels been suitably selected, aspects such as: making light levels adaptable to allow for different task conditions, the need for local task lighting, and reducing indirect and direct glare on displays (for both individual and team viewing conditions) have been considered in the design.
(3) The MCR environment is also protected from personnel health hazards such as radioactive contamination, smoke, excessive heat or cold, etc., in assumed plant conditions, including during foreseeable events.

### 21.3.3.2 Layout and Workspace in the MCR

(1) The workspace and layout of the controllers and displays in the MCR are designed using workspace task-based analysis (“link analysis”) as well as HFE Specification [Ref-7] reach, clearance and viewing requirements to facilitate the normal and routine operational tasks assigned to the MCR personnel, including for routine and corrective maintenance.
(2) The workspace and layout of the controllers and displays in the MCR are designed to take into account the actions which the MCR personnel have to perform under accident conditions, and in the case of fault conditions that require manual operations, including more interactive team communications and working.

### 21.3.3.3 Layout of WDP and MCC Workstation Equipment

(1) A unified logical overview display is utilised in the centre of the WDP to focus attention on key plant (reactor) parameters and allow all users to monitor and assess plant status simply and rapidly.
(2) The WDP and MCC are also designed in grouped layouts with logical arrangement of each system of alarms, display devices, and control equipment, which increases operator effectiveness and minimises the likelihood of operator misinterpretation and errors by ensuring the operator is easily able to correctly locate task-related HMI items.

### 21.3.3.4 Display System

(1) Information Display Functions
The displays of the information giving the state of plant systems and equipment, along with the information necessary for safety, are provided for operators in appropriate locations. They are displayed in an easy to understand and interpret manner.

(2) Information for Automatic Operation
The operators are able to monitor and confirm the progression of the automatic operations.

(3) Alarm Functions
In the case of an abnormality in the plant equipment or processes that requires operator attention (i.e. change in focus of monitoring the plant) or action, an alarm function notifies the operators regarding the occurrence of such fault conditions. Alarms are presented in logically-arranged groups and in an easy to understand manner.

The alarm system within the MCR is designed in accordance with the HF good practice and guidance which are derived from the HFE Specification [Ref-7]. Further information of alarm functions is shown in the BSC on Overall HMI [Ref-1].

### 21.3.3.5 Control Functions

(1) Control devices are designed to be easy to operate in order to minimise operator errors.
(2) Where misoperation of the control systems and equipment in the MCR can lead to potentially hazardous outcomes, appropriate considerations are given to providing protection covers, key attached switches or special labelling. This is in addition to various system interlocks and automatic overrides which prevent inappropriate actuation of systems based on plant status.

# 21.4 HMIs in the Remote Shutdown System Panel Rooms

## 21.4.1 Introduction

This section outlines the HMIs in the RSS panel rooms.
The details are described in the BSC on RSS HMI [Ref-3].

The RSS panel rooms are located remote from the MCR with a system that allows the reactor to be brought into a state of cold shutdown from a hot shutdown after initiating a scram operation from the MCR prior to the evacuation of the MCR.

The HMIs in the RSS panel rooms are designed to enable the operators to monitor and control the plant shutdown process.

The HMIs in the RSS panel rooms are designed to provide the operators with the required functionality to move the plant from a hot shutdown state to a cold shutdown state when MCR habitability is lost.

The HMIs in the RSS panel rooms are designed to minimise operator misinterpretation, errors, and omissions. Further descriptions of the HF requirements and assessments that have been used to support the optimal HMI design can be found in the PCSR Chapter 27 Human Factors and supporting documents.

## 21.4.2 Design of HMIs in the RSS Panel Rooms

### 21.4.2.1 Structure

The basic layout of RSS panel rooms is shown in Figure 21.4-1.
Further information regarding the layout of RSS panel rooms is shown in the BSC on RSS HMI [Ref-3].

There are two RSS panel rooms to provide controls which are diverse from the MCR; each room holds a Remote Shutdown Panel (RSP) and a desk.

(1) RSP
The RSP, located in the RSS panel rooms, allows the operators carry out operation, monitoring, and control. In order to allow the reactor to be brought into a cold shutdown state from a hot shutdown state, the RSP consists of the following:

- Monitoring Area

Equipment is installed to provide monitoring of the reactor plant and process during the transition from a hot shutdown state to a cold shutdown state.

- Operation Area

Operational equipment is installed to allow the reactor to be brought into a cold shutdown state from a hot shutdown state.

(2) Desks
Desks are provided taking the following factors into consideration:

- Writing and laying down documents and procedures
- Communication between operators

The RSP and other equipment located in the RSS panel rooms are designed to enable adequate and appropriate communication among operators. The requirements and principles for consideration of the relevant HFE aspects for the HMIs in the RSS panel rooms are detailed in the HFE Specification [Ref-7] taking account the necessary functions as per the operating aspects designed in the HF COR [Ref-14]

### 21.4.2.2 Function

When an evacuation from the MCR is necessary, the operators generally carry out a reactor scram before evacuating from the MCR. After the scram has been completed the operators can bring the reactor to a cold shutdown state from a hot shutdown state, safely and easily with the assistance of the RSS.

The HMIs in the RSS panel rooms support achieving the FSFs identified in section 21.2.2.
The FSF which is associated with the HMIs in the RSS panel rooms are described below;

FSF5 - Others
RSS functions are required to bring the reactor to a cold shutdown state from a hot shutdown state from outside control room.

In order to achieve the safety function mentioned above, adequate HMIs associated with operations and monitoring of the essential systems/equipment for the scenarios in which this HMI is intended to use, are installed in the RSS panel rooms.

Details of C&I systems relevant to the FSF mentioned above are shown in the PCSR Chapter 14 C&I. Further descriptions of the functionality which HMIs in the RSS panel rooms deliver are shown in the BSC on RSS HMI [Ref-3].

### 21.4.3 Consideration for User Task Performance

The HMIs in the RSS panel rooms are designed to enable comfortable, logical and effective task performance for all users. This includes taking the environmental conditions, layout and workspace into consideration for both operators and maintenance personnel.

In order to provide effective and reliable plant and process monitoring and control, the layout of the indicators and controls on the RSP has been designed by taking good-practice human interface design principles into consideration. For example, the display devices and operational equipment are grouped by system within the panel layout to make related system tasks easier to complete in a logical manner.

In order to minimise various types of errors (misinterpretation, omission, selection errors, etc.) by the operators, the design of the HMIs:

- has enabled the group monitoring of key plant parameters;
- follows HF good practice standards for labelling of indicators and controls; and
- has sorted the information according to relationship with the equipment and controls.

In order to further minimise commission errors by the operators, including inadvertent operation, the HMIs have been designed for easy identification by shape, labelling, etc., and placed on the panel so as to prevent confusion or being spaced too closely.

Further descriptions of the HF requirements and assessments that have been used to support the optimal HMI design can be found in the PCSR Chapter 27 Human Factors and supporting documents. The remainder of this section provides a summary of these considerations.

### 21.4.3.1 Environmental Conditions in the RSS Panel Rooms

In order for the operators to comfortably operate in the RSS panel rooms, environmental factors such as temperature, lighting, and noise have been taken into consideration and the room and supporting systems have been designed accordingly.

### 21.4.3.2 Layout and Work Space in the RSS Panel Rooms

(1) RSS panel rooms are established in a separate location with enough distance from the MCR so that they are not both affected by the same hazard. The path way leading toward the RSS panel rooms is designed so as to be safe for the operators to transit from the MCR, in the postulated conditions that have made the MCR uninhabitable.
(2) The selection and layout of indicators and controls on the HMIs in the RSS panel rooms are such that the design takes into account the tasks that the operators are required to carry out during foreseeable operations in fault conditions where there is a potential threat to MCR habitability.
(3) Access to the RSS panel rooms is controlled. A changeover switch needs to be operated for the RSP to be used to control plant. This measure reduces the likelihood of accidental or deliberate inappropriate RSP operation and meets current HF standards regarding prevention of more than one control point being active at any one time.

### 21.4.3.3 Layout of the Control Panel Surface

A grouped layout and logical arrangement are used for each system's display devices on the RSP. Control and display devices are selected and arranged in a manner that increases operator effectiveness and minimises the likelihood of operator misinterpretation and errors.

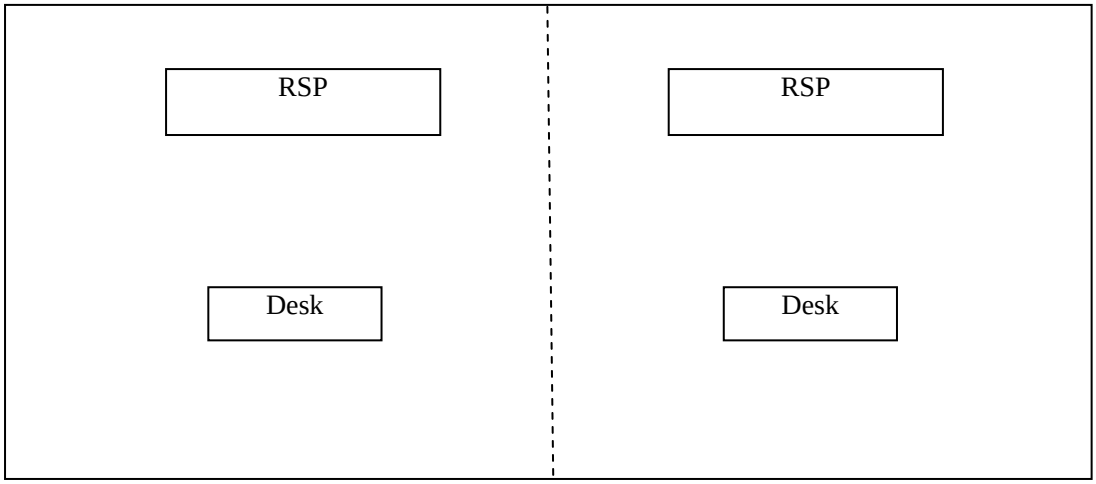
### 21.4.3.4 Display System

- Information Display Functions

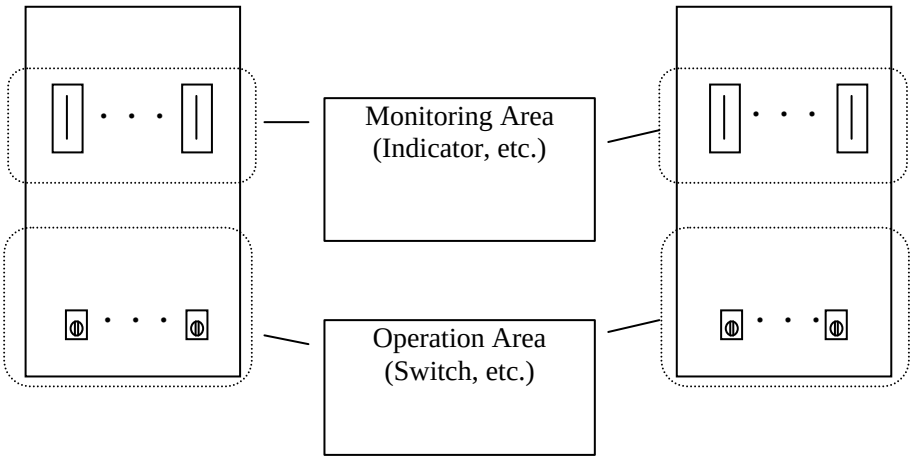
Information showing the state of plant systems and equipment, along with information necessary for safety, is provided for operators in appropriate locations, grouped, and displayed in an easy to understand and interpret manner.

### 21.4.3.5 Control Functions

(1) Control devices are designed to be easy to operate in order to minimise operator errors.
(2) The control devices in the RSS panel rooms are designed to be easily identified by shapes, labels, and so on.




TOP VIEW




RSP FRONT VIEW

**Figure 21.4-1: The Basic Layout of RSS Panel Rooms**

# 21.5 HMIs in the Back-up Building Control Panel Room

## 21.5.1 Introduction

This section outlines the HMIs in the B/B control panel room.
The details are described in the BSC on B/B HMI [Ref-4].

C&I systems are provided in the B/B control panel room to deliver the SA and other C&I safety measures identified and allocated to the B/B control panel room. The HMIs provide appropriate operation, monitoring and manual control facilities to interface with those systems.

The B/B control panel room and its HMI are designed to minimise operator misinterpretation, errors and omissions.

## 21.5.2 Design of HMIs in the B/B Control Panel Room

### 21.5.2.1 Structure

The basic layout of the B/B control panel room is shown in Figure 21.5-1.
Further information regarding the layout of the B/B control panel room is shown in the BSC on B/B HMI [Ref-4].

The B/B control panel and Desk are installed in the B/B control panel room.

(1) B/B control panel
The B/B control panel located in the B/B control panel room is designed to enable the operators to concentrate on monitoring and control of the plant. The B/B control panel consists of the following indicators and controls, selected to provide required functionality during a SA coupled with evacuation from the MCR.

- Alarm Display Area

An alarm display is installed to alert operators in the B/B control panel room to plant, process or system conditions requiring operator attention or action.

- Monitoring Area

Monitoring equipment is installed to let the operators in the B/B control panel room monitor the plant in the B/B control panel room and key plant and process conditions in the R/B.

- Operation Area

Operational equipment is installed to let the operators in the B/B control panel room control the plant in the B/B control panel room.

(2) Desk
A desk is installed taking the following factors into consideration:

- Writing and laying down documents and procedures
- Communication between operators

The requirements and principles for consideration of the relevant HFE aspects for the HMIs in the B/B control panel rooms are detailed in the HFE Specification [Ref-7] taking account the necessary functions as per the operating aspects defined in the HF COR [Ref-14].

### 21.5.2.2 Function

The HMIs in the B/B control panel room allow operators in the B/B control panel room to monitor and control key operating conditions in certain fault conditions and during a SA, when the MCR and/or R/B are not inhabitable.

The HMIs in the B/B control panel room support achieving the FSFs identified in section 21.2.2. The FSFs which are associated with the HMIs in the B/B control panel room are described below;

FSF2 - Fuel cooling: Alternative means using the Flooding System of Specific Safety Facility (FLSS), Reactor Depressurization Control Facility (RDCF).
FSF3 - Long term heat removal: Through containment venting.
FSF4 - Confinement/Containment of radioactive materials: Using FLSS.
FSF5 - Others: Especially the monitoring of key plant parameters during accidents.

In order to achieve the safety functions mentioned above, adequate HMIs associated with operations and monitoring of the essential systems/equipment for the scenarios in which this HMI is intended to be used are installed in the B/B control panel room.

Details of C&I systems relevant to the FSFs mentioned above are shown in the PCSR Chapter 14 C&I. Further descriptions of the functionality which HMIs in the B/B control panel room deliver are shown in the BSC on B/B HMI [Ref-4].

## 21.5.3 Consideration for User Task Performance

The HMIs in the B/B control panel room are designed to enable comfortable, logical and effective task performance for all users. This includes taking the environmental conditions, layout and workspace into consideration for both operators and maintenance personnel.

In order to provide effective and reliable task performance during the postulated scenarios in which the B/B is used, indicators, controls and alarms are determined considering Emergency Operating Procedures, SA Guidelines, and HFE analysis of tasks needed to achieve preventive and mitigative actions when B/B functions are required. For example, the display devices and operational equipment are grouped by function and task within the panel layout to make related tasks and sequential task steps easier to complete in a logical manner.

In order to minimise various types of errors (misinterpretation, omission, selection errors, etc.) by the operators, the design of the HMIs:

- has enabled the group monitoring of key plant parameters;
- follows HF good practice standards for labelling of indicators and controls; and
- has sorted the information according to relationship with the equipment and controls.

In order to further minimise commission errors by the operators, including inadvertent operation, the HMIs have been designed for its easy identification by shape, labelling, etc., and placed on the panel so as to prevent confusion or being spaced too closely.

Further descriptions of the HF requirements and assessments that have been used to support the optimal HMI design can be found in the PCSR Chapter 27 Human Factors and supporting documents. The remainder of this section provides a summary of these considerations.

### 21.5.3.1 Environmental Conditions in the B/B Control Panel Room

(1) In order for the operators to comfortably operate in the B/B control panel room, environmental factors such as temperature, lighting and noise have been taken into consideration and the room and supporting systems have been designed accordingly.
(2) The B/B control panel room environment is also protected from personnel health hazards such as radioactive contamination, smoke, excessive heat or cold, etc., in all expected conditions that might impact the B/B, during the postulated events for which it is to be used.

### 21.5.3.2 Layout and Work Space in the B/B Control Panel Room

(1) The selection and layout of indicators and controls on the HMIs in the B/B control panel room are such that the design takes into account the tasks that the operators are required to carry out during fault conditions including a SA situation.
(2) The layout of the desk and B/B control panel in the B/B control panel room enables good communication among operators, and takes the operator visibility and use of the controllers and displays into account.
(3) The B/B, and thus its control panel room, is established in a separate location with enough distance from the MCR and R/B so they are not all affected by the same hazard, and the pathway leading to the B/B control panel room is designed to be kept safe for operators to transit from the MCR and R/B, in the postulated conditions that have made the R/B uninhabitable.
(4) Access to the B/B is controlled. A changeover switch needs to be operated for the B/B control panel to be used to control SSCs. This measure reduces the likelihood of accidental or deliberate inappropriate B/B control panel operation and meets current HF standards regarding prevention of more than one control point being active at any one time.

### 21.5.3.3 Layout of the Control Panel Surface

A grouped layout and logical arrangement are used for each system’s display devices on the B/B control panel. Control and display devices are selected and arranged in a manner that increases operator effectiveness and minimises the likelihood of operator misinterpretation and errors.

### 21.5.3.4 Display System

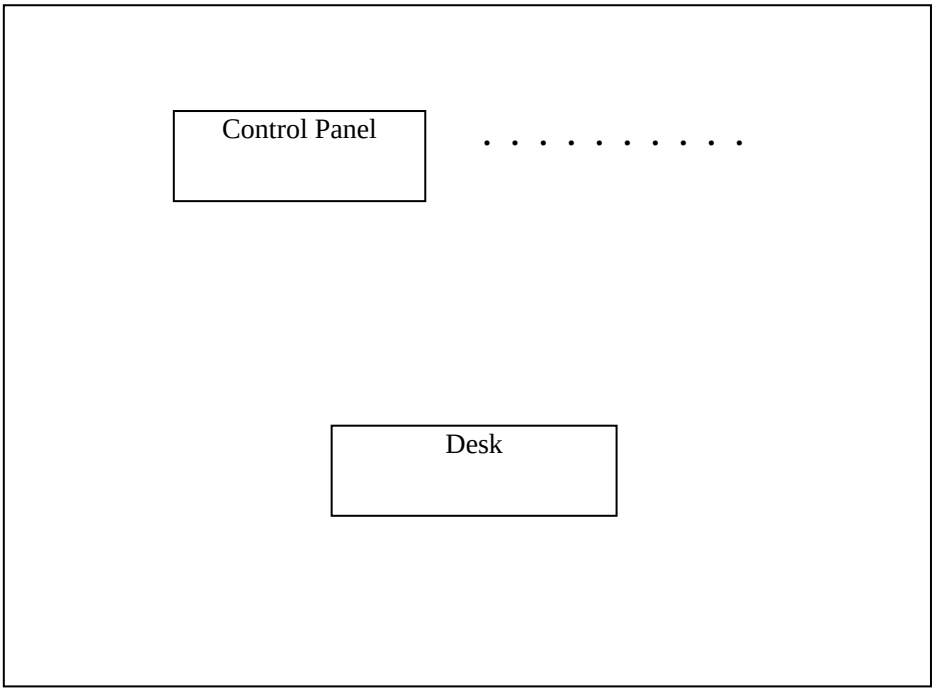
(1) Information Display Functions
Information showing the state of plant systems and equipment, along with information necessary for safety, is provided for operators on the B/B control panel, grouped, and displayed in an easy to understand and interpret manner.

(2) Alarm Functions
In the case of an abnormality in the plant's SA management equipment or processes that requires operator attention (i.e. change in focus of monitoring the plant) or action, an alarm function notifies the operators regarding the occurrence of such fault conditions. Alarms are presented in logically-arranged groups and in an easy to understand manner.

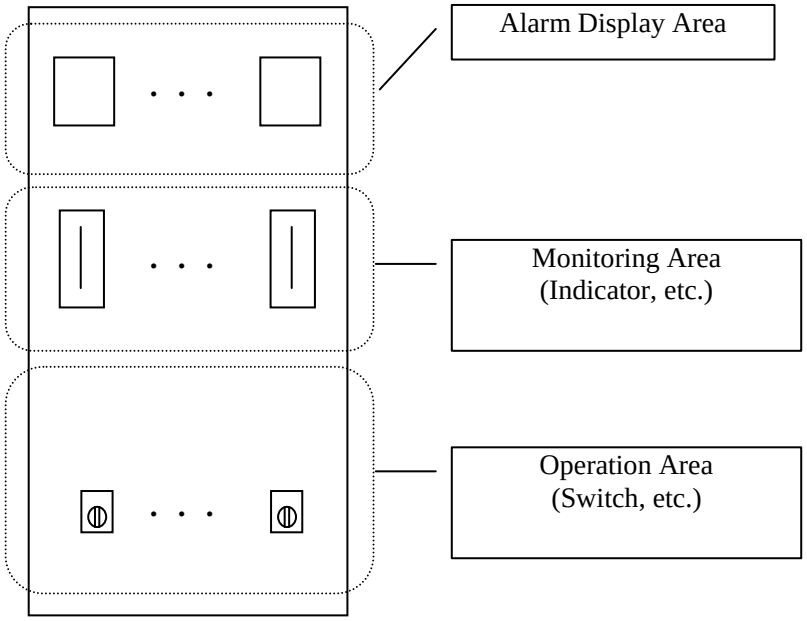
The alarm system within the B/B control panel room is designed in accordance with the HF good practice and guidance which are derived from the HFE specification [Ref-7]. Further information of alarm functions is shown in the BSC on Overall HMI [Ref-1].

### 21.5.3.5 Control Functions

(1) Control devices are designed to be easy to operate in order to minimise operator errors.
(2) The control devices in the B/B control panel room are designed to be easily identified by shapes, labels, and so on.




TOP VIEW




CONTROL PANEL FRONT VIEW

**Figure 21.5-1: The Basic Layout of the B/B Control Panel Room**

# 21.6 HMIs in the Radwaste Building Main Control Room

## 21.6.1 Introduction

The main HMI of Liquid Radioactive Waste Management System (LWMS) is established in the Rw/B MCR to provide a facility for effective and reliable operation, monitoring and control of the RW facilities and process.

The operators in the Rw/B MCR are provided with monitoring and control of the LWMS. These are suitable for periods of normal treating operations, transferring operations, outages and fault condition.

Note that control and monitoring of the Gaseous Waste Management or “off-gas” process equipment are performed remotely from the MCR. Indications, recording and alarm functions are shown on the MCR; system control is generally from the MCR as well.

The HMIs in the Rw/B MCR are designed to minimise of operator errors and omissions by taking into consideration HF standards, basic principles and HFE analysis results. Further descriptions of the HF requirements and assessments that have been used to support the optimal HMI design can be found in the PCSR Chapter 27 Human Factors and supporting documents.

## 21.6.2 Design of HMIs in the Rw/B MCR

### 21.6.2.1 Structure

The basic layout of operator console is shown in Figure 21.6-1.
Further information regarding the layout of the operator console is shown in the BSC on RW HMI [Ref-5].

An operator console and Desk are installed in the Rw/B MCR.

(1) Operator console
The operator console is based on a number of Visual Display Units (VDU) that allow the operator to effectively monitor and control the RW facilities through the other C&I system related to the RW facility. The operator console provides monitoring, control, alarms and trending of major parameters.

(2) Desk
A desk is installed taking the following factors into consideration:

- Writing and laying down documents and procedures
- Communication between operators

The requirements and principles for consideration of the relevant HFE aspects for the HMIs in the Rw/B MCR are detailed in the HFE Specification [Ref-7] taking account the necessary functions as per the operating aspects defined in the HF COR [Ref-14].

### 21.6.2.2 Function

The operator console for the LWMS is designed to be equipped with those functions necessary to enable operator monitoring and controlling of the operating conditions and any foreseeable fault condition for such facilities.

The HMIs in the Rw/B MCR support achieving the FSFs identified in section 21.2.2.
The FSF which is associated with the HMIs in the Rw/B MCR is identified below;

FSF4 - Confinement/Containment of radioactive materials (which is relevant to liquid RW facilities)

In order to achieve the safety function mentioned above, adequate HMIs associated with operations and monitoring of systems/equipment required functions are installed in the Rw/B MCR.
Details of systems relevant to the FSF mentioned above are shown in the PCSR Chapter 18.2 Liquid Radioactive Waste Management System.

Further descriptions of the functionality which HMIs in the Rw/B MCR deliver are shown in the BSC on RW HMI [Ref-5].

### 21.6.3 Consideration for User Task Performance

The HMIs in the Rw/B MCR are designed to enable comfortable, logical and effective task performance for all users. This includes taking the environmental conditions, layout and workspace into consideration for both operators and maintenance personnel.

In order to provide effective and reliable plant and process monitoring and control, the layout of the indicators and controls of the operator console has been designed by taking good-practice human interface design principles into consideration. For example, the display devices and operational equipment are grouped by process and/or task within the panel layout to make related processing tasks easier to complete in a logical manner.

In order to minimise various types of errors (misinterpretation, omission, selection errors, etc.) by the operators, the design of the HMIs:

- has enabled the group monitoring of key plant parameters;
- follows HF good practice standards for labelling of indicators and controls; and
- has sorted the displays according to relationship with the equipment and controls.

In order to further minimise commission errors by the operators, including inadvertent operation, the HMIs have been designed with protection on certain controls, for example by utilising key-operated switches, where appropriate. In addition, such equipment is also designed for its easy identification by shape, labelling, etc., and placed on the panel so as to prevent confusion or being spaced too closely.

Further descriptions of the HF requirements and assessments that have been used to support the optimal HMI design can be found in the PCSR Chapter 27 Human Factors and supporting documents. The remainder of this section provides a summary of these considerations.

#### 21.6.3.1 Environmental Conditions in the Rw/B MCR

In order for the operators to comfortably operate in the Rw/B MCR, environmental factors such as temperature, lighting, and noise have been taken into consideration and the room and supporting systems have been designed accordingly. The Rw/B MCR is part of the un-designated area of the RW facility.

### 21.6.3.2 Layout and Work Space in the Rw/B MCR

(1) The system layout in the HMIs in the Rw/B MCR is designed to take into account the tasks that the operators are required to carry out during normal operation, plant startup, shutdown, outage, refuelling outage and fault conditions.
(2) In order to ensure the safety in the case of fault conditions that require manual operations, a suitable workspace link analysis is performed to consider the range of movements of the RW facilities personnel and to evaluate their ability to effectively and correctly survey and operate the plant, both individually and as a team.
(3) The layout of the desk and operator console in the Rw/B MCR is such that is enables good communication among operators, and takes operator visibility and use of the controllers and displays into account.

### 21.6.3.3 Layout of the Control Console

A grouped layout and logical arrangement are used for each system's display devices and the control equipment on the operator console. Control and display devices are selected and arranged in a manner that increases operator effectiveness and minimises the likelihood of operator misinterpretation and errors.

### 21.6.3.4 Display System

(1) Information Display Functions
Information showing the state of LWMS and equipment, along with information necessary for safety, is provided for operators in appropriate locations, grouped, and displayed in an easy to understand and interpret manner.

(2) Information for Automatic Operation
The operators are able to monitor and confirm the progression of the automatic operations.

(3) Alarm Functions
In the case of an abnormality in the plant equipment or processes that requires operator attention (i.e. change in focus of monitoring the plant) or action, an alarm function notifies the operators regarding the occurrence of such fault conditions. Alarms are presented in logically-arranged groups and in an easy to understand manner.

The alarm system within the Rw/B MCR is designed in accordance with the HF good practice and guidance which are derived from the HFE specification [Ref-7]. Further information of alarm functions is shown in the BSC on Overall HMI [Ref-1].

### 21.6.3.5 Control Functions

(1) Control devices are selected and arranged to be easy to operate in order to minimise operator errors.
(2) Where misoperation of the control systems and equipment in the Rw/B MCR can lead to potentially hazardous outcomes, appropriate considerations are given with labelling for them.
(3) The control systems and equipment in the Rw/B MCR are designed to be easily identified by shapes, labels, and so on.

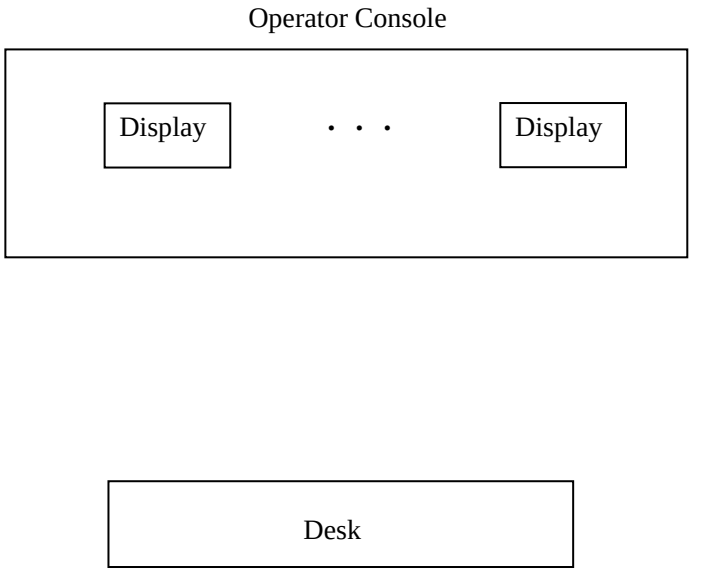



**Figure 21.6-1: The Basic Layout of Operator Console**

# 21.7 HMIs in the Local Control Locations

## 21.7.1 Introduction

In addition to the HMIs described in the previous sections (HMIs in the MCR, RSS panel rooms, B/B control panel room and Rw/B MCR), there are several types of local panel and relevant HMIs that are installed in local areas within the plant.

This section outlines several HMIs associated with the Class 1 SSCs which are controlled and monitored locally. As an example of local HMIs, descriptions about HMIs associated with the following systems or equipment are given in this section.

- Heating Ventilating and Air Conditioning System (HVAC) Emergency Cooling Water System (HECW)
- Fuel Handling Machine (FHM)
- Reactor Building Crane (RBC)

## 21.7.2 Design of HMIs in the Local Control Locations

### 21.7.2.1 Function

Adequate HMIs associated with the operations and/or monitoring of the systems/equipment which are relevant to the local control are installed in each local control location.

The HMIs in each local control location allow operators to control and/or monitor functions locally. Local control locations are provided or enabled where there is an advantage to providing local control facilities and where provision of such facilities does not lead to an undesirable risk of inappropriate operation. Where appropriate, local control locations are alarmed to the MCR. Functions of each system (HECW, FHM and RBC) are summarised here. Details are described in the relevant BSC and support documents respectively.

(1) HECW
HECW is a system which provides chilled water to cooling coils within the normal/emergency HVAC and consists of 3 divisions (divisions A, B and C). Chilled water is supplied according to the needs from each HVAC division.

Details of the functions of HECW are described in the PCSR Sub-chapter 16.1 Water Systems.

(2) FHM
The main functions of the FHM are as below;

- To transport fuel assemblies between the reactor core and the fuel storage racks in the spent fuel pool.
- To transport the Reactor Internal Pump (RIP).

Details of the functions of FHM are described in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-16].

(3) RBC
The main functions of the RBC are as below;

- To transport heavy loads.
- To transport a new fuel from a truck bay to an operating deck.
- To transport casks containing spent fuel assemblies from the cask pit in the Spent Fuel Pool (SFP) to the truck bay.

Details of the functions of RBC are described in the BSC on Fuel Handling Systems and Overhead Crane Systems [Ref-16].

## 21.7.3 Consideration for User Task Performance

The local HMIs are designed to enable comfortable, logical and effective task performance for all users. This includes taking the environmental conditions, layout and workspace into consideration for both operators and maintenance personnel.

In order to provide effective and reliable monitoring and control, the layout of the indicators and controls on each local panel has been designed by taking good-practice human interface design principles into consideration.
For example, the display devices and operational equipment are arranged within the panel layout to make related tasks easier to complete in a logical manner.

In order to minimise various types of errors (misinterpretation, omission, selection errors, etc.) by the operators, the design of the HMIs:

- has enabled the group monitoring of parameters relevant to the system or equipment controlled and/or monitored from local control location;
- follows HF good practice standards for labelling of indicators and controls; and
- has sorted the information according to relationship with the equipment and controls.

In order to further minimise commission errors by the operators, including inadvertent operation, the HMIs have been designed for its easy identification by shape, etc., and placed on the panel so as to prevent confusion or being spaced too closely.

Further descriptions of the HF requirements and assessments that have been used to support the optimal HMI design can be found in the PCSR Chapter 27 Human Factors and supporting documents. The remainder of this section provides a summary of these considerations.

### 21.7.3.1 Environmental Conditions in the Local Control Locations

The environmental conditions of local control locations, including at local panels, are variable depending on each location. However environmental factors such as temperature, lighting and noise have been taken into consideration in respect of the tasks to be carried out using the local control location. Further information regarding the environmental conditions of local control locations is shown in Section 2.3 of the HF COR [Ref-14].

### 21.7.3.2 Layout of the Control Panel Surface

A grouped layout and logical arrangement are used for each system's display devices on each local control panel. Control and display devices are selected and arranged in a manner that increases operator effectiveness and minimises the likelihood of operator misinterpretation and errors.

### 21.7.3.3 Display System

- Information Display Functions

Information showing the state of plant systems and equipment, along with information necessary for safety, is provided for operators in appropriate locations, grouped, and displayed in an easy to understand and interpret manner.

### 21.7.3.4 Control Functions

(1) Control devices are designed to be easy to operate in order to minimise operator errors.
(2) The control devices in the local control panel are designed to be easily identified by shapes, labels, and so on.

## 21.8 References

[Ref-1] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Overall Human-machine Interface", GA91-9201-0002-00109 (3E-GD-A0166) Rev.0, August 2015.

[Ref-2] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Main Control Room Human-machine Interface", GA91-9201-0002-00060 (3E-GD-A0029) Rev.1, August 2015.

[Ref-3] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Remote Shutdown System Human-machine Interface", GA91-9201-0002-00061 (3E-GD-A0030) Rev.1, August 2015.

[Ref-4] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Backup Building Human-machine Interface", GA91-9201-0002-00062 (3E-GD-A0031) Rev.1, August 2015.

[Ref-5] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Radioactive Waste Human-machine Interface", GA91-9201-0002-00063 (3E-GD-A0032) Rev.1, August 2015.

[Ref-6] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Control and Instrumentation Architecture", GA91-9201-0002-00022 (3D-GD-A0001) Rev.1, August 2015.

[Ref-7] Hitachi-GE Nuclear Energy, Ltd., "Human Factors Engineering Specification", GA91-9201-0001-00037 (HFD-GD-0001) Rev.B, March 2015.

[Ref-8] Hitachi-GE Nuclear Energy, Ltd., "Human Factors Design and Engineering Report", GA91-9201-0001-00039 (3E-UK-0181) Rev.A, August 2014.

[Ref-9] Hitachi-GE Nuclear Energy, Ltd., "Human Reliability Analysis Report", GA91-9201-0001-00041 (HFE-GD-0066) Rev.B, March 2015.

[Ref-10] Hitachi-GE Nuclear Energy, Ltd., "Human-Based Safety Claims Report", GA91-9201-0001-00043 (HFE-GD-0064) Rev.A, March 2015.

[Ref-11] Hitachi-GE Nuclear Energy, Ltd., "Topic Report on Fault Assessment", GA91-9201-0001-00022 (UE-GD-0071) Rev.2, May 2015.

[Ref-12] Hitachi-GE Nuclear Energy, Ltd., "List of Safety Category and Class for UK ABWR", GA91-9201-0003-00266 (AE-GD-0224) Rev.1, June 2015.

[Ref-13] Hitachi-GE Nuclear Energy, Ltd., "Allocation of Function Report", GA91-9201-0001-00040 (HFE-GD-0063) Rev.B, April 2015.

[Ref-14] Hitachi-GE Nuclear Energy, Ltd., "Human Factors Concept of Operations Report", GA-91-9201-0001-00034 (HFE-GD-0060) Rev.B, May 2015.

[Ref-15] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Heating Ventilating and Air Conditioning System", GA-91-9201-0002-00041 (HPE-GD-H006) Rev.1, February 2015.

[Ref-16] Hitachi-GE Nuclear Energy, Ltd., "Basis of Safety Cases on Fuel Handling Systems and Overhead Crane Systems", GA-91-9201-0002-00056 (M1D-UK-0006) Rev.0, January 2015.

Appendix A1: List of Claims

| Top Claim for HMIS | | | | | | Safety Functional Claim for the HMI System and Components (SFC) | | |
|---|---|---|---|---|---|---|---|---|
| Fundamental Safety Function (FSF) | | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | |
| PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions) | | | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification) | | Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule | State | Claim ID | Claim Contents |
| | | | | | | | | |
| 1 | Control of Reactivity | 1-1 | Functions to prevent excessive reactivity insertion | - | - | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 1-2 | Functions to maintain core geometry | - | - | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 1-3 | Emergency shutdown of the reactor | FS1 | RPS SCRAM (A1) | Fault Scenarios | HMIS SFC 1-3.1 | The HMI provides indicators and controls to perform and monitor an emergency shutdown of the reactor. |
| | | 1-4 | Functions to maintain sub-criticality | FS1<br>FS2 | RPS SCRAM (A1)<br>SLC(A2) | Fault Scenarios | HMIS SFC 1-4.1 | The HMI provides indicators and controls for the equipment and systems to maintain sub-criticality. |
| | | 1-5 | Function of alternative reactivity control | FS2<br>FS3<br>FS4<br>FS5 | SLC (A2)<br>RPT (A2)<br>Feedwater Runback (A2)<br>ARI (A2) | Fault Scenarios | HMIS SFC 1-5.1 | The HMI provides indicators and controls for the equipment and systems for alternative means to control reactivity. |
| | | 1-6 | Functions to circulate reactor coolant (functions to control reactivity of the core in normal operational states) | - | - | Normal | HMIS SFC 1-6.1 | The HMI provides indicators and controls for the equipment and systems to control reactivity in normal operational states by circulating reactor coolant. |
| | | 1-7 | Functions to plant instrument and control (except for safety protection function) (functions to control reactivity of the core in normal operational states) | - | - | Normal | HMIS SFC 1-7.1 | The HMI provides indicators and controls for the equipment and systems to monitor and control the reactivity of the core in normal operational states. |
| | | 1-8 | Functions to suppress reactor power increase with other system | - | - | Fault Scenarios | HMIS SFC 1-8.1 | The HMI provides indicators and controls for the equipment and systems to suppress inappropriate reactor power increase. |

| Top Claim for HMIS | | | | | | Safety Functional Claim for the HMI System and Components (SFC) | | |
|---|---|---|---|---|---|---|---|---|
| Fundamental Safety Function (FSF) | | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | |
| PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions) | | | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification) | | Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule | State | Claim ID | Claim Contents |
| | | | | | | | | |
| 1 | Control of Reactivity | 1-9 | Functions to maintain sub-criticality of spent fuel outside the reactor coolant system | - | - | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 1-10 | Functions to maintain sub-criticality of spent fuel during processes of spent fuel removal from SFP to storage area and during interim storage period | - | - | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| 2 | Fuel Cooling | 2-1 | Functions to cool reactor core | FS6<br>FS7<br>FS9<br>FS10 | RCIC(A1)<br>HPCF(A1)<br>ADS(A1)<br>LPFL(A1) | Fault Scenarios | HMIS SFC 2-1.1 | The HMI provides indicators and controls for the equipment and systems to cool reactor core. |
| | | 2-2 | Function of alternative fuel cooling | FS11<br>FS12 | RDCF(A2)<br>FLSS(A2) | Fault Scenarios | HMIS SFC 2-2.1 | The HMI provides indicators and controls to inject water for the equipment and systems to inject water into the reactor pressure vessel as alternative measures. |
| | | 2-3 | Function to make up reactor coolant with other system | - | - | Normal | HMIS SFC 2-3.1 | The HMI provides indicators and controls for the equipment and systems to make up reactor coolant with other systems. |
| | | 2-4 | Function to cool spent fuel outside the reactor coolant system | - | - | Normal | HMIS SFC 2-4.1 | The HMI provides indicators and controls for the equipment and systems to cool spent fuel pool. |
| | | 2-5 | Functions to make up water for spent fuel pool | - | - | Fault Scenarios | HMIS SFC 2-5.1 | The HMI provides indicators and controls for the equipment and systems to make up water for spent fuel pool. |
| | | 2-6 | Functions to provide fuel cooling during canister preparation works (canister lid welding, drying, inspection) | - | - | | | N/A |
| | | 2-7 | Functions to provide back-up fuel cooling as secondary means during canister preparation works (canister lid welding, drying, inspection) and transfer cask handling in the RB | - | - | | | N/A |

| Top Claim for HMIS | | | | | | Safety Functional Claim for the HMI System and Components (SFC) | | |
|---|---|---|---|---|---|---|---|---|
| Fundamental Safety Function (FSF) | | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | |
| PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions) | | | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification) | | Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule | State | Claim ID | Claim Contents |
| | | | | | | | | |
| 2 | Fuel Cooling | 2-8 | Function to provide passive spent fuel cooling during interim storage period | - | - | | | N/A |
| | | 2-9 | Function to provide passive spent fuel cooling in between canister cooling system removal and transfer into overpack | - | - | | | N/A |
| | | 2-10 | Functions to support passive cooling of spent fuel during processes of spent fuel removal from SFP to storage area and during interim storage period | - | - | | | N/A |
| | | 2-11 | Functions to prevent fuel cladding temperature to elevate over the temperature limit during canister drying process | - | - | | | N/A |
| 3 | Long term heat removal | 3-1 | Functions to remove residual heat after shutdown | FS13<br>FS14 | SRV –Manual depressurization– (A1)<br>RHR(A1) | Fault Scenarios | HMIS SFC 3-1.1 | The HMI provides indicators and controls for the equipment and systems to remove heat from the reactor core. |
| | | 3-2 | Function of alternative containment cooling and decay heat removal | FS15 | Containment venting(A2) | Fault Scenarios | HMIS SFC 3-2.1 | The HMI provides indicators and controls for the equipment and systems to remove residual heat as alternative measures. |
| 4 | Confinement/Containment of radioactive materials | 4-1 | Functions to form reactor coolant pressure boundary | - | - | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 4-2 | Functions to prevent overpressure within the reactor coolant pressure boundary | - | - | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 4-3 | Functions to contain reactor coolant (Except for: small-diameter pipes excluded from the reactor coolant pressure boundary such as instrumentation pipes; other pipes and equipment which are not directly connected to the boundary) | - | - | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |

| Top Claim for HMIS | | | | | | | Safety Functional Claim for the HMI System and Components (SFC) | | |
|---|---|---|---|---|---|---|---|---|---|
| Fundamental Safety Function (FSF) | | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | | |
| PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions) | | | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification) | | Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule | | State | Claim ID | Claim Contents |
| | | | | | | | | | |
| 4 | Confinement/Containment of radioactive materials | 4-4 | Functions to retain reactor coolant (other than No.4-1 and 4-3) | - | - | | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 4-5 | Functions to reseat safety valves and relief valves | - | - | | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 4-6 | Functions to mitigate reactor pressure increase with other system (other than No.4-2) | - | - | | Fault Scenarios | HMIS SFC 4-6.1 | The HMI provides indicators and controls for the equipment and systems to mitigate reactor pressure increase with other systems. |
| | | 4-7 | Functions to confine radioactive materials, shield radiation, and reduce radioactive release | FS16<br>FS17 | MSIV(A1)<br>PCIS(A1) | | Fault Scenarios | HMIS SFC 4-7.1 | The HMI provides indicators and controls for the equipment and systems to confine radioactive materials, shield of radiation and to reduce radioactive release. |
| | | 4-8 | Functions to minimise the release of radioactive gases | - | - | | Fault Scenarios | HMIS SFC 4-8.1 | The HMI provides indicators and controls for the equipment and systems to minimise the release of radioactive gases. |
| | | 4-9 | Functions to contain radioactive materials in the event of a severe accident | - | - | | Fault Scenarios | HMIS SFC 4-9.1 | The HMI provides indicators and controls for the equipment and systems to contain radioactive materials in the event of a severe accident. |
| | | 4-10 | Functions to prevent the dispersion of fission products into reactor coolant and spent fuel pool | - | - | | - | - | N/A (This HLSF is achieved by the Mechanical Equipment system) |
| | | 4-11 | Functions to store the radioactive materials as gaseous waste | - | - | | Normal | HMIS SFC 4-11.1 | The HMI provides indicators and controls for the equipment and systems to store the radioactive materials as gaseous waste. |
| | | 4-12 | Functions to store the radioactive materials as liquid wastes | - | - | | Normal | HMIS SFC 4-12.1 | The HMI provides indicators and controls for the equipment and systems to store the radioactive materials as liquid wastes. |

| Top Claim for HMIS | | | | | | | Safety Functional Claim for the HMI System and Components (SFC) | | |
|---|---|---|---|---|---|---|---|---|---|
| Fundamental Safety Function (FSF) | | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | | |
| PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions) | | | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification) | | Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule | | State | Claim ID | Claim Contents |
| | | | | | | | | | |
| 4 | Confinement/Containment of radioactive materials | 4-13 | Functions to store the radioactive materials as solid wastes | - | - | | Normal | HMIS SFC 4-13.1 | The HMI provides indicators and controls for the equipment and systems to store the radioactive materials as solid wastes. |
| | | 4-14 | Functions to provide containment barrier during processes of spent fuel removal from SFP to storage area and during interim storage period | - | - | | | | N/A |
| | | 4-15 | Method to provide containment barrier to canister | - | - | | | | N/A |
| 5 | Others | 5-1 | Functions to generate actuation signals for the engineered safety features and reactor shutdown system | - | - | | Fault Scenarios | HMIS SFC 5-1.1 | The HMI provides information of the actuation signals for engineered safety features and reactor shutdown. |
| | | 5-2 | Supporting functions especially important to safety | - | - | | Fault Scenarios | HMIS SFC 5-2.1 | The HMI provides indicators and controls for the supporting functions especially important to safety. |
| | | 5-3 | Function of alternative supporting system | - | - | | Fault Scenarios | HMIS SFC 5-3.1 | The HMI provides indicators and controls for the supporting functions for alternative measures. |
| | | 5-4 | Functions to monitor plant conditions in case of an accident | - | - | | Fault Scenarios | HMIS SFC 5-4.1 | The HMI provides information to monitor the key plant conditions in the event of an accident. |
| | | 5-5 | Functions to shut down safely from outside the control room | - | - | | Fault Scenarios | HMIIS SFC 5-5.1 | The HMI provides indicators and controls to bring safe shutdown from outside the control room. |
| | | 5-6 | Functions to handle fuel and heavy equipment safely | - | - | | Normal | HMIIS SFC 5-6.1 | The HMI provides indicators and controls to handle fuel and heavy equipment safely. |

| Top Claim for HMIS | | | | | | Safety Functional Claim for the HMI System and Components (SFC) | | |
|---|---|---|---|---|---|---|---|---|
| Fundamental Safety Function (FSF) | | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | |
| PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions) | | | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification) | | Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule | State | Claim ID | Claim Contents |
| | | | | | | | | |
| 5 | Others | 5-7 | Functions to limit the effect of hazard | - | - | Normal | HMIIS SFC 5-7.1 | The HMI provides information about the status of watertight and/or fire resistant doors. |
| | | 5-8 | Functions to clean up reactor coolant | - | - | Normal | HMIS SFC 5-8.1 | The HMI provides information and controls about the cleanliness of the reactor coolant and the status of the reactor coolant clean up systems. |
| | | 5-9 | Functions to clean up water except for reactor coolant | - | - | Normal | HMIS SFC 5-9.1 | The HMI provides indicators and controls for equipment and systems to clean up water except for reactor coolant. |
| | | 5-10 | Functions to supply electric power (except for emergency supply) | - | - | Normal | HMIS SFC 5-10.1 | The HMI provides indictors and controls for equipment and systems to supply electric power. |
| | | 5-11 | Supporting functions to supply power (except for emergency supply) | - | - | Normal | HMIS SFC 5-11.1 | The HMI provides indicators and controls for the key supporting functions to supply power. |
| | | 5-12 | Functions for plant instrumentation and control (except for safety protection function) | - | - | Normal | HMIS SFC 5-12.1 | The HMI provides indicators and controls for the reactor plant control functions and systems. |
| | | 5-13 | Auxiliary functions for plant operation | - | - | Normal and Fault Scenarios | HMIS SFC 5-13.1 | The HMI provides indicators and controls for auxiliary functions for plant operation. |
| | | 5-14 | Functions important to emergency measures and monitoring of abnormal conditions | - | - | Fault Scenarios | HMIS SFC 5-14.1 | The HMI provides indicators and controls for emergency measures and to monitor key plant conditions during fault condition (or abnormal conditions). |
| | | 5-15 | Functions to provide radiation shield, canister handling method, fuel retrievability and protection of canister during processes of spent fuel removal from SFP to storage area | - | - | | | N/A |

| | Top Claim for HMIS | | | | | | Safety Functional Claim for the HMI System and Components (SFC) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Fundamental Safety Function (FSF) | | High Level Safety Function (HLSF) | | Fault Schedule (Bounding Fault) | | | | |
| | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.2 Identification of ABWR Safety Functions) | | PCSR Ch.5.4 (List of Safety Category and Class for UK ABWR (AE-GD-0224) 3.6 Summary of Safety Category and Classification) | | Topic Report on Fault Assessment (UE-GD-0071) Table.4.2-1 Fault Schedule | | State | Claim ID | Claim Contents |
| | | | | | | | | | |
| | 5 | Others | 5-16 | Functions to provide radiation shield, canister handling method, fuel retrievability and protection of canister during interim storage period | - | - | | | N/A |
| | | | 5-17 | Functions to provide handling of transfer cask and retrievability of fuel | - | - | | | N/A |
| | | | 5-18 | Functions to provide handling of transfer cask or concrete overpack and retrievability of fuel | - | - | | | N/A |