# 18.4 Control Room Standard Design Features

## 18.4.1 Introduction

This section presents the standard design features of the HSI in the control room (Subsection 18.4.2). These basic design features are based upon proven technologies and have been demonstrated, through broad scope control room dynamic simulation tests and evaluation, to satisfy the ABWR operator interface design goals and design bases as given in Section 18.2. The specific technologies utilized in the main control room HSI are listed in Subsection 18.4.3. Appendix 18C presents an example of a control room HSI design implementation which incorporates these design features. Validation of the implemented MCR design will include evaluation of the standard design features and will be performed as part of the design implementation process as defined by the acceptance criteria presented in Tables 18E-1 through 18E-4. See Subsection 18.8.5 for COL license information requirements.

## 18.4.2 Standard Design Feature Descriptions

### 18.4.2.1 Listing of Features

The ABWR control room HSI design incorporates the following standard features:

(1) A single, integrated control console staffed by two operators; the console has a low profile such that the operators can see over the console from a seated position.

(2) The use of plant computer functions driven on-screen control video display units (VDUs) for safety system monitoring and non-safety system control and monitoring.

(3) The use of a separate set of on-screen control VDUs for safety system control and monitoring; the operation of these VDUs is entirely independent of the plant computer functions. Further, the VDUs and all equipment associated with their functions of safety system control and monitoring are divisionally separate and qualified to Class 1E standards.

(4) The use of dedicated function switches on the control console.

(5) Operator selectable automation of predefined plant operation sequences.

(6) The incorporation of an operator selectable semi-automated mode of plant operations, which provide procedural guidance on the control console VDUs.

(7) The capability to conduct all plant operations in an operator manual mode.

(8) The incorporation of a large display panel which presents information for use by the entire control room operating staff.

(9) The inclusion on the large display panel of fixed-position displays of key plant parameters and major equipment status.

(10) The inclusion in the fixed-position displays of both 1E-qualified and non-1E display elements.

(11) The independence of the fixed-position displays from the plant computer functions.

(12) The inclusion within the large display panel of a large video display unit which is driven by the plant computer functions.

(13) The incorporation of a "monitoring only" supervisor's console which includes VDUs on which display formats available to the operators on the main control console are also available to the supervisors.

(14) The incorporation of the safety parameter display system (SPDS) function as part of the plant status summary information which is continuously displayed on the fixed-position displays on the large display panel.

(15) The use of fixed-position alarm tiles on the large display panel.

(16) The application of alarm processing logic to prioritize alarm indications and to filter unnecessary alarms.

(17) A spatial arrangement between the large display panel, the main control console and the shift supervisors' console which allows the entire control room operating crew to conveniently view the information presented on the Class 1E large display panel.

(18) The use of VDUs to provide alarm information in addition to the alarm information provided via the fixed-position alarm tiles on the large display panel.

Validation of the design of each of the main control room standard design features is a COL license information requirement (Subsection 18.8.5).

The remainder of this subsection provides further descriptions of these standard design features.

### 18.4.2.2 Main Control Console

The main control console comprises the work stations for the two control room plant operators. It is configured such that each operator is provided with controls and monitoring information necessary to perform their assigned tasks and allows the operators to view all of the displays on the large display panel (Subsection 18.4.2.7) from a seated position.

The main control console, in concert with the large display panel, provides the controls and displays required to operate the plant during normal plant operations, abnormal events and emergencies. These main control console controls and displays include the following:

(1) On-screen control VDUs for safety system monitoring and non-safety system control and monitoring which are driven by the plant computer functions (Subsection 18.4.2.3).

(2) A separate set of on-screen control VDUs for safety system control and monitoring; the operation of these VDUs is entirely independent of the plant computer functions. Further, the VDUs and all equipment associated with their functions of safety system control and monitoring are divisionally separate and qualified to Class IE standards (Subsection 18.4.2.4).

(3) Dedicated function switches (Subsection 18.4.2.5).

The main control console is also equipped with a limited set of dedicated displays for selected functions (e.g., the Standby Liquid Control System).

In addition to the above equipment, the main control console is equipped with both intraplant and external communications equipment and a laydown space is provided for hard copies of procedures and other documents required by the operators during the performance of their duties.

### 18.4.2.3 VDUs Driven by Plant Computer Functions

A set of onscreen control VDUs is incorporated into the main control console design to support the following activities:

(1) Monitoring of plant systems, both safety and non-safety-related

(2) Control of non-safety system components

(3) Presentation of system and equipment alarm information

This set of VDUs is driven by the plant computer functions. Thus, data collected by the plant computer functions is available for monitoring on these VDUs. All available display formats can be displayed on any of these VDUs.

### 18.4.2.4 VDUs Independent of Plant Computer Functions

A set of VDUs which are independent of the plant computer functions are also installed on the main control console. These VDUs are each driven by independent processors. These VDUs are dedicated, divisionally separated devices. The VDUs in this group can only be used for monitoring and control of equipment within a given safety division. The VDUs are qualified, along with their supporting display processing equipment, to Class 1E standards.

### 18.4.2.5 Dedicated Function Switches

Dedicated function switches are installed on the main control console. These devices provide faster access and feedback compared to that obtainable with soft controls. These dedicated switches are implemented in hardware, so that they are located in a fixed-position and are dedicated in the sense that each individual switch is used only for a single function, or two very closely related functions (e.g., valve open/close).

The dedicated function switches on the main control console are used to support actions such as initiation of automated sequences of safety and non-safety system operations, manual scram and reactor operating mode changes.

### 18.4.2.6 Automation Design

The ABWR incorporates selected automation of the operations required during a normal plant startup/shutdown and during normal power range maneuvers. Subsection 7.7.1.5.1 describes the Power Generation Control (PGC) System, which is the primary ABWR system for providing the automation features for normal ABWR plant operations.

#### 18.4.2.6.1 Automatic Operation

When placed in automatic mode, the PGC System performs sequences of automated plant operations by sending mode change commands and setpoint changes to lower-level, non-safety-related plant system controllers. The PGC System cannot directly change the status of a safety-related system. When a change in the status of a safety-related system is required to complete the selected operation sequence, the PGC System provides prompts to guide the operator in manually performing the change using the appropriate safety-related HSI controls provided on the main control console.

The operator can stop an automatic operation at any time. The PGC logic also monitors plant status, and will automatically revert to manual operating mode when a major change in plant status occurs (e.g., reactor scram or turbine trip). When such abnormal plant conditions occur, PGC automatic operation is suspended and the logic in the individual plant systems and equipment directs the automatic response to the plant conditions. Similarly, in the event that the operational status of the PGC or interfacing systems changes (e.g., equipment failures), operation reverts to manual operating mode. When conditions permit, the operator may manually re-initiate PGC automatic operation.

Evaluation of the effects of automation strategies on operator reliability and the appropriateness of the ABWR automation design is a COL license information requirement (Subsection 18.8.3).

Also, a consideration of malfunctions of the PGCS is a COL license information requirement. (See Subsection 18.8.10).

#### 18.4.2.6.2 Semi-Automated Operation

The PGC System also includes a semi-automatic operational mode which provides automatic operator guidance for accomplishing the desired normal changes in plant status; however, in this mode, the PGC System performs no control actions. The operator must activate all necessary system and equipment controls for the semi-automatic sequence to proceed. The PGC System monitors the plant status during the semi-automatic mode in order to check the progression of the semi-automatic sequence and to determine the appropriate operator guidance to be activated.

#### 18.4.2.6.3 Manual Operation

The manual mode of operation in the ABWR corresponds to the manual operation of conventional BWR designs in which the operator determines and executes the appropriate plant control actions without the benefit of computer-based operator aids. The manual mode provides a default operating mode in the event of an abnormal condition in the plant. The operator can completely stop an automated operation at any time by simply selecting the manual operating mode. The PGC System logic will also automatically revert to manual mode when abnormal conditions occur.

### 18.4.2.7 Large Display Panel

The large display panel provides information on overall plant status with real-time data during all phases of plant operation. The information on the large display panel can be viewed from the main control console and the supervisors' console. The large display panel includes fixed-position displays (Subsection 18.4.2.8), a variable display (Subsection 18.4.2.9) and spatially dedicated alarm windows (Subsection 18.4.2.12).

### 18.4.2.8 Fixed-Position Display

The fixed-position portion of the large display panel provides key plant information for viewing by the entire control room staff. The dynamic display elements of the fixed-position displays are driven by dedicated microprocessor-based controllers which are independent of the plant computer functions.

Those portions of the large display panel which present safety-related information are qualified to Class 1E standards. The COL applicant shall address the human factors aspects of TMI Item I.E.3, Safety System Status Monitoring, as a COL license information requirement (Subsection 18.8.9).

The information presented in the fixed-position displays includes the critical plant parameter information, as defined by the SPDS requirements of NUREG-0737, Supplement 1, and the Type A post-accident monitoring (PAM) instrumentation required by Regulatory Guide 1.97

(refer to Section 18.4.2.11 for a discussion of the SPDS and to Section 7.5 for a discussion of the PAM variables).

### 18.4.2.9 Large Variable Display

The large variable display which is included on the large display panel is a VDU which is driven by the plant computer functions. Any screen format resident in the plant computer functions can be shown on this large variable display.

### 18.4.2.10 Supervisors' Console

The console provided for the control room supervisors is equipped with VDUs on which any screen format resident in the plant computer functions available to the operators at the main control console is also available to the shift supervisor. The location of this console in the control room is discussed in Subsection 18.4.2.15.

### 18.4.2.11 SPDS

NUREG-0737 provided guidance for implementing Three Mile Island (TMI) action items. NUREG-0737, Supplement 1, clarifies the TMI action items related to emergency response capability, including item I.D.2, "Safety Parameter Display System" (SPDS). The principal purpose of the SPDS is to aid control room personnel during abnormal and emergency conditions in determining the safety status of the plant and in assessing whether abnormal conditions warrant corrective action by operators to prevent core damage. During emergencies, the SPDS serves as an aid in evaluating the current safety status of the plant, in executing symptom-based emergency operating procedures, and in monitoring the impact of engineered safeguards or mitigation activities. Selection of the parameters for inclusion in the SPDS display is based upon the ABWR Emergency Procedure Guidelines (Appendix 18A). The SPDS also operates during normal operation, continuously displaying information from which the plant safety status can be readily and reliably assessed. The ABWR does not provide a separate SPDS, but rather, the principal functions of the SPDS are integrated into the overall control room display capabilities in a manner which complies with all relevant requirements of NUREG-0737, Supplement 1. Displays of critical plant variables sufficient to provide information to plant operators about the following critical safety functions are continuously displayed on the large display panel as an integral part of the fixed-position displays:

(1) Reactivity control

(2) Reactor core cooling and heat removal from the primary system

(3) Reactor coolant system integrity

(4) Radioactivity control

(5) Containment conditions

Displays to assist the plant operator in execution of symptom-based emergency operating procedures are available at the main control console VDUs. Examples of these VDU displays are trend plots and operator guidance. Information regarding entry conditions to the symptomatic emergency procedures is provided through the fixed-position display of the critical plant parameters on the large display panel. The critical plant parameters on the large display panel are also viewable from the control room supervisors' monitoring station. The supplemental SPDS displays on the VDUs on the main control console are also accessible at the control room supervisors' monitoring station and may be provided in the technical support center (TSC) and, optionally, in the emergency operations facility (EOF). It is the responsibility of the COL applicant to provide.

Entry conditions to the symptomatic EOPs are annunciated on the dedicated hardware alarm windows on the large display panel. The large display panel also displays the containment isolation status, safety systems status, and the following critical parameters:

(1) RPV pressure

(2) RPV water level

(3) Core neutron flux (startup range and power range instruments)

(4) Suppression pool temperature

(5) Suppression pool water level

(6) Drywell temperature

(7) Drywell pressure

(8) Drywell water level

(9) Control rod scram status

(10) Drywell oxygen concentration (when monitors are in operation)

(11) Drywell hydrogen concentration (when monitors are in operation)

(12) Wetwell oxygen concentration (when monitors are in operation)

(13) Wetwell hydrogen concentration (when monitors are in operation)

(14) Containment radiation levels

(15) Wetwell pressure

The oxygen monitoring instrumentation system is normally in continuous operation and, hence, the large display panel also includes continuous fixed-position display of wetwell and drywell oxygen concentrations. The hydrogen monitoring instrumentation is automatically started on a LOCA signal and, hence, continuous display is not required. Additional post-accident monitoring parameters, such as effluent stack radioactivity release (refer to Section 7.5 for a list of post-accident monitoring parameters), may be displayed at the large variable display or at the main control console VDUs on demand by the operator.

The SPDS is required to be designed so that the displayed information can be readily perceived and comprehended by the control room operating crew. Compliance with this requirement is assured because of the incorporation of accepted human factors engineering principles into the overall control room design implementation process (refer to Subsection 18.7 for a discussion of the design implementation process).

All of the continuously displayed information necessary to satisfy the requirements for the SPDS, as defined in NUREG-0737, Supplement 1, is included in the fixed-position displays listed in Table 18F-2. Table 18F-2 also includes other displays, beyond those required for the SPDS.

The evaluation of the SPDS against the requirements of Paragraph 3.8a of NUREG-0737, Supplement 1, and confirmation that the design meets all applicable criteria is a COL license information requirement (Subsection 18.8.4).

### 18.4.2.12 Fixed-Position Alarms

Fixed-position alarm tiles on the large display panel annunciate the key, plant-level alarm conditions that potentially affect plant availability or plant safety, or indicate the need for immediate operator action.

### 18.4.2.13 Alarm Processing Logic

Alarm prioritizing and filtering logic is employed in the ABWR design to enhance the presentation of meaningful alarm information to the operator and reduce the amount of information which the operators must absorb and process during abnormal events.

Alarm prioritizing is accomplished in the ABWR through the designation of three categories of alarm signals. The first of these is the important alarms. These are defined as those alarms which notify the operators of changes in plant status regarding safety and include those items which are to be checked in the event of accidents, principle events or transients. The important alarms are displayed on the fixed-position tiles discussed in Subsection 18.4.2.12.

The second category is the system-specific alarms which are provided to notify the operators of system-level abnormalities or non-normal system statuses. Examples of these are:

(1) Main pump trips caused by system process, power sources or control abnormalities

(2) Valve closures in cooling or supply lines

(3) Decreases in supply process values

(4) Loss of a backup system

(5) System isolation

(6) Safety systems are being bypassed

(7) Systems are undergoing testing

The system-specific alarms are also shown on the fixed-position tiles discussed in Subsection 18.4.2.12.

Equipment alarms make up the third category of alarms in the prioritizing scheme and are discussed in Subsection 18.4.2.14.

Alarm suppression in the ABWR is based upon the following concepts:

(1) **Suppression Based on the Operating Mode:** The plant operating mode is defined on the basis of the hardware or process status, and alarms which are not relevant to the current operating mode are suppressed. For example, alarms which are needed in the "RUN" mode but are unnecessary in the "SHUTDOWN" mode are suppressed.

(2) **Suppression of Subsidiary Alarms**: Alarms are suppressed if they are logically consequent to the state of operation of the hardware or to the process status. For example, scram initiation (a plant-level alarm condition announced with a fixed-position alarm tile on the large display panel) will logically lead to an FMCRD HCU scram accumulator low pressure (also an alarm condition). Such subsidiary alarms are suppressed if they simply signify logical consequences of the systems operation.

(3) **Suppression of Redundant Alarms**: When there are overlapping alarms, such as "high" and "high-high" or "low" and "low-low", only the more severe of the conditions is alarmed and the others are suppressed.

Operators may activate or deactivate the alarm suppression logic at any time.

### 18.4.2.14 Equipment Alarms

Alarms which are not indicated by fixed-position alarm tiles on the large display panel (i.e., those alarms of nominally lower level importance such as those related to specific equipment status) are displayed to the control room operating staff via the main control console VDUs. The supplemental alarm indications and supporting information regarding the plant-level alarms which are presented on the large display panel are also presented on the VDUs.

### 18.4.2.15 Control Room Arrangement

In the ABWR main control room arrangement, the main control console is located directly in front of the large display panel for optimum viewing efficiency by the plant operators seated at the main console. The shift supervisor's console is also placed in front of the large display panel, but at a somewhat greater distance than the main control console. The shift supervisor is, thus, in a position behind the control console operators. This arrangement allows all control room personnel to view the contents of the large panel displays.

## 18.4.3 Control Room HSI Technology

The ABWR main control room standard design features described in Subsection 18.4.2 include equipment which utilizes a variety of technologies to control and monitor the plant processes. This subsection provides a summary listing and description of the technologies which are utilized to support personnel execution of these control and monitoring functions. For this purpose, the term "technology" is taken to have the following definition:

> "the equipment, including both hardware and software, employed to directly accomplish the functions of control and monitoring of the plant processes."

Hardware such as consoles, panels, cabinets, control room lighting and HVAC and plant communication equipment which has a supporting role but is not directly involved in the control and monitoring processes is excluded.

The scope of this section is limited to the main control room and the remote shutdown station areas of the plant and includes all human-system interface (HSI) equipment technologies which may be applied, regardless of use in prior designs:

(1) Hardware switches such as multi-position rotary, push-button, rocker, toggle and pull-to-lock types.

(2) Soft switch, the functions of which may be changed through the execution of software functions

(3) Continuous adjustment controls, such as rotary controls and thumbwheels.

(4) Visual display units with full color screens, including large reverse projection screens, cathode ray tubes and flat panel display screens.

(5) On-screen control utilized with the cathode ray tubes and flat panel display devices.

(6) VDU screen formats such as large screen optical projection display formats; text displays, including menus and tabular information and graphical displays, including Trend Plots, 2-D Plots, P&IDs and other diagrams and pictorial information.

(7) Analog Meters which employ a hardware medium to pictorially or graphically present quantitative and qualitative information concerning plant process parameters. This includes analog meters using digitally controlled LEDs and digital readouts.

(8) Fixed-Position Digital Displays which present alphanumeric information in a hardware medium. These can be back-lit.

(9) Fixed-position hardware mimic displays which schematically represent plant systems and components and their relationships utilizing pictorial elements, labels and indicator lights.

(10) Fixed-Position alarm tiles which use light to indicate the alarm state.

(11) An Audio Signal system which is coordinated to the fixed-position alarm tiles and utilizes prioritization and alarm reduction logic and predefined setpoints to alert operators to plant status changes.

(12) Printers and Printer/Plotters used to provide hard copy output in the form of plots, logs and text.

(13) Keyboards which are composed of alphanumeric and/or assignable function keys and function as computer input devices.