7.7 Control Systems Not Required for Safety

The information in this section of the reference ABWR DCD, including all subsections and figures, is incorporated by reference with the following departures and supplements.

STD DEP T1 2.2-1 (Figure 7.7-7)

~~STD DEP T1 2.12-1~~

STD DEP T1 3.4-1 (Figures 7.7-4, 7.7-5, 7.7-8, 7.7-11)

STD DEP 5.4-1 (Figures 7.7-8, 7.7-9)

STD DEP 7.7-1

STD DEP 7.7-2

STD DEP 7.7-3

STD DEP 7.7-4 (Figure 7.7-7)

STD DEP 7.7-5

STD DEP 7.7-6

STD DEP 7.7-7 (Figures 7.7-2, 7.7-3)

STD DEP 7.7-8

STD DEP 7.7-9

STD DEP 7.7-10

STD DEP 7.7-11

STD DEP 7.7-12

STD DEP 7.7-13

STD DEP 7.7-14

STD DEP 7.7-15

STD DEP 7.7-16

STD DEP 7.7-17

STD DEP 7.7-18

STD DEP 7.7-19

STD DEP 7.7-20 (Figure 7.7-5)

STD DEP 7.7-21 (Figure 7.7-8)

STD DEP 7.7-22

STD DEP 7.7-23

STD DEP 7.7-24 (Figures 7.7-12, 7.7-13)

STD DEP 7.7-25 (Figure 7.7-14)

STD DEP 7.7-27 (Table 7.7-1)

STD DEP 9.5-3

STD DEP 8.3-1

STD DEP Admin

7.7.1.1 Nuclear Boiler System—Reactor Vessel Instrumentation

STD DEP 7.7-1

STD DEP 7.7-2

STD DEP 7.7-3

STD DEP Admin

(6) Reactor Vessel Water Level

The concern that non-condensable gasses may build-up in the water column in the reactor vessel reference leg water level instrument lines, i.e., the reactor vessel instrument lines at the elevation near the main steam line nozzles, has been addressed by continually flushing these instrument lines with water supplied by the Control Rod Drive (CRD) System for those instrument lines with a condensing chamber. This applies to (a) through (e) above.

(10) Safety/Relief Valve Seal Leak Detection

Thermocouples are located in the discharge exhaust pipe of the safety/relief valve. The temperature signal goes to a ~~multipoint recorder with an~~ historian function. An *alarm ~~and~~ will be activated by any temperature in excess of a set temperature signaling that one of the SRV seats has started to leak.*

(11) Other Instruments

The feedwater temperature is measured and transmitted to the main control room.

~~*The feedwater turbidity is monitored and the signal is transmitted to the main control room for recording.*~~

(15) Reactor Operator Information

The information that the operator has at his disposal from the instrumentation discussed in this subsection is discussed below:

(b) The core plate differential pressure provides a signal to the ~~*process computer*~~ historian function*.*

(f) The discharge temperatures of all the safety/relief valves are shown on a ~~*multipoint recorder*~~ historian function *in the control room. Any temperature point that has exceeded the trip setting will turn on an annunciator, indicating that a SRV seat has started to leak.*

(g) ~~*Feedwater turbidity is recorded in the main control room. The recorder will turn on an annunciator in the main control room for either a high or low signal.*~~Not Used

(16) Setpoints

The annunciator alarm setpoints for the reactor head seal leak detection and *SRV seat leak detection*~~*, and feedwater corrosion product (turbidity) monitor*~~ *are set so the sensitivity to the variable being measured will provide adequate information.*

(b) Level transmitters and trip actuators for initiating containment or vessel isolation are discussed in Subsection ~~*7.3.1.2*~~ 7.3.1.1.2*.*

7.7.1.2 Rod Control and Information System—Instrumentation and Controls

STD DEP 7.7-4

STD DEP 7.7-5

STD DEP 7.7-7

STD DEP 7.7-8

STD DEP 7.7-9

STD DEP T1 3.4-1

(1) System Identification

The main objective of the Rod Control and Information System (RCIS) is to provide the capability to control the fine motion control rod drive (FMCRD) motors of the Control Rod Drive (CRD) System (explained in Sections 4.6.1 *and 4.6.2) to permit changes in core reactivity so that reactor power level and power distribution can be controlled.*

The RCIS performs the following functions:

(a) *Controls changes to the core reactivity, and thereby reactor power, by moving neutron absorbing control rods within the reactor core as initiated by:*

   (i) *The plant operator, when the RCIS is placed in manual or semiautomatic mode of operation*

   (ii) ~~*The Power Generation and Control System (PGCS) when the PGCS, automatic power regulator (APR), and RCIS are in automatic mode*~~ The automatic rod movement mode of the automatic power regulator (APR), when RCIS is placed in the automatic mode of operation.

(b) ~~*Provides summary display information for the plant operator, indicative of aggregated control rod positions, status of the control rods, and the FMCRDs on the RCIS dedicated operator interface (DOI).*~~ Displays summary information for the plant operator about positions of the control rods in the core and status of the FMCRDs and RCIS. This summary information is provided by a RCIS dedicated operator interface (DOI) on the main control panel. There are dual-redundant measurements of the absolute rod position during normal FMCRD conditions. If one position detector fails for an individual FMCRD, the failed position detector can be bypassed and the unit can continue to operate without power restrictions.

(c) *Provides FMCRD status and control rod position and status data to other plant systems which require such data (e.g., the ~~plant process computer system).~~ ~~Plant Computer Function~~* plant computer function).

(f) *Provides the capability for insertion of all rods by an alternate and diverse method, based on receiving ~~a~~ command* signals *from the Recirculation Flow Control System (RFCS). This function is called the alternate rod insertion (ARI) function.*

(g) *Provides for insertion of selected control rods for core thermal-hydraulic stability control or for mitigation of a loss of feedwater heating event; called the selected control rod run-in (SCRRI) function, based on receiving SCRRI command* signals *from the RFCS.*

(2) *System Description*

The RCIS is a dual redundant system consisting of two independent channels for normal monitoring of control rod positions and executing control rod movement commands. ~~Each channel receives separate input signals and~~

~~*both channels perform the same function. Disagreement between the two channels results in rod motion inhibit.*~~ Under normal conditions, each channel receives separate input signals and both channels perform the same functions. The outputs of the two channels are continuously compared. For normal functions of enforcing and monitoring control rod positions and emergency rod insertion, the outputs of the two channels must be in agreement. Any sustained disagreement between the two channels would result in a rod block. However, when the conditions for generating a rod block signal in a single channel are satisfied, that channel alone can issue a rod block signal. For the FMCRD emergency insertion functions (~~Scram-Follow~~, scram-follow, ARI, SCRRI), 3-out-of-3 logic is used in the inverter control logic with the additional input signal coming from the associated emergency rod insertion panels. An automatic single channel bypass feature (only activated when an emergency insertion function is activated) is also provided to assure high availability for the emergency insertion functions when a single channel failure condition exists.

Failure or malfunction of RCIS has no impact on the hydraulic scram function of CRD. The circuitry for normal insertion and withdrawal of control rods in RCIS is completely independent of the Reactor Trip and Isolation System (RTIS) circuitry controlling the scram valves. This separation of the RPS scram function of the RTIS and RCIS normal rod control functions prevents failure in the RCIS circuitry from affecting the scram circuitry.

The RCIS consists of several different types of cabinets (or panels), which contain special electronic/electrical equipment modules for performing RCIS logic located in the ~~reactor building and control building and a dedicated operator interface (DOI) on the main control panel in the main control room~~ Reactor Building and Control Building and a DOI on the Main Control Panel in the Main Control Room(MCR). The RCIS DOI provides summary information to the plant operator with respect to control rod positions, FMCRD and RCIS status and hydraulic control unit (HCU) status. Controls are also provided for performing normal rod movement functions, bypassing of major RCIS subsystems, performing CRD surveillance tests, and resetting RCIS trips and most abnormal status conditions. There are nine types of electronic/electrical cabinets/panels that perform logic functions of the RCIS:

~~*The RCIS consists of several different types of cabinets (or panels), which contain special electronic/electrical equipment modules and a dedicated operator interface on the main control panel in the control room. There are four types of electronic/electrical cabinets that make up the RCIS:*~~

(a) *Rods Action Control* ~~*Cabinet (RACC)*~~ Subsystem (RACS) Cabinets

~~*There are two RACCs consisting of RACC-Channel A and RACC-Channel B, that provide for a dual redundant architecture. Each RACC subsystem consists of three main functional subsystems, as follows:*~~

~~*(i) Automated Thermal Limit Monitor (ATLM)*~~

~~*(ii) Rod Worth Minimizer (RWM)*~~

~~*(iii) Rod Action and Position Information (RAPI)*~~

There are two types of cabinets in the back-panel area referred to as the RACS, consisting of rod action and positioning information (RAPI) panels and an ATLM/RWM panel, which provide for a dual-redundant architecture. The RAPI panels consist of a RAPI-A panel and RAPI-B panel with the channel A logic in the RAPI-A panel and the channel B logic in the RAPI-B panel. In addition, the RAPI-A panel includes the RAPI DOI, which displays the same information that is available on the RCIS DOI in the MCR. The RAPI DOI also serves as a backup for the RCIS DOI control capabilities, should the RCIS DOI become unavailable. A hard switch located in the RAPI-A panel is used to change the selection of DOI control operation capability between the RCIS DOI and the RAPI DOI (i.e. only one of these DOIs can be selected for control capability at any given time).

There is also an dedicated RCIS MUX Monitoring feature located in the RAPI panels for providing direct hardwired outputs to the reactor internal pump (RIP) adjustable speed drives (ASDs) of RFCS for runback initiation upon detection of an all FMCRD run-in (i.e. scram-follow or ARI function) command condition.

The ATLM/RWM panel contains two channels of logic for the automatic thermal limit monitor (ATLM), the rod worth minimizer (RWM) and the RAPI signal interface units (SIUs).

(b) *Remote Communication Cabinets (RCC)*

~~*The RCCs contain a dual channel file control module (FCM) that interfaces with the rod server modules (RSMs) that are contained in the same cabinets, and RAPI in the control room.*~~ The RCCs are located in sets of 4 RCCs that each contain a dual channel file control module (FCM). The FCMs interface with the rod server modules (RSMs) that are contained in the same set of cabinets, and interface with the RAPI subsystems in the MCR, via the dedicated RCIS multiplexing network. Each RSM is composed of two Rod Server Processing Channels (RSPCs A and B) so that there is a dual-redundant logic design for each RSM and associated Synchro-to-Digital Converters (SDCs A and B) that provide for conversion of the Synchro A and Synchro B analog signals into a two independent digital representations of the absolute position of the corresponding FMCRD. Both RSPCs receive the digital representations from both SDCs for use in the RSPC control and monitoring logic.

(c) *Fine Motion Driver Cabinets (FMDC)*

The FMDCs consist of several inverter controllers (ICs) and stepping motor driver modules (SMDMs). ~~Each SMDM contains an electronic converter/inverter to convert incoming three-phase AC power into DC and inverts the DC power to variable voltage/frequency power pulses for the FMCRD stepping motor.~~ Each SMDM contains an electronic converter/inverter to convert incoming three-phase AC power into DC and invert the DC power to variable voltage/frequency output power provided to the FMCRD stepping motor to accomplish rod movement. The IC includes logic to process rod movement commands received from the associated RSPCs in a RCC. Also, IC and SMDM status signals are also provided to the associated RSPCs. Each IC also receives a separate discrete input signal from a Emergency Rod Insertion Panel that is used in the IC logic for providing the emergency rod insertion movement functions (i.e. scram-follow, ARI or SCRRI).

(d) *Rod Brake Controller Cabinets (RBCC)*

The RBCCs contain electrical and/or electronic logic and other associated electrical equipment for the proper operation of the FMCRD brakes. Signals for brake disengagement or engagement are received from the associated rod server module, and the brake controller logic provides two separate (channel A and channel B) brake status signals to its corresponding rod server module.

(e) Emergency Rod Insertion Control Panel

The emergency rod insertion control panel is located in the back-panel area of the MCR. It serves as an additional logic panel to contain relays (or solid-state equivalent) hardware needed to transmit discrete output signals to the emergency rod insertion panels in the Reactor Building (RB). The discrete output signals are activated based upon input signals received from the RPS related portion of the ~~Reactor Trip and Isolation System (RTIS)~~ RTIS panels that indicate a scram-follow function is active or based upon input signals received from the RFCS that indicate a ARI function or SCRRI function is active or by input signals from the two manual SCRRI pushbuttons on the Main Control Room Panel (MCRP).

(f) Emergency Rod Insertion Panels

The emergency rod insertion panels are located in the reactor building and provide discrete output signals to the inverter controllers in the

FMDCs. The discrete output signals are activated based upon input signals received from the emergency rod insertion control panel in the MCR and indicate a scram-follow function, an ARI function or SCRRI function is active. The emergency insertion condition is considered active if any one of these three rod insertion functions is active.

(g) Scram Time Recording Panels (STRPs)

The scram time recording panels (STRPs), located in the RB, monitor the FMCRD position reed switch status using reed switch sensor modules (RSSMs) and communicate this information to the RAPI via the dedicated RCIS multiplexing network. Also, the STRPs automatically record and time tag FMCRD scram timing position reed switch status changes either: 1) after initiation of an individual HCU scram test at the RPS Scram Time Test Panel, or 2) after a full-core reactor scram has been initiated. The recorded scram timing data can be transmitted to the STRAP in the MCR back-panel

(h) Scram Time Recording and Analysis Panel (STRAP)

The STRAP, located in the MCR back-panel area, receives scram timing position information from the STRPs which can be used for comparing the recorded scram timing performance results to the applicable Technical Specification requirements. This information can also be transmitted to the Plant Computer Function (PCF) for further data analysis and archiving.

(i) Rod Action and Position Information (RAPI) Auxiliary Panels

RAPI Auxiliary Panels, located in the Reactor Building, provide output signals to open a purge water valve whenever either FMCRD associated with the corresponding HCU receives an insertion command from RAPI subsystem. These panels also monitor scram valve position status as well as HCU accumulator water pressure and level status (i.e. normal or abnormal). Communication of this information to and from the RAPI subsystem is achieved via the non-essential Plant Data Network (PDN) equipment. Two of the nonsafety Remote Digital Logic Controller (RDLC) panels are used as the RAPI auxiliary panels.

(3) RCIS Multiplexing Network

~~*The RCIS multiplexing network consists of two independent channels (A and B) of fiber-optic communication links between the RACCs (channels A and B), and the dual channel file control modules located in the remote communication cabinets.*~~

~~*The plant essential multiplexing network interfaces with FMCRD dual redundant separation switches (A/B) and provides the appropriate status signals to the RACCs to be used in the RCIS logic for initiating rod block*~~

~~*signals if a separation occurs. The essential multiplexing network is not part of the RCIS.*~~ The dedicated RCIS multiplexing network consists of two separate channels. Fiber-optic communication links are used in this dedicated multiplexing network to handle communication between the RACS and the RSPCs in the RCCs (via the FCMs), communication between the STRPs and the RACS, and communication between the STRPs and the STRAP. Communication between the RAPI auxiliary panels (for HCU purge water valve control and HCU status monitoring) and the RAPI channels is achieved by the Plant Data Network (PDN) of the nonsafety Plant Information and Control System (PICS) equipment, not by the dedicated RCIS multiplexing network.

The Data Communication Function (DCF) of the ESF Logic and Control System (ELCS) interfaces with FMCRD dual redundant separation switches (A and B) and provides the appropriate status signals to the RACS Cabinets to be used in the RCIS logic for initiating rod block signals of the appropriate FMCRD if a separation occurs. The DCF of the ELCS equipment provides these signals to the RAPI SIUs of the RCIS via associated datalink interfaces of the Plant Data Network (PDN). The DCF of the ELCS equipment and the PDN equipment are not part of the RCIS. Each RAPI SIU transmits these status signals to the associated RAPI channel for use in the RAPI rod block logic.

(4) Classification

The RCIS is not classified as a safety-related system, as it has a control design basis only and is not required for the safe and orderly shutdown of the plant. A failure of the RCIS will not result in gross fuel damage. The rod block function of the RCIS, however, is important in limiting the consequences of a rod withdrawal error during normal plant operation. An abnormal operating transient that might result in local fuel damage is prevented by the rod block function of the RCIS.

The RCIS is single-failure proof with high reliability and availability. In accordance with the non-safety-related system application procedure section of the plant general system application requirement document, the RCIS is classified as a non-safety-related, Class 3, power generation system.

(5) Power Sources

(a) Normal

~~*The incoming three-phase AC power for the stepping motor driver modules and the rod brake controller power supplies is derived from the Division I Class 1E AC power bus.*~~ The incoming three-phase AC power for the stepping motor driver modules and inverter controllers in the FMDCs, for the rod brake controller power supplies in the RBCCs, and for power required by the emergency rod insertion panels and the emergency rod insertion control panel is derived from the Division I

Class 1E AC power bus. The FMCRD power distribution panels distribute the power normally derived from the Division I Class 1E AC power bus to the associated FMCDs, RBCCs, and emergency rod insertion panels. Excitation power required for logic in the emergency rod insertion control panel is provided directly from the emergency rod insertion panels. The power distribution design provides three distinct electrical groups of power. The distribution of these three groups of electrical power to FMCRDs is such that approximately one third of the FMCRDs belong to each group. The distribution of FMCRDs in each electrical group is scattered throughout the reactor core such that complete insertion of the FMCRDs in any two of the three electrical groups to the full-in position will assure the reactor reaches hot shutdown conditions. This approach provides increased reliability for the capability of the motor run-in ARI function, if activated, to assure the reactor achieves hot shutdown conditions.

The power for all RCIS equipment, except as noted above and below for the non-critical Scram Time Recording and Analysis Panel (STRAP) equipment, *is derived from two separate, nondivisional uninterruptible AC power sources (UPS) (Subsection 8.3.1 and 8.3.1.1.4).*

~~*Each of the two RACCs has redundant auxiliary electrical power supplies and cooling fans, as required, for proper operation of their associated subsystems.*~~

~~*The RCC contains the necessary redundant power supplies for channels A and B of the rod server modules, file control modules, electrical equipment, and cooling fans (if required).*~~ For the RCIS controller equipment that derives power from the two separate, non-divisional uninterruptible AC power sources, loss of only one power source does not impact the other power source and does not impact the operation of the associated RCIS controller equipment.

The power for the STRAP equipment is derived from a single non-divisional uninterruptible AC power source. Operation of the STRAP is not required in order for achieving automatic recording of scram timing performance information by the separate STRPs. The STRAP equipment operation is only required for obtaining the recorded scram timing performance information from the STRPs for further review and evaluation. Therefore, there is no need for the STRAP equipment of the RCIS to have redundant power sources.

(6) RCIS Scope

The RCIS scope includes the following equipment:

(a) All the electrical/electronic equipment contained in the ~~*RACCs, the RCCs, the FMDCs, and the RBCCs.*~~ RACS cabinets, the RCCs, the

FMDCs, the RBCCs, the STRPs, the STRAP, the emergency rod insertion panels and the emergency rod insertion control panel.

(b) *The* dedicated *RCIS multiplexing network equipment.*

(c) *The cross-channel communication link between the two RACS* ~~*channels*~~*.*

(d) *The dedicated RCIS operator's interface and the communication links from the equipment to this interface.*

(e) The FMCRD power distribution panels that provide for distribution of the incoming power from the three electrical groups that derive power from the Division I Class 1E Bus to the associated FMDCs, RBCCs, and emergency rod insertion panels.

The Control Rod Drive (CRD) System performs the following functions:

(d) *Provides for electromechanical insertion of selected control rods for core thermal/hydraulic stability control* or for mitigation of a loss of feedwater heating event*.*

7.7.1.2.1 Control Rod Drive Control System Interfaces

STD DEP 7.7-10

STD DEP T1 3.4-1

STD DEP T1 2.2-1

STD DEP 7.7-11

STD DEP 7.7-12

STD DEP 7.7-13

STD DEP 7.7-14

STD DEP 7.7-15

STD DEP 7.7-16

STD DEP Admin

(1) ~~*Introduction*~~ Single Rod Movement

When an operator selects a control rod for motion (Figure 7.7-3), the operator first selects the manual rod movement mode at the dedicated RCIS operator panel, by depressing the manual mode switch to place the RCIS in manual mode. Then the operator depresses the select pushbutton for either single rod movement or for ganged rod movement. The operator must then select a *specific rod (or a gang) to be moved ~~at the normal operational manual mode CRT display under the control of the Performance Monitoring and Control System (PMCS).~~* using the RCIS ~~Dedicated Operator Interface (DOI)~~ DOI on the main control room panel.

~~*A CRT display generated by PMC presents to the operator a full core array of all 205 control rods in addition to 52 local power range monitors (LPRMs) schematically as a group of boxes.*~~

~~*Each box represents a control rod containing the core coordinates and vertical rod position of that rod in white numbers on a black background. The vertical rod position information is normally not visible but becomes visible in response to actuation of various rod status and position requestor poke points. The core coordinates are always visible to the operator.*~~

~~*The CRT display*~~ The RCIS DOI *provides the operator with a capability to move a single rod or a ganged selection. For this discussion, the operator selects a single rod for withdrawal.* ~~*Four*~~ Three *rod movement commands* ~~*(poke points)*~~ *serve as a means to initiate all rod movements controlled from this display. They are identified as* ~~*"SINGLE ROD", "ROD GANG",*~~ *"STEP",* "NOTCH", and ~~*or*~~ *"CONTINUOUS"*~~*, and "IN" or "OUT"*~~*.*

When a "STEP" movement is performed for a selected single rod, the rod moves a nominal distance of 18.3 mm, with the associated rod step position value corresponding to the number of "STEP" withdrawal movements from the normal full-in position value. A rod at normal full-in position has an associated rod step position value of "0" steps withdrawn. A rod at normal full-out position has an associated rod step position value of "200" steps withdrawn, as the normal full-out position value is 3660 mm below the normal full-in position value of 0 mm.

When a "NOTCH" movement is performed for a selected single rod, the rod moves a nominal distance of 73.2 mm (i.e. 4 times the nominal step movement distance), with the restriction that the nominal stopping position for the "NOTCH" movement in terms of the distance withdrawn from the normal full-in position is an integer multiple of 73.2 mm. For example, if the selected rod were initially at a step position value of "6" steps withdrawn and one "NOTCH" withdrawal movement is performed, the selected rod would stop at a step position value of "8" steps withdrawn. If a "NOTCH" insert movement was then performed, the selected rod would stop at a step position value of "4" steps.

When a "CONTINUOUS" movement is performed for a selected single rod, the rod target stopping position value is continuously updated to an integer multiple of 18.3 mm as long as the operator continuously depresses the "withdraw" (or "insert") movement pushbutton. For example, if the selected rod were initially at a step position value of "8" steps withdrawn and a "CONTINUOUS" withdrawal movement is performed, the rod target stopping position value would be updated initially to "13" steps and then would be updated at a predetermined rate corresponding to the nominal continuous rod movement speed to "14", "15", etc. When the operator ceases to continuously depress the "withdraw" movement pushbutton in this case, the rod target stopping position value then no longer changes and the rod then moves to and stops upon reaching the applicable rod target stopping position value. A "CONTINUOUS" withdrawal movement would be similar, except the nominal rod target position value would decrease, instead of increase, while the "insert" movement pushbutton remains depressed.

Manual gang movements in the "STEP", "NOTCH" and "CONTINUOUS" movement modes would be accomplished in a similar manner to that described above; however, all operable rods of the selected gang move simultaneously during each movement operation. Also, normal manual rod movements are limited such that insertion beyond normal full-in or full-out position is not allowed unless RCIS is placed in a special test mode used for performing the CRD coupling check surveillance test.

~~*The operator first identifies the rod status from the rod status requestor information display, then makes a decision for either a withdrawal or an insertion of a control rod and sets up the display. The operator can request rod status information by actuating poke points on the CRT for the required rod.*~~ Then, to request the desired movement in the selected movement mode, the operator then activates "insert" or "withdraw" movement command by activating associated hard pushbutton switches located adjacent to the RCIS DOI on the main control panel.

The RAPI of the RCIS enforces rod blocks based upon signals internal or external to the system. These rod blocks can prevent desired rod movements or stop rod movements, if activated while normal rod movements are underway. This applies to both single rod movement and ganged rod movement modes.

The internal signals include those signals from the ATLM and RWM subsystems of RCIS. During normal RCIS operating conditions with no single channel bypass condition active, if there is any disagreement between the two channel logic of the subsystems of the RCIS, rod block signals are transmitted to the rod server module.

Examples of external input signals which could cause rod withdrawal blocks include rod block signals from the SRNM and APRM subsystems of the NMS; and FMCRD separation status signals received via associated datalink signal transmission to the RCIS. A complete list of rod block conditions is provided later in this section.

When normal rod movements are performed, the RAPI of the RCIS transmits the appropriate rod movement command signals to a dual channel file control module (FCM) located in a RCC. These rod movement command signals are received at the dual channel FCM and routed to rod server processing channel (RSPC) A and RSPC B of the rod server modules (RSMs) of the selected rod. The RSPCs transmit signals to channel A and channel B inputs for the corresponding inverter controller and transmit brake energization signals to the associated rod brake controller (RBC). The inverter controller then performs two-out-of-two voting on the command signals received and activates the proper power control signals to the SMDM to accomplish the FMCRD motor movement desired. The rod brake controller similarly performs two-out-of-two voting and mechanically releases the FMCRD brake just prior to the start of FMCRD motor movement and then re-engages the FMCRD brake after the normal rod movement is complete.

The SDCs of the RSM also interface with instrumentation of the FMCRD (a subsystem of the CRD), collects absolute rod position for the corresponding FMCRD by converting the Synchro A and Synchro B analog signals into digital data representing the FMCRD rod position for use in the associated RSPCs' logic and transmission (via the RCIS dedicated multiplexing network) to the RAPI logic and for the RAPI to transmit rod position data to other systems and subsystems and to the RCIS DOI.

(2) ~~*Withdrawal Cycle*~~ Not Used

~~*Following is a description of steps the operator performs at the RCIS dedicated operator's interface panel in selecting a rod for movement in the manual mode. The operator depresses the manual rod movement mode switch, which enables the RCIS for manual mode. The operator then verifies indicator/alarm status at the control panel for the following conditions:*~~

~~*(a) Reactor power level is below low power setpoint (LPSP).*~~

~~*(b) Manual rod movement indicator is illuminated.*~~

~~*(c) Verifies status of channel bypass conditions for RWM, RACS, and ATLM.*~~

~~*(d) RCIS trouble indicator is not illuminated.*~~

~~*(e) RCIS rod block status indicator is not illuminated.*~~

~~*(f) No audible alarms are present.*~~

~~*(g) Verify status of FMCRDs, for number rods, in "Full In" or "Full Out", "Latched Full In", or in an "Inoperable Bypass" condition.*~~

~~*Following is a description of steps an operator performs at the PMCS CRT display in selecting a single rod for continuous withdrawal with RCIS initially in manual mode. The detailed operations between the RCIS and the CRD System with specific response when various commands are transmitted are discussed.*~~

~~The setup at the CRT display for continuous withdrawal of a single control rod is as follows:~~

– ~~With top level CRT display, the operator requests the display of rod position data by actuating the rod position data poke points. The screen display changes to the RCIS normal operation/manual mode screen and shows all control rods and their positions. The screen display has other poke points for operating in the manual mode.~~

– ~~Under rod command display, if it shows “IN” and “STEP”, the operator can change the setup. A touch of “IN” poke point changes it to “OUT” and a touch of the “STEP” poke point changes it to “NOTCH” or to “CONTINUOUS” if “NOTCH” is touched. After proper selections are verified, the operator can then select the single rod by actuating the poke points for a “SINGLE ROD”. The operator verifies the selections by observing the status indicators. The operator then follows up by touching the display array box representing the rod (ROD SELECTED) to be moved.~~

~~This setup and action by the operator sends rod coordinates and other setup data to the PMCS. The data representing a single rod to be withdrawn is coded and stored in PMCS memory. The PMCS addresses the RCIS and sends the coded messages. The coded messages are received at the RCIS and stored in the Rod Position and Information Subsystem memory. The operator has an option to stop the rod movement by using the light pen. Touching the “SINGLE ROD” poke point a second time causes rod motion stop signals to be sent to the RCIS interface.~~

~~The information displayed to the operator at this time is the vertical position of the rod selected and it remains displayed until a new selection is made or the rod is deselected. The display array boxes representing all other rods in the core at this time dim to approximately half brightness.~~

~~The CRT display stores information in memory during the initial setup and transmits the information to the PMCS. When the operator initializes the last poke point (ROD SELECTED), the information stored in memory addressing the manual rod movement command signals in the PMCS are downloaded, as two independent signals, into channels A and B of the RCIS Rod Action and Position Information (RAPI) Subsystems.~~

~~The RCIS receives the two independent streams of data signals transmitted from the PMCS. The data are received and loaded into memory at the RAPI Subsystems (channel A/B). Both channel A/B are identical and perform the same functions. If there is a disagreement between A and B, the logic issues a rod motion inhibit signal. The operator has the capability to bypass certain functions in the manual mode.~~

~~*The PMCS also sends data to the Automated Thermal Limit Monitor (ATLM) of the RCIS on the calculated fuel thermal operating limits and corresponding initial LPRM values when an ATLM setpoint update is requested.*~~

~~*The logic of the ATLM subsystem issues a rod block signal that is used in the RAPI System logic to enforce a rod block that prevents violation of the fuel thermal operating limits. The ATLM interfaces with and receives signals from the RAPI Subsystem control logic for rod position data, other plant data and control signals.*~~

~~*The ATLM interfaces with Recirculation Flow Control (RFC) System and when it trips, a signal is sent to the RFCS which would cause a flow increase block.*~~

~~*The ATLM also receives input signals, based upon the LPRMs and APRMs of the Neutron Monitoring System (NMS). The RAPI Subsystem logic enforces ATLM rod block signals to the RCIS rod server modules located in the remote communication cabinets. Either channel of an ATLM subsystem can independently cause a rod withdrawal block.*~~

~~*The Rod Worth Minimizer (RWM) Subsystem logic issues rod block signals that are used in the Rod Action Control Subsystem rod block logic to assure that absolute rod pattern restrictions are not violated (e.g., the ganged withdrawal sequence restrictions). The logic of the RWM also receives rod position data and control status signals from the logic of the RAPI Subsystem and feeds back RWM status signals.*~~

~~*The RCIS responds to data signals originating from the CRT displays of the PMCS for operator requested rod withdrawal or insertion commands.*~~

~~*The RAPI Subsystem of the RCIS enforces rod blocks based upon signals internal or external to the system.*~~

~~*The internal signals include those signals from any of the above MRBM, ARBM, RWM. If there is any disagreement between the two channel logic of the RAC and/or the RAPI subsystems of the RCIS, rod block signals are transmitted to the rod server module and sent to the PMCS.*~~

~~*External input signals which could cause rod blocks originate from the SRNM and PRNM Subsystems or from the four divisions of the essential multiplexing system, reflecting the status of separation switches of the FMCRDs.*~~

~~*After performing the required validity checks within each subsystem and verifying that there are no rod block conditions existing, the RAPI Subsystem of the RCIS transmits command data signals (representing the selection of a single rod for withdrawal via the RCIS multiplexing system channel A and channel B) to a dual channel file control module (FCM) located in a remote communication cabinet. The selected rod command withdrawal signals are*~~

~~*received at the dual channel FCM and routed via channel A and channel B of the dual channel rod server modules (RSMs) and then are loaded into data buffers A and B of the inverter controller.*~~

~~*The FCM also interfaces with instrumentation of the FMCRD (a subsystem of the control rod drive system), collects data associated with the position reed switches and converts the synchro A and synchro B analog data into digital data for use in the RSM logic and transmission (via the RCIS multiplexing system) to the RAPI Subsystem logic.*~~

~~*The RSM, which consists of two rod server processing channels and one inverter controller, interfaces with the rod position instrumentation through its two processing channels and with the associated stepper motor driver module of the FMCRD System via the inverter controller. After receiving the proper command signals for a single rod to be withdrawn continuously, the inverter controller sends the proper motor power control information to the stepper motor driver module. In turn, the stepper motor driver module sends power pulses to the FMCRD motor.*~~

~~*Each of the rod server processing channels A and B also interfaces with the rod brake controller to provide brake disengagement and/or engagement signals required for normal rod movement. This is based on two-out-of-two logic where both channels A and B of the RSM should agree, and on one-out-of-two logic for ARI and scram following functions.*~~

~~*Each rod server processing channel of the RCIS obtains rod position status information signals via hardwired interfaces with its associated FMCRD synchro and obtains additional rod position and status information via hardwired interfaces with the reed switches included in the FMCRD. The reed switch based position signals are mainly used for recording FMCRD scram timing analysis data. Each rod server processing channel exchanges the continuous synchro position information and transmits the data to the RAPI Subsystem of the RCIS for usage in its logic. This data is also used to provide position status signals to the PMCS and to the RCIS dedicated interface panel.*~~

(3) ~~*Insert Cycle*~~ Not Used

~~*An operator action to insert a rod while in the manual mode would be processed in a similar manner as above, except that signals for an insertion of the rod would be decoded at the rod server module (RSM). On receiving the correct signals from the RSM, the stepper motor driver module would provide power pulses to the FMCRD motor such that control rod insertion would result.*~~

(4) ~~Ganged Rod Motion~~ Ganged Rod Movement

There are three means of controlling ganged rod ~~motion~~ movement. The RCIS provides for automatic mode, semi-automatic, and manual mode. ~~When in the automatic mode of operation, commands for reactivity insertion or withdrawal are received from the Automatic Power Regulator (APR) System.~~

The RCIS dedicated operator interface provides ~~switches for an~~ controls for activating the automatic, semi-automatic, or manual rod movement mode of operation. When the system is in semi-automatic mode, all rod movements are controlled by the operator. However, the RCIS, by using a database called reference rod pull sequence (RRPS) and keeping track of the current control rods' positions, prompts the operator to the selection of the next gang.

When the RCIS is in manual mode and ganged rod movement mode has also been chosen, if the operator selects a specific rod in a gang, the logic will automatically select all associated rods in that gang.

When the automatic mode is active, the RCIS responds to signals for rod movement request from the APR System. In this mode, the APR simply requests either reactivity insertion or withdrawal. The RCIS responds to this request by using the RRPS and the current rods positions and automatically selects and executes the withdrawal/insert commands for the next gang.

In order for the automatic rod movement feature of the RCIS to be active, the power generation control ~~system~~ function of PCF must be in the automatic mode, ~~the automatic power regulator system must be in the automatic mode, and the switch on the RCIS dedicated operator interface for automatic rod movement mode must be depressed. The operator has an option of discontinuing the automatic operation by placing either the PGCS/APR or RCIS mode switches back to manual mode,~~ the switch for automatic rod movement mode must have been activated, and there must be no abnormal conditions that prevent operation in the RCIS automatic mode. The operator has an option of discontinuing the automatic operation by placing either the RCIS mode switches back to manual mode or back to the semi-automatic mode.

(5) Ganged Withdrawal Sequence Restrictions

The RWM of the RCIS ensures adherence to certain ganged withdrawal sequence restrictions by generating a rod block signal for out-of-sequence rod withdrawals ~~when the reactor power is below the LPSP and the reactor mode switch is in STARTUP or RUN mode~~. These types of restrictions are specified as follows:

(a) *The ganged rod mode consists of one or two sets of fixed control rod gang assignments. The two sets of rod gang assignments correspond to sequences A and B of the ABWR ganged withdrawal ~~sequence, as specified in the reactivity control document.~~* sequence. For either sequence, when all of groups 1 through 4 control rods only have been withdrawn, there is a checkerboard pattern in the reactor core of the rods fully withdrawn as opposed to the rods still fully-inserted. For Sequence A, the center control rod in the core would still be fully-inserted. For Sequence B, the center control rod in the core would be fully-withdrawn.

(b) *The system allows up to 26-rod gangs, for control rods in rod groups 1, 2, 3, and 4, to be withdrawn simultaneously when the reactor is in the startup* or run *mode. These withdrawals are permitted only under the following conditions:*

(i) *Reactor power level is below the low power setpoint (LPSP).*

(ii) *A group 1, 2, 3, or 4 gang of rods is selected. Only one group at a time is allowed for normal rod movement.*

(iii) *Groups 1-4 may only be withdrawn before groups 5-10 are in the full-in position.*

(iv) *The other three groups (of groups 1-4) that are not selected must be either full-in or full-out. Groups 1-4 are withdrawn from the full-in position to the full-out position before another group is moved.*

(v) *The chosen alternative sequence for withdrawing the first four groups is consistent with one of the following allowable alternate sequences:*

(a) *(1, 2, 3, 4)*

(b) *(1, 2, 4, 3)*

(c) *(2, 1, 3, 4)*

(d) *(2, 1, 4, 3)*

(e) *(3, 4, 1, 2)*

(f) *(3, 4, 2, 1)*

(g) *(4, 3, 1, 2)*

(h) *(4, 3, 2, 1)*

No sequences other that those indicated above are allowed within the logic of the RCIS. The logic of the RCIS also ensures that, when single rod movements of rods in groups 1-4 are made, they are in accordance with the above restrictions (e.g., if one of the rods from group 1 is withdrawn, all the other group 1 rods are to be withdrawn before withdrawal of rods in another group is permitted).

(vi) *The RCIS logic enforces additional ganged withdrawal sequence restrictions when the reactor power level is below the low power level setpoint* and the reactor mode switch is in STARTUP or RUN mode as follows*:*

(a) *The RCIS logic prevents two groups of rods from being withdrawn simultaneously.*

(b) *Allows only groups 1-6 to be withdrawn as one single gang.*

(c) *Assures that the maximum allowable difference between the leading and trailing operable control rods in each of groups 3, 4, 7, 8, 9, and 10 to be within* ~~*146 mm when any operable rod in the group is less than or equal to 0.914m withdrawn. This restriction is not applied to groups 1, 2, 5, and 6 or to any group when all operable rods in that group are greater than 0.914m withdrawn. This restriction applies to rod pull sequence (5)a through (5)d above.*~~ 152 mm when any operable rod in the group is less than 48 steps withdrawn from the normal full-in position. This restriction is not applied to groups 1, 2, 5, and 6 or to any group when all operable rods in that group are greater than or equal to 48 steps withdrawn from the normal full-in position. This restriction applies to rod pull sequence (v) a through (v) d above.

(d) *Assures that the maximum allowable difference between the leading and trailing operable control rods in each of groups 1, 2, 7, 8, 9, and 10 to be within* ~~*146.4 mm when any operable rod in the group is less than or equal to 0.914m withdrawn. This restriction is not applied to groups 3, 4, 5, and 6 or to any group when all operable rods in that group are greater than 0.914m withdrawn.The restriction applies to rod pull sequence (5)e through (5)h above.*~~ 152 mm when any operable rod in the group is less than 48 steps withdrawn from the normal full-in position. This restriction is not applied to groups 3. 4, 5, and 6 or to any group when all operable rods in that group are greater than or equal to 48 steps withdrawn from the normal full-in position. This restriction applies to rod pull sequence (v) e through (v) h above.

(e) *Enforces restrictions on withdrawal of rods in groups 5-10 if rods in group 7 or 8 are moved first. Movement of rod gangs in groups 9 and 10 are then blocked until all operable rods in groups* ~~*5, 6 and 7 or 8 are greater or equal to 0.914m withdrawn. The RCIS also enforces rod restrictions if rods in group 9 or 10 are moved first. Movement of rod gangs in groups 7 and 8 is blocked until all operable rods in group 5, 6 and 9 or 10 are greater than or equal to 0.914m withdrawn.*~~ 5 or 6 are greater than or equal to 48 steps withdrawn from the full-in position AND Group 7 or 8 are greater than or equal to 48 steps withdrawn from the full-in position.

(f) Enforces restrictions on withdrawal of rods in groups 5-10 if rods in group 9 or 10 are moved first. Movement of rod gangs in groups 7 and 8 are then blocked until all operable rods in groups 5 or 6 are greater than or equal to 48 steps withdrawn from the full-in position AND Group 9 or 10 are greater than or equal to 48 steps withdrawn from the full-in position.

(6) *Establishment of Reference Rod Pull Sequence (RRPS)*

The reference rod pull sequence is normally established before plant startup and stored in memory ~~*at the Performance Monitoring and Control System (PMCS)*~~ associated with the Plant Computer Function (PCF)*. The* ~~*PMCS*~~ PCF *allows modifications to be made to the RRPS through operator actions. The* ~~*PMCS*~~ PCF *provides compliance verification of the changes to the RRPS, with the ganged withdrawal sequence requirements.*

The RCIS provides a capability for an operator to request a download of the RRPS from the ~~*PMCS, a subsystem of the Process Computer System*~~ PCF*. The new RRPS data is loaded into the RAPI* ~~*System*~~ Subsystem*. Download of the new RRPS data can only be completed when the RCIS is in manual rod movement mode and* ~~*when both keylock permissive switches located at each rod action control cabinet are activated.*~~ when a permissive switch located at the RAPI-A panel is activated.

The RCIS provides feedback signals to the ~~*PMCS*~~ PCF *for successful completion of downloaded RRPS data for displaying on the* ~~*CRT*~~ nonsafety *display.*

A rod ~~*Rod*~~ *withdrawal block* ~~*signals are*~~ signal is *generated whenever selected* ~~*single or*~~ *ganged rod movements differ from those allowed by the RRPS, when the RCIS is in automatic or semi-automatic rod movement mode.*

The RCIS ~~sounds~~ activates *an audible alarm at the operators panel for a RRPS violation.*

(7) Rod Block Function

The rod block logic of the RCIS, upon receipt of input signals from other systems and internal subsystems, inhibits movement of control rods.

All Class 1E systems rod block signals to the RCIS are optically isolated. ~~The rod block signals change the state of the light emitting diode at the external interface of an isolator. The light crosses the boundary of the isolator to the interface of the RCIS where a photo transistor changes state, thereby communicating the information to the logic within the RCIS.~~ This provides complete isolation while keeping electrical failures from propagating into the RCIS and vice versa.

The presence of any rod block signal, in either channel or both channels of the RCIS logic, causes the automatic changeover from automatic mode to manual mode. The automatic rod movement mode can be restored by taking the appropriate action to clear the rod block and by using the selector switch to restore the automatic rod movement mode.

If either channel or both channels of the RCIS logic receive(s) a signal from any of the following type of conditions, a rod block is initiated:

(a) *~~Rod separation, only for those rod(s) for which separation is detected.~~* Rod separation, (rod withdrawal block only for those rod(s) for which the separation condition is detected, if selected for movement, applicable when the RPS reactor mode switch is in STARTUP or RUN).

(b) *~~Reactor in SHUTDOWN mode (all control rods).~~* Reactor mode switch in SHUTDOWN (rod withdrawal block for all control rods, applicable when the RPS reactor mode switch is in SHUTDOWN).

(c) *~~SRNM period alarm (all control rods, but not applicable when reactor in RUN mode).~~* Startup Range Neutron Monitor (SRNM) withdrawal block (rod withdrawal block for all control rods, not applicable when the RPS reactor mode switch is in RUN).

(d) *~~SRNM downscale alarm or SRNM upscale alarm or APRM set down upscale alarm (all control rods, but not applicable when in RUN mode).~~* Average Power Range Monitor (APRM) withdrawal block (rod withdrawal block for all control rods).

(e) *~~SRNM inoperative (all control rods, but not applicable when reactor is in RUN mode).~~* CRD charging water low pressure (rod withdrawal block for all control rods).

(f) ~~APRM downscale (all control rods, only applicable when reactor in RUN mode).~~ CRD charging water low-pressure trip bypass (rod withdrawal block for all control rods).

(g) ~~Flow-biased APRM rod block (all control rods, only applicable when reactor in RUN mode).~~ RWM withdrawal block (rod withdrawal block for all control rods, applicable below the Low Power Setpoint).

(h) ~~APRM inoperative (all control rods, only applicable when reactor in RUN mode).~~ RWM insert block (rod insertion block for all control rods, applicable below the Low Power Setpoint).

(i) ~~Low CRD charging header pressure (all control rods).~~ ATLM withdrawal block (rod withdrawal block for all control rods, not applicable below the Low Power Setpoint).

(j) ~~Low CRD charging header pressure trip function bypass switches of the reactor protection system are in a bypass position (all control rods).~~ Multi-channel Rod Block Monitor (MRBM) withdrawal block (rod withdrawal block for all control rods, not applicable below the Low Power Setpoint).

(k) ~~Violation of ganged withdrawal sequence restrictions (all control rods in the selected gang or the selected control rod if the single rod movement mode is being used; applicable below the low power setpoint).~~ RFCS withdrawal block (rod withdrawal block for all control rods).

(l) ~~Automated Thermal Limit Monitor (ATLM) rod block (all control rods, only applicable above the low power setpoint).~~ Gang large deviation (i.e., gang misalignment) withdrawal block (rod withdrawal block for all operable control rods of the selected gang, applicable when RCIS GANG mode selection is active).

(m) ~~Multi-channel Rod Block Monitor (MRBM) rod block (all control rods, only applicable above the low power setpoint).~~ REFUEL mode withdrawal block (rod withdrawal block for all control rods, applicable when the RPS reactor mode switch is in REFUEL).

(n) ~~ATLM trouble (all control rods, only applicable above the low power setpoint).~~ STARTUP mode withdrawal block (rod withdrawal block for all control rods, applicable when the RPS reactor mode switch is in STARTUP).

(o) ~~RWM trouble (all control rods, applicable below the low power setpoint).~~ Rod Action and Position Information (RAPI) trouble (rod withdrawal block and rod insertion block for all control rods).

(p) ~~*MRBM inoperative (all control rods, only applicable above the low power setpoint).*~~ RAPI Signal Interface Unit (SIU) trouble (rod withdrawal block for all control rods).

(q) ~~*Rod action position information trouble (all control rods).*~~ Electrical group power abnormal (rod withdrawal block and rod insertion block for all control rods).

~~*(r) Two or more recirculation pump trips when reactor power is above approximately 25% of rated and core flow is below approximately 36% or rated. The logic to generate this rod block resides in the RFCS and the discrete rod block signal is sent to the RCIS from the RFCS.*~~

~~*(s) Refueling platform control computer interlock rod block (all control rods, only applicable when the reactor is in the refuel mode).*~~

~~*(t) Reactor SCRAM condition exists (all control rods).*~~

~~*(u) Existence of ARI or SCRRI condition (all control rods).*~~

~~*(v) Gang misalignment [i.e. position difference between any two gang members of more than 38.1 mm (all control rods)].*~~

The RCIS enforces all rod blocks until the rod block condition is cleared. The bypass capabilities of the RCIS permit clearing certain rod block conditions that are caused by failures or problems that exist in only one channel of the logic.

(9) *RCIS Bypass Capabilities*

The RCIS provides the capability to bypass ~~*synchro A, if it is bad, and select synchro B for providing rod position data to both channels of the RCIS. The number and distribution of bypassed synchros are procedurally controlled by applicable plant Technical Specifications.*~~ Synchro A (or Synchro B), if it is bad, and select Synchro B (or Synchro A) for providing rod position data to both channels of the RCIS. The RCIS logic prevents the simultaneous bypassing of both synchro signals for an individual FMCRD.

The RCIS allows the operator to completely bypass up to eight control rods by declaring them "Inoperable" and placing them in a bypass condition. Through operator action, an update in the status of the control rods placed into "inoperable" bypassed condition ~~*is available at the CRT display. At the display, the operator can request the data to be downloaded into the memory of the RAPI Subsystem logic with confirmation of a successful download completion signal being sent back to the CRT display.*~~ can be performed at the RCIS DOI.

Download of a new RCIS “Inoperable Bypass Status” to the RAPI Subsystem is only allowed when the RCIS is in a manual rod movement mode and ~~when both keylock permissive switches are activated at the RCIS panels.~~ when the bypass permissive switch located near the RCIS DOI is activated.

The operator can substitute a position for the rod that has been placed in a bypass state into both channels of the RCIS, if the substitute position feature is used. The substituted rod position value entered by the operator is used as the effective measured rod position that is stored in both ~~rod action control channels and sent to other systems (e.g., the Process Computer System).~~ RAPI channels and sent to other subsystems of the RCIS and to other plant systems (e.g., the Plant Information and Control System).

For purposes of conducting ~~periodical~~ periodic *inspections on FMCRD components, RCIS allows placing up to ~~21~~* 35 *control rods in “inoperable” bypass condition, only when the reactor mode switch is in REFUEL mode.*

The RCIS enforces rod movement blocks when the control rod has been placed in an inoperative bypass status. This is accomplished by the RCIS logic by not sending any rod movement pulses to the FMCRD.

In response to activation of special insertion functions, such as ARI, control rods in bypass condition do not receive movement ~~pulses~~ commands.

(10) Single/Dual Rod Sequence Restriction Override (S/DRSRO) Bypass

The RCIS single/dual rod sequence restriction override bypass feature allows the operator to perform special dual or single rod scram time surveillance testing at any power level of the reactor. In order to perform this test, it is often necessary to perform ~~single~~ rod movements that are not allowed normally by the sequence restrictions of the RCIS.

When ~~a control rod is placed in~~ a S/DRSRO bypass ~~condition, that control rod is no longer~~ condition exists, the control rod positions are no longer *used in determining compliance to the RCIS sequence restrictions (e.g., the ganged withdrawal sequence and RRPS).*

The operator can only perform manual rod movements of control rods in the S/DRSRO bypass condition. The logic of the RCIS allows this manual single/dual rod withdrawals for special scram time surveillance testing.

The operator can place up to two control rods associated with the same hydraulic control unit (HCU) in the S/DRSRO bypass condition.

The dedicated RCIS operator interface panel contains status indication of ~~control rods in~~ a S/DRSRO bypass condition.

The RCIS ensures that S/DRSRO bypass logic conditions have no effect on special insertion functions for an ARI or SCRAM following condition and also no effect on other rod block functions, such as MRBM, APRM, or SRNM ~~period~~ rod blocks*.*

The drive insertion following a dual/single rod scram test occurs automatically. The operator makes the necessary adjustment of control rods in the system prior to the start of test for insertions, and restores the control rod to the desired positions after test completion.

(11) Single RCIS Channel Bypass Features

The RCIS is a dual channel system and the logic of the system provides a capability for the operator to invoke bypass conditions that affect only one channel of the RCIS. The interlock logic prevents the operator from placing both channels in bypass. Logic enforces bypass conditions to ensure that the capability to perform any special function (such as an ARI, scram following, and SCRRI) is not prevented.

The RCIS logic ensures that any special restrictions that are placed on the plant operation are enforced as specified in the applicable plant Technical Specifications for invoked bypass conditions.

The status and extent of the bypass functions are identified on the RCIS dedicated operator interface panel ~~and the PMCS CRT displays at the main control panel~~.

Bypass conditions allow continuation of normal rod movement capability by bypassing failed equipment in one RCIS channel. After repair or replacement of the failed equipment is completed, the operator can restore the system or subsystem to a full two-channel operability. The operator has the capability to invoke bypass conditions within the following system or subsystems:

(a) ~~*Synchro A or B position bypass*~~ Not Used

(b) *Rod server* processing ~~*module*~~ *channel A or B bypass*

(c) ~~*Inoperable condition bypass*~~ Not Used

(d) *File control module channel A or B bypass*

(e) *ATLM channel A or B bypass*

(f) *RWM channel A or B bypass*

(g) ~~*RACS*~~ RAPI *channel A or B bypass*

(12) ~~*(11)*~~ Scram Time Test Data Recording

The logic of the RCIS provides the capability to automatically record individual FMCRD scram timing data based upon scram timing reed switches. When a FMCRD scram timing switch is activated, the time of actuation is recorded by the ~~*RAPI System*~~ Scram Time Recording Panel (STRP) *for time tagging of stored scram time test data in the* ~~*RSPC*~~ Scram Time Recording and Analysis Panel (STRAP) *for that particular FMCRD. The time-tagged data is stored in memory until the next actuation of that particular reed switch is detected again.*

The RCIS also time tags the receipt of a reactor scram condition being activated based upon the scram-following function input signals from the Reactor Protection System.

The resolution of this time-tagging feature is less than 5 milliseconds. Contact bounce of the reed switch inputs are properly masked to support this function. The reference ~~*real time*~~ *clock for time tagging is the* ~~*real time*~~ RCIS *clock* ~~*of the RCIS*~~*.*

~~*When the RCIS detects a reactor scram condition, the current positions of all control rods in the core are recorded, time tagged, and stored in memory.*~~ *RCIS logic stores this data in memory until a request is received from the* ~~*PMCS. The transmitted data is used by the PMCS to calculate and summarize*~~ PCF for transfer of the stored scram timing performance data from the STRAP to the PCF. The transmitted data is used by PCF to summarize *scram time performance based on the scram timing data received from the RCIS.*

~~*In an alternate design, the scram time recording and analysis functions are performed by two separate panels called scram time test panel (STTP) and scram time test recording/analysis panel (STR/AP). The STTP function is to directly interface with FMCRD reed switches and gather all FMCRD status and scram information. The function of STR/AP is to receive FMCRD information from STTP, process and analyze FMCRD scram time data, generate scram time test reports, and communicate FMCRD reed-switch-based status data to other plant systems.*~~

(13) ~~*(12)*~~ ATLM Algorithm Description

The ATLM is a microprocessor based subsystem of the RCIS that executes two different algorithms for enforcing fuel operating thermal limits. One algorithm enforces operating limit minimum critical power ratio (OLMCPR), and the other the operating limit minimum linear heat generation rate (OLMLHGR). For the OLMCPR algorithm, the core is divided into 48 regions, each region consisting of 16 fuel bundles and the detailed algorithm used is based upon using the regional Maximum Fraction of Limiting Critical Power Ratio (MFLCPR) values of the Plant Computer Function (PCF) core thermal limit monitoring function. The PCF download information includes calculated initial regional MFLCPR values along with other required download values for the ATLM algorithm. The ATLM then continuously performs calculation of the applicable regional MFLCPR Trip Setpoint based upon equation 7.7-1 described below.

For the OLMLHGR algorithm, each region is further vertically divided up into four Levels (i.e. Level A, B, C or D) and the detailed algorithm used is based upon using the regional and Level dependent Maximum Fraction of Limiting Power Density (MFLPD) values of the PCF core thermal limit monitoring function. The PCF download information includes calculated initial regional MFLPD values for each Level along with other required download values for the ATLM algorithm. The ATLM then continuously performs calculation of the applicable regional MFLPD Trip Setpoint for each Level based upon equation 7.7-2 described below. Each ATLM instrument calculates the regional MFLCPR Trip Setpoints (48 values) and regional MFLPD Trip Setpoints for each Level (i.e. 48 x 4 values) every ATLM calculation cycle (about 100 msec) and compares the relevant current averaged LPRM readings for each region. *segments. During a calculation cycle of ATL (about 100 msec), rod block setpoints (RBS) are calculated for OLMCP monitoring (48 values) and for OLMLHGR monitoring (48 x 4 values). Then the calculated setpoints are compared with the real time averaged LPRM readings for each region/segment. The ATLM issues a trip signal if any regionally averaged LPRM reading exceeds the calculated RBS* trip setpoint*. This trip signal causes a rod block within the RCIS and also a flow change block in the Recirculation Flow Control System (RFCS).*

Provided below is a summary description of OLMCPR and OLMLHGR RBS MFLCPR and MFLPD trip setpoint calculation methodology.

(a) ***OLMCPR RBS Calculation Methodology**. The 16 fuel bundles of each region are surrounded by four LPRM strings. There are four LPRMs in each string. For regional OLMCPR monitoring, the sum of the average of each level of B, C, and D of the four LPRM strings is used. The formula for calculating the OLMCPR RBS is:*
MFLCPR_TRIP_SETPOINT value for Region K is calculated using the following equation:

(7.7-1)

$$RBS_o = \frac{LPRM_i * A_o * RMCPR_i}{OLMCPR}$$

where:

RBSo	=	*Operating limit rod block setpoint.*
LPRMi	=	*Initial sum of average of four LPRMs of B, C, and D levels that surround each region.*
Ao	=	*Margin factor for operating limit rod block; a known function of rod pull distance.*
RMCPRi	=	*Regional initial MCPR (i.e., the minimum CPR of the 16 bundles in the region spanned by the four LPRM strings). Known input from predictor (process computer).*
OLMCPR	=	*Operating limit MCPR in the current cycle; a known function of power.*

Equation is applicable to cases where there is no core flow change and when only one control rod is moved. Adjustments are made to the calculated RBSo to account for changes in core flow and adjacent control rods movements.

Above equation is replaced by equation listed below

MFLCPR_TRIP_SETPOINT (K) = [LPRMi (K) * Af * A-Factor (K) * OLMCPRF-I] / [OLMCPRF * RMFLCPRi (K)] (7.7-1)

where:

LPRMi(K)	=	Regional Initial value of the averaged LPRM signals of levels B, C and D
Af	=	Adjustment factor to account for changes of reactor core flow
A-Factor (K)	=	Regional Adjustment factor to account for changes of the control rod positions in that region
OLMCPRF-I	=	The applicable reactor OLMCPR value at the time of the last successful update process with the PCF
OLMCPRF	=	The current applicable OLMCPR value

RMFLCPRi (K) = Regional initial MFLCPR value based upon the highest MFLCPR value for the 16 bundles in the region at the time of the last successul update process with PCF.

(b) ***OLMLHGR RBS Calculation Methodology.*** *The formula for calculating the OLMLHGR RBS is:* MFLPD_TRIP_SETPOINT value for Region K, Level L (i.e. Level A, B, C or D) is calculated using the following equation:

(7.7-2)

$$RBS_m(X) = \frac{LPRM_i(X)*B_m*M_p}{MAPRAT_i(X)}$$

where:

RBSm(X) = *Calculated operating limit maximum average planar linear heat generation rate (OLMAPLHGR) RBS at LPRM level X.*

LPRMi(X) = *Initial average of the four LPRMs (level X) at the four corners of each 16-bundle fuel region. The region monitored by the level LPRM is the region covered up to .46m above and below the LPRM (0.914m total).*

B(X) = *Margin factor for MAPLH GR operating limit rod block for X level LPRMs. A known function of power and rod position.*

Mp = *Off-rated power factor to consider overpower condition during worst transient at off-rated condition. A known function of power.*

MAPRATi(X) = *Regional initial maximum MAPRAT for level X (i.e., the maximum MAPRAT of the 16 bundles within the 0.914m section covered by the X level LPRMs). A known input from 3D monitor.*

In Equations and above, “initial” refers to values that are downloaded from the “3D Predictor Monitor” subsystem of the PMCS. A download is requested by the ATLM whenever changes in reactor power and/or core flow exceed a preset limit. A download can also be manually requested by the operator.

Above equation is replaced by equation listed below

MFLPD_TRIP_SETPOINT (K,L)=[B-Factor (K,L) * OLLPDF * LPRMi(K,L)-I] / [OLLPDF-I * RMFLPDi (K,L)] (7.7-2)

where:

LPRMi(K,L)-I = Regional Initial value of the averaged LPRM signals for Level L

B-Factor (K,L) = Regional Adjustment factor for Level L to account for any changes of the control rod positions

OLLPDF = The applicable reactor OLLPD value corresponding to current applicable OLMHGR value)

OLLPDF-I = The applicable reactor OLLPD value corresponding to the applicable OLMHGR value at the time of the last successful update process with the PCF

RMFLPDi (K,L) = Regional initial MFLCPR value for Level L based upon the highest MFLPD value for the 16 bundles in the region for that Level at the time of the last successul update process with PCF.

In Equations 7.7-1 and 7.7-2 above, ~~*"initial" refers to values that are downloaded from the "3D Predictor Monitor" subsystem of the PMCS*~~ the applicable "Regional Initial value of the averaged LPRM signals" for each equation is based upon the associated average of the LPRM signal values received from the Neutron Monitoring System at the time of the last successful ATLM update process. ~~*A download*~~ An update process *is requested by the ATLM whenever changes in reactor power and/or core flow exceed a preset limit.* ~~*A download*~~ An update process *can also be manually requested by the operator.*

7.7.1.2.2 System Interfaces

STD DEP 7.7-7

STD DEP 7.7-17

STD DEP T1 3.4-1

STD DEP Admin

The following information in this section provides descriptions for important RCIS interfaces with other key plant systems. See the RCIS IED, Figure 7.7-2 and RCIS IBD, Figure 7.7-3 for identification of additional plant system interfaces with the RCIS. Any setpoint values described are nominal values.

(1) Control Rod Drive (CRD) System

The RCIS interfaces with the CRD System are as follows:

(a) Synchros A and B of each FMCRD

(b) Coupling check (overtravel-out) position reed switch and buffer contact reed switch *of each FMCRD*

(c) ~~Latched Full-In and Full-In position reed switches of each FMCRD~~ Status signal for each FMCRD indicating that either the ~~Latched~~ latched full-in or normal full-in position reed switch is closed.

(d) *Scram Timing position reed switches which include reed switches at 0%, 10%, 40%, 60%, +100% rod insertion for each FMCRD*

(e) *Separation reed switches (A&B) through the* ~~plant essential multiplexing system~~ Data Communication Function (DCF) equipment of Division I and Division II of the ELCS *for each FMCRD*

(f) *"LOW CRD CHARGING WATER HEADER PRESSURE" condition (four* associated *signals* are provided *to each channel of RCIS* by the Reactor Protection System*)*

(g) *Electrical power connections from RCIS to* ~~FMCRD motor, brake, and valve 143~~ motor and brake of each FMCRD and the purge valve of each HCU.

(2) *Recirculation Flow Control System (RFCS)*

(a) *Alternate Rod Insertion (ATWS) (Anticipated Transient Without Scram)*

The RCIS logic (during an ATWS), on receipt of ARI signals from the RFCS, initiates the RCIS ARI function which controls the FMCRD motors such that all control rods are driven to their full-in position automatically. ~~The three channels of the RFCS provide each of the two channels of the RCIS logic with the ARI signal.~~ The RFCS provides each of the two channels of RCIS logic with 3 hardwired signals that are activated when the ARI condition exists. *RCIS internal logic to initiate the RCIS ARI function is based on two-out-of-three logic within each channel of the RCIS. The operator, at the RCIS* ~~dedicated operator interface~~ main control room panel, *can take action and initiate the ARI function. Two manual actions are required to manually initiate ARI.*

The logic of the RCIS is designed such that no single failure results in failure to insert more than one operable control rod when the ARI function is activated.

(b) *Selected Control Rod Run In (SCRRI) and Rod Block Functions*

~~*The three channels of the Recirculation Flow Control System (RFCS) provide each of the two channels of the RCIS with the separate isolated trip signals indicating the need for rod block automatic selected control rod run in.*~~ The RFCS provides each of the two channels of RCIS logic with 3 hardwired signals that are activated when the automatic SCRRI condition exists. In addition, the RFCS provides each of the two channel of RCIS logic with 3 hardwired signals that are activated if SCRRI related rod withdrawal block condition exists. *The operator, at the* ~~*RCIS dedicated operator interface,*~~ main control room panel, *can also take action and initiate the SCRRI function. Two manual actions are required to manually initiate SCRRI.*

The automatic SCRRI can either be initiated from the Feedwater Control System (FWCS) ~~*of the RFCS*~~ or the RFCS logic*. The initiating event for the FWCS to generate a SCRRI signal is loss of feedwater heating (for detailed description of SCRRI initiation by FWCS, see Subsection 7.7.1.4).* The FWCS provides each of the RFCS logic with 3 hardwired signals that are activated when the loss of feedwater condition exists. The RFCS, after a 2-out-of-3 voting of these signals, generates SCRRI signals which are ~~*Each channel of the FWCS provides three signals to three channels of the RFCS. Each RFCS channel, after a two-out-of-three voting of these signals, generates a RFCS SCRRI signal which is*~~ *sent to both channels of RCIS.*

When two or more RIPs are tripped, the trip signal is "ANDED" with the reactor power level and core flow signals. If core flow is < ~~*36*~~ 41.5*% of rated and rated reactor power level is >* ~~*25% but less than 30*~~ 33*%, the RFCS* ~~*issues a rod block signal*~~ activates the SCRRI rod block signals sent to RCIS*. In the same manner, if reactor power is ≥*~~*30*~~ 38*%, the RFCS* ~~*issues the SCRRI signal.*~~ activates the automatic SCRRI status signals sent to RCIS.

The RFCS receives reference power level signals from the Neutron Monitoring System and compares the reference power level signals with the nominal power level setpoint.

The RFCS rod block or SCRRI function is bypassed when power level is below the applicable specified setpoints, or when the core flow is above the specified setpoint.

The SCRRI function is not a safety-related function. The function is designed to meet the reliability requirement that no single failure shall cause the loss of SCRRI function.

The RFCS automatic initiation signal for the rod block/SCRRI function is sent as two independent sets of signals, two sets of three signals to each channel of RCIS. After two-out-of-three voting within each channel, depending on the signals received, the RCIS either issues a rod block signal and/or uses the FMCRD stepping motors of preselected control rods to drive them to their target SCRRI positions. Either channel of RCIS is capable of initiating the rod block/SCRRI functions on receipt of the signals from the RFCS.

The preselected control rods and their target positions are established using the Plant Computer Function and downloaded to both RAPI channels of RCIS.~~for a SCRRI function are selected at the RCIS CRT displays of the performance monitoring and control system in the main control room.~~ The preselected SCRRI rod data are stored in memory in the RAPI Subsystem of the RCIS. The total control rod worth for the preselected control rods is designed to bring down the reactor power rod line from the 100% power rod line to the ~~80~~ 60% power rod line.

The ~~RCIS dedicated operation interface~~ main control room panel, also provides control switches that require two manual operator actions for the operator to manually initiate the SCRRI function.

For manual or automatic initiation of the SCRRI function, ~~the~~ associated RCIS ~~dedicated operator interface provides~~ status indications and alarm annunciators are provided in the control room.

The total delay time from the recirculation pump trip to the start of control rod motion, for the preselected control rods, is less than or equal to ~~2 seconds.~~ 3 seconds, provided 2 or more RIPs have tripped and the reactor power is above the applicable setpoint and the reactor core flow is below the applicable setpoint.

(c) RFCS Core Flow Signal to RCIS

The RFCS provides signals to both channels of the RCIS that represent validated total core flow. These signals are used for part of the validity checks when performing an ATLM operating limit setpoint update. The RCIS obtains these signals from the RFCS ~~via the multiplexing system links~~ the nonsafety Plant Data Network (PDN) communication function and associated datalinks to the RCIS channels.

(d) RCIS Signals to RFCS

The ATLM Subsystem of the RCIS issues ~~a Flow Increase Block signal~~ Flow Increase Block signals to RFCS whenever there is an ATLM trip.

The dedicated RCIS MUX Monitor provides hard-wired run-back signals to adjustable speed drives of the RFCS.

(e) *RFCS Hard-Wired Signals to RCIS*

~~*Each of the three channels of RFCS provides the status of six relay contacts (12 wires per RFCS channel) to the RCIS. These signals are used by RCIS logic to minimize the likelihood inadvertent FMCRD run-in.*~~ RFCS also provides redundant control signals for implementation of the FMCRD emergency rod insertion functions to the RCIS Emergency Insertion Control Panel. These signals are activated when either the ARI or SCRRI condition exists to minimize the likelihood of inadvertent FMCRD run-in.

(3) *Feedwater Control System (FWCS)*

The Feedwater Control System provides signals to both channels of the logic of the RCIS that represents validated total feedwater flow to the vessel and validated feedwater temperature. These signals are used as part of the validity checks when performing an ATLM operating limit setpoint update.

The RCIS can obtain these signals from the FWCS via ~~*the multiplexing system communication links*~~ the nonsafety PDN communication function and associated datalinks *to the RCIS channels.*

(4) *Neutron Monitoring System*

Each of the four divisions of the Neutron Monitoring System provides independent signals to both channels of the RCIS that indicate when the following conditions are active:

(g) ~~*Flow-biased APRM rod block*~~ Not Used

Whether or not some of the signals result in a rod block depends on reactor mode switch status which is provided to the RCIS from the reactor protection system ~~*via the essential multiplexing system*~~ using dedicated signal interfaces*.*

Each of the four divisions of NMS provides APRM, LPRM and core flow signals to the two channels of logic in the ~~*RAPI*~~ ATLM *Subsystem for determining whether reactor power is above or below the low power setpoint and usage by ATLM*, RAPI and RWM subsystems of the RCIS.

The four divisions of the NMS provide the same signals to both channels of the RCIS. These signals meet the isolation and separation requirements of interfacing the Class 1E NMS with the non-Class 1E RCIS.

Each of the two MRBM non-safety subsystems of the NMS provide their rod block signals to the RCIS. The RCIS, in return, provides ATLM status signals and coordinates of the selected rods to MRBM.

(5) Reactor Protection System

Each of the four divisions of the RPS provides the RCIS two-channel system with separate isolated signals for indication of the reactor mode switch positions: SHUTDOWN, REFUEL, STARTUP and RUN.

The four divisions of the Reactor Protection System (RPS) each provide RCIS with two separate isolated signals for the low charging water header pressure trip switches in bypass position and for low CRD charging header ~~pressure status of the CRD System~~.pressure status of the CRD System.

~~*The Essential Multiplexing System provides the above signals to the RCIS with complete isolation between the safety-related system and the non-safety- related system equipment.*~~ The preceding signals are transmitted through isolated fiber-optic data links to RCIS. This provides complete isolation between the safety related system and the nonsafety related system equipment.

Divisions II and III of the RPS each provide the two channels of RCIS with two separate isolated signals that indicate a scram condition. The signals remain active until the scram condition is cleared by the operator. ~~*In addition, Divisions II and III of RPS each provide the RCIS with hard-wired relay contact status to minimize the likelihood of inadvertent FMCRD run-in.*~~ In addition, Divisions II and III of RPS each provide the RCIS Emergency Rod Insertion Control Panel with the hardwired RPS ~~Scram-Follow~~ scram-follow signals to minimize the likelihood of inadvertent FMCRD run-in.

(6) Performance Monitoring and Control System Plant Computer Function (PCF)

~~*The PMCS provides the data update from the 3-D predictor function calculations associated with ATLM parameters based on actual measured values from the plant. This data is downloaded into the ATLM memory. This is to assure that rod blocks occur if the operating limits (e.g., MCPR and MLHGR) are approached. This feature allows the ATLM rod block setpoint calculation to be based on actual, measured plant conditions.*~~

~~*The RCIS provides the PMCS with control rod position information along with other RCIS status information for use in other PMCS functions and for the PMCS CRT displays related to the RCIS.*~~

~~*The RCIS gathers, time tags, stores, and transmits scram timing data to the PMCS. The PMCS utilizes rod scram timing data to evaluate scram performance of the CRD System. The PMCS provides for the capability of printing or displaying of scram time logs. The scram time data sent to the PMCS provides the capability for comparing received data from the RCIS with the specification for control rod scram timing. Included in these comparisons are the averages and trends for data collected from past rod*~~

~~*scrams or rod testing. The output for this function consists of, but is not limited to, the following type of data:*~~

~~*(a) Scram time measurements of any selected rod or group of rods to a particular position.*~~

~~*(b) A listing of INOPERABLE rods.*~~

~~*(c) Statistical analysis and average calculations of insertion times.*~~

~~*(d) List of rods which do not meet technical specification requirements.*~~

~~*In the alternate design, scram time recording and analysis functions are performed by separate panels.*~~

PCF includes the 3-D core monitoring function that supports the function of updating the setpoints of the ATLM. The core monitoring function calculates appropriate core thermal limits parameters, based on actual measured values from the reactor and the plant. This data is downloaded into the ATLM memory either automatically or by request from the operator. This download ensures that rod block occurs if the fuel operating thermal limits (e.g., MCPR and MLHGR) are approached. This feature allows the ATLM rod block setpoint calculation to be based on actual, measured plant conditions.

RCIS provides PCF with control rod position information, along with other FMCRD and RCIS status information, for use in other PCF applications and for PCF displays related to RCIS.

In addition, the Plant Computer Function supports the RCIS in performing the establishment of a common RRPS database and the establishment of the SCRRI Target Positions database. The PCF also supports establishing and removing substitute rod position values for control rods placed in the RCIS INOPERABLE BYPASS status.

The STRPs provide the necessary functions to gather, time-tag, store, and transmit CRD Scram timing data to the STRAP. The STRAP provides for transmission of this data to the PCF for further review, analysis and archiving.

(7) Automatic Power Regulator (APR) System

The APR System provides the automatic control rod movement commands to the two channels of the RCIS when the APR System and RCIS are in the automatic mode. The APR System includes the supervisory control logic for determining when to insert, withdraw, or stop control rods. The RCIS then determines which rods to move, based ~~of~~ on *the RRPS and current rods positions.* The RCIS also provides RCIS operating status information to the APR System. *The APR System is described in Subsection 7.7.1.7.*

7.7.1.2.3 Reactor Operator Information

STD DEP 7.7-18

(1) *The RCIS provides for the activation of the following annunciation at the main control panel.*

(a) *Rod withdrawal blocks.*

(b) *Rod Control & Information System trouble.*

(c) ~~*Low power transient zone (i.e., reactor power above but nearing the LPSP).*~~ Rod insert block.

(d) *Gang misalignment.*

(e) *Selected control rod run-in (SCRRI).*

(f) *Alternate rod insertion initiated.*

(g) ~~*CRD charging water header pressure low.*~~ RWM trouble.

(h) *Reference rod pull sequence (RRPS) violation.*

(i) *ATLM trouble.*

(2) *The RCIS provides status information indication on the RCIS dedicated operators interface on the main control panel as follows:*

(a) *Whether RCIS rod movement mode is automatic*, semi-automatic *or manual.*

(b) ~~*Number of*~~ *FMCRDs in* ~~*their full-in position.*~~ normal full-in position (based upon synchro signals).

(c) ~~*Number of*~~ *FMCRDs in* ~~*latched full-in position.*~~ full-in/latched full-in position (based upon position reed switch signals).

(d) ~~*Number of*~~ *FMCRDs in full-out position.*

(e) ~~*Average percent insertion*~~ Position *of all FMCRDs.*

(f) *Identification of selected gang (or selected single rod).*

(g) ~~*Average percent insertion*~~ Target position value *of selected gang (or selected single rod).*

(h) *Number of FMCRDs in an inoperable bypass condition.*

(i) *Existence of any rods withdrawal blocks.*

(j) Existence of any single channel bypass of the ~~RACCS~~ RAPI and/or any subsystem within the ~~RACCS~~ RCIS.

(k) Whether reactor power is above the LPSP.

(l) Existence of RCIS trouble.

(m) ~~Activation of scram following function.~~ Whether a control rod is at the over travel out position during the coupling check test.

(n) ~~Activation of the ARI function.~~ Whether a control rod is uncoupled during a coupling check test.

(o) ~~Status of SCRRI function.~~ Control rods with bypassed synchros.

(p) ~~Successful completion of ATLM operating limit setpoint update.~~ The applicable SCRRI Target Position Value for each FMCRD.

(q) ~~Any control rod in~~ Existence of a S/DRSRO bypass condition.

(r) Activation of a rod block by MRBM condition.

(3) The dedicated operators interface panel of the RCIS ~~provides logic and operator controls, so that the operator can~~ and related RCIS displays, indications and associated controls provided on the main control room panel and on the RCIS cabinets and panels, allow the operator to perform the following functions:

(a) Change the RCIS mode of operation from manual to semi-automatic or automatic rod movement modes.

(b) Manually initiate the SCRRI function.

(c) Manually initiate the ~~two CRD test functions.~~ CRD Scram Test mode.

(d) Request a bypass of ~~RACCS~~ RAPI channel A or B (normal position: no bypass).

(e) Request a bypass of ATLM or RWM channel A or B. (Normal positions are not bypassed.)

(f) Request an ATLM operating limit setpoint update be performed.

(g) Perform a reset of any RCIS abnormal condition.

(h) Manually initiate CRD brake test, CRD coupling check and CRD ~~step~~ double notch test functions.

NOTE: Interlock logic may prevent certain combinations of bypasses from being activated even though the above bypass controls have been activated.

(4) *The CRT displays, which are part of the PMCS, provide information to the operator on demand.* Main control room panel equipment other than the RCIS dedicated operator interface provides for display of the following RCIS related information for the operator.

The following status and controls are available through the CRTs:

(a) *RCIS rod movement status (automatic/semi-automatic/manual).*

(b) *Position of all rods, based on synchro signals.*

(c) *Selected gang (or selected single rod). plus the four LPRM readings of the closest LPRM strings to the selected gang or selected single rod. If the closest LPRM reading at a given level is inoperable, as determined by the Neutron Monitoring System LPRM status information, an INOP status is displayed instead of actual LPRM reading*

Identification of: (d through v)

(d) *All rods in rod* Rod *withdrawal block condition.*

(e) *BYPASSED or INOPERABLE control rods.* Control rods that have been placed in the INOPERABLE bypass condition.

(f) *Control rods with bypassed synchros.* Scram following function status.

(g) *Control rods that separation has been detected.*

(h) *Control rods full-in status.*

(i) *Control rods in latched full-in status.* full-in/latched full-in position status (based upon position reed switch signals).

(j) *Control rods in overtravel-out status.* ARI function status.

(k) *Control rods full-out status.*

(l) *Control rods in overtravel-out status.* SCRRI function status.

(m) *Control rods for which uncoupled condition has been detected.* ATLM operating limit setpoint update status.

(n) *Control rods for which drift condition has been detected.*

(o) *Control rods for which abnormal movement (other than drift) has been detected.*

(p) *Control rods that are SCRRI selected control rods.* Not Used

(q) *Control rods that can be inserted.* Not Used

(r) ~~Control rods that can be withdrawn.~~ Not Used

(s) *All RCIS bypasses in effect.*

(t) *All detected conditions that have resulted in an RCIS trouble alarm being activated, when applicable.*

~~(u) All detected conditions that have resulted in rod withdrawal block conditions being active, when applicable.~~

~~(v) Obtain ATLM operating limit setpoint update, when requested.~~

7.7.1.2.4 Test and Maintenance

STD DEP 7.7-19

The RCIS equipment is designed with online testing capabilities. The system can be maintained on line while repairs or replacement of hardware take place without causing any abnormal upset condition.

The system has been designed so that removal or repair of modules or cards can be performed without the use of special tools except for the combined inverter controller/stepping motor driver module equipment in the FMDCs. Because of the weight of these modules a special lifter tool is provided for the safe removal and replacement of these heavy modules*.*

7.7.1.3 Recirculation Flow Control System—Instrumentation and Controls

STD DEP 7.7-20

STD DEP ~~T1 2.12-1~~ 8.3-1

STD DEP 9.5-3

(1) *Identification*

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 reactor internal pumps (RIPs) and the surveillance of associated equipment. Recirculation flow control is achieved either by manual operation or by automatic operation if ~~the power level is above 70% of rated~~. The reactor internal pumps 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. 30% rated speed corresponds to the minimum operating speed to be used during initial pump startups. The instrument electrical diagram (IED) is provided in Figure 7.7-5 and the interlock block diagram (IBD) is provided in Figure 7.7-7.

(2) Normal Operation

Reactor recirculation flow is varied by modulating the recirculation internal pump speeds through the voltage and frequency modulation of the adjustable speed drive output. By properly controlling the operating speed of the RIPs, the recirculation system can automatically change the reactor power level.

Control of core flow is such that, at various control rod patterns, different power level changes can be automatically accommodated. For a rod pattern where rated power accompanies 100% flow, power can be reduced to 70% of full power by full automatic or manual flow variation. At other rod patterns, automatic or manual power control is possible over a range of approximately 30% from the maximum operating power level for that rod pattern. Below ~~70% power level, only manual control of power (i.e., by means of manual flow setpoint control) is available~~ approximately 25% reactor power the speed of all RIPs is normally maintained at the normal minimum operating speed (in either manual or automatic speed control mode).

An increase in recirculation flow temporarily reduces the void content of the moderator by increasing the flow of coolant through the core. The additional neutron moderation increases reactivity of the core, which causes reactor power level to increase. The increased steam generation rate increases the steam volume in the core with a consequent negative reactivity effect, and a new (higher) steady-state power level is established. When recirculation flow is reduced, the power level is reduced in the reverse manner. The RFC System, ~~operating in conjunction with the main turbine pressure regulator control, provides fully automatic load following.~~ the Automatic Power Regulator System (APR), the Steam Bypass and Pressure Control System (SB&PC) and the main Turbine Electro-Hydraulic Control System (EHC) provides for fully automatic load following operation.

The RFC System is designed to allow both automatic and manual operation. In the automatic mode, either total automatic or semi-automatic operation is possible. Fully automatic, called "Master Auto" mode, refers to the automatic load following (ALF) operation in which the master controller receives a load demand error signal from the ~~main turbine pressure regulator~~ APR*. The load demand error signal is then applied to a cascade of lead/lag and proportional-integral (PI) dynamic elements in the master controller to generate a flow demand signal for balancing out the load demand error to zero. The flow demand signal is forwarded to the flow controller for comparing with the sensed core flow. The resulting flow demand error is used to generate a suitable gang speed demand to the ASDs. The speed demand to the individual ASDs causes adjustment of RIP motor power input, which changes the operating speed of the RIP and, hence, core flow and core power. This process continues until both the errors existing at the input of the flow controller and master controller are driven to zero. Fully automatic control is provided by the master controller when in the automatic mode. The flow* *controller can remain in automatic even though the master controller is in manual.*

The reactor power change resulting from the change in recirculation flow causes the pressure regulator to reposition the turbine control valves. If the original demand signal was a load/speed error signal, the turbine responds to the change in reactor power level by adjusting the control valves, and hence its power output, until the load/speed error signal is reduced to zero.

In the ~~semi-automatic~~ core flow *mode, the operator sets the total core flow demand and the RFC System responds to maintain a constant core flow. Core flow control is achieved by comparing the core flow feedback, which is calculated from the core plate differential pressure signals, with the operator-supplied core flow setpoint.*

(7) *Recirculation Pump Trip (RPT)*

In the event of either (a) turbine trip or generator load rejection when reactor power is above a predetermined level (EOC RPT), (b) reactor pressure exceeds the high dome pressure trip setpoint, or (c) reactor water level drops below the Level 3 setpoint, the RPT logic will automatically trip off a group of four RIPs. The group of the RIPs being tripped is the same group which derives its power source directly from the ~~6.9~~ 13.8 *kV buses (i.e., the group not having the M-G set interface).*

The three inputs required to determine the preceding three RPT conditions are provided by the Reactor Protection System, the Feedwater Control System, and the Steam Bypass and Pressure Control System. These inputs consist of three sets of discrete signals for each of the end-of-cycle (EOC), high pressure and low level (Level 3) trip conditions. Each set represents the status of four channel outputs. A two-out-of-four logic is used by the RFC System to confirm the validity of the EOC trip condition. Two-out-of-three logic is used for the high pressure and Level 3 trip conditions. Any one of the three trip conditions can initiate a RPT. All switching logics are performed by the triplicate RFC controller. RPT is implemented by tripping the ~~gate-turn-off (GTO)~~ inverters in the adjustable speed drives.

(8) *~~Equipments~~* Equipment

(c) *Adjustable Speed Drives (ASDs)*

Each ASD consists of (1) an AC-to-DC rectifier ~~section~~ circuitry; *(2) a solid state, variable frequency DC-to-AC inverter ~~section~~* circuitry, *which ~~includes gate-turn- off thyristors~~* provides the required circuitry *for implementation of the RPT function; (3) a control and regulation section; and (4) measurement and protection circuits.*

(d) Fault-Tolerant Digital Controller

The FTDC performs many functions. It reads and validates inputs off the ~~Non-Essential Multiplexing System (NEMS)~~ ~~Plant Data network~~ PDN interface once every sampling period. It performs the specific recirculation flow control calculations and processes the pertinent alarm and interlock functions, then updates all RFC System outputs to the ~~NEMS~~ PDN. To prevent computational divergence among the three processing channels, each channel performs a comparison check of its calculated results with the other two redundant channels.

The internal FTDC architecture features three ~~multiplexing (MUX)~~ redundant interfacing units for communication between the ~~NEMS~~ PDN and the FTDC processing channels, and fiber optic communication links for interprocessor and channel communication, and for communication with the technician interface unit (TIU).

(e) Recirculation Flow Control System Algorithms

A function generator converts the speed demand output to frequency demand for the ASDs. A rate limiter on the output of the function generator limits the rate of change in speed demand to ~~1.5~~ +5%/s for increasing speed changes and ~~5~~ -5%/s for decreasing speed changes during normal operation. This prevents rapid changes in pump speed as a result of multiple processing channel failure.

In the ALF mode, the master controller receives a load demand error signal from the ~~Steam Bypass and Pressure Control (SB&PC)~~ APR System in response to any combination of local operator load setpoint inputs, automatic generation control inputs, or grid load changes indicated by grid frequency variation.

(11) Operational Considerations

The FTDC, which commands RIP speed changes, is located in the main control room. Provisions are made to allow either automatic or manual operation for each control loop (master, flow and speed). All transfers between the manual and automatic operations are designed to be bumpless. RFCS control modes, as well as setpoint changes, can be initiated by either the operator or by the ~~PMCS~~ APR, depending on whether the “local” or the “auto” system control has been selected.

(12) Reactor Operator Information

Control room indications include both dedicated displays and on-demand displays ~~from the Process Monitoring and Control System~~. These indications include the digital recirculation flow controller process variables, the recirculation pump speed and POWER SUPPLY operating status, and the *core flow measurement system outputs. Also, indicating lights are provided to indicate the control system configuration and the trip function status.*

7.7.1.4 Feedwater Control System—Instrumentation and Controls

STD DEP T1 3.4-1

STD DEP 7.7-21

(5) Reactor Vessel Water Level Measurement

Reactor vessel narrow range water level is measured by three identical, independent sensing systems which are a part of the Nuclear Boiler System (NBS). For each level measurement channel, a differential pressure transmitter senses the difference between the pressure caused by a constant reference column of water and the pressure caused by the variable height of water in the reactor vessel. The differential pressure transmitter is installed on lines which are part of the Nuclear Boiler System (Subsection 7.7.1.1). The FWCS FTDCs will determine one validated narrow range level signal using the three level measurements, received from NBS ~~via the Non-Essential Multiplexing System (NEMS),~~ as inputs to a signal validation algorithm. The validated narrow range water level is indicated on the main control panel and continuously recorded in the main control room.

(6) Steam Flow Measurement

The steam flow in each of four main steamlines is sensed at the reactor pressure vessel nozzle venturis. Two transmitters per steamline sense the venturi differential pressure and send these signals to the FTDCs~~ via the NEMS~~. The ~~NEMS~~ signal conditioning algorithms take the square root of the venturi differential pressures and provide steam flow rate signals ~~to the FTDCs~~ for validation into one steam flow measurement per line. These validated measurements are summed in the FTDCs to give the total steam flow rate out of the vessel. The total steam flow rate is indicated on the main control panel and recorded in the main control room.

(7) Feedwater Flow Measurement

Feedwater flow is sensed at a single flow element in each of the two feedwater lines. ~~Two~~ Three *transmitters per feedwater line sense the differential pressure and send these signals to the FTDCs~~ via the NEMS~~. The ~~NEMS~~ signal conditioning algorithms take the square root of the differential pressure and provide feedwater flow rate signals ~~to the FTDCs~~ for validation into one feedwater flow measurement per line. These validated measurements are summed ~~in the FTDCs~~ to give the total feedwater flow rate into the vessel. The total feedwater flow rate is indicated on the main control panel and recorded in the main control room.*

Feedpump suction flow is sensed at a single flow element upstream of each feedpump. The suction line flow element differential pressure is sensed by ~~a single transmitter~~ three transmitters and sent to the FTDCs ~~via the NEMS~~. The ~~NEMS~~ signal conditioning algorithms take the square root of the differential pressure and provide the suction flow rate measurements to the FTDCs. The feedpump suction flow rate is compared to the demand flow for that pump, and the resulting error is used to adjust the actuator in the direction necessary to reduce that error. Feedpump speed change via adjustable speed drives and low flow control valve position control are the flow adjustment techniques involved.

(8) Feedwater/Level Control

Each FTDC will execute the control software for all three of the control modes. Actuator demands from the triply redundant FTDCs will be sent ~~over the NEMS~~ to field voters which will determine a single demand to be sent to each actuator. Each feedpump speed or control valve demand may be controlled either automatically by the control algorithms in the FTDCs or else manually from the main control panel through the FTDCs.

(9) Interlocks

The level control system also provides interlocks and control functions to other systems. When the reactor water level reaches the Level 8 trip setpoint, the FWCS simultaneously annunciates a control room alarm, sends a trip signal to the Turbine Control System to trip the turbine generator, and sends trip signals to the Condensate, Feedwater and Condensate Air Extraction (CF&CAE) System to trip all feed pumps and to close the main feedwater discharge valves and feedpump bypass valves. This interlock is enacted to protect the turbine from damage from high moisture content in the steam caused by excessive carryover while preventing water level from rising any higher. This interlock also prevents overpressurization of the vessel by isolating the condensate pumps from the vessel and it is implemented by an independent FTDC from the FTDC that performs level control function.

(10) Feedwater Flow Control

Feedwater flow is delivered to the reactor vessel through ~~a combination of three~~ adjustable speed motor-driven feedpumps which are arranged in parallel. During planned operation, the feedpump speed demand signal from the FTDCs is sent to a field voter which sends a single demand signal to the feed pump speed control systems. Each adjustable speed drive can also be controlled by its manual/automatic transfer station which is part of the Feedwater and Condensate System. A low flow control valve (LFCV) is also provided in parallel to a common discharge line from the feedpumps. During low flow operation, the LFCV demand signal from the FTDCs are sent to a field voter which sends a single demand signal to the LFCV control system.

The LFCV can also be controlled by the manual/automatic transfer station which is part of the feedwater and condensate system.

7.7.1.5 ~~*Process Computer System (PCS)*~~ Plant Computer Functions (PCF) — Instrumentation and Controls

STD DEP T1 3.4-1

STD DEP 7.7-22

STD DEP Admin

(1) System Identification

The ~~PCS includes~~ PCF include *two subsystems, the Performance Monitoring and Control Subsystem (PMCS) and the Power Generation Control Subsystem (PGCS). Between them, the two subsystems perform the process monitoring and control and the calculations that are necessary for the effective evaluation of normal and emergency power plant operation. The ~~PCS is~~* PCF are *designed for high reliability utilizing redundant, network combined processing equipment which is capable of processing data, servicing subsystems, providing supervisory control over digital control systems and presenting data to the user.*

The purpose of the ~~PCS~~ PCF *is to increase the efficiency of plant performance by:*

(a) performing the functions and calculations defined as being necessary for the effective evaluation of nuclear power plant operation;

(c) Providing a permanent record and historical perspective for plant operating activities and abnormal events via the historian function*;*

The calculations performed by the process plant computer include process validation and conversion, combination of points, nuclear system supply performance calculations, and balance-of-plant performance calculations.

(2) Classification

The ~~Process Computer System (PCS) is~~ Plant Computer Functions (PCF) are *classified as ~~a~~ ~~non-safety-related~~* nonsafety-related *~~system~~ and has no safety-related design basis. However, it is designed so that the functional capabilities of safety-related systems are not affected by it.*

(3) Power Sources

The power for the ~~PCS is~~ PCF are *supplied from two vital ac power supplies. These are redundant, uninterruptible non-Class 1E 120 Vac power supplies. No single power failure will cause the loss of any ~~PCS~~* PCF *function.*

(4) Equipment

The ~~PCS is~~ PCF are *composed of the following features and components:*

(a) The central processing units, which perform various calculations, make necessary interpretations and provide for general input/output device control between I/O devices and memory.

(5) Testability

The ~~PCS has~~ PCF have *self-checking provisions. ~~It performs~~* They perform *diagnostic checks to determine the operability of certain portions of the system hardware and performs internal programming checks to verify that input signals and selected program computations are either within specific limits or within reasonable bounds.*

(7) NSS Performance Calculation Programs

The NSS programs provide the reactor core performance information. The functions performed are as follows:

(c) ~~After~~ When an ATLM setpoint update is requested and after *calculating the power distribution within the core, the computer* sends data to the ATLM of the RCIS on the calculated fuel thermal operating limits and corresponding initial LPRM values. The ATLM monitors LPRM, ARRM, control rod position, and other plant readings (refer to 7.7.1.2.1 Control Rod Drive Control System Interfaces) and issues rod block signals to prevent violation of the fuel thermal operating limits. *~~uses appropriate reactor operating limit criteria to establish alarm trip settings (ATS) for each LPRM channel. These settings are expressed as maximum acceptable LPRM values to which the actual scanned LPRM readings are compared. The scanned LPRM, when exceeding the ATS, will sound an alarm and thereby assist the operator to maintain core operation within permissible thermal limits established by the prescribed maximum fuel rod power density and minimum critical power ratio criteria.~~ LPRM calibration constants are periodically calculated.*

(e) Each LPRM reading is scanned at an appropriate rate and, together with data from PCF downloaded to the ATLM, *~~appropriate computational methods, provides nearly~~* the ATLM provides nearly *continuous reevaluation of core thermal limits ~~with subsequent modification to the LPRM ATS~~ based on the new reactor operating level. The range of surveillance and the rapidity with which the computer responds to the reactor changes permit more rapid power maneuvering with the assurance that thermal operating limits will not be exceeded.*

7.7.1.5.1 Performance Monitoring and Control Subsystem

STD DEP 7.7-22

STD DEP 7.7-23

STD DEP Admin

NSS Performance Module *— The NSS performance module provides the reactor core performance information. The calculations performed are as follows:*

- ~~*After*~~ When an Automatic Thermal Limit Monitor (ATLM) setpoint update is requested and after *calculating the power distribution within the core, the computer* sends data to the ATLM of the RCIS on the calculated fuel thermal operating limits and corresponding initial LPRM values. The ATLM monitors LPRM, APRM, control rod position, and other plant readings (see 7.7.1.2.1 Control Rod Drive Control System Interfaces) and issues rod block signals to prevent violation of the fuel thermal operating limits. ~~*uses appropriate reactor operating limit criteria to establish alarm trip settings for each LPRM channel. These settings are expressed as maximum acceptable LPRM values to which the actual scanned LPRM readings are compared. The scanned LPRM, when exceeding the alarm trip settings, will sound an alarm and thereby assist the operator to maintain core operation within permissible thermal limits established by the prescribed maximum fuel rod power density and minimum critical power ratio criteria.*~~ *LPRM calibration constants are periodically calculated.*
- *Each LPRM is scanned at an appropriate rate and, together with* the ATLM function, ~~*appropriate computational methods,*~~ *provides nearly continuous reevaluation of core thermal limits* ~~*with subsequent modification to the LPRM alarm trip settings*~~ *based on the new reactor operating level. The range of surveillance and the rapidity with which the computer responds to the reactor changes permit more rapid power maneuvering with the assurance that thermal operating limits will not be exceeded.*
- *Flux level and position data from the automatic* ~~*fixed in-core probe (AFIP)*~~ traversing incore probe (ATIP) *equipment are read into the computer. The computer evaluates the data and determines gain adjustment factors by which the LPRM amplifier gains can be altered to compensate for exposure-induced sensitivity loss. The LPRM amplifier gains are not to be physically altered except immediately prior to a whole core calibration using the* ~~*AFIP*~~ ATIP *system. The gain adjustment factor computations help to indicate to the operator when such a calibration procedure is necessary.*

Point Log and Alarm Module

Analog Variable Alarms*—The processor is capable of checking each analog input variable against two types of limits for alarming purposes:*

The alarming sequence consists of an audible alarm, a console alarm, and a descriptive message for the variables that exceed process alarm limits. The processor provides the capability to alarm on the main control room annunciator system in the event of abnormal ~~*PCS*~~ PCF *operation.*

7.7.1.5.2 Power Generation Control Subsystem

STD DEP T1 3.4-1

The Power Generation Control Subsystem (PGCS) is a top level controller that monitors the overall plant conditions, issues control commands to ~~*non-safety-related*~~ nonsafety-related *systems, and adjusts setpoints of lower level controllers to support automation of the normal plant startup, shutdown, and power range operations. The PGCS is a separate function of the* ~~*Process Computer System*~~ Plant Computer Functions. *The PGCS contains the algorithms for the automated control sequences associated with plant startup, shutdown and normal power range operation. The PGCS issues reactor command signals to the automatic power regulator (APR). The reactor power change algorithms are implemented in the APR.*

7.7.1.5.3 Safety Evaluation

STD DEP T1 3.4-1

~~*The Process Computer System is*~~ Plant Computer Functions are *designed to provide the operator with certain categories of information and to supplement procedure requirements for control rod manipulation during reactor startup and shutdown. The system augments existing information from other systems such that the operator can start up, operate at power and shut down in an efficient manner. The PGCS function provides signals to the APR as explained in Subsection 7.7.1.5.2. However, this is a power generation function. Neither the* ~~*Process Computer System*~~ Plant Computer Functions *nor* ~~*its*~~ *their PGCS function initiate or control any engineered safeguard or safety-related system.*

7.7.1.5.4 Testing and Inspection Requirements

STD DEP T1 3.4-1

The ~~*Process Computer System has*~~ Plant Computer Functions have *self-checking provisions.* ~~*It performs*~~ They perform *diagnostic checks to determine the operability of certain portions of the system hardware and performs internal programming checks to verify that input signals and selected program computations are either within specific limits or within reasonable bounds.*

7.7.1.5.5 Instrumentation Requirements

STD DEP T1 3.4-1

There is no instrumentation in the ~~Process Computer System~~ Plant Computer Functions *other than the video display units (VDUs). Control of the ~~Process Computer System~~* Plant Computer Functions *is accomplished with on- screen methods and a few hard switches. System auxiliaries such as printers* and, *plotters~~, and tape handlers~~ have their own local controls.*

7.7.1.6 Neutron Monitoring System— Nonsafety-Related Subsystems

7.7.1.6.1 Automatic Traversing Incore Probe (ATIP)

STD DEP 7.7-23

(1) Description

Flux readings along the axial length of the core are obtained by first inserting the sensor fully to the top of the calibration tube and then taking data as the sensor is withdrawn continuously from the top. Sensor flux reading, sensor axial positions data in the core, and LPRM location data are all sent to an ATIP control unit located in the control room, where the data can be stored. The data are then sent to the ~~process~~ plant *computer for calibration and performance calculations. The whole ATIP scanning sequence and instructions are fully automated, with manual control available.*

(2) Classification

The ATIP is ~~non-safety-related~~ nonsafety-related, but contains components that have been designated as safety-related *as shown in Table 3.2-1. The subsystem is an operational system and has no safety function.*

(4) Testability

The ATIP equipment is tested and calibrated using ~~heat balance data and~~ procedures described in the instruction manual.

7.7.1.7 Automatic Power Regulator System—Instrumentation and Controls

STD DEP T1 3.4-1

(1) Identification

The primary objective of the Automatic Power Regulator (APR) System is to control reactor power during reactor startup, power generation, and reactor shutdown, by appropriate commands to change rod positions, or to change reactor recirculation flow. The secondary objective of the APR System is to control the pressure regulator setpoint (or turbine bypass valve position) during reactor heatup and depressurization (e.g., to control the reactor cooldown rate). The APR System consists of redundant process controllers.

Automatic power regulation is achieved by appropriate control algorithms for different phases of the reactor operation which include approach to criticality, heatup, reactor power increase, automatic load following, reactor power decrease, and reactor depressurization and cooldown. The APR System receives input from the ~~plant~~ process *computer, the Power Generation Control System (Subsection 7.7.1.5.1), the Steam Bypass and Pressure Control System (Subsection 7.7.1.8), and the operator's control console. The output demand signals from the APR System are to the RCIS to position the control rods, to the RFC System to change reactor coolant recirculation flow, and to the SB&PC System for automatic load following operations. The PGS performs the overall plant startup, power operation, and shutdown functions. The APR System performs only those functions associated with reactor power changes and with pressure regulator setpoint (or turbine bypass valve position) changes during reactor heatup or depressurization. A simplified functional block diagram of the APR System is provided in Figure 7.7-11.*

(4) Normal Operation

For reactor power control, the APR System contains algorithms that can change reactor power by control rod motions, or by reactor coolant recirculation flow changes, but not both at the same time. A prescribed control rod sequence is followed when manipulating control rods for reactor criticality, heatup, power changes, and automatic load following. Each of these functions has its own algorithm to achieve its designed objective. The control rod sequence can be updated from the ~~*process*~~ plant computer based on inputs from the reactor engineer. A predefined trajectory of power-flow is followed when controlling reactor power. The potentially unstable region of the power- flow map is avoided during plant startup, automatic load following, and shutdown. During automatic load following operation, the APR System interfaces with the SB&PC System to coordinate main turbine and reactor power changes for optimal performance.

(6) Equipment

The APR System control functional logic is performed by redundant, microprocessor-based fault-tolerant digital controllers (FTDC). The FTDC performs many functions. It reads and validates inputs from the ~~*Non-Essential Multiplexing System (NEMS)*~~ Plant Data Network (PDN) interface once every sampling period. It performs the specific power control calculations and processes the pertinent alarm and interlock functions, then updates all system outputs to the ~~*NEMSPDN*~~ ~~*NEMS*~~*PDN*. To prevent computational divergence among the redundant processing channels, each channel performs a comparison check of its calculated results with the other redundant channels. The internal FTDC architecture features redundant ~~*multiplexing*~~ interfacing units for communications between the ~~*NEMS*~~ PDN and the FTDC processing channels..

(9) Operator Information and Operational Considerations

During operation of the APR System, the operator observes the performance of the plant via ~~*CRTs*~~ VDUs on the main console or on large screen displays in the main control room. The APR System can be switched into the manual mode by the operator, and a control sequence, which is in progress, can be stopped by the operator at any time. This will stop automatic reactor power changes. If any system or component conditions are abnormal during execution of the prescribed sequences, continued operation is stopped automatically and alarms will be activated to alert the operator. With the APR System in manual mode, the operator can manipulate control rods and recirculation flow through the normal controls. A failure of the APR System will not prevent manual controls of reactor power, nor will it prevent safe shutdown of the reactor.

7.7.1.8 Steam Bypass & Pressure Control System—Instrumentation and Controls

STD DEP Admin

STD DEP 7.7-24

(5) Abnormal Plant Operation

The SB&PC System is also designed for operation with other reactor control systems to avoid reactor trip after significant plant disturbances. Examples of such disturbances are loss of one feedwater pump, loss of three recirculation pumps, inadvertent opening of one *safety/relief* ~~*valves*~~ valve *or* two *steam bypass valves, main turbine stop/control valve surveillance testing, and MSIV testing.*

(7) I&C Interface

The external signal interfaces for the SB&PC System are as follows:

(a) ~~*Narrow range dome pressure signals*~~ Validated dome pressure signal *from the SB&PC System to the Recirculation Flow Control System.*

(e) Output signals from the SB&PC System to the performance monitoring and control function of the ~~*process*~~ plant *computer.*

(h) Bypass valve position, ~~*servo current, position error*~~ *and valve open and closed signals from the Turbine Bypass System.*

(i) Emergency bypass valve fast opening signals ~~*and bypass valve flow demand signals*~~, servo current, and valve position error *from the SB&PC System to the Turbine Bypass System.*

(l) ~~*Governor free demand signal to the reactor power compensator in the APR system.*~~ Automatic Frequency Control signal sent from the APR system to the SB&PC system.

(m) ~~Reactor power compensation signal in accordance with speed error from the SB&PC System to the APR System.~~ SB&PC system sends limited speed regulator output to the reactor power compensator in the APR system.

(o) Pressure regulator output signal is sent in accordance with speed error from the SB&PC system to the APR system.

(8) *Operational Considerations*

During abnormal conditions that result in low main condenser vacuum, the steam bypass valves ~~and MSIVs~~ close to prevent positive pressure conditions that would rupture main condenser diaphragms. ~~Manually operated provisions permit opening of the MSIVs (i.e., inhibit the closure function) during startup operation.~~ This vacuum protection function bypass permits heatup of the main steamlines (up to the steam bypass valves and turbine stop valves) before normal condenser vacuum is obtained and permits cold shutdown testing of the isolation valves.

(10) *Operator Information*

During operation of the SB&PC System, the operator may observe the performance of the plant via ~~CRTs~~ VDUs *on the main control console or on large screen displays in the main control room. As described in (8) above, the self-test provision assures that all transducer/controller failures are indicated to the operator and maintenance personnel. The triplicated logic facilitates online repair of the controller circuit boards.*

7.7.1.9 ~~Non-Essential Multiplexing System~~ Plant Data Network

STD DEP Admin

The discussion of the Plant Data Network has been relocated to Subsection 7.9S.

~~The Non-Essential Multiplexing System(NEMS) is separate and distinct from the Essential Multiplexing System (EMS), though both are similar in design and architecture. Except for system interfaces and quality assurance requirements unique to Class 1E systems, specific design attributes discussed in Section 7A.2 pertain to the NEMS as well. Both systems are fully described in their subsection design specifications available from the Master Parts List referenced in Subsection 1.1.3. This subsection describes those features which are unique to the NEMS.~~

~~(1) System Description~~

~~The NEMS provides distributed control and instrumentation data communication networks to support the monitoring and control of interfacing plant power generation (non-safety-related) systems. [The EMS performs the same function for the protection (safety-related) systems.] The NEMS provides all the electrical devices and circuitry (such as multiplexing units, data transmission line and transmission controllers), between sensors,~~

~~*display devices, controllers and actuators, which are defined by other plant systems. The NEMS also includes the associated data acquisition and communication software required to support its function of transmitting plant wide data for distributed control and monitoring.*~~

~~*The NEMS acquires both analog and digital signals from remote process sensors and discrete monitors located within a plant, and multiplexes the signals to a central control room to drive annunciators, monitors and recorders, and to send signals, and output control signals are multiplexed to actuators, valves, motor drives and other control equipment in the plant associated with non-safety-related systems.*~~

~~*Consistent with fault-tolerant (triplicated) digital control systems utilized in feedwater control, reactor recirculation flow control and steam bypass and pressure regulation, the NEMS is also triplicated for these systems interfaces, as appropriate, each with its own independent control.*~~

~~*The remaining communication functions of the NEMS provides the following system functions:*~~

~~*(a) Acquires non-safety-related data (e.g., sensed input and equipment status signals) throughout the plant.*~~

~~*(b) Conditions, formats and transmits signals via fiber optics to displays, controllers, and the PCS.*~~

~~*(c) Receives signals via fiber optics, then multiplexes and prepares them for use in interfacing non-safety-related equipment as required.*~~

~~*(d) Formats and transmits processed control signals via fiber optics to actuator circuits, and then converts the fiber optic control signals to electrical signals for the actuator circuits.*~~

~~*(2) System Interface*~~

~~*The NEMS interfaces with the following systems, which are all non-safety-related:*~~

- ~~*Reactor*~~
- ~~*Nuclear Boiler (non-safety-related portion)*~~
- ~~*Reactor Recirculation*~~
- ~~*Rod Control*~~
- ~~*Feedwater Control (including feedwater pump turbine)*~~
- ~~*Recirculation Flow Control*~~

- ~~Steam Bypass and Pressure Control~~
- ~~Process Computer~~
- ~~Power Generation Control~~
- ~~Process Radiation Monitoring (non-safety-related portion)~~
- ~~Area Radiation Monitoring~~
- ~~Dust Radiation Monitoring~~
- ~~Refueling and Reactor Servicing~~
- ~~Reactor Water Cleanup~~
- ~~Fuel Pool Cooling and Cleanup~~
- ~~Suppression Pool Cleanup~~
- ~~Control Complex~~
- ~~Makeup Water (purified, condensated)~~
- ~~HVAC Normal Cooling Water~~
- ~~Ultimate Heat Sink~~
- ~~Turbine Service Water~~
- ~~Steam and Heated Water~~
- ~~Compressed Gas~~
- ~~Sampling~~
- ~~Condensate Demineralizer/Filter Facility~~
- ~~Radwaste (includes Offgas)~~
- ~~Turbine Bypass~~
- ~~Turbine Control~~
- ~~Feedwater Condensate Water~~
- ~~Heater Drain~~
- ~~Lubricating Oil~~
- ~~Turbine Gland Steam~~

- ~~*Extraction*~~
- ~~*Main Generator*~~
- ~~*HVAC-Reactor Building*~~
- ~~*HVAC-Other Buildings*~~
- ~~*Electrical Power Distribution (non-safety-related portion)*~~
- ~~*Annunciator*~~

~~*(3) Classification*~~

~~*The NEMs, of itself, is neither a power generation system nor a protection system. It is a support system utilized for assimilation, transmission and interpretation of data for power generation (non-safety-related) systems and their associated sensors, actuators and interconnections. It is classified as non-safety-related.*~~

~~*(4) Power Sources*~~

~~*The NEMS receives its power from three separate non-Class 1E distribution panels from the non-Class 1E 120 VAC UPS. This redundancy allows the NEMS to supply triplicated logic functions such that any single failure in the system power supplies will not cause the loss of the validated outputs to the interfacing actuators and to the monitors and displays.*~~

~~*(5) Equipment*~~

~~*The hardware and "firmware" architectures for the NEMS are the same as those of the EMS, which are described in Appendix 7A [see the response to NRC Requests (10) and (11) of Section 7A.2].*~~

~~*(6) Testability*~~

~~*The EMS test features described in Appendix 7A, Section 7A.2, Items (3), (4) and (6) are generally equivalent for the NEMS, except that the NEMS does not interface with, nor rely upon, the SSLC [see the response to NRC Request (6) of Section 7A.2]. Also, the NEMS self-test features include the analog fault-tolerant voting system unique to the control systems employing logic.*~~

~~*(7) Environmental Considerations*~~

~~*The NEMS is not required for safety purposes, nor is it required to operate after the design basis accident. Its support function serves power generation purposes only and it is designed to operate in the normal plant environment.*~~

~~(8) Operational Considerations~~

~~The system automatically initiates for both cold and warm starts. No operator actions are required in that the system is capable of self-starting following power interruptions, or any other single failure, including any single processor failure. After repairs or replacements are performed, the system automatically re-initializes to normal status when power is restored to any unit and automatically resets any alarms.~~

~~(9) Operator Information~~

~~The self-test provisions are designed to alert the operator to system anomalies via interfaces with the process computer and the annunciator. Problems significant enough to cause system channel failures are annunciated separately from those which allow continued operation. The circuitry is designed such that no control output or alarm is inadvertently activated during system initialization or shutdown. For such events, control outputs change to predetermined fail-safe outputs.~~

7.7.2.1 Nuclear Boiler System—Reactor Vessel Instrumentation

7.7.2.1.2 Specific Regulatory Requirements Conformance

STD DEP T1 3.4-1

(2) Regulatory Guides (RGs)

In accordance with the Standard Review Plan for Section 7.7 and with Table 7.1-2, only RG 1.151(Instrument Sensing Lines) need be addressed for the ABWR.

*(a) ~~(e)~~ **Criteria**: RG 1.151— "Instrument Sensing Lines"*

*(b) ~~((f)~~ **Conformance**: There are four independent sets of instrument lines which are mechanically separated into each of the four instrument divisions of the NBS (see Figure 5.1-3, NBS P&ID). Each of the four instrument lines interfaces with sensors assigned to each of the four Class 1E electrical divisions for safety-related systems.*

There are also non-Class 1E instruments that derive their input for the reactor vessel instrumentation portion of the NBS from these lines. There is no safety-related controlling function involved in this instrumentation and it is entirely separate (including its own ~~MUX system~~ data communication network*) from the safety-related instruments and their associated systems.*

The safety-related instrumentation provides vessel pressure and water level sensing for all protection systems. These instruments are arranged in two-out-of-four logic combinations and their signals are shared by both safety-related and non-safety-related systems. All of *these signals are ~~multiplexed and~~ passed through fiber-optic media before entering the voting logic of the redundant divisions of the safety-related systems; or of non-safety-related systems which make up the various networks. Separation and isolation is thus preserved both mechanically and electrically in accordance with IEEE ~~279~~* 603 *and Regulatory Guide 1.75.*

7.7.2.5 ~~*Process Computer System*~~ Plant Computer Functions—Instrumentation and Controls

General Functional Requirements Conformance

STD DEP T1 3.4-1

STD DEP Admin

The ~~Process Computer System (PCS)~~ Plant Computer Functions (PCFs) *~~is~~* are *designed to provide the operator with certain categories of information and to supplement procedure requirements for control rod manipulation during reactor startup and shutdown. ~~The system augments~~* These functions augment *existing information from other systems such that the operator can start up, operate at power, and shut down in an efficient manner. The ~~PGCC~~* PGCS *function provides signals to the ~~Automated~~* Automatic *Power Regulator (APR) as explained in Subsection 7.7.1.5.1. However, this is a power generation function. Neither the ~~PCS~~* PCF *nor its ~~PGCC~~* PGCS *function initiate or control any engineered safeguard or safety-related system.*

7.7.2.5.2 Specific Regulatory Requirements Conformance

STD DEP T1 3.4-1

Table 7.1-2 identifies the non-safety-related control systems and the associated codes and standards applied in accordance with Section 7.7 of the Standard Review Plan for BWRs. However, since the computer has no controlling function, none of the listed criteria is applicable.

Input data for the ~~PCS~~ PCF *are derived from both Class 1E and non-Class 1E sources. All such interfaces are optically isolated, where necessary, to assure the proper separation of redundant signals in accordance with Regulatory Guide 1.75.*

7.7.2.6 Neutron Monitoring System—ATIP Subsystem Instrumentation and Controls

7.7.2.6.2 Specific Regulatory Requirements Conformance

STD DEP 7.7-23

Table 7.1-2 identifies the non-safety-related control systems and the associated codes and standards applied in accordance with Section 7.7 of the Standard Review Plan for BWRs. However, since Since the ATIP System has no controlling function, and is used only for calibration of the LPRMs, none of the listed criteria is applicable. However, the

ATIP system does have isolation valves, which are safety-related components that would require the system to perform automatic containment isolation function. The following analysis lists the applicable criteria in order of the listing on the table, and discusses the degree of conformance for each. Any exceptions or clarifications are so noted.

(1) General Design Criteria (GDC)

(a) **Criteria**: GDC 56

(b) **Conformance**: The ATIP component design is in compliance with this GDC by following the guidance of Reg. Guide 1.11.

(2) Regulatory Guide (RG)

(a) **Criteria**: RG 1.11

(b) **Conformance**: The ATIP component design conforms to the above-listed RG.

7.7.2.8 Steam Bypass and Pressure Control System—Instrumentation and Controls

7.7.2.8.1 General Functional Requirements Conformance

STD DEP 7.7-24

The Steam Bypass & Pressure Control (SB&PC) System is a power generation system in that it inputs information to the Automatic Power Regulator, which, in turn, controls reactor power by manipulating control rods (via the RCIS) or recirculation flow (via the RFC System). The protective scram function is entirely separate (via the RPS).

The SB&PC is classified as ~~non-safety-related~~ nonsafety-related *~~and does not interface with any engineered safeguard or safety-related system.~~*; SB&PC system does receive reactor pressure and water level from the NBS system (safety system) but only from nonsafety instrumentation.

7.7.2.8.2 Specific Regulatory Requirements Conformance

STD DEP T1 2.2-1

Table 7.1-2 identifies the ~~non-safety-related~~ nonsafety-related *control systems and the associated codes and standards applied in accordance with Section 7.7 of the Standard Review Plan for BWRs. The following analysis lists the applicable criteria in order of the listing on the table, and discusses the degree of conformance for each. Any exceptions or clarifications are so noted.*

(1) General Design Criteria (GDC)

*(a) **Criteria:** GDCs 13 and 19*

*(c) **Conformance:** The SB&PC System is in compliance with these GDCs, in part, or as a whole, as applicable. The GDCs are generally addressed in Subsection 3.1.2.*

(2) Regulatory Guides (RGs)

In accordance with the Standard Review Plan for Section 7.7 and with Table 7.1-2, only RG 1.151 ("Instrument Sensing Lines") need be addressed for the ABWR.

*(a) **Criteria**: Regulatory Guide 1.151—Instrument Sensing Lines*

*(d) **Conformance**: The SB&PC interfaces with sensors connected to instrument lines on both the reactor and the turbine. The reactor instrument line interface is via the Nuclear Boiler System, which is in full compliance with this guide as discussed in Subsection 7.7.2.1.2 (2).*

~~*There are four independent turbine instrument lines, which contain turbine first-stage pressure sensors as part of the Turbine Control System, in addition to the non-Class 1E sensors associated with the SB&PC System. The first-stage turbine pressure signals are used as bypass interlocks for the turbine control valve fast closure and turbine stop valve closure scram functions [Subsection 7.2.1.1.4.2 (6) (d)]. No single failure can cause this function to be disabled. In addition, since the Turbine Building itself is a non-seismic structure, these scram functions are backed up by diverse reactor variables [reactor high pressure and high flux (via NMS)] which will independently initiate scram, should the turbine signals be lost. Therefore, no event associated with turbine instrument lines can cause an action requiring scram, while at the same time disabling the scram function.*~~ The SB&PC System fully complies with Regulatory Guide 1.151.

7.7.2.9 ~~*Non-Essential Multiplexing System*~~ Plant Data Network—Instrumentation and Controls

7.7.2.9.1 General Requirements Conformance

STD DEP T1 3.4-1

The ~~NEMS~~ PDN, of itself, is neither a power generation system nor a protection system. It is a ~~support system~~ data communication network utilized for assimilation, transmission and interpretation of data for power generation (non-safety-related) systems and their associated sensors, actuators and interconnections. It is classified as non-safety-related and does not interface with any engineered safeguard or safety-related system except for isolated alarms for annunciation.

The ~~NEMS~~ PDN is an integral part of the power generation systems which it supports. As such, it meets the same functional requirements imposed on those systems. Although not required to meet the single-failure criterion, the system is redundant and receives its power from redundant, highly reliable power sources such that no single failure will cause its basic function to fail.

7.7.2.9.2 Specific Regulatory Requirements Conformance

STD DEP T1 3.4-1

Table 7.1-2 identifies the ~~non-safety related~~ nonsafety-related *control systems and the associated codes and standards applied in accordance with Section 7.7 of the Standard Review Plan. However, as mentioned above, the ~~NEMS~~* PDN *is not a separate control system subject to separate review, but is the data communication vehicle for virtually all of the non-safety- related systems. It provides specific enhancement for all control systems in their conformance with GDCs 13 and 19.*

Table 7.7-1 ~~RCIS Module Operation Environment~~ Not Used

	~~Minimum~~	~~Design Center~~	~~Maximum~~	~~(Units)~~
~~(1)Temperature~~				
~~(a) Operating~~	~~–10~~	~~20~~	~~50~~	~~°C~~
~~(b) Non-operating~~	~~–20~~		~~60~~	~~°C~~
~~(2)Relative Humidity (Non-condensing)~~				
~~(a) Operating~~	~~10~~	~~50~~	~~90~~	~~%RH~~
~~(b) Non-operating~~	~~5~~		~~95~~	~~%RH~~
~~(3)Atmospheric Pressure~~				
~~(a) Static~~	~~0.09~~	~~0.1~~	~~0.11~~	~~MPa~~
~~(4)Radiation:~~	~~Operating gamma dose rate [0.036 mGy (carbon)/h] integrated dose over qualified life [100 Gy (carbon)]~~			
~~(5)Seismic:~~	~~All RCIS modules and cabinets are designed to operate correctly during accelerations of 2 g's in any plane for one minute over the frequency range of 0.1 to 30 Hz. All RCIS cabinets are designed to be capable of withstanding an acceleration of 5 g's in any plane for one minute over the frequency range of 0.1 to 30 Hz without sustaining damage.~~			

The following figures are located in Chapter 21:

- Figure 7.7- 2 Rod Control and Information System IED (Sheets 1-5)
- Figure 7.7- 3 Rod Control and Information System IBD (Sheets 1-114, including 17A, 18A, 31A, 43A and 47A)
- Figure 7.7-4 Control Rod Drive System IBD (Sheet 1)
- Figure 7.7- 5 Recirculation Flow Control System IED (Sheets 1-2)
- Figure 7.7- 7 Recirculation Flow Control System IBD (Sheets 1,2,3,5,6,7,8)
- Figure 7.7- 8 Feedwater Control System IED (Sheets 1-3)
- Figure 7.7- 9 Feedwater Control System IBD (Sheets 1-3,7-14)

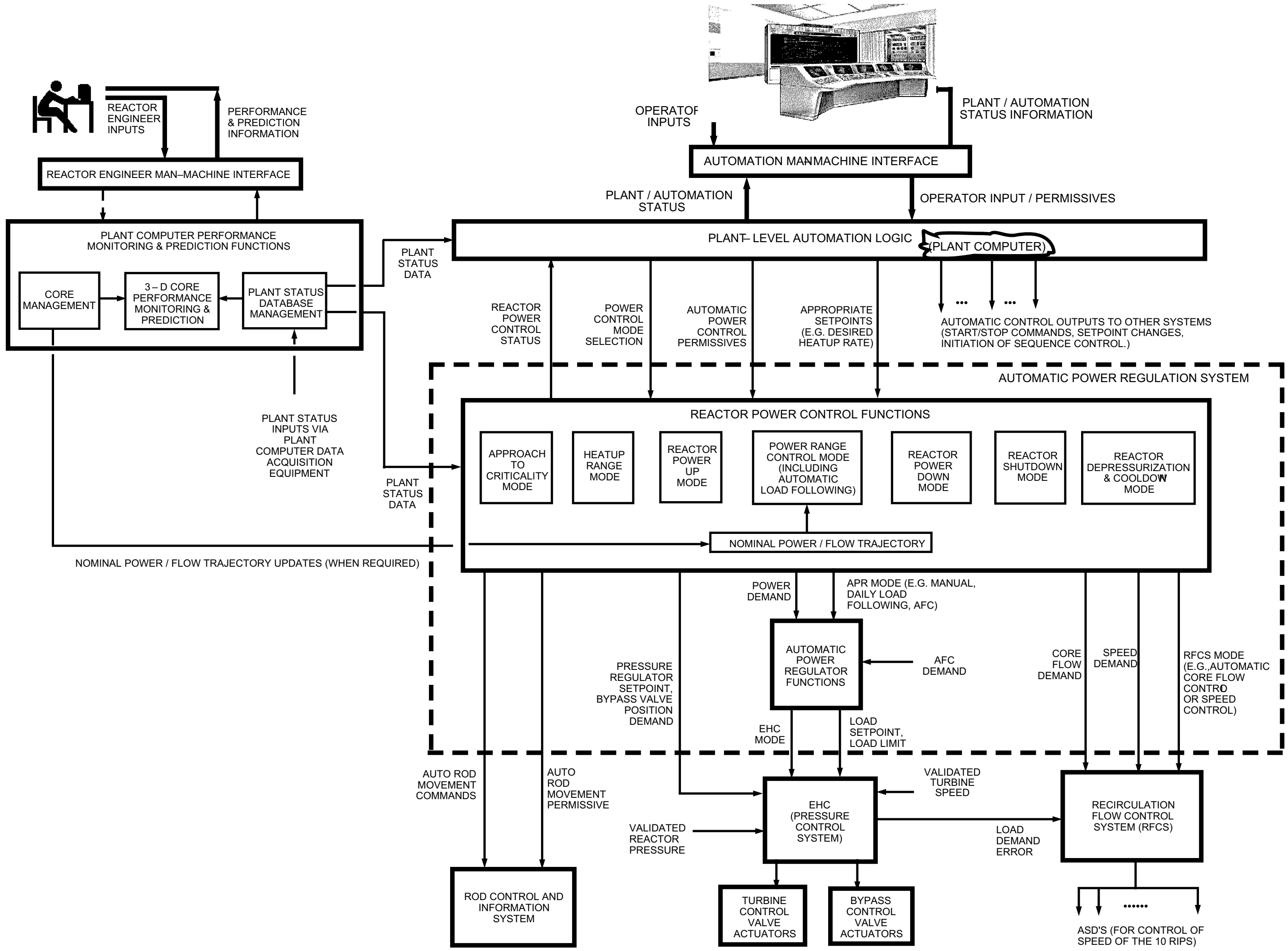

Figure 7.7-11 Simplified Functional Diagram of the Automatic Power Regulation System

The following figures are located in Chapter 21:

- Figure 7.7-12 Steam Bypass and Pressure Control System IED (Sheets 1-2)
- Figure 7.7-13 Steam Bypass and Pressure Control System IBD (Sheets 2-5)
- Figure 7.7-14 Fuel Pool Cooling & Cleanup System IBD (Sheets 2,3,6,7,8)