Revision	Approved by	Number of Pages
000	[signature]	40
Approval Date	12/11/2018	

General Nuclear System Ltd.

UK HPR1000 GDA Project

Document Reference:	HPR/GDA/PCSR/0015

Title:

Pre-Construction Safety Report

Chapter 15

Human Factors

This document has been prepared on behalf of General Nuclear System Limited (GNS) with the support of China General Nuclear Power Corporation (CGN) and Électricité de France S.A. (EDF).

Although due care has been taken in compiling the content of this document, neither GNS, CGN, EDF nor any of their respective affiliates accept any liability in respect to any errors, omissions or inaccuracies contained or referred to in it.

DISTRIBUTION LIST

Recipients	Cross Box
GNS Executive	☐
GNS all staff	☐
GNS and BRB all staff	☒
CGN	☒
EDF	☒
Regulators	☒
Public	☒

MODIFICATION RECORD

Revision	Section	Page	Modification
000	ALL	ALL	First Issue

TABLE OF CONTENTS

15.1 List of Abbreviations and Acronyms

ACP	Auxiliary Control Panel
ALARP	As Low As Reasonably Practicable
AoF	Allocation of Function
CGN	China General Nuclear Power Corporation
CRS	Control Room System
DAP	Duly Authorised Person
DBC	Design Basis Condition
DEC-A	Design Extension Condition A
DHP	Diverse Human interface Panel
EMIT	Examination, Maintenance, Inspection and Testing
EOP	Emergency Operating Procedure
FCG3	Fangchenggang Nuclear Power Plant Unit 3
GDA	Generic Design Assessment
HBSC	Human-Based Safety Claim
HEP	Human Error Probability
HF	Human Factors
HFE	Human Factors Engineering
HFI	Human Factors Integration
HFIP	Human Factors Integration Plan
HMI	Human Machine Interface
HPR1000 (FCG3)	Hua-long Pressurised Reactor under construction at Fangchenggang nuclear power plant unit 3
HRQ	Human Reliability Quantification
HTA	Hierarchical Task Analysis
IAEA	International Atomic Energy Agency
I&C	Instrumentation and Control
ITS	Issue Tracking System

KIC	Plant Computer Information and Control System[PCICS]
MCA	Main Control Area
MCR	Main Control Room
NOP	Normal Operating Procedure
NPP	Nuclear Power Plant
OER	Operating Experience Review
ONR	Office for Nuclear Regulation (UK)
OPEX	Operating Experience
OTS	Operating Technical Specification
PCSR	Pre-Construction Safety Report
PIE	Postulated Initiating Event
PSA	Probabilistic Safety Assessment
PSF	Performance Shaping Factor
RCP[RCS]	Reactor Coolant System
RGP	Relevant Good Practice
RSS	Remote Shutdown Station
SAA	Severe Accident Analysis
SAMG	Severe Accident Management Guideline
SAP	Safety Assessment Principle (UK)
SHP	Severe accident Human interface Panel
SPAR-H	Standardised Plant Analysis Risk - Human Reliability Analysis
SQEP	Suitably Qualified and Experienced Personnel
SRO	Senior Reactor Operator
SSC	Structures, Systems and Components
TAG	Technical Assessment Guide (UK)
TLA	Time Line Analysis
TSC	Technical Support Centre
TTA	Tabular Task Analysis

UK HPR1000	UK version of the Hua-long Pressurised Reactor
V&V	Verification and Validation
WANO	World Association of Nuclear Operators

Note:

System codes (XXX) and system abbreviations (YYY) are provided for completeness in the format (XXX [YYY]), e.g. Extra Cooling System (ECS [ECS]).

15.2 Introduction

Human Factors (HF) has been adequately considered for this stage of the GDA in the design to support the safety case assertion of achieving the plant's fundamental safety functions and to reduce the risks associated with human interactions with the system to As Low As Reasonably Practical (ALARP).

This chapter describes how HF claims have been addressed in the UK version of the Hua-long Pressurised Reactor (UK HPR1000) Pre-Construction Safety Report (PCSR). Because HF is a cross-cutting discipline, this chapter also supports relevant claims made in other chapters that are associated with HF. During the Generic Design Assessment (GDA) phase, the contents of the HF topic area are as follows:

a) Identify and summarise the HF safety case claims (specified as sub-claims in this chapter), one of which is the identification of Human-Based Safety Claims (HBSCs);

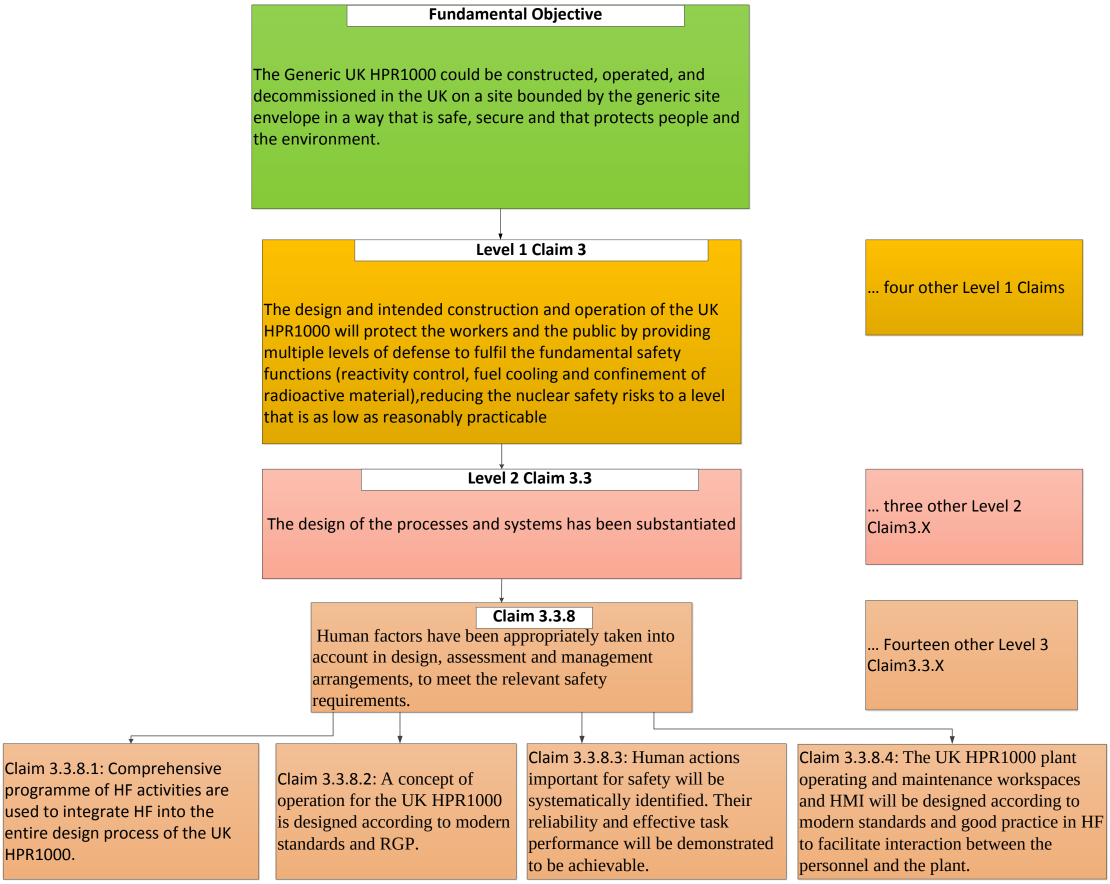
b) Demonstrate that the HF safety case claims are realistic, and can be substantiated by the appropriate evidence in the form of HF analysis and assessment;

c) Demonstrate that the risks related to human elements are adequately considered and ALARP; and

d) Summarise the HF-related activities to be carried out as part of GDA phase.

15.2.1 Chapter Route Map

This subchapter describes the HF route map. The HF claims development process is shown in F-15.2-1.



F-15.2-1 HF Claims Development Process

The **Fundamental Objective** of UK HPR1000 is: The generic UK HPR1000 could be constructed, operated, and decommissioned in the UK on a site bounded by the generic site envelope in a way that is safe, secure and that protects people and the environment.

To underpin this objective**,** five high-level claims and a number of level 2 claims have been developed and presented in Chapter 1. This chapter supports **Claim 3.3.8** derived from the high-level **Claim 3.3** and **Claim 3**.

Claim 3: The design and intended construction and operation of the UK HPR1000 will protect the workers and the public by providing multiple levels of defence to fulfil the fundamental safety functions (reactivity control, fuel cooling and confinement of radioactive material), reducing the nuclear safety risks to a level that is as low as reasonably practicable.

Claim 3.3: The design of the processes and systems has been substantiated and the safety aspects of operation and management have been substantiated.

Claim 3.3.8: Human Factors have been appropriately taken into account in the design, assessment and management arrangements, to meet the relevant safety requirements.

To support Claim 3.3.8, four Sub-claims and a number of relevant arguments have been made, and to be completed with the required evidence, which are listed below.

a) **Sub-claim 1**: A comprehensive programme of HF activities is used to integrate HF into the entire design process of UK HPR1000.

1) **Argument 1.1**: The HF activities are organised and managed by an HF Integration Plan (HFIP – see subchapter 15.5.1).

- **Evidence 1.1.1**: *Human Factors Integration Plan*, Reference [1], is produced to organise and manage the HF activities.

2) **Argument 1.2**: The HFIP is understood and adhered to by other disciplines (see subchapter 15.5.2).

- **Evidence 1.2.1**: Process documents used to demonstrate that the HFIP is understood and adhered to are available.

3) **Argument 1.3**: The HF activities are carried out by Suitably Qualified and Experienced Personnel (SQEP) (see subchapter 15.5.3).

- **Evidence 1.3.1**: *HF Organisation and Operation Principles*, Reference [2], has been prepared to describe that a dedicated HF team, comprising SQEP China General Nuclear Power Corporation (CGN) multi-disciplines engineers and HF specialists, has been assembled.

- **Evidence 1.3.2**: *HFE Training Plan*, Reference [3], has been prepared to enable members of the CGN multi-disciplines to acquire the appropriate Human Factors Engineering (HFE) qualification.

b) **Sub-claim 2:** A concept of operation for the UK HPR1000 has been designed according to modern standards and Relevant Good Practice (RGP).

1) **Argument 2.1**: Suitable RGP & Operating Experience (OPEX) has been identified (see subchapter 15. 3 and 15.4).

- **Evidence 2.1.1**: The relevant codes and standards are listed in subchapter 15.3.3.

- **Evidence 2.1.2**: The OPEX reviewed for Fangchenggang Nuclear Power Plant Unit 3 (FCG3) and a further review for UK HPR1000, which is presented in the *Operating Experience Review Implementation Plan*, Reference [4], details how the OPEX identified is suitable.

- **Evidence 2.1.3**: The Operating Experience Review Summary Report will be updated .

2) **Argument 2.2**: The concept of operation is suitable for the UK HPR1000 (see subchapter 15.6.1).

- **Evidence 2.2.1**: The UK HPR1000 operational concept has been developed based on FCG3 (see subchapter 15.6.1).

- **Evidence 2.2.2:** The operational concept can be adjusted according to HBSCs' substantiation.

3) **Argument 2.3**: The allocation of safety functions between human and engineered systems is designed to be commensurate with human capabilities (see subchapter 15.6.2).

   - **Evidence 2.3.1**: *Function Allocation Methodology*, Reference [5], has been produced, which provides the Allocation of Function (AoF) criteria based on human capabilities and limitations.

   - **Evidence 2.3.2**: According to the methodology, the function allocation between system and human will be reviewed and the *Allocation of Function Review Report* will be produced .

   - **Evidence 2.3.3**: The *Allocation of Function Improvement Report* will be produced if modifications are required .

4) **Argument 2.4:** The concept for the use of computerised procedures, supported by paper-based procedures, for reliable operation is demonstrated during the GDA phase (see subchapter 15.6.3).

   - **Evidence 2.4.1:** Operating feedback for procedures from existing plants with similar designs will support demonstration that the concept of procedures can support reliable operation .

   - **Evidence 2.4.2:** The procedures will be assessed against the relevant HBSCs and associated substantiation using the Hua-long Pressurised Reactor Simulator under construction at Fangchenggang nuclear power plant unit 3 (HPR1000 (FCG3)) .

5) **Argument 2.5:** The appropriate staffing and qualification requirements have been identified based on the defined job roles, for all essential plant operations in normal operation and accident conditions (see subchapter 15.6.4).

   - **Evidence 2.5.1:** Staffing requirements for existing similar plants have been developed using available OPEX, which is will be reported.

   - **Evidence 2.5.2:** Task analysis will provide the basis for establishing required staffing and qualifications, for normal operation and accident conditions.

b) **Sub-claim3**: Human actions important to safety will be systematically identified. Their reliability and effective task performance will be demonstrated to be achievable.

1) **Argument 3.1**: A systematic approach will be taken to identify Type A, B and C human actions and administrative controls that could impact safety under Design Basis Conditions (DBCs), Design Extension Condition A (DEC-A) and severe accident conditions (see subchapter 15.7.1).

   - **Evidence 3.1.1**: The strategy for identification and assessment of HBSCs is described in *Treatment of Important Human Actions Implementation Plan*, Reference [6].

2) **Argument 3.2**: Human activities related to conventional safety, security, environmental protection, radiological protection and decommissioning will be identified (see subchapter 15.7.3).

   - **Evidence 3.2.1**: The strategy for identification and assessment of HBSCs is described in *Treatment of Important Human Actions Implementation Plan*, Reference [6].

3) **Argument 3.3**: Proportionate human reliability assessment will be carried out for all human actions important to safety (see subchapter 15.7.2).

   - **Evidence 3.3.1**: The strategy for identification and assessment of HBSCs is described in *Treatment of Important Human Actions Implementation Plan*, Reference [6].

   - **Evidence 3.3.2**: *Task Analysis Methodology*, Reference [7], has been produced, which provides the qualitative analysis methodology of the proportionate human reliability assessment.

   - **Evidence 3.3.3**: *Methodology of Human Reliability Analysis*, Reference [8], has been produced, which provides the quantitative analysis methodology of the proportionate human reliability assessment.

   - **Evidence 3.3.4**: The *Report of Human Reliability Analysis* will be produced.

c) **Sub-claim 4**: The UK HPR1000 plant operating and maintenance workspaces and Human Machine Interfaces (HMIs) will be designed according to modern standards and good practice in HF to facilitate interaction between the personnel and the plant.

1) **Argument 4.1**: Suitable RGP & OPEX has been identified (see subchapter 15. 3 and 15.4).

   - **Evidence 4.1.1**: The relevant codes and standards are listed in subchapter 15.3.3.

   - **Evidence 4.1.2**: The OPEX reviewed for FCG3 and a further review for UK HPR1000, which is planned in *Operating Experience Review*

Implementation Plan, Reference [4], shows the OPEX identified is suitable.

- **Evidence 4.1.3**: The Operating Experience Review Summary Report will be updated.

2) **Argument 4.2**: RGP & OPEX has been used and will be used to support the design (see subchapter 15. 8.1).

   - **Evidence 4.2.1**: RGP has been integrated into the HFE guidelines, References [9] and [10].

   - **Evidence 4.2.2**: HFE guidelines have been and will be used to support the design.

3) **Argument 4.3**: The HF evaluation will be completed on HMIs and workspaces (see subchapter 15. 8.2).

   - **Evidence 4.3.1**: HF review of HMIs and workspaces or HF Verification and Validation (V&V) reports will be produced.

   - **Evidence 4.3.2:** The task analysis for HBSCs will demonstrate the suitability of the key HMIs and workspace designs.

15.2.2 Chapter Structure

The structure of this chapter is as follows:

a) Subchapter 15.1 lists the abbreviations and acronyms mentioned in this chapter;

b) Subchapter 15.2 gives the brief introduction of this chapter;

c) Subchapter 15.3 gives the applicable codes and standards;

d) Subchapter 15.4 presents the OPEX consideration;

e) Subchapter 15.5 provides a description of HFI to support HF sub-claim 1;

f) Subchapter 15.6 gives the concept of operation information for UK HPR1000 to support HF sub-claim 2;

g) Subchapter 15.7 gives a description of substantiation of HBSCs, including the process and methodology, to support HF sub-claim 3;

h) Subchapter 15.8 gives a description of design support of HF activities to support HF sub-claim 4;

i) Subchapter 15.9 presents the general description of ALARP;

j) Subchapter 15.10 gives a summary of the main aspects of this chapter;

k) Subchapter 15.11 provides the reference documents.

15.2.3 Interfaces with Other Chapters

The interfaces with other chapters are listed in the following table.

T-15.2-1 Interfaces between Chapter 15 and Other Chapters

No.	PCSR Chapter	Interface
1	Chapter 1 Introduction	Chapter 1 presents the high-level objectives and claims. Chapter 15 provides the substantiation of high-level objectives and claims relative to HF.
2	Chapter 4 General Safety and Design Principles	Chapter 4 presents the HF principles. Chapter 15 presents substantiation of HF principles.
3	Chapter 6 Reactor Coolant System	Chapter 6 provides the substantiation of RCP [RCS], which is taken into account for further estimate in HF area. Chapter 15 provides the principles and methodology of HF integration that shall be considered in system and component design.
4	Chapter 7 Safety System	Chapter 7 provides the substantiation of safety systems, which is taken into account for further estimate in HF area. Chapter 15 provides the principles and methodology of HF integration that shall be considered in system and component design.
5	Chapter 8 Instrumentation & Controls	Chapter 8 provides the specific design of Instrumentation and Control (I&C) systems, which is taken into account for further estimate in HF area. Chapter 15 provides the principles and methodology of HF integration that shall be considered in I&C system and component design.
6	Chapter 9 Electric Power	Chapter 9 provides the specific design of electric systems, which is taken into account for further estimate in HF area. Chapter 15 provides the principles and methodology

No.	PCSR Chapter	Interface
		of HF integration that shall be considered in Electric system and component design.
7	Chapter 10 Auxiliary Systems	Chapter 10 provides the substantiation of the principles in auxiliary systems design, which is taken into account for further estimate in HF area. Chapter 15 provides the principles and methodology of HF Integrity that shall be considered in auxiliary system and component design.
8	Chapter 11 Steam and Power Conversion System	Subchapter 11.3 provides the substantiation of Steam and Power Conversion Systems, which is taken into account for further estimate in HF area. Chapter 15 provides the principles and methodology of HF integration that shall be considered in system and component design.
9	Chapter 12 Design Basis Condition	Chapter 12 provides human-related claims (implied and explicit) in fault studies, which need SQEP HF analysis and/or review. Chapter 15 substantiates the claims on operator actions under DBCs.
10	Chapter 13 Design Extension Conditions and Severe Accident Analysis	Chapter 13 provides human-related claims (implied and explicit) in design extension conditions and Severe Accident Analysis (SAA), which need SQEP HF analysis and/or review. Chapter 15 substantiates the claims on operator actions under DEC-A and severe accident conditions.
11	Chapter 14 Probabilistic Safety Assessment	Chapter 14 provides human-related claims (implied and explicit) in Probabilistic Safety Assessment (PSA), which need SQEP HF analysis and/or review. Chapter 15 provides the scope, methodology and principle of HRA in PSA. And also substantiates the claims on operator actions to support an iterative analysis of PSA.
12	Chapter 18 External	Chapter 18 provides human-related claims (implied

No.	PCSR Chapter	Interface
	Hazards	and explicit) in external hazards, which need SQEP HF analysis and/or review. Chapter 15 substantiates the claims on operator actions relating to external hazards.
13	Chapter 19 Internal Hazards	Chapter 19 provides human-related claims (implied and explicit) in internal hazards, which need SQEP HF analysis and/or review. Chapter 15 substantiates the claims on operator actions relating to internal hazards.
14	Chapter 20 MSQA and safety case management	The organisational arrangements and quality assurance arrangements set out in Chapter 20 are implemented in Chapter 15.
15	Chapter 23 Radioactive Waste Management	PCSR Chapter 23 provides the concept design of radioactive waste management systems, which is further estimated in HF area. PCSR Chapter 15 provides the principles and methodology of HF integration that shall be considered in the system and component design.
16	Chapter 24 Decommissioning	Chapter 24 provides the concept design of decommissioning, which is taken developed further in consideration of HF requirements. Chapter 24 provides decommissioning design considerations relevant to the HF of UK HPR1000. Chapter 15 provides the principles and methodology of HF integration that shall be considered in decommissioning design.
17	Chapter 25 Conventional Safety and Fire Safety	Chapter 15 supports the conventional health and safety risk management and references the health and safety risk management techniques.
18	Chapter 28 Fuel Route and Storage	Chapter 28 provides the substantiated HBSCs that are achievable and supported by appropriate HF assessments, including fuel handling operations that are taken into account under the HF area.

No.	PCSR Chapter	Interface
		Chapter 15 provides the principles and methodology of HF integration that shall be considered in the design of fuel handling and storage related operations.
19	Chapter 31 Operational Management	Chapter 31 provides procedure types and the process of procedure development. Chapter 15 provides the principles and methodology of HF integration that shall be considered.
20	Chapter 33 ALARP Evaluation	Chapter 15 provides the assessment of human actions impacting safety which supports the overall ALARP demonstration addressed in Chapter 33.

15.3 Applicable Codes and Standards

Based on HPR1000 design, the applicable codes and standards for UK HPR1000 HF design are predominantly selected and determined according to the selecting principles and the process presented in the PCSR chapter 4 and *General Principles for Application of Laws, Regulations, Codes and Standards*, Reference [11], to ensure the applied codes and standards comply with the existing UK requirements, applicable acts, regulations, as well as taking cognisance of international good practice or RGP recognised by UK regulators.

15.3.1 Codes and Standards Selection Principle

The main principles for the selection of design codes and standards are listed as follows:

a) International good practice or recognised RGP by UK authorities is selected for use;

b) The latest versions of design codes and standards are selected. Whenever historic versions are to be chosen in FCG3, a gap analysis has been carried out, and remedial measures have been identified and applied, as appropriate;

c) Nuclear-specific design codes and standards are selected in preference where available to ensure that the design is conservatively produced to a level commensurate with the importance of the delivered safety function(s);

d) Evaluation of each selected design code or standard is required to determine its applicability, adequacy and sufficiency. If necessary and appropriate, selected design codes are to be supplemented and/or modified to ensure requirements are met.

15.3.2 Applicability Analysis of Codes and Standards

FCG3 adopts HAF 102-2004 Safety regulations for design of nuclear power plants of the People's Republic of China, which is equivalent to International Atomic Energy Agency (IAEA) NS-R-1-2000 (updated to *IAEA SSR-2/1-2016)*, Reference [12], and with the exception of HAF 102-2004 considering the regulatory practices of Nuclear Power Plants (NPPs) in China. As such, HAF 102-2004 reflects both the international and Chinese consensus on how to ensure safety is maintained to a high level and has, therefore, been considered as the best practice for the newly-designed NPPs in China. After the Fukushima nuclear accident (March 2011), the "*General Technical Requirements for Post-Fukushima-Accident Improvement Actions of Nuclear Power Plants*", Reference [13], was established by the National Nuclear Safety Administration (China) in June 2012 in order to draw lessons from the Fukushima nuclear accident in Japan and further improve the safety level of NPPs in China. HPR1000 (FCG3) was then reviewed against those requirements to confirm that the relevant safety improvements had already been considered in the design. Thereafter, a similar review against *IAEA SSR-2/1-2016*, Reference [12], was conducted to ensure that the design of HPR1000 (FCG3) was benchmarked against, and in line with, international good practices.

The other available Chinese standards, such as "GB (Chinese National Standard)" standards series and "NB (Chinese Energy Standard)" standards series are also used, the main technical clauses of which are equivalent to international codes and standards, such as "IEC (International Electrotechnical Commission)". In addition, "NUREG (Nuclear Regulatory Commission Technical Report Designation)" guidelines, "ISO (International Organization for Standardization)" series and "IEEE (Institute of Electrical and Electronics Engineers)" standards are adopted.

UK HPR1000 HF activities are based on the current status of HPR1000 (FCG3) design, and good practice from the NPPs in China has been considered and taken into account where appropriate. However, the HPR1000 (FCG3) design will also reflect guidance from *Safety Assessment Principle for Nuclear Facilities*, Reference [14], and *Technical Assessment Guides*, Reference [15] to [20], and adopt British Standards (BS), such as "BS IEC", "BS EN (European Norm)", and "BS ISO".

15.3.3 Codes and Standards in UK HPR1000 HF Design

The scope of UK HPR1000 codes and standards covers the main topics of the HF activities and the HF support activities to other disciplines, such as HMI; Control Room System (CRS) workspace; and Structures, Systems and Components (SSCs) in local areas.

The current identified applicable codes and standards for HF topics are listed in T-15.3-1. These codes and standards are identified as RGP, and are, therefore, appropriate for supporting the UK HPR1000 HF design.

T-15.3-1 Applicable codes and standards

Codes and Standards	Title	Year Issued	Topics
SSR-2/1	Safety of Nuclear Power Plants: Design	2016	Top requirements of HF
NUREG-0711	Human Factors Engineering Program Review Model	2012	HFIP, Task analysis, HF V&V, HBSC identification, OPEX
NUREG-0700	Human System Interface Review Guideline	2002	HFE guideline
NUREG/CR- 3331	A Methodology for Allocation Nuclear Power Plant Control Functions to Human or Automatic Control	1983	AoF
NUREG-1792	Good Practices for Implementing Human Reliability Analysis	2005	Human Reliability Quantification (HRQ)
NUREG/CR-6883	The SPAR-H Human Reliability Analysis Method	2005	HRQ
NUREG/CR-4772	Accident Sequence Evaluation Program Human Reliability Analysis Procedure	1987	HRQ
NUREG/CR-1278	Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Application	1983	HRQ
IEEE 1023	Recommended Practice for the Application of HFE to systems, equipment and facilities of Nuclear Power Generating Stations and other Nuclear facilities	2004	HFE guideline
BS EN 61839	Nuclear power plants – Design of control rooms – Functional analysis and assignment	2014	AoF
BS IEC 60964	Nuclear power plants – Control rooms – design	2009	HFE guideline, HFIP
BS EN 60965	Nuclear power plants – Control rooms – Supplementary control points for reactor shutdown	2016	HFE guideline, HFIP

Codes and Standards	Title	Year Issued	Topics
	without access to the main control room		
BS EN 61772	Nuclear power plants – Main control room – Application of visual display units (VDUs)	2013	HFE guideline
BS EN 62241	Nuclear power plants – Main control room – Alarm functions and presentation	2015	HFE guideline
BS EN 61227	Nuclear power plants – Control rooms – Operator control	2016	HFE guideline
BS EN ISO 11064-2	Ergonomic Design of Control Centers – Part 2: Principles for the Arrangement of Control Suites	2000	HFE guideline
BS EN ISO 11064-3	Ergonomic Design of Control Centers – Part 3: Control room layout	2002	HFE guideline
BS EN ISO 11064-4	Ergonomic Design of Control Centers – Part 4: Layout and dimensions of workstations	2004	HFE guideline
BS EN ISO 11064-6	Ergonomic Design of Control Centers – Part 6: Environmental requirements for control centres	2005	HFE guideline
BS EN ISO 9241-112	Ergonomics of human – system interaction Part 112: Principles for the presentation of information	2017	HFE guideline
BS EN ISO 12100	Safety of machinery – General principal for design-Risk assessment and risk reduction	2010	HFE guideline
ISBN 978 0 85293 555 2	Guidance on managing human and organizational factors in decommissioning	2010	HFE guideline
BS EN 12464	Light and lighting – Lighting of work places – Part 1: Indoor work places	2011	HFE guideline
IEC 62271-1	High – voltage switchgear and control gear – Part 1: Common specifications	2011	HFE guideline

15.4 OPEX

For FCG3, OPEX from the Chinese and international NPP fleets has been considered. HFE-related problems and issues for the Main Control Room (MCR), Remote Shutdown Station (RSS), and a proportion of HMIs in local areas have been identified and analysed. The content of the plant-wide operating experience review covers:

a) Previous plants and systems;

b) Recognised nuclear industry problems;

c) Relevant HMI technologies;

d) Problems identified by plant personnel;

e) Important human actions.

Furthermore, to obtain OPEX in the areas of operation, inspection and maintenance, the plant workers with experience have been interviewed by each participating discipline to identify relevant HF short-falls.

A further OPEX review will be carried out for the UK HPR1000 as defined in *Operating Experience Review Implementation Plan,* Reference [4]. This will expand the scope of the Operating Experience Review (OER) to include the newly-operating Taishan NPP and a world-wide review using information from World Association of Nuclear Operators (WANO). The HF OPEX review will be widened to include areas such as build, commissioning, operation, inspection and maintenance, and decommissioning to identify where human unreliability has been observed and to identify enhancements to the UK HPR1000 design.

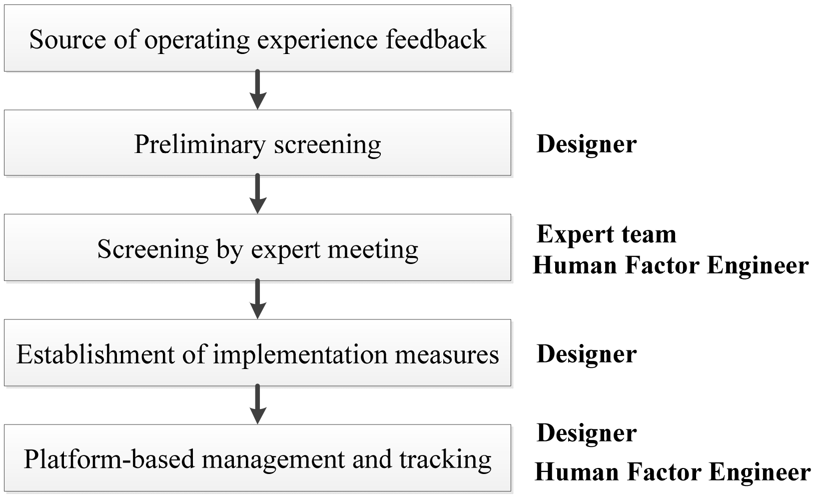
Therefore, the following work will be done:

a) The Operating Experience Review Summary Report will be updated;

b) OPEX related to existing NPPs procedures and staffing also will be reported.

The outcome of the OPEX review is to be made available to the HFE team and other designers where necessary.

The routine process for operating experience feedback review is summarised in F-15.4-1.



F-15.4-1 Routine Process for Operating Experience Feedback Review and Analysis

15.5 Human Factors Integration Management

This subchapter supports HF sub-claim 1.

15.5.1 Introduction

For FCG3, using *NUREG-0711*, Reference [21], a comprehensive programme of HF activities has been conducted, including HFE programme management, operating experience review, functional requirements analysis and functional allocation, task analysis, staffing and qualifications, treatment of important human actions, HMI design, procedure development and HF verification and validation.

The scope of HF activities covers the nuclear island, conventional island and balance of plant, including the MCR, RSS and other plant locations where operation and maintenance activities take place. Particular HF focus from the CGN HF team has been given to the MCR, the central location for monitoring and control of the plant. During SSC design (such as pumps and the refuelling crane), consideration of operator role has taken into account relevant codes and standards, engineering procedures and experience from previous plants.

For the UK HPR1000, the process by which the equipment and human components are brought together to work in a system is known as Human Factors Integration (HFI). According to *NS-TAST-GD-058*, Reference [14], “HFI is a good practice approach to the application of Human Factors (HF) to systems development. As a methodology, it provides an organising framework to help ensure that all relevant HF issues are identified and addressed. In addition, the HFI approach has a management strategy that aims for timely and appropriate integration of HF activities throughout the project.”

The aim of the HFI for UK HPR1000 is to support the GDA aim of reducing risks to ALARP. For HFI, it means integrating HF into the system design to minimise human error risk, identifying and substantiating human actions that are important to nuclear safety and ensuring that the AoF is appropriate and the task is feasible and can be undertaken reliably.

In order to manage the HFI in a well-managed and traceable fashion, an HFI Plan (HFIP) has been developed and used, Reference [1].

In the HFIP, the actual HF activities based on FCG3 and planned throughout the various stages of GDA are described, including RGP identification, gap identification, OER, AoF review, identification and substantiation of HBSCs, HFE guidelines development, HMIs and SSCs design review, HF V&V, etc. For each activity, further gap analysis is ongoing and the results will enable update to the HFIP and guide HF activities.

The HFIP is a separate live document which will be updated regularly as required during the GDA phase.

15.5.2 HFIP Understood and Adhered to by Other Disciplines

The HFIP is one of the top-level documents for UK HPR1000, which is included in the overall documents list. The project general management procedure shows the HFIP is used as a design input for all disciplines. To ensure the HFIP is understood and adhered to by other disciplines, the CGN HF team maintains communication with these disciplines, and the following aspects have been enforced:

a) Hold Points

Hold points will be set to enable HF checks. HF assessment will be carried out at these points.

b) Design Review

Design reviews are held as a governance mechanism to verify that the design is correct, complete (for that design stage), satisfies requirements and adheres to standards. Design reviews also provide a mechanism for confirming resolution of outstanding issues and trade-offs, reviewing resources and scheduling. Ultimately they formally enable the project to proceed to the next stage.

c) Process Monitoring and Reporting

The HF team will hold periodic meetings with the relevant disciplines, reporting current progress and existing issues, discussing solutions and implementation of the forward plan. If HF activities bring rise to issues relevant to specific disciplines, a specific meeting or discussion can be held to coordinate resolution.

The Issue Tracking System (ITS) is used for recording, tracking and management of all HF issues raised from HF activities, assumptions and elements of concept of operation. The tracking system is also used as a tool for clear and traceable handover from GDA phase to the site licensing phase. The contents of handover include issues to be resolved during the site licensing phase, assumptions and other information related to operation management and organisation.

Detailed information related to the process of HF issues tracking is described in *Human Factors Issue Management Method*, Reference [22].

15.5.3 HF Activities Carried Out by SQEP.

A dedicated HF team has been set up for the UK HPR1000 project. The team is fully integrated into the project and liaises with other disciplines. The organisation of HF team is described in *HF Organisation and Operation Principles*, Reference [2].

The HF team is responsible for the HF work and engages with the engineering areas to gain design information and provide support in terms of any HF analysis required in relation to plant safety case. HF issues and concerns will be fed “upwards” to the PSA, fault studies, I&C and other areas where necessary, to ensure the accurate reflection within on-going project discussions and planning.

HF team members cover multiple disciplines to ensure comprehensive integration of HF into all design areas including, but not limited to, mechanical design, PSA, electrical system design, I&C system design, architecture design, fault studies, internal and external hazards, plant operation, etc.

Meanwhile, CGN acquired support from external HF specialists.

To improve HF ability, the HF team will provide HF awareness training to the designers and engineers of disciplines interfacing with HF, and will explain the purpose and content of the HFIP and HFE guidelines. The objective of the training is to help the designers and engineers to understand the HFIP, key HF principles and the roles of operators in supporting the ALARP argument.

Further specific training will be provided to the HF team, designers and engineers of disciplines as specified in *HFE training plan*, Reference [3].

15.6 Concept of Operation

This subchapter supports HF sub-claim 2.

The concept of operations needs to be defined to a level of detail to underpin all relevant HF analysis and evaluation in GDA phase. It includes operational purpose of the plant, basic AoF concept, staffing and qualifications, command and control philosophy, concept of use of HMIs, and basic details of the working environment.

15.6.1 Concept of Operations for UK HPR1000

The concept of operations for the UK HPR1000 has been developed based on FCG3. The fundamental operational purpose of the UK HPR1000 is the safe and effective generation of electricity and protection of the public from potential radiological hazards.

a) Basic Allocation of Function Concept

The UK HPR1000 adopts a moderate level of automation and is designed in such a way to meet the following autonomy objectives:

1) Automatic power control (regulation) capability in the range of 15%-100% nominal power during the start-up process of the reactor;

2) No operator action required from the MCR in the first 30 minutes from accident initiation, and no action required outside the MCR within 1 hour from accident initiation;

3) The plant could be taken to the controlled state by the automatic protection functions for the most DBCs (and, therefore, relies less on the manual intervention of operators).

The UK HPR1000 optimises dependence on human actions to maintain or recover a stable, safe state, and, therefore, relies less on the manual intervention of operators during operation of the plant. The split of responsibility between human and engineered systems is clear. The functions allocated to humans match human capabilities. Situational awareness of operators during automatic operations is maintained by the requirement for specific supervisory operator actions and for operator confirmation of successful implementation of automated sequences.

b) Staffing and Qualifications

UK HPR1000 staffing and qualifications are based on OPEX from the 14 operating NPPs of CGN. The table below and following paragraphs describe the roles and responsibilities for each position of the operating staff.

T-15.6-1 Minimum Operating Staff Configuration

Position	Quantity
Shift supervisor	1
Safety technical advisor	1
Unit supervisor	1
Vice shift supervisor	2
Reactor operator in MCR (nuclear island)	1
Reactor operator in MCR (conventional island)	1

Position	Quantity
Auxiliary operator	8

1) Shift supervisor, holding a valid certification (Senior Reactor Operator (SRO)), is responsible for overall plant operation. Normally shift supervisor is in an office adjacent to the Main Control Area (MCA) within the MCR. However, the shift supervisor could be anywhere within the power plant during the plant operation;

2) Safety technical advisor, holding a valid certification (SRO), is responsible for providing independent supervision and evaluation of plant safety conditions. This individual is normally in the MCR, but could be anywhere within the power plant during the plant operation;

3) Unit supervisor, holding a valid certification (SRO), is responsible for the direct supervision of the reactor operators in the MCR. During the plant operation, this role can be anywhere within MCR.

4) Vice shift supervisor, holding a valid certification (SRO), as the unit supervisor and shift supervisor, is part of each shift. This individual is responsible for work permission and prevention activities. This individual assists the shift supervisor to lead, coordinate, command and control the whole shift. In addition, this individual assists the shift to complete the operational actions, to ensure the unit is safe, stable and economical.

5) Reactor operators, holding the certificate of RO issued by the regulation department, are responsible for plant operations in the MCA and are normally located within the MCA. One reactor operator is responsible for nuclear island and the other one is responsible for conventional island.

6) Auxiliary operators responsible for operating local equipment in the plant are normally located at various locations throughout the plant and take direction from reactor operators in the MCR. Auxiliary operators must have more than one year of local working experience in the nuclear power plant.

c) Command and Control Philosophy

During DBCs the operators are responsible for control of the unit and refer to procedures and other documents as required to keep or return the plant to within its defined safe operating envelope. The unit supervisor provides support and oversight to the operators.

In the event of a severe accident, operators are still responsible for implementing specific procedures and responding to emerging plant conditions as required. However, the Technical Support Centre (TSC) staffs has a greater role in developing the response strategy, advising on operational decisions, and keeping a broader overview based on the status of the entire station in the context of the conditions emerging throughout the event.

The shift supervisor will be the acting emergency controller if a site incident is declared, until the on-site emergency control centre is established.

d) Concept of Use of HMIs

With the MCR available, the plant is controlled by the Plant Computer Information and Control System (KIC [PCICS]). In the unlikely event that the KIC were to become unavailable, then control authority would be transferred to the Auxiliary Control Panel (ACP).

In the event of common cause failure of the protection system and safety automation system with a concurrent DBC-2/3/4, operators control and monitor the plant with the operational equipment and monitoring equipment on Diverse Human interface Panel (DHP).

In the event of a severe accident coincident with a total loss of alternating current power supply, the severe accident Human interface Panel (SHP) is used to perform the necessary mitigation functions.

The KIC, DHP and SHP are all located in the MCR. If the MCR were to become unavailable, control authority would be transferred to RSS to control and monitor the plant.

The HMIs in local areas are used by auxiliary operators cooperating with the MCR operators for plant operation.

e) Procedures Structure

There are three kinds of operating procedures, which are Normal Operating Procedures (NOPs), Emergency Operating Procedures (EOPs) and Severe Accident Management Guidelines (SAMGs). The UK HPR1000 uses computerised procedures, supported by paper-based procedures.

NOPs define a consistent set of actions utilised to operate the plant or individual systems within the operational limits and conditions, which includes:

1) Unit operating procedure: utilised for changing the state of the plant including start-up, shutdown, refuelling, etc., and to provide integrated operation of the plant;

2) System operating procedure: utilised for energising, starting up, shutting down, changing modes of operation, and other instructions appropriate for the operation of individual plant systems;

3) System alarm sheet: utilised to determine the action to be taken after an alarm

initiating;

4) Abnormal operating procedure: utilised to identify the cause of the deviation from normal range and to recover from it before the abnormality can escalate to the point where the protection system is called into effect.

EOPs define the actions necessary to prevent or mitigate the consequences of accident conditions. These procedures cover verification of automatic actions, operator actions to prevent or mitigate consequences, and operator actions necessary to stabilise the plant. EOPs are designed to be flexible to handle a variety of events in a conservative manner. As such, EOPs contain specified entry and exit conditions.

SAMGs provide guidance to MCR operators and emergency response personnel on how to respond to a plant emergency when specific plant parameters have reached a point where core damage may have occurred, which consists of control room SAMG, TSC SAMG, and TSC severe challenge response guidelines.

f) Basic details of the working environment

The working environment is based on HMI characteristics and work requirements. The considerations of physical work environments, including temperature, humidity, acoustics, illumination, personnel safety and environmental hazards, are addressed to ensure that the design accommodates personnel and supports task performance under all necessary and anticipated conditions.

The concept described above is the same as that for FCG3. Concept of operation for the UK HPR1000 will be reported in greater detail. Furthermore, it is anticipated that this concept could be partly adjusted during steps 3&4 of GDA to ensure consistency with substantiation of the HBSCs.

The operating assumptions (such as procedure structures, command and control philosophy, staffing and qualification) are captured and entered into the ITS. This will be used to ensure that the basis for the HF analyses and support provided during GDA phase can be understood and further validated as necessary in future stages of the plant lifecycle.

15.6.2 Allocation of Function Review

For the UK HPR1000, review and justification of existing AoF will be performed to ensure the validity of the current assignment, or to identify any mis-allocation. The details of AoF such as its methodology and criteria are described in *Function Allocation Methodology*, Reference [5]. And the function allocation review result will be specified in *Allocation of Function Review Report*. If any function allocation is changed based on the review or due to the design changes, then *Allocation of Function Improvement Report* will be produced.

15.6.3 Procedures Review

UK HPR1000 procedures are based on those used for FCG3. The final procedures will be developed during the site licensing phase. However, the concept of the use of computerised procedures, supported by paper-based procedures, for reliable operation will be justified during the GDA phase.

Operating experience on procedures is gathered from FCG3 and existing NPPs featuring similar and relevant designs to identify any issues with their format, navigation, content and presentation. This will be reported in the Operating Feedback Report of Procedure from Existing Plants with Similar Design.

In addition, as part of the HBSCs assessment, sample procedures (FCG3 procedures) will be used and any issues or concerns with procedures will be identified. This will include tests and review of reverting to paper-based procedures. Paper-based procedures for local operation and maintenance HBSCs assessed as part of GDA will be reviewed and any issues will be identified.

15.6.4 Staffing and Qualifications Review

Staffing and qualification requirements for the UK HPR1000 are based on FCG3 and the feedback from existing plants with similar design. The final staffing and qualification requirements will be developed and validated during the site licensing phase. However, the preliminary staffing and qualification requirements for the UK HPR1000 will be justified during the GDA phase.

Relevant staffing and qualification feedback collected from existing similar plants will be reported in *Feedback of Operating Staffing for Existing Similar Plants*.

In addition, as part of the HBSCs assessment, preliminary requirements for operating staffing and qualifications will be assessed through a task analysis and any issues will be identified. The task analysis will provide the basis for establishing staffing and qualifications requirements for both normal operation and accident conditions. Staffing requirements are typically lower for normal operation when compared to accident conditions. Therefore, the task analysis mainly focuses on accident conditions.

15.7 Substantiation of Human-Based Safety Claims

This subchapter supports HF sub-claim 3.

The systematic identification and assessment of all human actions important to achieve safety in all permitted operating modes and all accident conditions is known as the substantiation of HBSCs. The aim of substantiation of HBSCs is to demonstrate that important human actions are feasible and sufficiently reliable.

The identified HBSCs are traceable back to the fundamental safety functions including control of reactivity, removal of heat, confinement and additional safety functions. HBSCs are classified based on either the significance of the safety function affected or their risk significance, and are assessed proportionately at different levels based on their classification. The overall process is a closed loop with iterations. The HF issues raised are managed by the HF ITS.

15.7.1 Identification of HBSCs

In FCG3, the important human actions consist of those actions that meet either risk or deterministic criteria. The risk-important human actions are identified in the level 1 and level 2 PSA. Deterministic identification is an important supplement for probabilistic identification using accident analysis and severe accident analysis. Currently, the important human actions have been identified and grouped into 34 significant important human actions.

For the UK HPR1000, the HF team works closely with the PSA, DBC and SAA topic areas to identify HBSCs, including the safety actions of personnel responsible for monitoring and controlling the plant and of personnel carrying out maintenance, testing and calibration activities. The process to identify HBSCs for UK HPR1000 is as follows:

a) Review FCG3 important human actions list;

b) Identify HBSCs from the Examination, Maintenance, Inspection and Testing (EMIT) strategy of the UK HPR1000, particularly the list of class 1，2 or 3 components, to get type A human actions identified effectively;

c) Identify HBSCs from the Postulated Initiating Event (PIE) of UK HPR1000, to get type B human actions identified effectively;

d) Identify HBSCs through the developing of Fault Studies and SAA for the UK HPR1000, to get type C human actions identified effectively;

e) Identify HBSCs through the development of the PSA for the UK HPR1000, as a supplement for type A, B and C human action lists;

f) Identify administrative controls from the Operating Technical Specification (OTS), operating procedures and maintenance strategy. Typical technical administrative controls based on FCG3 are identified during the GDA phase;

g) Categorise and classify all the HBSCs into their respective levels based on the equipment safety class or associated consequence.

More detailed information is described in the *Treatment of Important Human Actions Implementation Plan*, Reference [6], and will be updated as necessary.

The identification of HBSCs is on-going and the list of HBSCs will be reported.

15.7.2 Assessment of HBSCs

For FCG3, the HF assessment activities for important human actions include task analysis and HRQ according to NUREG-0711.

Task analysis evaluates the demands of these tasks placing upon personnel in terms of perception, decision making and action. Physical and psychological factors that could impact on human performance are also taken into account. The detailed topics addressed in task analysis include information, decision-making, response, teamwork and communication, work load, task support, workplace factors, situation and Performance Shaping Factors (PSFs) and potential hazards. The result of the task analysis forms the basis for evaluating the design of HMIs, staffing and qualifications, procedures, training programmes, task support verification and HRQ analysis.

The preliminary calculation of HRQ has been completed and incorporated into the PSA model.

For the UK HPR1000, the identified HBSCs are assessed through qualitative and quantitative analysis and contribute to:

a) Identification of key design aspects (HMIs or procedures), which need rigorous assessment and/or improvement to ensure their expected support to task performance;

b) Identification of the recommendations related to operational arrangements (such as the minimum requirements for operation, training, qualifications) to ensure that the risk of human error in these tasks important to safety is reduced to ALARP.

According to the HBSCs classification, two levels of assessment are carried out. More significant HBSCs are assessed in detail, while less significant HBSCs are assessed to a high level.

The process of detailed assessment is as follows:

a) Define the context and requirements of HBSCs in consultation with the system designers and safety assessment teams;

b) Consider OPEX related to HBSCs;

c) Identify task-related information such as system descriptions and procedures to develop initial task analysis;

d) Task data collection. More task data such as perceived workload, task timing, observed errors and qualitative feedback from operators, are collected through simulator, plant representations (e.g. a 3D model) or paper-based system descriptions and drawings;

e) Task analysis. Hierarchical Task Analysis (HTA), Tabular Task Analysis (TTA) and Time Line Analysis (TLA) are used for task analysis. Through task analysis, how the constituent tasks interact and how the tasks performed are described. The topics include personnel requirements, task description, interface description, information needed/presented, location, timing, workload, stress, situational awareness, technological factors, environmental factors, organisational factors, job factors, errors of commission and omission and violation are analysed. The results of the task analysis are used as an input to the design of HMIs and workspaces, staffing and qualifications, procedures, training programmes, HBSCs verification and HRQ analysis, and forms the basis for their evaluation.

Detailed information is described in *Task Analysis Methodology*, Reference [7].

f) Task Assessment. A qualitative task assessment sheet is developed to provide a mechanism to consistently record the key aspects of the task as they are related to HRQ. Any assumptions are made explicitly and listed in ITS for tracking;

g) Quantification. Based on a sound understanding of the task, potential errors and PSFs provided by task analysis and the task assessment sheet, HRQ is carried out using the methodology described in *Methodology of Human Reliability Analysis*, Reference [8]. The results of HRQ are fed back to the appropriate iteration of PSA. This may require re-assessment of the existing assessment. The substantiation of HBSCs may be updated;

h) Reporting. Finally the assessment, findings, recommendations and conclusions will be reported.

The process of high-level assessment is as follows:

a) A structured review of the task and PSFs to get a concise description of the task, task requirements, PSFs and errors is made;

b) A task sheet is designed to ensure that the principle elements affecting task reliability are captured;

c) A judgment of task feasibility is made to support the HRQ;

d) Finally the assessment, findings, recommendations and conclusions are reported.

More detailed information is described in *Treatment of Important Human Actions Implementation Plan*, Reference [6].

15.7.3 Identification and Assessment of Human Actions Related to Other Areas

Besides HBSCs derived from the PSA, DBC and SAA topic areas, a risk identification and assessment will also be carried out on identified claims placed on personnel related to:

a) Conventional safety;

b) Security;

c) Environmental protection;

d) Radiological protection;

e) Decommissioning.

Further work is required to identify and assess the human actions in the above areas. It is anticipated that for the significant human actions in these areas, the same or similar assessment process would be used for the substantiation of these actions as is used for HBSCs.

15.8 Design Support Activities of HF

This subchapter supports HF sub-claim 4.

15.8.1 Development and Implementation of HFE Guidelines

Two HFE guideline documents have been developed for FCG3 to guide HF, CRS and HMI design integration. For SSC design in local areas (away from the CRS), HFE principles and requirements are taken into account through use of relevant codes and standards, working procedures and engineering practices.

For the UK HPR1000, HFE guideline documents have been developed based on CGN existing project experience and international codes and standards. This is to help ensure SSC design is consistent with the human cognitive and psychological characteristics, which covers aspects such as visibility or readability of information, operability and maintainability of components, comfort and safety of personnel, etc. The end user anthropometric data will be used for updating HFE guidelines during the site licensing phase.

There are three guideline documents, two for workspaces and HMIs in CRS and the third one for SSCs in local areas.

HFE Guidelines for Control Rooms Design, Reference [9], is applicable to the design of the MCR and the related rooms (shift handover room and computer room), RSS and TSC. This document includes the following topics:

a) Work space structure and layout;

b) Work space environment;

c) Operating workstation;

d) Vertical panel, desks and chairs;

e) Display devices;

f) Control devices;

g) Layout of the control and display devices;

h) Labelling.

HFE Guidelines for CRS HMI Design, Reference [10], is applicable to the design of HMI resources in the MCR, RSS, and TSC. This document includes the following topics:

a) Display elements;

b) Information coding;

c) Soft control;

d) Large display panels;

e) Touch screens;

f) Alarms;

g) Procedures.

HFE Guidelines for Local Areas SSCs Design, provides human factors good practice that will assist designers when considering the selection, location and layout of controls and displays outside the MCR. It is intended that this guidance is applied to both the operation of such equipment and its maintenance. This document will mainly include the following topics:

a) Local instruments and equipment design;

b) Local panels design;

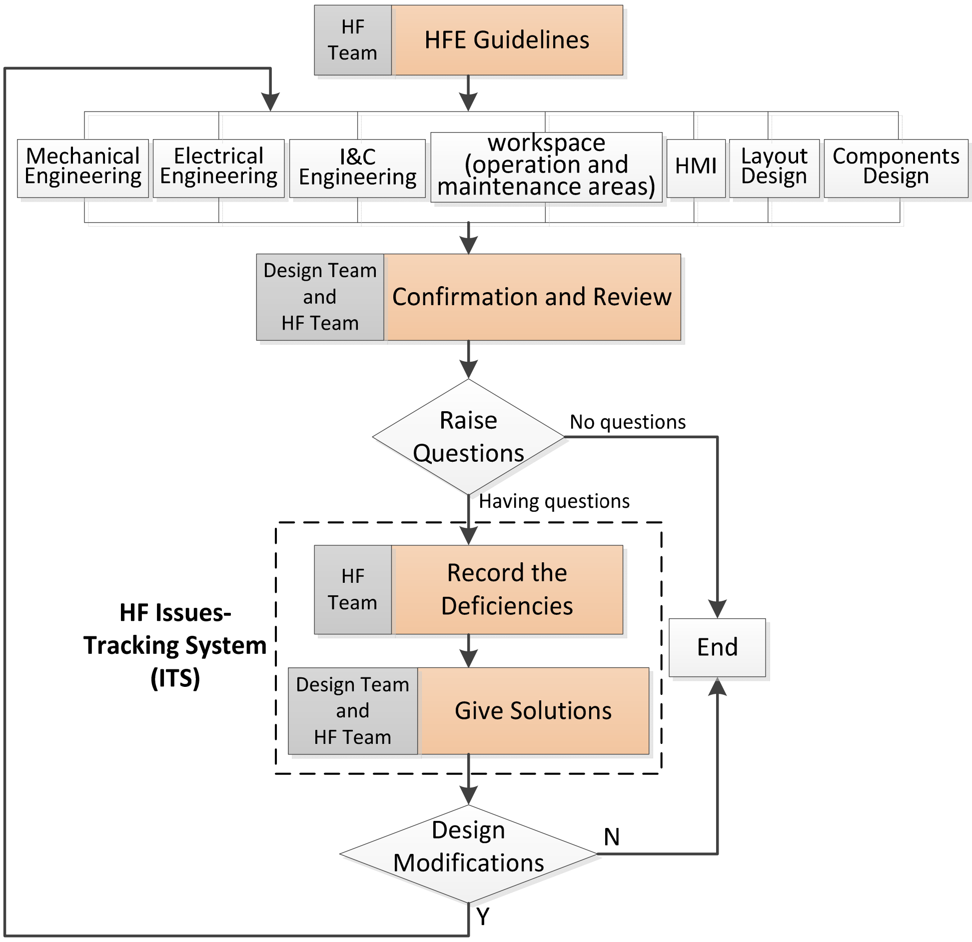
c) Local control rooms design;

d) Distribution cabinet/control cabinet;

e) Material handling;

f) Local working environment design.

The HFE guideline documents are developed by the HF team; they are used as the top level documents, and provide a key reference and evaluation principles for both the design and HFE teams. The process of integrating HFE guidelines into design is described in F-15.8-1. As shown in the upper section of the figure, the HF team delivers HFE guidelines to the necessary design disciplines. Each design discipline produces its design documents in consideration of HFE guidelines, and then coordinates with the HF team to evaluate and review the documents produced, and identify any discrepancies in accordance with HFE requirements described in the HFE guideline documents. Solutions to any discrepancies identified will be developed and the HF team records key deviation items into the ITS. HF reports covering HMIs and workspace design will be produced.



F-15.8-1 Process of Integrating HFE Guidelines into Design

15.8.2 HF Evaluation

HF V&V activities for FCG3 focus mainly on the HMIs and workspaces within the CRS. HF verification activities are currently in progress and the HF integrated system validation will be performed on the FCG3 training simulator.

For the UK HPR1000, in addition to the HF review, an HF evaluation on HMIs and workspaces is also carried out through task analysis and HF V&V.

The task analysis for HBSCs is to demonstrate the suitability of the key HMIs and workspace designs. These kinds of activities are described in section 15.7 and a sample analysis will be carried out during GDA step 3 using the FCG3 engineering simulator run by experienced operators.

HF V&V activities are to demonstrate that the UK HPR1000 design attains a high standard of HF adequacy and that it conforms to the HF principles as specified in the HFIP and requirements of the HFE guidelines. HF verification mainly focuses on the HMIs and workspaces related to significant HBSCs during the GDA phase.

HF verification is conducted as part of the overall verification programme providing evidence and substantiation of the HBSCs. As part of the GDA HF activities, it has been determined that safety-important human actions need to be examined to a more detailed level than that provided in desktop studies.

To support HF verification activities, data is collected using the FCG3 engineering simulator run by experienced operators. A wide variety of techniques of data collection will be used including: overview video cameras, head and gaze tracking system, sound recordings, status parameter recording, HF specialist observation, and briefing and debriefing interviews. For local tasks, 3D model plant walkthroughs, site interviews or physical site walkthroughs are used to carry out the HF verification testing.

Complete HF verification and HF validation, performed on a fully-integrated system representation with users, procedures and finalised design, will be conducted during the site licensing phase.

The detailed methodology for the HF V&V is described within *HFE Verification and Validation Methodology*, Reference [23].

The results of the HF verification will be documented in the respective report. The HF issues identified through HF V&V and the HF recommendations given to improve associated designs are recorded in the ITS along with their respective resolutions.

15.9 ALARP Assessment

This subchapter gives a high-level overview description of ALARP principles applied in this chapter. Chapter 33 presents a generic approach used for demonstrating ALARP of the design and operation. The ALARP process includes consideration of four areas that are common to the demonstration of ALARP in the UK, Reference [24]:

a) Comparison with RGP and OPEX;

b) Identification and evaluation of options;

c) Risk assessment, as a way of understanding the significance of the issue to the overall demonstration of ALARP;

d) Implementation of all reasonably practicable improvements.

15.9.1 Comparison with RGP and OPEX

Comparison with RGP is the starting point of the ALARP analysis. In addition, other sources, such as relevant OPEX and guidance are also analysed to identify potential improvements. In the UK HPR1000 HF design, the content of RGP and OPEX include, but are not limited to, the following aspects:

a) Recognised design codes and standards and guidance documents;

b) Regulator expectations;

c) OPEX;

d) Experiences from other GDA projects;

e) CGN NPPs fleet good practice.

The Safety Assessment Principles (UK) (SAP) and Technical Assessment Guides (UK) (TAGs) regarding HF have also been analysed in details.

HF standards are used as RGP for UK HPR1000 HF activities (subchapter 15.3). HF-relevant OPEX is presented in subchapter 15.4. Experience from other GDA projects is also properly considered, for example, HF organisational and SQEP issues raised during regulatory observations. Regulator expectations are properly considered, For example, all SSCs key to risk reduction are to be designed with consideration of HF RGP and utilise specialist HF input where appropriate. The practice gained from the CGN NPPs design and operation experience in HFE area includes the implementation of HFE activities, the application of proven technology for digital system, operation organisation and management, etc.

15.9.2 Identification and Evaluation of Options

Optioneering is the process of generation and evaluation of options which can potentially deliver a required specific potential improvement. A formal option assessment process is used for the evolution of numerous UK HPR1000 design aspects (refer to chapter 33). HF will be considered during all options assessment (in terms of benefits and dis-benefits). HF team members participate in the design improvement process in the options assessment process to ensure the HF requirements are properly considered, for example, in different HMIs and SSCs design options.

15.9.3 Risk Assessment

Risk assessment is considered as a way of understanding the significance of the issue to the overall demonstration of ALARP. The review of UK HPR1000 design includes the consistency review against RGP and OPEX and the insights of PSA and the results from PSA risk assessments are used to identify potential areas for enhancement, with each area identified subject to optioneering as discussed above. The output from PSA is the input for HF area to identify important human actions (see subchapter 15.7) and to screen them for further qualitative analysis (task analysis). The task analysis result will then be used in HRQ to substantiate or derive estimations of Human Error Probability (HEP) for HBSCs modelled in PSA. In addition, risk assessment according to HBSC will be implemented to identify the potential enhancement and lower the risk. The risk assessment will be described in “ALARP Demonstration Report of PCSR Chapter 15”.

15.9.4 ALARP Demonstration

Once the reviews discussed above have been completed, and all of the identified areas for potential enhancement have been subject to optioneering, and all of the reasonably practicable improvements have been incorporated, it will be possible to demonstrate that the HF area supports the demonstration that the nuclear safety risk is ALARP.

15.10 Concluding Remarks

For FCG3, the HF principles and analysis have been integrated within CRS and considered in system design on a case-by-case basis. The baseline for HF within FCG3 is presented in subchapters 15.4～15.8, which forms the starting point for the UK HPR1000 HF topic area. This baseline HF position has been assessed in the UK context and against modern practice requirements. Gaps have been identified and are to be resolved through the GDA HFI programme, as outlined in the HFIP, Reference [1].

CGN is currently implementing HFI activities to support the development of a design and safety case for UK HPR1000, which is described in the HFIP document.

Step 2 activities have been carried out that support both the design and safety case appropriate to their current state of maturity:

a) RGP relevant to HF has been identified;

b) OPEX on existing plants has been gathered and will be continued;

c) The methodologies used for AoF review and HBSCs identification have been developed and planned to be updated in early step 3;

d) HF guideline documents have been developed to support other disciplines;

e) The identification of HBSCs has not been finished at this stage and further work to identify and substantiate the HBSCs will be undertaken during future steps.

The HF activities will be continued throughout the GDA phase. At this stage, given the identification of HF claims, the arguments, evidence presented and the forward programme of HF integration, particularly to further identify and substantiate the HBSCs, the conclusion of this chapter is that there has been and will continue to be adequate and timely HF contribution to the UK HPR1000 design to help ensure that the nuclear safety risks associated with HBSCs are ALARP.

15.11 References

[1] CGN, Human Factors Integration Plan, GHX06001016DIKX03GN, Rev. B, 2018.

[2] CGN, HF Organisation and Operation Principles, NE15BW-X-KX-0000-000059, Rev. A, 2018.

[3] CGN, HFE Training Plan, NE15BW-X-KX-0000-000061, Rev. A, 2018.

[4] CGN, Operating Experience Review Implementation Plan, GHX06001003DIKX03GN, Rev. C, 2018.

[5] CGN, Function Allocation Methodology, GHX06001019DIKX03GN, Rev. B, 2018.

[6] CGN, Treatment of Important Human Actions Implementation Plan, GHX06001015DIKX03GN, Rev. D, 2018.

[7] CGN, Task Analysis Methodology, GHX06001042DIKX03GN, Rev. B, 2018.

[8] CGN, Methodology of Human Reliability Analysis, GHX00650030DOZJ02GN, Rev. A, 2018.

[9] CGN, HFE Guidelines for Control Room Design, GHX06001021DIKX03GN, Rev. D, 2018.

[10] CGN, HFE Guidelines for HMI Design, GHX06001039DIKX03GN, Rev. C, 2018.

[11] CGN, General Principles for Application of Laws, Regulations, Codes and Standards, GHX00100018DOZJ03GN, Rev. F, 2018.

[12] IAEA, Safety of Nuclear Power Plants Design, SSR-2/1, Rev. 1, 2016.

[13] NNSA, General Technical Requirements for Post-Fukushima-Accident Improvement Actions of Nuclear Power Plants, NNSA No.98, June 2012.

[14] ONR, Safety Assessment Principles for Nuclear Facilities, Rev. 0, 2014.

[15] ONR, the Purpose, Scope and Content of Safety Cases, NS-TAST-GD-051 Rev. 3, July 2013.

[16] ONR, Technical Assessment Guide: Human Factors Integration, NS-TSAT-GD -058, Rev.3, March 2017.

[17] ONR, Technical Assessment Guide: Human Machine Interface, NS-TSAT-GD -059, Rev.3, November 2016.

[18] ONR, Technical Assessment Guide: Workplaces and Work Environment, NS-TSAT-GD-062, Rev.3, February 2017.

[19] ONR, Technical Assessment Guide: Human Reliability Analysis, NS-TSAT-GD -063, Rev.3, April 2015.

[20] ONR, Technical Assessment Guide: Allocation of Function between Human and Engineered Systems, NS-TSAT-GD -064, Rev.2, December 2014.

[21] US NRC, Human Factors Engineering Program Review Model, NUREG-0711,

Rev. 3, November 2012.

[22] CGN, Human Factors Issue Management Method, GHX00100002DIKX03GN, Rev. A, 2018.

[23] CGN, HFE Verification and Validation Methodology, GH06001022DIKX03GN, Rev. B, 2018.

[24] ONR, Guidance on the Demonstration of ALARP (As Low As Reasonably Practicable), NS-TAST-GD-005, Revision 8, July 2017.