US-APWR

HSI Design Implementation Plan

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Prepared:	Eisuke Noda Eisuke Noda, Deputy Manager Human Factor and Training Facility Engineering Section Nuclear Electrical, Instrumentation & Control Engineering Department	12/19/2011 Date
Prepared:	Satoshi Hanada Satoshi Hanada, Deputy Manager Human Factor and Training Facility Engineering Section Nuclear Electrical, Instrumentation & Control Engineering Department	12/19/2011 Date
Prepared:	Koji Ito Koji Ito, Engineering Manager Human Factor and Training Facility Engineering Section Nuclear Electrical, Instrumentation & Control Engineering Department	12/19/2011 Date
Reviewed:	H. Tokunaga Hideaki Tokunaga, Deputy Manager Human Factor and Training Facility Engineering Section Nuclear Electrical, Instrumentation & Control Engineering Department	12/20/2011 Date
Approved:	Masanori Yokoyama Masanori Yokoyama, Manager Human Factor and Training Facility Engineering Section Nuclear Electrical, Instrumentation & Control Engineering Department	12/20/2011 Date
Approved:	Yuzuru Yasui Yuzuru Yasui, Director Nuclear Electrical, Instrumentation & Control Engineering Department	12/27/2011. Date

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Prepared	Satoshi Hanada	Eisuke Noda		
		Satoshi Hanada		
	Koji Ito	Koji Ito		
Reviewed	Hideaki Tokunaga	Hideaki Tokunaga		
Approved	Masanori Yokoyama	Masanori Yokoyama		
	Yoshinori Inazumi	Yuzuru Yasui		

Revision History

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0	April 2010	All	Original issued
1	November 2011	General	Revised capitalization of section and figure titles. Revised "US Basic" to "US-Basic"
		p.vi (Abstract)	Revised "describe" to "describes". Revised "HEDs" to "Human Engineering Discrepancies (HEDs)".
		p.1 (Section 1.0)	Revised description.
		p.2 (Section 2.0)	Added description to the end of third sentence in subsection 1. Added description to the end of sixth sentence in subsection 2. Added "or" in subsection 3. Added description to the last sentence in subsection 3.
		p.4 (Section 4.1)	Deleted "the". Revised "the" to "to". Revised "Stuffing" to "Staffing". Added "(TA for risk significant human actions, only)".
		pp.4-5 (Section 4.1, 1))	Added "HSI Design defines the HSI environment to meet the assumption …" for RAI Response No. 664 (Question No. 18-88).
		pp.5-6 (Section 4.1, 2))	Revised "function," to "functions and".

Revision	Date	Page (Section)	Description
			Revised description of first bullet in subsection 2) 2) a. HSI.
			Added "HSI".
			Revised description about regulatory requirements.
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		pp.8-9 (Section 4.2)	Revised "Shift supervisor" to "Shift manager" for RAI Response No. 792 (Question No. 18-140).
			Revised description about overriding automatic systems.
			Revised description about tagging.
		p.11 (Section 4.4, 1))	Revised description of second paragraph.
		pp.11-12 (Section 4.4, 2))	Added a sentence to last paragraph for RAI Response No. 797 (Question No. 18-180).
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		p.12 (Section 4.4, 3))	Revised "will be" to "are" for RAI Response No. 797 (Question No. 18-180).
			Added "2 and 3" for RAI Response No. 797 (Question No. 18-180).
		p.12 (Section 4.4, 4))	Revised "will be" to "are" for RAI Response No. 797 (Question No. 18-180).
			Added "2 and 3" for RAI Response No. 797 (Question No. 18-180).
		pp.12-13 (Section 4.4, 5))	Revised "concept" to "design" for RAI Response No. 797 (Question No. 18-180).
			Added "as documented in Topical Report MUAP-07007,".

Revision	Date	Page (Section)	Description
			Revised “will be updated to reflect” to “reflects” for RAI Response No. 797 (Question No. 18-180).
			Revised “Phase 1 design related HEDs” to “the significant HEDs from Phase 1” for RAI Response No. 797 (Question No. 18-180).
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		p.14 (Section 4.5)	Revised “… size etc).” to “… size, etc.).”.
		p.15 (Section 4.5, 2))	Revised “we conduct an … using…” to “an … is conducted using …”.
		p.15 (Section 4.5, 3))	Revised “stuffing” to “staffing”.
		pp.15-18 (Section 4.5, 8))	Added a sentence to the end of first paragraph.
			Revised “in” to “for the”.
			Added “operators”.
			Added “the”.
			Revised “is” to “are”.
		p.19 (Section 4.5, 9))	Revised “was” to “is”.
			Revised “were” to “are”.
			Revised “conducted” to “conduct”.
			Revised “allowed” to “allows”.
		p.22 (Section 4.6)	Revised “design plan” to “designs”.
			Revised “described” to “describe”.
			Added “(Phase 3)”.
		pp.22-23 (Section 4.7)	Added “and Monitoring Circuit Basic”.
			Revised “(e.g. “ to “(e.g., “.

Revision	Date	Page (Section)	Description
		p.23 (Section 4.8)	Added new section 4.8 about results summary report.
		p.24 (Section 5.0)	Added reference 5-20. Revised description of references.

Mitsubishi Heavy Industries, Ltd.
16-5, Konan 2-chome, Minato-ku
Tokyo 108-8215 Japan

Abstract

This document describes the Human System Interface (HSI) design implementation plan of the US-APWR Human Factors Engineering (HFE) process for the US-APWR. The methodology for the function design used for the HSIS design such as alarms, displays, controls, and other aspects of the HSI are described in this document. This document describes two activities (1) Design activities to create the US-APWR HSI inventory (2) Design activities to resolve Human Engineering Discrepancies (HEDs) from Phase 1 that impact the US-Basic HSI System design. Item 1 includes resolution of the HEDs from Phase 1 that impact the USAPWR HSI inventory. The topical report "HSI System Description and HFE Process" MUAP-07007 addresses the functional design of the HSI System and the HFE process used to create this system. In addition to the topical report and Design Certification Document (DCD) Chapter 18, this document supplements the methodology and the process of how HSI designs are created.

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List of Acronyms

APWR	Advanced Pressurized Water Reactor
BISI	bypassed and inoperable status indication
CBP	computer-based procedure
CSF	critical safety function
D3	defense-in-depth and diversity
DAS	diverse actuation system
DC	Design Certification
DCD	Design Control Document
DHP	diverse HSI panel
DMC	data management console
EOF	Emergency operations facility
EOP	Emergency operating procedure
FA	function allocation
FRA	functional requirements analysis
HA	human action
HED	human engineering discrepancy
HFE	human factors engineering
HPM	human performance monitoring
HRA	human reliability analysis
HSI	human system interface
HSIS	human system interface system
I&C	instrumentation and control
LCS	local control station
LDP	large display panel
MCR	main control room
MELCO	Mitsubishi Electric Corporation
MHI	Mitsubishi Heavy Industries
NRC	Nuclear Regulatory Commission, U.S.
OER	operation experience review
OSD	operational sequence diagram
PCMS	plant control and monitoring system
PRA	probabilistic risk assessment
PSF	performance shaping factor
PSMS	protection and safety monitoring system
QA	quality assurance
R.G.	Regulatory Guide
SA	staffing analysis
SDCV	spatially dedicated continuously visible
SI	safety injection

SPDS	safety parameter display system
TA	task analysis
US, U.S.	United States
US-APWR	US Advanced Pressurized Water Reactor
V&V	verification and validation
VDU	visual display unit

1.0 Purpose

The purpose of this implementation plan is to describe the approach being applied to translate functional and task requirements to define the US-APWR HSI inventory and the detailed HSI design of alarms, displays, controls, layout and other aspects of the HSI that have been defined for the US-APWR. The HEDs from phase 1 V&V that pertain to the US-Basic HSI System are incorporated to complete the design of the US-APWR Basis HSI System. The HEDs from phase 1 V&V that pertain to the HSI inventory of the simulator reference plant are incorporated, as applicable to the US-APWR, to complete the US-APWR HSI Inventory. The subsequent US-APWR V&V program is applied to the completely integrated design of the US-APWR HSI System, as described in MUAP-10012.

2.0 Scope

The US-APWR HSI development is divided into three phases.
The functional requirement specification serves as the initial source of input to the HSI design effort. The US-APWR design is a direct evolution from a predecessor and the criteria is considered relative to operating experience of the predecessor and the design features (e.g., aspects of the process, equipment, or operations) of the new design that is different from the predecessor. Human performance issues identified from operating experience with the predecessor design is resolved. The initial source of input to the US-APWR HSI design is addressed in Reference 5-8, 5-9 and 5-10.

1. Phase 1 yields the US-Basic HSI System (HSIS). The conversion from the Japanese Standard HSI System to the US-Basic HSI System includes only changes in presentation, such as translation to English and American engineering units, anthropometric changes, and changes due to US nuclear power plant cultural differences. The conversion does not change the design unless the Phase 1 V&V indicates a design change is needed by the creation of Human Engineering Discrepancies (HEDs); HEDs are resolved and any needed design changes are implemented and verified in Phase 2. The Phase 1 V&V is conducted with full scale simulation using a typical 4-loop PWR plant model. (Reference 5-8, 5-9 and 5-10)
2. Phase 2 develops the US-APWR Inventory and combines it with the US-Basic HSI Design to yield the US-APWR HSI System. The basis for the US-APWR HSIS Inventory is defined according to NUREG-0711 process. The US-Basic HSI System is instantiated using the US-APWR HSIS Inventory, which is developed using the US-APWR plant design data. That is, the US-APWR HSI System becomes one specific application of the US-Basic HSI System. The US-APWR site-specific assumptions are made to develop a complete set of plant design data. This process does not change the US-Basic HSI System design unless Phase 2 V&V indicates a design change is needed by the creation of HEDs; HEDs are resolved and any needed those design changes are implemented and verified in Phase 3. The Phase 2 V&V is conducted with full scale simulation using a US-APWR plant model, including site-specific assumptions.
3. Phase 3 confirms the applicability of the site-specific assumptions from Phase 2 for a specific US-APWR plant application (e.g., Comanche Peak 3&4) or makes minor site specific changes to the US-APWR HSIS to yield a site-specific HSIS (e.g. Comanche Peak 3&4 HSIS). Phase 3 ensures all outstanding HEDs from previous phases are resolved.

Since Phase 1 has been completed at the middle of 2009, the scope of this document includes the US-APWR HSI Design Implementation Plan in Phase 2 and 3. In other words, the design input for the HSI Design Implementation Plan is the US-Basic HSI System design (Phase 1) which is addressed in Reference 5-8. Other design inputs include the outputs of the following US-APWR HFE Program Elements, as described in Section 4 below:

- OER
- FRA/FA
- HRA
- SA
- TA

3.0 Applicable Codes, Standards and Regulatory Guidance

The compliance to the applicable codes and standards for the US-APWR HSIS design is identified in section 3.0 of Reference 5-8. Reference 5-8 includes following standards and guidelines.

- Code of Federal Regulations
- Staff Requirements Memoranda
- NRC Regulatory Guides
- NRC Branch Technical Positions
- NUREGs
- Other Reference Guidelines

4.0 Implementation Plan

4.1 HSI Design Input

The basic HSI design which is described in Reference 5-8 is the initial design input for the US-APWR. The following sources of the US-APWR information, developed as described in Reference 5-4, Sections 18.2 through 18.6 provide input to the US-APWR HSI design process:

1) Analysis of Personnel Task Requirements

The analyses performed in earlier stages (including the design of the Japanese basic HSI, the OER, FA, TA and HRA) of the design process are used to identify requirements for the HSIs. Section 18.7.2.1 of the Reference 5-4 addresses the HSI design inputs. Section 18.7 of Reference 5-4 refers to Reference 5-8 which contains the process of Operating Experience Review (OER), Functional Allocation (FA)/Functional Requirement Analysis (FRA), Task Analysis (TA), and Staffing and Qualification. The process and the result summary report for OER, FA/FRA and TA (TA for risk significant human actions, only) are provided in Reference 5-9 Part 2 and Reference 5-10 Part 2.

These analyses include the following:

- OER (Reference 5-4 Section 18.2)

  Issues identified during the OER include human performance issues, problems, and sources of human error as well as design elements that support and enhance human performance. The OER identified potential human engineering deficiencies (HEDs) that impact either the US-Basic HSI System or the US-APWR. Those HEDs that impact the US-Basic HSI System design or the US-APWR HSI inventory, rather than procedures or training, are inputs to the HSI design process. The design related HEDs that were not closed in Phase 1 are inputs to the HSI Design Implementation Plan.

- FA/FRA (Reference 5-4 Section 18.3)

  The output of the FA/FRA for the US-APWR is used for functional elements of the HSI development such as key parameters and components that are used to control critical system and functions. The key input of FA is operator's role in the plant (e.g., appropriate levels of automation and manual control).

- TA (Reference 5-4 Section 18.4)

  The TA is the key input to developing the HSI inventory. It ensures the inventory directly supports the operating procedures and the risk significant human actions by identifying the specific inventory needed and the characteristics of that inventory, including HFE and other design aspects.

- Risk-important Human Actions (HAs) and their associated Performance Shaping Factors (PSFs), as identified through Human Reliability Analysis (HRA) (Reference 5-4 Section 18.6)

  All risk important HAs are reviewed in light of the US-APWR HSI design to ensure that the interface design (1) supports timely and accurate identification that a risk significant action is needed (2) limits the probability of errors occurring when taking the action and (3) increases the probability of timely error identification and recovery if an error does occur. HSI Design defines the HSI environment to meet the assumption of the HFE integrated HRA for all RI HAs. For example, HSI Design ensures necessary plant information and control functions are available on the same Operational VDU display, or are easily accessible through efficient display navigation. To help HSI design implementation, TA is used to determine what HSI environment should be used for all RI HAs.

– Staffing/qualifications and job analyses (Reference 5-4 Section 18.5)

The minimum and maximum licensed operator staffing and qualifications are an assumption and design basis for the US-Basic HSI System. Therefore this staffing range was a key input into the US-Basic HSI System design. Phase 1 confirmed that the US-Basic HSI System adequately supports the minimum and maximum staffing. Minimum and maximum licensed operator staffing is also an important assumption and design basis for the US-APWR HSI System. Phase 2 will reconfirm that the US-APWR HSI System adequately supports the minimum and maximum licensed operator staffing.

The details for the US-APWR staffing and qualification implementation plan are described in technical report (Reference 5-11). The staffing and qualifications program element will define the staffing numbers and qualifications for non-licensed personnel that perform operations or maintenance tasks directly related to plant safety. The staffing numbers and qualifications and Task Analysis are an input to the design of the HSI used for the safety significant tasks performed by this personnel. The HSI is confirmed through the V&V program element or the Design Implementation program element.

The development of the above key implementation plans, analysis, evaluations and correlation between the elements is identified and described in Figure 4.1-1.

2) System Requirements

Constraints imposed by the overall I&C system, such as redundancy, equipment qualification, and coping with common cause failures (CCF) are significant inputs for the HSI design and are considered throughout the HSI design process. The HSI Design constraint and criteria input from the overall I&C configuration is identified based on Reference 5-2, and Reference 5-5. The Diverse Actuation System (DAS) provides diverse automatic actuation for time critical functions and diverse HSI to allow the operator to monitor critical safety functions and manually actuate safety process systems. The approach includes design features and design processes for the Defense in Depth and Diversity (D3) for I&C systems are described in Reference 5-7.

The system requirements as mentioned above are applied to the following functions and Operation and Monitoring equipment for HSIS.

1) Functions

-Operation Function: Non-safety operation function, Safety operation function

-Plant Monitoring: Non-safety monitoring functions, Safety monitoring function and Alarm monitoring function

-Operation data management function: Recording, logging, performance calculation, tag management and printing

2) Operation and Monitoring equipment (including communication system)

a. HSI

-Operator console (including Hard-wired switches, Operational visual display units (VDU), alarm VDUs, Computer-Based Procedure (CBP) VDUs, safety VDUs, and Data Management Console (DMC))

-Supervisor console

-Shift technical advisor console

-Large Display Panel (LDP)

-Maintenance console

b. Plant computer system

c. Data communication

d. DAS HSI panel

· Regulatory Requirements

Applicable regulatory requirements and industry standards, including those identified in Reference 5-8 are inputs to the HSI design process. (Refer to section 3 of this document)

US-APWR plant design specifications, which include Piping and Instrumentation Diagram (P&ID), functional diagrams for plant safety, component control logics, electrical diagrams, and alarm requirement, are used to develop the US-APWR HSI inventory. Those input documents of plant design are used for HFE analysis such as FRA/FA, TA and HRA. The outputs from FRA/FA, TA and HRA may also provide feedback for changes in the plant design. The OER is input to the plant design and HSI design.

· Other Requirements

The HSI design style guide which is in conformance to NUREG-0700 and other human ergonomic criteria is used for display design of HSIS:

Other HSI design inputs include:

- HEDs from US-APWR Phase 1 V&V, or from any other phases as the design progresses

- The Component Control and Monitoring Circuit Basic Design Guide (See Reference 5-20)

- Expert recommendations (see Reference 5-10)

etc

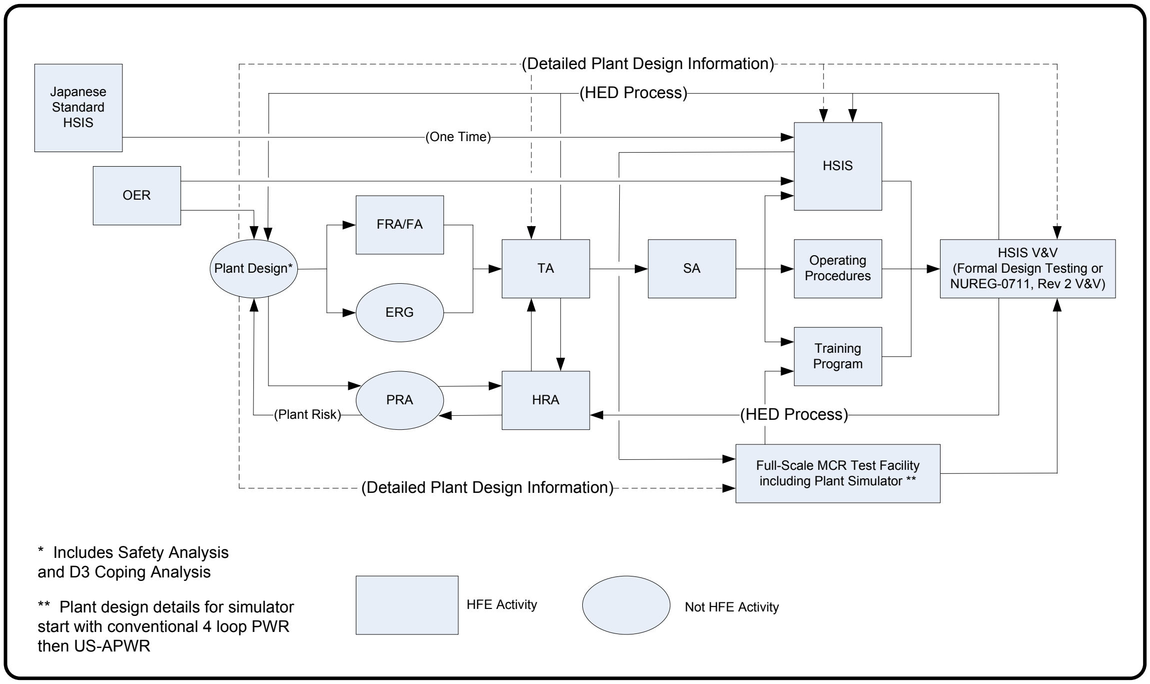

Figure 4.1-1 Overall Design Process

4.2 Concept of Operation

The concept of operations for the US-APWR is as described in Reference 5-8, and includes:

- Crew composition (Reference 5-8 Subsection 4.1.f and Section 4.2.1)
- Roles and responsibilities of individual crewmembers (Reference 5-8, Subsection 4.1.g)

  Plant personnel addressed by the HFE program include licensed control room operators as defined in 10 CFR Part 55 and the following categories of personnel defined by 10 CFR 50.120:

  - Non-licensed operators,
  - Shift manager,
  - Shift technical advisor,
  - Instrument and control technician,
  - Electrical maintenance personnel,
  - Mechanical maintenance personnel,
  - Radiological protection technician,
  - Chemistry technician,
  - Engineering support personnel.

  The details for roles and responsibilities are described in Staffing and Qualification Implementation Plan (Reference 5-11).

  In addition, any other plant personnel who perform tasks that are directly related to plant safety are addressed in the HFE program.

  There is no computerized operator support system other than the HSIS which is described in Reference 5-8.

- Personnel interaction with plant automation (Reference 5-8, Subsections 4.1.a, 4.1.b, 4.1.e, 4.1.h)

  -Overriding automatic systems

  Automatic interlocks and actuation signals are distinguished from automatic control signals. Automatic interlocks and actuation signals are provided for plant, system or equipment protection. Automatic control signals are provided to reduce operator task burden for functions that meet HFE automation criteria, such as frequent or complex operation.

  All automatic interlocks and actuation signals are always enabled and initially prioritized over opposite manual actuation signals and automatic control signals. After actuation, automatic safety actuation signals can be overridden by manually resetting the actuation signal at the train level. Where the plant designer has predetermined a specific need, automatic interlocks or actuation signals can be overridden at the component level.

  To allow periodic testing or maintenance, interlocks and actuation signals can be manually inhibited at the component level by the “Lock” button. To ensure situation awareness of bypass conditions and to avoid potential human error of unintentionally leaving a component in the “Lock” mode after testing or maintenance, bypass alarms for each train of each safety function are continuously displayed on the LDP.”

Automatic control signals can be manually enabled or disabled by the plant operator. For situation awareness, the LDP displays the status of automated systems that are critical to power production critical functions.

· Use of control room resources by crewmembers (Reference 5-8, Sections 4.1.c, 4.1.d and 4.2)

· Methods used to ensure good coordination of crewmember activities, including non-licensed operators, technicians, and maintenance personnel. These coordination tools/methods include:

-Large display panel (LDP) (Reference 5-8, Section 4.9)

LDP in Main Control Room (MCR) is designed to support crew situation awareness, coordination and communications;

1) By providing continuously visible information to the crewmembers in order to ensure that the operator and SRO have all relevant plant information.

2) By making plant information simultaneously available to all plant operating staff on duty and to support operator team activities.

-Local Control Station (LCS) (Reference 5-8, Subsection 4.2.5)

In order to facilitate the communication between MCR and LCSs, the communication systems provide for effective intra-plant and plant-to-offsite communications during normal, transient, fire, accidents, off-normal phenomena (e.g., LOOP), and security-related events. The various plant communication systems provide independent, alternate, redundant communication paths to ensure the ability to communicate with station and offsite agencies during all operating conditions. The design interface requirement between MCR and LCS is confirmed through V&V activities. (Reference 5-14) Those HSI/HFE interface such as local panel design, communications are performed in accordance with US-APWR QAPD (Reference 5-17)

When communication between personnel is required to perform the task, the specifics of the communication is identified in the Task Analysis documentation. This includes the type of communication (e.g., verbal, written, hand signal), purpose (e.g., coordination, feedback) and equipment used (i.e., telephone, radio, public address, text pager).

-The distance between each console and between the consoles and the LDP is set considering the vertical and horizontal viewing field of the operator, and the visibility of information displayed on the LDP.

-Tagging (Reference 5-8, Section 4.5)

To support maintenance and testing, plant components are tagged to bring attention to operability restrictions. The tagging feature of the HSI system is used to display tags for components controlled by Operational VDUs.

In addition, distribution of plant data via the unit bus and the plant station bus is described in Reference 5-2 Section 7.9, voice communications systems for the US-APWR are described in Reference 5-3 Subsection 9.5.2.

The key design goals of the US-APWR HSI system are to:

- Ensure the ability to continue to monitor the 'big picture' status of the plant while taking control actions

- Minimize task burden related to display management (ensure there is not excessive need to switch between displays to collect needed information, make comparisons or execute a control sequence)
- Ensure the ability to take control actions in pace with plant dynamics,
- Ensure the ability to maintain broad situation awareness and stay 'mentally' ahead
- Ensure the ability to maintain awareness of the status of the critical safety functions
- Ensure the ability to take control actions in pace with plant dynamics
- Ensure the ability to follow procedures in pace with plant dynamics
- Ensure the ability to catch and correct errors
- Ensure mental workload is not excessive
- Ensure physical workload is not excessive
- Ensure ability to maintain awareness of what other crew members are doing; ensure ability to communicate and coordinate actions; ensure ability to catch and correct misunderstandings or errors, ensure ability to maintain shared situation awareness.
- Ensure ability to supervise automated systems and take-over manually as necessary.

Personnel interactions involving decision making, coordination and feedback within the control room and between the MCR and LCSs and support centers is evaluated in the Dynamic V&V. (Details for V&V are described in Reference 5-14)

Since the Concept of Operations is already described in Reference 5-8, it is not an output of the HSI Design Implementation Plan.

4.3 Functional Requirement Specification

Functional requirements for the HSIs are developed to address:

- The concept of operations
- Personnel functions and tasks that support their role in the plant as derived from function, task, and staffing/qualifications analyses
- Personnel requirements for a safe, comfortable working environment

The functional design requirements specify the control room system and equipment that perform the assigned monitoring and control functions. It also specifies the interface between the human and the control room equipment. The design is based on an integrated HSIS engineering approach which includes consideration for:

-Human capabilities and characteristics

-Location, environment and protection

-Space and configuration

-Panel layout

-Information and control systems

-Control-display integration

-Communication systems

-Other requirements

Power supplies

Qualification

Maintainability

Testability

The basic functional requirements for all HSI resources for the Functional Requirement Specification are reflected in the HSI design as described in Reference 5-8. During the detailed design process the HSI inventory is added reflecting the output from the task analysis, including alarm, information and control content for specific displays

4.4 HSI Concept Design

1) The US-Basic HSI System which is described in Reference 5-8 serves as the initial source of input to the HSI design. The development of the HSI design, from basic design phase through final design is also described in Reference 5-8.

The phase 1 V&V design testing of the US-Basic HSI design resulted in HEDs being identified, and many being resolved. Outstanding HEDs from Phase 1 will be resolved in Phase 2.

The Human Engineering Discrepancy (HED) process is used to resolve HFE issues identified during any phase of the HFE program. The HED process has four steps:

1. Discrepancy Problem Statement
2. Discrepancy Evaluation
3. Discrepancy Resolution
4. Discrepancy Closure

The details for each step are identified in Reference 5-10. The HEDs evaluation process shall be executed according to Part1 Section 6 of Reference 5-10.

2) Additional approaches for addressing HSI functional requirements

As part of developing the US-Basic HSI System, a survey of the state-of-the-art in HSI technologies was conducted to:

- Support the development of concept designs that incorporate advanced HSI technologies
- Provide assurance that proposed designs are technically feasible
- Support the identification of human performance concerns and tradeoffs associated with various HSI technologies

During the concept design, the digital I&C/ HSI technology such as touch-panel display, communication network, basic/application software for HSI, communication equipment in MCR was surveyed and introduced to develop the HSIS. Additionally, the R&D-based activities regarding HSI technology, I&C and IT technology were conducted separately from the development of the HSI design.

The US-Basic HSI design (Topical Report MUAP-07007) addressed “alternative approaches for addressing HSI functional requirements". Additional approaches for addressing HSI functional requirements are assessed for resolving Phase 1, 2 and 3 design related HEDs.

3) Alternative approaches for addressing HSI functional requirements

- The operating experience is an input to develop the HSI design as described in section 4.1 design input.
- The literature analyses (desk-check), tradeoff studies and engineering evaluation were conducted from the view point of HSI functional requirement such as safety including regulatory requirement, maintainability, testability, operability and crew coordination/performance etc. (e.g. new concept of HSIS, new alarm system concept, virtual reality, new technology of displays etc)

Alternate approaches for addressing HSI functional requirements are assessed for resolving Phase 1, 2 and 3 design related HEDs.

4) Alternative concept designs

-The design evaluation was provided through the HSI design review. The evaluations and the design review were performed in accordance with the US-APWR Quality Assurance Program Description (QAPD) and design standard/procedure. (e.g., document/drawing review, check list, etc) The review criteria include;

- Situation Awareness,
- Operability,
- Following Procedures,
- Error-tolerance,
- Mental workload,
- Physical workload,
- Teamwork,
- Supervising Automated Systems,
- Shift staffing, etc

The same process of evaluations and design reviews are applied to any design changes resulting from the resolution of Phase 1, 2 and 3 design related HEDs.

5) HSI design performance requirements

-As a result of the design evaluation, the selected HSI concept design is defined with the functional requirement specification and it also includes the result of the HSI technology considerations which is described above.

The US-Basic HSI System design as documented in Topical Report MUAP-07007, reflects the resolution of the significant HEDs from Phase 1. Other Phase 1 HEDs will be addressed in either the generic US-APWR HSI System design developed in Phase 2 or the site specific US-APWR HSI System design developed in Phase 3, as appropriate. The US-Basic HSI System design, as documented in Topical Report MUAP-07007, will not be revised unless this simplifies the licensing application for a future project which references that Topical Report.

4.5 HSI Detailed Design and Integration

1) Style Guide development

US-APWR design-specific HFE design guidance is the HSI design style guide (Reference 5-19). This style guide is utilized in the design of the HSI features, layout, and environment. The Style Guide will also be applied in the HSI system verification process of Phase 2b V&V implementation Plan. (Reference 5-14)

The HSI design style guide is derived from NUREG-0700 as a generic HFE guidance and Mitsubishi's own guidelines based upon design-related analysis and Japanese experience. This style guide is updated by incorporating the resolution of HEDs of phase 1 testing. The Style Guide has and updates undergo verification review to the requirements of NUREG 0700. The HSI design style guide will be made available for NRC audit.

The style guide is addressing the (1) general guidelines for display development, (2) guidelines for each display elements including the functional description of the elements, (3) display system description, (4) display formats of the scope of HSIS.

General guidelines for display includes following:

- Display design consistency
- Understandability of information
- Grouping of information
- Readability of information
- Distinctive coding
- Uncluttered displays
- Status indication of display
- Display update rate requirements

Guideline for display elements includes following:

- Character
- Labels
- Color
- Tables and Lists
- Graphs
- Mimics
- Icons and Symbols
- Alarms
- Controllers

Display format includes following:

- Monitoring and Control display (operational VDU screens)
- LDP
- Alarm display
- Operating procedure VDU
- Monitoring and Control display for safety system

The individual guideline is expressed in concrete, easily observable terms. (e.g., VDU character size, etc.).

The style guide supports the interpretation and comprehension of design guidance by supplementing text with graphical examples, figures, and tables. For example, guideline of the trend graph using the graphical example is shown below.

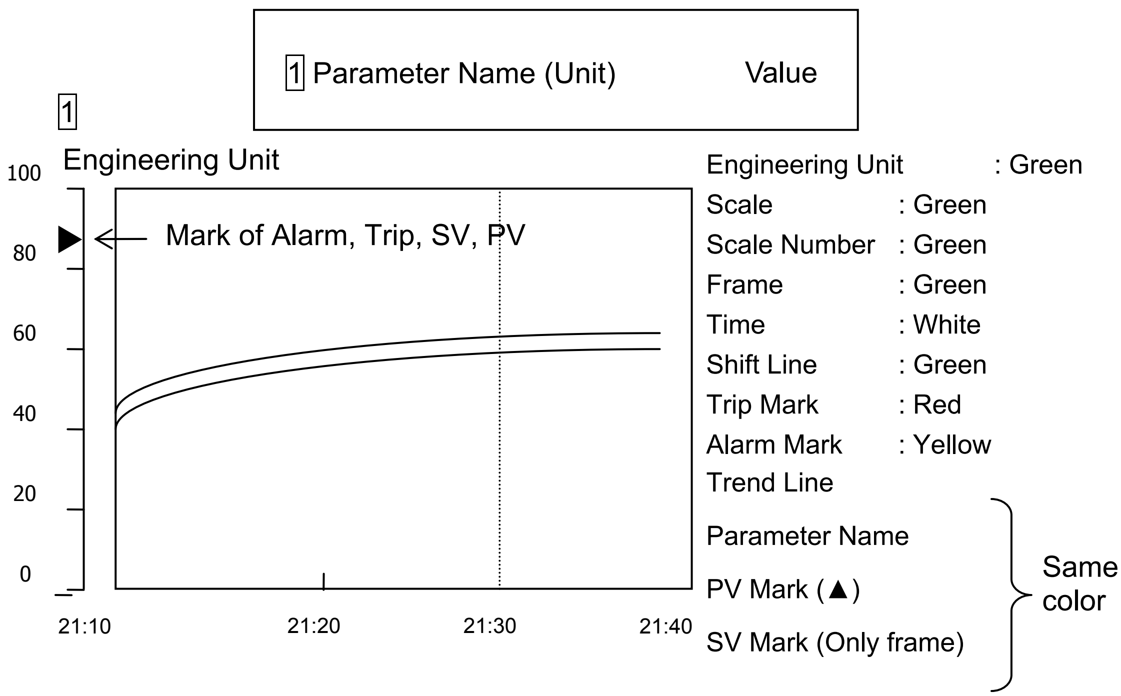

Figure 4.5-1 Trend Graph Using the Graphical Example

The style guide is maintained in a form that is readily accessible and usable by designers and that facilitates modification when the contents require updating as the design matures. Each guideline included in the style guide documentation includes a reference to the source upon which it is based (as applied in NUREG-0700).The style guide ensures the screen elements (e.g., graphic symbols, tables, graphs, etc.) and their coding are consistent across all displays (e.g., Monitoring and Operational display, alarm display, LDP, etc).The style guide ensures plant conditions are consistent across information screens to allow operators to quickly and accurately assess the status of the plant. The V&V Team verifies all displays against the style guide.

Section 18.7.2.5 of the Reference 5-4 addresses the style guide. The basic design of the display and the style guide is provided in Section 5.7.3.2 of the Reference 5-8. Section 4.4 through 4.9 of the Reference 5-8 contains the basic display design.

In the HSI design, especially in the screen design for HSIS, the style guide is applied to develop the screens for each HSI element such as monitoring and control display and LDP. Detail rules of the element for the screen design such as font size, color coding and symbols are followed when the screen is developed. The HSI details such as window manipulation, display selection, display system navigation are designed to support personnel in their role of monitoring and controlling the plant while minimizing personnel demands associated with use of the HSIs. These principles in NUREG-0700 are reflected during the HSI development. Additionally, the style guide is applied in combination with the other design guidelines and specifications (e.g., controller, alarm), and the results of the screen are documented as a display specification.

2) Risk important HAs

Section 18.7.2.5 of the Reference 5-4 addresses how the design minimizes the probability of error in the performance of risk-important HAs and provides the opportunity to detect errors. There are a minimum of two actions required for all controls, to reduce the potential for erroneous operator actions, that may cause a transient. In addition, operational VDU displays are designed to support credited manual operator actions for event-based mitigation.

In accordance with the overall HFE process shown in Figure 4.1-1, after the HSI design such as the alarms, graphics and controls in the VDU screen are developed based on input from the plant design and the TA, an independent table top walkthrough is conducted using operations and HFE experts to assess those designs against the HRA.

3) Functional requirements to MCR and LCS

When developing functional requirements for monitoring and control capabilities that are provided either in the control room or locally in the plant, the following factors are considered:

- Communication, coordination, and workload
- Feedback
- Local environment
- Inspection, test, and maintenance
- Importance to safety

All control functions are accessible in the MCR and RSR and no LCS controls are credited for normal operation or accident condition operator response under normal HSI conditions. The basis for the MCR layout, and the organization of HSIs within consoles, panels, and workstations – the MCR is designed to support the range of crew tasks and staffing (MCR layout is discussed in Section 4.3.1 of Reference 5-8, staffing and qualification is addressed in Reference 5-11); operational VDUs which are used during all normal and emergency modes of operation are centrally located.

4) Analyses of operator roles

Section 18.7.2.5 of the Reference 5-4 addressed how the control room supports a range of anticipated staffing situations – the design accommodates minimum and nominal staffing, as described in Section 18.5 of the Reference 5-4; in addition, sufficient space is available to accommodate shift turnover transitions.

5) Performance due to fatigue

Reference 5-8 Section 4.3, Reference 5-3 Subsection 9.5.3 describes how the HSI characteristics mitigate excessive fatigue – lighting, ergonomics and layout design.

6) Environmental conditions

Reference 5-2, Reference 5-3 Subsection Section 9.4 and 9.5.3 descries how the HSI characteristics support human performance under a full range of environmental conditions – highly controlled environment without a significant fluctuation of environmental conditions, including emergency lighting, ventilation and control room habitability.

7) Inspection, maintenance tests and repair of HSIs

The means by which inspection, maintenance, tests, and repair of HSIs is accomplished without interfering with other control room tasks are described in Reference 5-8 Section 4.11 “Response to HSI Equipment Failures”, which discusses response to HSI equipment failures without impacting plant control functions.

8) HSI inventories

The US-APWR MCR development work sequence is based on modeling the HSIS as two components, a generic constituent and a plant specific constituent. The generic part is referred to as the “Basic HSI System” and the plant specific part is referred to as the “HSI Inventory.” The Basic HSI System is common to all nuclear power plants (e.g. the US-APWR and US operating plant control board replacements). The US-APWR HSI Inventory is unique to the US-APWR.

The Basic HSI System comprises the HSI elements and it performs the HSI operation method or technique. The Basic HSI System is defined by Reference 5-8, which includes a design basis and functional design specification that includes specifications for data processing, access, and presentation, and a style guide defining the HSI attributes. Examples of HSI attributes are general display guidelines, display element design, display screen format, and display hardware requirements.

The HSI Inventory is the set or collection of specific indications, alarms, controls, and procedures implemented using the HSI techniques defined by the Basic HSI System for all plant systems and tasks for all HSI media for a specific nuclear power plant. For example, the HSI inventory includes, but is not limited to, the mimic screens, alarm messages, control stations, and procedures. The HSI inventory is developed from an HFE analyses.

The US-APWR HSI inventory is defined and specified by the HSI system designers through an HFE analysis. The US-APWR HSI inventory shall be developed through the HFE analysis defined by the Reference 5-4 and this Implementation Plan. As described in Reference 5-4, to develop the US-APWR HSI Inventory the US-APWR HFE program shall reassess each NUREG-0711 element with emphasis on changes from prior analysis, assessment, and experience. The US-APWR Phase 2a HFE analysis results (Reference 5-10) and the US-APWR plant design data are used to generate the US-APWR HSI Inventory for the alarms, displays, procedures, and controls. The HSI Inventory constituent generation activities are interrelated and can be iterative with the HFE products being refined as more detailed plant design data becomes available. Site-specific assumptions are included in the generic US-APWR HSI Inventory, as necessary, to complete the total plant design data set. Intermediate states of the constituents are checked against each other for consistency.

- Functions and Roles in MCR

For the development of the HSI inventory for the MCR, the work by operators is classified based on the TAs, and the roles and role sharing of MCR operators are clarified. Then, the function classification required for MCR development is performed.

a. Classification of operation tasks

Operation task are analyzed in the TA, and the work categories, outlined frequencies and the systems required along the work flow were investigated, so that the operator work might be classified. Table 4.5-1 shows the operation work performed at MCR.

b. Function classification required for MCR development

i) Basic functions

Requirements related to the operating functions shown in below. Further by surveying these functions from the plant as a whole, the roles of main control room are put in order as shown in Figure 4.5-2.

Requirements related to operation:

1. Central power supply command receiving function (external communication function)
2. Paging / broadcast function
3. Clock function
4. On-site communication function
5. Operating function
6. Display function
7. Function to communicate with locals
8. Test function
9. Operating function by shift supervisor
10. Data recording function
11. System isolation control function (outage)
12. Test function (outage)

ii) Requirements related to spaces in MCR

By focusing on the space as one of the elements realizing the basic functions, the requirements related to the spaces are shown in below:

1. Space for transition meeting
2. Space to prepare operating records and forms
3. Space for operations
4. Space for operations in coordination with maintenance personnel
5. Space for operation monitoring
6. Space for reporting the result of patrol checks
7. Space for treatment in accident or other fault
8. Space for operations by manager on-duty

9. Space within hearing of oral instructions, citation, name-calling by finger pointing

10. Space capable of storing various documents and forms

- HSI inventory requirement

As a result of the process of the HSI inventory mentioned above, the following inventories are derived (the HSI inventory is broadly classified into following categories):

Plant management

Supervisor Console

Data Management Console

Monitoring and Control (Operation)

LDP

Operation Console

DHP

Maintenance and Testing

Maintenance Console

Communications

Desk for meetings

Paging, communication systems etc.

-Minimum Inventory of HSI

The fixed area of LDP presents SDCV information to the operating staff. The parameters and alarms on the LDP are described in Reference 5-8 section 4.9, including SDCV indications for BISI of RPS, ESFAS and plant safety systems.

Means are provided in the MCR for manual initiation of protective functions at the system level. These functions are realized by conventional hard-wired Class 1E switches that enable easy and prompt access by the operator. Means for manual control of safety systems at the component level are realized by the safety VDUs described in Reference 5-8 section 4.6.

The minimum SDCV inventory and the minimum inventory for degraded HSI conditions are established to monitor and control the six critical safety functions:

- Reactivity Control
- RCS Inventory
- Core Cooling
- Secondary Heat Sink
- RCS Integrity
- Containment Integrity

This applies to all normal and emergency plant modes. The specific functions and tasks and the key required HSI resources, including alarms, controls, displays and procedures, are extracted from Normal Operating Procedures (NOP), Emergency Operating Procedure (EOP) and Plant probabilistic risk assessment (PRA), which are described in plant licensing documents. The minimum inventory is based on monitoring key performance parameters for each critical function and controlling the preferred non-safety and safety success paths. The design of the minimum inventory HSI is developed and evaluated through the HFE design process described in Reference 5-8 section 5.

The design of the minimum inventory HSI (SDCV and Class 1E) is developed and evaluated through the HFE design process described in Reference 5-8 section 5.

9) Qualification of HSI designers

The HFE team including technical reviewer is made up of personnel that are experienced in HFE, the personnel;

-Have experience related to the human factors aspects of human-system interfaces.

-Have experience in design, development, and test and evaluation of human-system interfaces.

-Have experience related to the human factors aspects of workplace design.

The HFE Team personnel who conduct the HFE are trained in the purpose, scope and methodology of the HFE in accordance with US-APWR QAPD (Reference 5-17). HSI personnel are trained in the Basic HSI Design and HFE Design Process, and the plant systems of the US-APWR. This training allows HFE personnel to evaluate the applicability of an HFE issue to the US-APWR, to assess those items that are considered to be already included in the US-APWR HSI System and those items not already addressed in the US-APWR HSI System. Personnel are trained in identifying HEDs and entering those HEDs in the HFE issues tracking system.

Table 4.5-1 Classification of Operation Tasks

1	Transition of work	Relay work securely by using transition book, etc. in work shift.
2	Receiving power supply command	Perform operation/steps according to the power supply command received from the center.
3	Operation contact	Take cautions to prevent accident or calamity due to insufficient communication.
4	Operation records	Record and study necessary things to maintain efficient operation and prevent accidents.
5	Operating work by on-duty personnel	On-duty personnel shall work under the direction/supervision of on-duty section manager.
6	Security system & protective relays (control)	If any fault occurs in the system, investigate the condition, and issue work form if necessary.
7	Operation standard values & operation limit values	Ensure the operation standard values/limit values in every operation.
8	System operation (daily operation)	Operate the system deliberately and securely by identifying the operation and work condition so that quick actions can be taken.
9	System operation (associated with work & test run)	Perform work while operation/maintenance personnel are ensuring the operation/steps associated with work and its completion.
10	Operation monitoring	By monitoring the equipment and measurement controllers, make efforts to maintain the best condition at all times.
11	Patrol checks	Carry out patrol checks of the specified systems.
12	Periodical testing	Carry out periodical tests of equipment, measurement controllers and security system in operation.
13	Provisional testing	Carry out irregular or provisional tests and special tests.
14	Treatment in accident & other faults	Perform necessary restoration work or take actions to prevent expansion according to the detailed rules for operation in accidents.
15	Accident prevention	Carry out patrol checks and treatment to prevent accidents.
16	Safety control	Take every measure to prevent accidents.
17	Operation maintenance	Carry out daily checks, treatment, easy maintenance work and first-aid treatment.
18	Performance control, etc.	By identifying the performance of equipment, try to maintain safe and functional operation.
19	Radiation control	By heeding the indications on radiation monitor, try to find faults such as in radiation early.

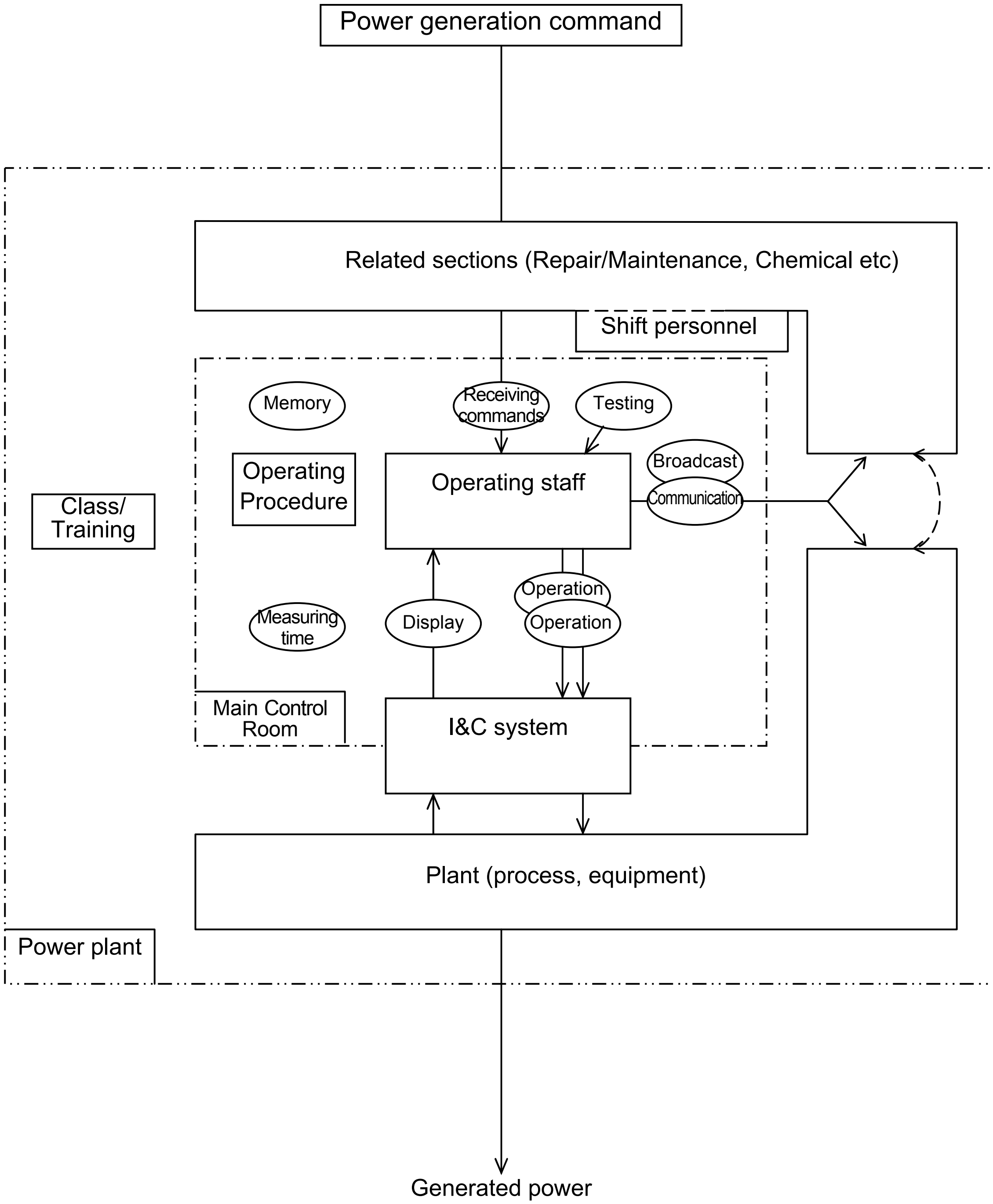

Figure 4.5-2 Roles and Interfaces in MCR

4.6 HSI Tests and Evaluations

The design process that is applied to the resolution of Phase 1 design related HEDs for the US-Basic HSI System is one of iterative design and test. These tests are focused on specific interface elements and conducted as a human in the loop scenarios on a dynamic part task simulator, applying similar data collection and analysis as will be used in the final validation of the US-APWR HSI. As the final design matures additional testing will be used, as appropriate, to evaluate important design resolution choices prior to entering the validation phase, 2b.

Testing and evaluation of US-Basic HSI design changes to resolve Phase 1 HEDs are conducted throughout the HSI development process and evaluations are performed iteratively. Trade-off evaluations are executed for selecting alternative HSI designs from viewpoint of reliability and usability. Some prototype of HSI design (part) such as CBP mock-up is made for performance-based tests.

Reference 5-8 Appendices A and B describe the tests and evaluations conducted for the Japanese Standard HSI System, which is the basis of the US-Basic HSI System described in Reference 5-8 Section 4.0. Appendix C describes the additional tests and evaluations conducted for the development of the US-Basic HSI System (Phase 1), and the additional tests and evaluations that will be conducted for the plant specific application of that system (Phase 2), and the site specific application of that system (Phase 3). The V&V activities conducted during Phase 2b and Phase 3a of the HFE program are conducted on the ‘final’, integrated design. Phases 2 and 3 are applicable to new plants and operating plant modernization programs. (The testing and evaluation of the HSI designs are addressed in Reference 5-4 section 18.7.2.6. These methodologies are provided in Section 18.10 of Reference 5-4.The details for V&V and how to incorporate HEDs are described in Reference 5-9 and 5-10).

4.7 HSI Design Documentation

The HSI design is documented to include the detailed HSI description including its form, function and performance characteristics, the basis for the HSI requirements and design characteristics with respect to operating experience and literature analyses, tradeoff studies, engineering evaluations and experiments, and benchmark evaluations records of the basis of the design changes.

Following documentation is provided to define the US-Basic HSIS as described in Reference 5-8:

- The HSI Design Style Guide.
- The US-Basic HSI Nomenclature which defines the standard acronyms and abbreviations and equipment description guidelines used in the HSI design.
- The US-Basic HSI Component Control and Monitoring Circuit Basic Design Guide that describes generic control logic and information processing logic to support operator control face plate operation, including associated indications and alarms.
- US-Basic HSI System Detailed Design Description

Key design documents complete the integrated US-APWR HSI design:

- Graphic display and panel layout drawings
- HSI database, which defines characteristics (e.g., Instrumentation ranges, alarm prioritization) and links the VDU display icons, parameters, trends, alarms, soft controls, etc. and panel hardware devices to the database of the control and protection systems
- Logic and algorithm diagrams for HSI function processing, such as OK status monitoring, BISI and critical safety function monitoring.
- Detailed room and console configuration diagrams. (Layout drawings)

All of the documents defined in the two sections above are developed and maintained in accordance with QAPD (Reference 5-17) for important to safety functions. Graphics and panel layout drawings for the S-VDU and console sections that are safety related are developed and maintained in accordance with QAPD for safety related functions.

The following apply to both the US-Basic HSI System and US-APWR HSI System:

- HED data base
- All QAP required configuration control documentation

The design documentation for the US-APWR HSI is developed based on the US-Basic HSI design documentation. The record of the design changes are incorporated in the design documentation.

The outcomes of test and evaluation such as V&V activity and part task design evaluation is documented as a Quality Record.

4.8 Results Summary Report

The HSI design results which are described in Section 4.1 through 4.7 are summarized in a HSI design Implementation results summary report. This report will be made available for NRC for review. This report is intended to fulfill the reporting requirements of the Inspections, Tests, Analyses, and Acceptance Criteria defined in Tier 1 of the DCD.

5.0 References

5-1 Design Control Document for the US-APWR, Chapter 6, Engineered Safety Features, MUAP-DC006, Revision 3, MHI, March 2011

5-2 Design Control Document for the US-APWR, Chapter 7, Instrumentation and Controls, MUAP-DC007, Revision 3, MHI, March 2011

5-3 Design Control Document for the US-APWR, Chapter 9, Auxiliary Systems, MUAP-DC009, Revision 3, MHI, March 2011

5-4 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP-DC018, Revision 3, MHI, March 2011

5-5 Safety I&C System Description and Design Process, MUAP-07004, Revision 6, MHI, March 2011

5-6 Safety System Digital Platform -MELTAC- , MUAP-07005, Revision 7, MHI, March 2011

5-7 Defense-in-Depth and Diversity, MUAP-07006, Revision 2, MHI, June 2008

5-8 HSI System Description and HFE Process, MUAP-07007, Revision 4, MHI, July 2011

5-9 US-APWR Human System Interface Verification and Validation (Phase 1a), MUAP-08014, Revision 1, MHI, May 2011

5-10 US-APWR HSI Design, MUAP-09019, Revision 0, MHI, June 2009

5-11 US-APWR Staffing and Qualifications Implementation Plan, MUAP-10008, Revision 0, MHI, April 2010

5-12 US-APWR Procedure Development Implementation Plan, MUAP-10010, Revision 0, MHI, April 2010

5-13 US-APWR Training Program Development Implementation Plan, MUAP-10011, Revision 0, MHI, April 2010

5-14 US-APWR Verification and Validation Implementation Plan, MUAP-10012, Revision 0, MHI, April 2010

5-15 US-APWR Design Implementation Plan, MUAP-10013, Revision 0, MHI, April 2010

5-16 US-APWR Human Performance Monitoring Implementation Plan, MUAP-10014, Revision 0, MHI, April 2010

5-17 Quality Assurance Program (QAP) Description For Design Certification of the US-APWR, PQD-HD-19005, Revision 4, MHI, April 2011

5-18 Nuclear power plants – Control rooms – Design, IEC 60964

5-19 HSI Design Style Guide, JEJC-1763-1001, MELCO

5-20 Component Control and Monitoring Circuit Basic Design Guide, N0-EJ30102, MHI