Overview

The ABWR instrumentation and control (I&C) design features system redundancy, fault tolerant operation, and self-diagnostics while the system is in operation. This is made possible by the extensive use of advanced digital technologies. The ABWR I&C System represents the largest system change from previous BWR designs.

Previous BWRs used hard wired point-to-point control room to field monitoring and control systems; essentially there was one wire per function or ~30-50,000 wires coming from the field to the cable spreading room and then control room. The ABWR, instead, is designed with a three-layer I&C system that uses extensive multiplexing and fiber optics. The three layers are:

- Remote Multiplexer Units (RMUs) in the field. This equipment generally handles 300-400 signals per RMU and interfaces the I&C system with the normal field signals and actuators.
- A computer/controller layer. This layer has all of the dual and triple redundant controllers that operate the plant and a networked computer system - there is no single process computer.
- A display, control and alarm/annunciator layer. This layer is basically all the screens, peripherals and alarms in the control room and forms the I&C interface to the operator.

The instrumentation of the ABWR is generally associated with the control of the reactor, control of the balance of plant (BOP), an extensive alarm system, prevention of the operation of the plant under unsafe and potentially unsafe conditions, monitoring of process fluids and gases, and monitoring of the performance of the plant.

Design goals of the I&C System include:

- Minimize reactor trips/system unavailability due to human errors or single active component failures.
- Design any systems necessary for power generation (except the electrical system) to be single-failure proof for both control and trips.
- Achieve a one-in-fifty-year or less failure rate for I&C.
- Computerize operator aids and normal/emergency procedures to reduce “manual” data processing and centralize human engineered operator interface to minimize operator burden.
- Provide for most I&C equipment communication and display protocols to follow internationally recognized standards.
- Use standardized modular equipment and extensive self-diagnostics/fault identification to minimize operation and maintenance costs and reduce the burden on the maintenance staff.
- Achieve a high degree of plant automation.
• Provide automatic load-following capability over the 50-100% power range.

Digital Measurement and Control

A standardized set of microprocessor-based instrument modules is used to implement most ABWR monitoring and control functions. The standardized Digital Measurement Controllers (DMCs) and Remote Multiplexer Units (RMU) exploit the many advantages of digital technology, including self-test, automatic calibration, user interactive front panels, standardization of the man-machine interface and, where possible, use of common circuit cards. These features reduce calibration, adjustment, diagnostic and repair time and reduce spare circuit card inventory requirements, as well as reduce control room instrument volume. As a result, system availability is improved due to the enhanced reliability and reduced mean time to repair.

The DMC chassis, RMU chassis and Man-Machine Interface (MMI) chassis are standard for all similar ABWR applications; only modular, plug-in interchangeable, circuit boards differ between systems. Functional features provided in the I&C design include:

• Sensor signal processing.
• Redundant sensor power supplies to meet the requirements of all sensors.
• Functional microcomputers implementing data transfers, self-test functions and communications.
• High speed parallel data bus for communication between the functional microcomputer and other modules.
• Trip and analog outputs driving external relays, actuators, logic circuits, meters, and recorders.
• Redundant power supplies for the electronics.
• Fiber optic and other interfaces, allowing the DMC and MMI units to communicate directly with plant multiplexing networks.
• Menu-driven front panel for operator/technician interface.

Multiplexing

The Multiplexing System provides redundant and distributed control and instrumentation data communications networks to support the monitoring and control of interfacing plant systems. The system contains an Essential Multiplexing System (EMS) and a Non-Essential Multiplexing System (NEMS) for safety and non-safety/BOP systems, respectively. The system provides all electrical devices and circuitry (such as multiplexing units, bus controllers, formaters and data buses) between sensors, display devices, controllers and actuators which are defined and provided by other plant systems. The multiplexing system also includes the associated data acquisition and communication software required to support its function of plant-wide data and control distribution. As shown on Figure 7-1, digital technology and multiplexed fiber optic signal transmission technology have been combined in the ABWR design to integrate control and data acquisition for both the Reactor and Turbine Buildings.

Signals from various plant process sensors provide input to RMUs located near the sensors. The RMUs digitize input signals and multiplex the signals via fiber optic cables to the control room. There the signals are sent to the various computers, controllers and display devices as needed. The process is bidirectional in that signals from the operator or plant controllers are put on the network and directed to the various actuators for control action.
The EMS has four control data networks (each of which is redundant), one per division with the NEMS being a control data network with dual redundancy. Whether EMS or NEMS, redundancy is such that a single cable can be lost or any RMU fail without affecting the operation of the remainder of the system.

Finally, each RMU is itself single-failure proof down to a small number of signals; all single failures are self-diagnosed. The RMUs are located throughout the plant in 1E and non-1E areas to keep plant wiring as short as possible.

**Figure 7-1. ABWR Integrated Multiplexing System Architecture**

**Digital Protection System Applications**

**Advanced Safety Systems Design**

The Reactor Protection System (RPS), Neutron Monitoring System (NMS) and Leak Detection and Isolation System (LDI) are four-channel, while
the ECCS are three-mechanical divisions actuated by two-out-of-four logic from four-channel sensor input. NMS is described in Chapter 6.

**Safety System Logic and Control**

Safety System Logic and Control (SSLC) and the associated EMS equipment is divided into four divisions. Each division is physically and electrically separated from the other divisions. Communications between divisions, as with communications with the NEMS, process computer, and control room instruments, is via fiber optic cable which provides complete electrical isolation and prevents spreading of electrical faults between safety system divisions and between safety and non-safety-related equipment. Communication between safety divisions and nonessential equipment is through “Data Gateways” which allow information to flow in only one direction.

Some control signals bypass the EMS when the signal design requirements are such that processing the signal through the EMS would cause the established design requirements (signal processing speed) to be exceeded.

The SSLC also controls the automatic actuation and operation of the following systems during emergency operation:

- High Pressure Core Flooder.
- Reactor Core Isolation Cooling.
- Residual Heat Removal.
- Automatic Depressurization.
- Emergency Diesel Generators.
- Reactor Building Cooling Water.

Standby Liquid Control System (SLCS) and Standby Gas Treatment System (SGTS) logic are separate from SSLC.

**Reactor Protection System**

The Reactor Protection System (RPS) is the overall complex of instrument channels, trip logic, trip actuators and scram logic circuitry that initiate rapid insertion of control rods (scram) to shut down the reactor if monitored system variables exceed preestablished limits. This action avoids fuel damage, limits system pressure and thus restricts the release of radioactive material. The RPS also establishes reactor operating modes and provides status and control signals to other systems and annunciators. To accomplish its overall function, the RPS interfaces with the Essential Multiplexing System, Neutron Monitoring System, Process Radiation Monitoring System, Control Rod Drive System, Rod Control and Information System, Reactor Recirculation Control System, Process Computer System, Leak Detection and Isolation System, Nuclear Boiler System and associated plant systems and equipment.

The RPS overrides all operator actions and process controls and is based on a fail-safe design philosophy that allows appropriate protective action by providing reliable single-failure-proof capability to automatically or manually initiate a reactor scram while maintaining protection against unnecessary scrams resulting from single failures. This is accomplished through the combination of fail-safe equipment design and redundant two-out-of-four logic arrangement that automatically reconfigures to a two-out-of-three logic if a channel fails or is bypassed. Manual RPS actions (scrams) are hard wired and always available to the operator.

**Leak Detection and Isolation System**

The Leak Detection and Isolation System (LDI) is a four-channel system consisting of temperature, pressure, flow and fission-product sensors with
associated instrumentation, alarm, and isolation functions. This system detects and annunciates leakage and provides signals to close containment isolation valves, as required, in the following systems:

- Main Steamlines.
- Reactor Water Cleanup System.
- Residual Heat Removal System.
- Reactor Core Isolation Cooling System.
- Feedwater System.
- Emergency Core Cooling Systems.
- Other miscellaneous systems.

Small leaks are generally detected by monitoring the air cooler condensate flow, radiation levels, equipment space temperature, and drain sump fill-up and pump-out rates. Large leaks are also detected by changes in reactor water level, drywell pressure, and changes in flow rates in process lines.

Manual isolation control switches are provided to permit the operator to manually initiate (at the system level) isolation from the control room. In addition, each MSIV is provided with a separate manual control switch in the control room which is independent of the automatic and manual leak detection isolation logic.

**Fault-Tolerant Process Control Systems**

The entire ABWR control system necessary for power generation is made up of a network of triple redundant and dual redundant Fault Tolerant Digital Controllers (FTDCs). Single controllers are used where the function is not important to power generation. In general, the key ABWR boiler control systems such as the feedwater control, recirculation flow control, turbine control, automatic power regulator and reactor pressure regulator systems are based on the triplicated, microprocessor-based FTDC. The remaining important BOP control systems are based on dual redundant FTDCs. Each FTDC includes two or three identical processing channels, which receive all the redundant process sensors inputs and perform the system control calculations in parallel.

For triple redundant process control, all FTDCs are active simultaneously and each provides an output to the NEMS network to the RMUs where the outputs are two-out-of-three voted (mid-value voting on continuous output signals (e.g., valve position demand) and two-out-of-three voting on discrete outputs (e.g., pump trip). Thus, the FTDC design eliminates plant trips due to single failures of control system components.

For dual redundant process control, one FTDC is active and the other is in “hot standby”; only one processor at a time provides an output to the NEMS network and to the RMUs but the other FTDC is “live” and can automatically and bumplessly assume command if the primary FTDC fails.

All important control signals are typically measured with three independent transducers (and occasionally measured with two); these input signals are delivered to all controllers by the NEMS and validated before control action is taken. This scheme and the controller redundancy eliminates plant trips due to single failures of control system components.

The FTDC hardware for all two or three process control systems is identical. Only the imbedded application firmware and the quantity and types of input and output modules deviate between the systems. The FTDC architecture includes:
• Two or three identical processing channels, each of which contains the hardware and firmware necessary to control the system.

• Dual multiplexing interface units per controller for communication to the redundant Non-Essential Multiplexing System.

• Interprocessor communication links between processing channels to exchange data in order to prevent divergence of outputs and to monitor processor failures.

• Redundant power supplies.

• Signal processing techniques applied to validate the redundant input signals for use in control computations.

• A portable Technician Interface Unit (TIU) to provide a menu-driven system which allows the technician to inject test signals, perform troubleshooting and calibrate process parameters.

The fault-tolerant architecture of the FTDC design provides assurance that no single active component failure within the sensing, control, or communication equipment can result in loss of system function or plant power generation. The dual and triplicated design also provides on-line repair capability to allow repair and/or replacement of a faulty component without disrupting any important plant process.

Automatic Power Regulator System
The primary objective of the Automatic Power Regulator System (APR) is to control reactor power during normal power generation by appropriate commands to change rod positions, or the change reactor recirculation flow. Either thermal power or gross generator electrical power can be controlled/demanded by the operator. Alternatively, the operator can engage a pre-programmed daily load-following schedule. The APR System always follows a predefined “trajectory” on the power/flow map for any mode of power operation.

The APR System also has the ability to pull the reactor critical and heat it to rated temperature and pressure from either a cold or hot standby condition. The APR System can also bring the reactor down to cold shutdown conditions. For either heatups or cooldowns, the reactor temperature rate is controlled to within Tech Spec limits by the APR commands to the Steam Bypass and Pressure Control System (SBPC) and RCIS.

The APR System consists of triply redundant process controllers; these receive information from the various plant sensors and issue commands to the RCIS to position control rods, to the RFC System to change reactor coolant recirculation flow, and to the SBPC System to set pressure.

The APR System generally controls the nuclear control systems and works in parallel (but not synchronously) with the Power Generation Control System function of the plant Process Computer System; the latter system controls most other automation functions. The normal mode of operation of the APR System is automatic but if any abnormal plant condition is detected or if the downstream controllers receiving the APR commands fail or are switched to manual, the APR will automatically cease control operations, switch all downstream controllers to manual, and alarms will be activated to alert the operator. A failure of the APR System will not prevent manual controls of reactor power, nor will it prevent safe shutdown of the reactor.

Feedwater Control System
The Feedwater Control System (FWC) automatically controls the flow of feedwater into the reactor pressure vessel to maintain the water within the vessel at normal
and predetermined levels for all modes of reactor operation, including heatup and shutdown. The operator can control reactor level between the requirements of the steam separators (this includes limiting carryover, which affects turbine performance, and carryunder, which affects RIP operation).

A fault-tolerant triplicated, digital controller using a conventional three-element control scheme, provides control signals to adjustable speed drives (ASDs) for the feedwater pump motors, to accomplish the control function.

The FWC System may operate in either single- or three-element control modes. At feedwater and steam flow rates below 25% of rated when the steam flow measurement is outside of the required accuracy or below scale, the FWC System utilizes only water level measurement in the single-element control mode.

When steam flow is negligible, as during heatup and cooldown, the FWC System automatically controls both the Reactor Water Cleanup (RWCU) System dump valve and the feedwater low flow control valve to control reactor level in the single element mode in order to counter the effects of density changes during heatup and purge flows into the reactor. At higher flow rates, the FWC System in three-element control mode uses water level, main steamline flow, main feedwater line flow, and feedpump suction flow measurements for water level control.

Steamp Bypass and Pressure Control System

The Steam Bypass and Pressure Control System (SBPC) is a triply redundant process control system: in Manual, the operator can adjust bypass valve position and provide reactor pressure setpoint demands; in Automatic, these functions are provided by the APR. Only the operator can switch the SBPC System to Automatic, but either the operator or the APR can switch the SBPC System to Manual.

Unlike previous BWRs, reactor pressure and not turbine inlet pressure is controlled by the SBPC System. In normal power generation, reactor pressure is controlled by automatically positioning the turbine control valves - the pressure control signal “passes through” the SBPC System to the turbine control system. During modes of operation where the turbine is off-line, flow limited, tripped or under control of its speed/acceleration control system during turbine roll or coastdown, reactor pressure is controlled by the bypass valves which pass steam directly to the main condenser under the control of the pressure regulator. Steam is also automatically bypassed to the condenser whenever the reactor steaming rate exceeds the flow permitted to pass to the turbine generator. With a full bypass design option, the turbine bypass system has the capability to shed up to 100% of the turbine-generator rated load without reactor trip or operation of SRVs. For all these modes of operation, the pressure regulation system provides main turbine control valve and bypass valve flow demands so as to maintain a nearly constant reactor pressure; it also indirectly (through the APR) provides demands to the recirculation system to optionally aid in maintenance of grid frequency.

Recirculation Flow Control System

The Recirculation Flow Control (RFC) System is a triply redundant process control system: in Manual, the operator can adjust individual or gang RIP speeds or demand a specific core flow; in Automatic, these functions are provided by the APR. Only the operator can switch the RFC System to Automatic, but either the operator or the APR can switch the RFC System to Manual.
CHAPTER 7 — INSTRUMENTATION AND CONTROL

The RFC System consists of three redundant process controllers, adjustable speed drives (ASDs), switches, sensors, and alarm devices provided for operational manipulation of the ten RIPS and the surveillance of associated equipment. The solid-state ASDs provide variable voltage, variable frequency electrical power to the RIP induction motors. In response to either the plant operator or the APR or, optionally, grid frequency demands, the RFC System adjusts the ASD power supply output to vary RIP speed, core flow and reactor power. Extremely rapid reactor power changes can be achieved either by manual operation or by automatic operation from ~65-100% reactor power.

The objective of the RFC System is to control reactor power level, over a limited range, by controlling the flow rate of the coolant flow through the reactor. To change the coolant flow rate through the core, the speed of the RIPS is adjusted, either together in the gang mode or individually by commands from the RFC System to the ASDs controllers of the individual RIPS. The RIPS can be driven to operate anywhere between 30 to 100% of rated speed with the variable voltage, variable frequency power source supplied by the ASDs. Due to the low rotating inertia of the RIPS, which are coupled with the solid-state ASDs, the RIP can respond quickly to load transients and operator demands.

**Turbine Control System**

The Turbine Control System is a redundant process control system: in Manual, the operator can adjust the turbine load set; in Automatic, this function is provided by the APR. Only the operator can switch the turbine controller to Automatic, but either the operator or the APR can switch the turbine controller to Manual.

The turbine generator uses a digital monitoring and control system which, in coordination with the turbine SBPC System, controls the turbine speed, load, and flow for startup and normal operations. The control system operates the turbine stop valves, control valves, and combined intermediate valves. The turbine control system also provides automation functions like sequencing the appropriate turbine support systems and controlling turbine roll, synchronization of the main generator and initial loading.

Non-redundant turbine-generator supervisory instrumentation is provided for operational analysis and malfunction diagnosis. Automatic control functions are programmed to protect the turbine-generator from overspeed and to trip it; the trip logic for all but bearing vibration is at least two-out-of-three logic.

**Other Control Functions**

The following control functions are dual redundant. The software functions are deliberately spread through many controllers to facilitate verification and validation (V&V), quality assurance and initial construction setup.

**Power Generation Control System:** The Power Generation Control System (PGCS) is a subset of the process computer function implemented as a dual redundant controller. The APR System provides automation of the reactor control functions and the PGCS provides other Nuclear Island and BOP automation functions by providing the setpoints of lower level controllers and commands to various BOP equipment for normal plant startup, shutdown, and power range operations.

The PGCS works in parallel but is not synchronous with the APR System; one of the design features of the PGCS is that it contains no control algorithms but instead issues only supervisorial commands to the BOP
controllers and systems which otherwise remain responsible for their own availability and operation. PGCS contains the algorithms for the automated control sequences associated with plant startup, shutdown, and power range operations.

The plant operator interfaces with the PGCS through a series of breakpoint controls to initiate automated sequences from the operator control console. In general, plant automation is broken down into logical steps and sequences like heatup or turbine roll which the operator can initiate and which then proceed to completion and halt until the operator initiates the next sequence. For selected operations that are not automated or that are contained within 1E systems, the system prompts the operator to perform such operations. A semiautomatic mode is also provided where the PGCS provides only guidance messages to the operator but does not actually operate plant equipment.

**Rod Control and Information System:** The Rod Control and Information System (RCIS) is a dual redundant process control system: in Manual, the operator can select and position the control rods manually, either one at a time or in a gang mode. If the RCIS is in Semi-Automatic mode, the operator needs to only give permission to start and stop control rod motion and the RCIS will insert or withdraw the control rods following a predefined control rod sequence. If the RCIS is in Automatic mode, it responds to commands for rod insertion or withdrawal from the APR; this will also follow a predefined control rod sequence. Only the operator can switch the RCIS controllers to Automatic, but either the operator or the APR can switch the RCIS to Manual.

The RCIS provides the means by which control rods are positioned from the control room for power control. The RCIS controls changes in the core reactivity, power, and power shape via the FMCRD mechanisms which move the neutron absorbing control rods within the core. For normal power generation, the control rods are moved by their electric motors in relatively fine steps; for reactor scrams, the control rods are inserted both hydraulically and electrically. For operation in the normal gang movement mode, one gang of control rods can be manipulated at a time. The system includes the logic that restricts control rod movement (rod block) under certain conditions as a backup to procedural controls.

The RCIS contains as a subsystem, the ATLM (automatic thermal limit monitor), which provides an on-line measurement of plant thermal limits from the LPRMs and periodic process computer updates. The ATLM will automatically block rod motion if it detects operation near Tech Spec thermal limits.

Another RCIS subsystem is the Rod Worth Minimizer (RWM) Subsystem, which forces compliance to the defined control rod sequencing rules by independently issuing rod blocks should a high worth rod pattern develop.

The RCIS and the scram timing panel also support automatic measurement of control rod Tech Spec scram speeds for either planned or unplanned scrams.

**Process Radiation Monitoring System:** The Process Radiation Monitoring System (PRM) monitors and controls radioactivity in process and effluent streams and activates appropriate alarms, isolations, and controls. The PRM System indicates and records radiation levels associated with selected plant liquid and gaseous process streams and effluent paths leading to the environment. All effluents from the plant, which are potentially radioactive, are monitored both locally and in the control room. These include the following:
- Main steamline tunnel area.
- Reactor Building ventilation exhaust (including fuel handling area).
- Control Building air intake supply.
- Drywell sumps liquid discharge.
- Radwaste liquid discharge.
- Offgas discharge (pretreated and post-treated).
- Gland steam condenser offgas discharge.
- Plant stack discharge.
- Turbine Building vent exhaust.
- Radwaste Building ventilation exhaust.

**Area Radiation Monitoring System:** The Area Radiation Monitoring (ARM) System provides operating personnel with a record and indication, in the main control room, of gamma radiation levels at selected locations within the various plant buildings and gives warning of excessive gamma radiation levels in areas where nuclear fuel is stored or handled.

The ARM System consists of gamma-sensitive detectors, digital radiation monitors, auxiliary units, and local audible warning devices. System recording, like all process functions, is done by the process computer. The detector signals are digitized and multiplexed for transmission to the radiation monitors and to the main control room. Each local monitor has two adjustable trip circuits for alarm initiation. Auxiliary units are provided in local areas for radiation indication and for initiating the sonic alarms on abnormal levels. Radiation detectors are located in various areas of the plant to provide early detection and warning for personnel protection.

**Containment Atmospheric Monitoring System:** The Containment Atmospheric Monitoring (CAM) System measures alarms and records radiation levels and the hydrogen and oxygen concentration in the primary containment under post-accident conditions. It is automatically put in service upon detection of LOCA conditions.

The CAM System provides normal plant shutdown and post-accident monitoring for gross gamma radiation and hydrogen/oxygen concentration levels in both drywell and suppression chamber. The CAM System consists of two divisions which are redundantly designed so that failure of any single element will not interfere with the system operation. Electrical separation is maintained between the redundant divisions. All components used for safety-related functions are qualified for the environment in which they are located. The system can be actuated manually by the operator, or automatically initiated by a LOCA signal (high drywell pressure or low reactor water level). The CAM System does not actuate nor interface with any other safety-related systems.

**Process Computer:** On-line networked computers are provided to monitor and log process variables and make certain analytical computations. The process computer cabinets are really several redundant computer functions that may, in fact, be several physical computers. These functions include:

- Most non-1E display support.
- Core three-dimensional power monitoring (3D Monicore).
- Balance-of-plant (BOP) performance calculations.
- Sequence of events.
- Manual and automatic logging.

**Remote Shutdown System:** In the event that the control room becomes inaccessible, the reactor can be brought from power range operation to cold shutdown conditions by use of controls and equipment that are available outside the control room. Manual transfer devices are provided which override control outputs from the main control room and transfer controls to remote shutdown control. Control signals
Instrumentation and controls on the remote shutdown panels include the following:

- Controls and indications for operation of one HPCF loop to control reactor water level.
- Controls and indications for operation of two RHR loops to support shutdown cooling once reactor pressure has been reduced, and suppression pool cooling to control suppression pool temperature which may rise due to SRV operation.
- Controls to operate three SRVs for maintaining and reducing reactor pressure.
- Indications of reactor vessel water level and pressure, and suppression pool temperature and level.
- Controls and indications for operation of the RBCW and RBSW Systems.
- Controls and indications for electrical power distribution.
- Controls for manually starting and stopping two of the emergency diesel generators.

Main Control Room

The key elements of the ABWR main control room (MCR) design (Figure 7-2) are (1) the compact main control console (MCC) for primary operator control and monitoring functions, and (2) the integrated wide display panel, which presents an overview of the plant status that is clearly visible to the entire operating crew. Each of the units incorporates advanced man-machine interface technologies to achieve enhanced operability and improved reliability. Human factors engineering principles have been incorporated into the design of the MCR panels and into the overall MCR arrangement.

Total plant control is achieved from the Main Control Console (MCC) for all phases of operation. The console design incorporates touch-screen cathode ray tubes (CRTs), flat panel display devices, and a limited number of hard switches as the primary operator interface devices. The CRTs and flat panel displays are driven by the Plant Computer System (PCS). The main control console has a low profile so that the operators can perform their duties from a seated position.

The Wide Display Panel (WDP) provides summary information on plant status parameters and key alarms to the operators, supervisors, and other technical support personnel in the MCR. The WDP is located immediately in front of the operators when they are at their normal work station seated at the main control console. This WDP includes a fixed mimic display, an approximately 100-inch large variable display, top-level plant alarms, detailed system level alarms, and touch-control flat panel displays. The WDP incorporates the Safety Parameter Display System (SPDS) as part of the plant status summary information.
The MCR also includes a supervisors’ console which has CRTs for monitoring plant status. The supervisors’ console is set back directly behind the operators in a position which ensures that a clear view of all operating activities is available to the supervisors.

**Main Control Console**

The Main Control Console (MCC) provides the displays and controls necessary to maintain and operate the plant during normal, abnormal, and emergency conditions. This console is used in conjunction with the information provided on the vertical surface of the Wide Display Panel.

The MCC comprises the work stations for the two control room plant operators, and is configured such that the operators are provided with controls and monitoring information necessary to perform assigned tasks and allows the operators to view all of the WDP from their seated position at the MCC. The console is configured in a truncated “V” shape. The normal plant control and monitoring functions are performed in the central area of the console, while the safety-related Nuclear Steam Supply (NSS) functions are located on the left-hand side and the balance-of-plant (BOP) functions are located on the right-hand side.
A primary means for operator control and monitoring is provided by the color-graphic, touch-screen CRTs mounted on the MCC. The CRT displays are driven by the Process Computer. There are many types of display formats which can be shown on the CRTs, including summary plant status displays, trend plots, system status formats, alarm summaries, plant operating procedure guidance displays, and plant automation guidance displays. Although each CRT is assigned a default display for a given operating condition, the operators have the flexibility to select any display on each of the seven touch-screen CRTs. This multi-redundant display capability ensures continued normal plant operation in the event of a failure of one or more of the CRTs.

The system status displays provide information on individual plant systems. The touch screens on the CRTs provide direct control for nonsafety-related systems at the system component level. The application of this touch screen capability for control of nonsafety systems, along with the incorporation of automated plant operation features, was a major factor in reducing the size of the MCC to its present compact dimensions.

The alarm summary displays on the MCC CRTs support the operators’ decision-making process. The presentation of alarms employs optimization techniques designed to prioritize alarms and filter or suppress nuisance alarms which require no specific operator action. An example of this alarm processing would be the suppression of the audible alarms associated with the Reactor Protection System during the period of a reactor scram.

The ABWR MCC also provides flat panel displays (e.g., electroluminescent, plasma, or liquid crystal displays) for extended monitoring and control capability. These touch-control flat panel displays are driven by microprocessor-based controllers which are completely diverse from the controllers. This diversity of displays and controls in the console design enables continued plant operation even in the unlikely event of a total loss of all CRTs.

The flat panel display devices are used to support both safety and nonsafety system monitoring and control functions. The flat panel displays which are used as safety-system interfaces are fully qualified to Class 1E standards. The safety-related flat displays are located on the left side of the MCC. For control and monitoring of the three redundant and independent divisions of the Emergency Core Cooling System (ECCS) and reactor primary containment heat removal, two flat panel display devices are provided in each of those divisions. One flat panel display is typically used for monitoring and the other is used for control. Flat panel displays for monitoring and control of major nonsafety systems are also located on the MCC.

In addition to the touch-screen CRTs and flat panel display devices described above, the MCC is equipped with dedicated, “hard” switches located on the horizontal desk surfaces of the console. Some of these hard switches are the sequence master control push-button switches used for initiating automation sequences for normal plant operations and for changing system operating modes. Other hard switches are hard-wired directly to the actuated equipment (for absolute assurance of function) and provide backup capability for initiating safety system functions and key plant protection features, such as manual scram, SLCS initiation and turbine trip functions.

A limited number of dedicated operator interfaces are provided in the center of the MCC for key systems such as the Rod Control and
Information System. These dedicated interfaces contain hard switches and indicators to provide quick and convenient access to key system interfaces under all plant conditions.

Wide Display Panel
The Wide Display Panel (WDP) is a large vertical board which provides information on overall plant status with real-time data during all phases of plant operation. The information presented on the WDP is clearly visible from the Main Control Console, the supervisors’ console, and other positions in the control room where support personnel may be stationed. The WDP provides a fixed mimic display, a large (~100-inch diagonal) variable display. Spatially dedicated alarm windows for critical, plant-level alarms are also provided on the left-hand side WDP. Spatially-dedicated detailed system level alarms are located above their respective systems on the fixed-mimic display. At the base of the WDP, there are multiple flat display devices for individual system surveillance, monitoring and control.

The fixed mimic display is arranged on two, adjacent, upright panels which comprise the center and right-hand sections of the WDP. The two panels are driven by independent microprocessor-based controllers. The center panel is seismically qualified and is driven by safety-related, Class 1E microprocessors. Information on this panel includes the critical plant parameters required for a safety parameter display system and Type A post-accident monitoring indications. Specific information displayed on this panel includes the status of the core cooling systems, reactor pressure vessel and core parameters, containment and radiation parameters, and the status of safety-related equipment. The information displayed completely satisfies the requirement for safety parameter and post-accident monitoring without the need for any other display equipment. The right panel of the fixed mimic display contains information on the BOP power generation cycle, such as the condensate and feedwater system, turbine/generator, and power transmission systems.

Also, within the area of the fixed mimic display, dedicated alarm windows are provided for important, plant-level alarms that affect plant availability or safety. Examples of the plant-level alarms include high reactor pressure, low reactor water level and high suppression pool temperature.

The large variable display is located on the right upright panel of the Wide Display Panel. The basic purpose of the large variable display is to provide information on important plant process parameters which supplements the overview information on the fixed mimic display. The information presented on the large variable display can be changed, depending on the plant operating conditions and the needs of the operating crew. Any display format available on the MCC CRTs can also be displayed on the large variable display. Examples of the full color graphic displays that can be shown on the variable display are the various CRT display formats which would be selected under plant emergency conditions.

Closed circuit TVs are provided which allow remote observation of equipment and operations in areas that are not normally accessible and of other critical activities such as fuel handling and maintenance tasks. Communication between the control room crew and other areas of the plant is enhanced with this visual feedback capability. These closed circuit TVs have high definition with color capability.

The touch-control flat displays located at the base of the WDP provide the capability for surveillance of systems and equipment during normal plant operation. In addition, these devices can be used for control and
monitoring of plant systems during maintenance and refueling outages and during periods when a portion of the MCC may be taken out of service for maintenance. These flat displays are driven by microprocessor-based controllers which are separate from the plant Process Computer System.

Plant Automation

The ABWR design incorporates extensive automation of the operator actions which are required during a normal plant startup, shutdown and power range maneuvers. The automation features adopted for the ABWR provide for enhanced operability and improved capacity factor relative to conventional BWR designs. However, the extent of automation implemented in the ABWR has been carefully selected to ensure that the primary control of plant operations remains with the operators. The operators remain fully cognizant of the plant status and can intervene in the operation at any time, if necessary.

The ABWR automation design provides for three distinct automation modes: Automatic, Semi-Automatic, and Manual. In the Automatic mode, the operator initiates automated sequences of operation from the MCC. Periodic breakpoints are inserted in the automated sequence which require operator verification of plant status and manual actuation of a breakpoint control push-button to allow the automated sequence to continue. When a change in the status of a safety system is required, automatic prompts are provided to the operator and the automation is suspended until the operator manually completes the necessary safety system status change.

In the Semi-Automatic mode of operation, the progression of normal plant operations is monitored and automated prompts and guidance are provided to the operator; however, all actual control actions must be performed manually by the operator. In the Manual mode of operation, no automated operator guidance or prompts are provided. The operator can completely stop an automatic operation at any time by selecting the Manual mode of operation.

Operation

The ABWR control room design provides the capability for a single operator to perform all required control and monitoring functions during normal plant operations as well as under emergency plant conditions. One-man operation is possible due to implementation of several key design features: (1) the Wide Display Panel for overall plant monitoring; (2) plant-level automation; (3) system-level automation; (4) the compact MCC design; and (5) implementation of operator guidance functions which display appropriate operating sequences on the main control panel CRTs. The role of the operator will primarily be one of monitoring the status of individual systems and the overall plant and the progress of automation sequences, rather than the traditional role of monitoring and controlling individual system equipment. However, to foster a team approach in plant operation and to maintain operator vigilance, the operating staff organization for the reference ABWR control room design is based upon having two operators normally stationed at the control console.

During emergency plant operations, plant-level automation is automatically suspended, but system level automation is available. One operator
would be responsible for the NSS systems and the other for the BOP systems, with the supervisors providing direction and guidance. Again, system-level automation allows for simplified execution of both the safety and nonsafety system operations. In lieu of system-level automation, direct manual control of individual system equipment is available on the touch-screen CRTs and flat displays.