JAN 27 1986

CONF-851009--57

The TREAT Upgrade Manual Reactor Control System and its
Interface with the Automatic Reactor Control System
and the Plant Protection System

William P. McDowell

Argonne National Laboratory
Argonne, Illinois 60439

CONF-851009--57

DE86 005542

ABSTRACT

The Transient Reactor Test Facility (TREAT) at Argonne National Laboratory is being upgraded to to simulate extreme conditions in a reactor. This facility will be used to subject test assemblies of fuel bundles to very rapid and intense power transients. This paper will describe in detail the manual reactor control system and its interfaces with the plant protection system the automatic reactor control system.

The CRIS stands between the source of all requests for rod motion from both the manual and the automatic control systems and the rod drive mechanisms. The system acts to minimize the probability that the consequence of an operator error or equipment malfunction will require intercession by the reactor trip system. The CRIS is designed to limit reactivity insertion rates by restricting the MRCS to single and sequential rod withdrawals while allowing multiple rod insertions. All operations of the CRIS can be overridden by the reactor trip system.

INTRODUCTION

The Transient Reactor Test Facility (TREAT) at Argonne National Laboratory West located on the site of the National Reactor Engineering Laboratory near Idaho Falls, Idaho is being upgraded to simulate extreme conditions in a reactor. This facility will be used to subject test assemblies of fuel bundles to very rapid and intense power transients. The reactor control system (RCS) provides control and interlock interfaces with the control rod drive assemblies and the support and instrument systems required to operate the reactor. The RCS is designed to (1) provide the information and control functions required to start up the reactor from a shutdown state, (2) to conduct operations and irradiate experiments in both steady-state and transient modes, (3) to shutdown the reactor either manually or automatically at the attainment of predetermined but variable power levels, transient energy releases or time periods and (4) to maintain the reactor in a safe shutdown condition during removal of test or calibration equipment from the reactor.

The principle elements in the RCS are the control and interlock interfaces with the electric and hydraulic rod operating systems, the manual reactor control system (MRCS) and the automatic reactor control system (ARCS). The ARCS has been described elsewhere. This paper describes the the manual reactor control system, the control rod interface system (CRIS) the Transient Rod Signal Interface (TRSI) and the MRCS interface with the ARCS and the hardwired plant protection system.

The Manual Reactor Control System provides the instrumentation and manually operated controls required to bring the reactor from shutdown condition to initial criticality; operate the reactor at low power; up to 120 kW, for neutron radiography, fuel pin and flux monitoring irradiation, reactor power measurements and similar operations; move the transient and control rods to the pre-transient positions required for transient operation; manually shut down the reactor to safe shutdown condition; and position the compensation rods during reactor startup

The Transient Rod Signal Interface (TRSI) monitors all elements of the system to determine if the system is ready for transient production. If an element reports that it is not ready for transient the TRSI inhibits high-speed transient rod motion. If all elements are ready it allows the control of the transient rods to be switched from manual to automatic. The system also interfaces the control computer with the hydraulic rod control system providing isolation as well as analog and digital signal switching.

MANUAL REACTOR CONTROL SYSTEM

Figure 1. Control Console

Figure 1 shows the operators view of the control console. These displays and controls provide the discrete logic and control functions which are required to operate all the rods in the startup,

MASTER
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

steady-state, and pre-transient modes. Directly in front of the operator are the rod control switches. The select switches for each group of rods has a different shape to provide tactile differentiation between rod functions.

There are three groups of four rods which must be controlled by the operator during a reactor startup. The compensation rods, the control rods and the transient rods. Each group of four may be withdrawn individually or inserted individually or as a bank.

The operator controls the rod positions during startup and steady-state operations by means of electrically interlocked, manually operated switches. The rod select switches allow the operator to choose one of the four rods in each group for a withdraw operation, or, if an insert operation is to be performed, the operator may select the "ALL" position. The "INSERT-WITHDRAW" switches allow the operator to move the selected rod in the desired direction. The system is designed so that only one rod may be withdrawn under manual control at any one time. Attempting to activate more than one "WITHDRAW" switch will cause all withdrawal activity to stop until such time as only one "WITHDRAW" switch is activated. The switch sections are arranged so that it is possible to insert one transient rod while withdrawing one control rod.

As shown in figure 2 the manual reactor control system is based on passive switch element logic. Switch 1, a 5-position, 5-section switch selects the rod to be operated. Any of the four rods can be selected for the insert or withdraw operation by selecting positions 1 through 4 on switch 1 and then moving switch 2 from its center spring return "OFF" position to either the "INSERT" or "WITHDRAW" positions. The "ALL" position allows all the rods to be inserted. Section 1E of switch 1 along with electronic logic in the control rod interlock system prevents multiple rod withdrawals. Switch sections S4C and S6C prevent the compensation rods from being withdrawn if either the control rods or the transient rods are being moved. All withdrawal action will stop until only one "INSERT-WITHDRAW" switch is activated.

For the compensation and control rods the control rod interlock system interfaces with the rods at a motor starter. The interlock design requires the coincident assertion of two enabling terms at this interface to energize the motor starter. The logic criteria imposed on an operator request for rod motion is shown in figure 3.

FIGURE 3 CONTROL AND SHUTDOWN ROD LOGIC DIAGRAM

The system used to insert a transient rod under manual control is identical to that for the compensation and control rods except that no motor starter is involved. In place of the motor starter the transient rods are operated by a servo system which, in the manual mode, responds to a voltage signal generated by the control rod interface system.

CONTROL ROD INTERLOCK SYSTEM

The control rod interlock system for each bank of rods is comprised of two sections, the rod select logic, and the rod operation logic.

The rod select logic is common to all four rods in a bank and provides the interface between the manual reactor control system and the rod operation logic. As illustrated in figure 4 each of the manual rod control lines from the reactor console (Master runback, ALL, Select Rod (1-4), Insert and Withdraw) supplies a 5 volt signal to the input of an optical isolator. When the input light emitting diode of the isolator is energized the output phototransistor turns on, driving the output signal low. Each rod select line is gated by the insert or withdraw signal to generate the insert and withdraw enable signals

for the individual rods. The insert lines are further processed by a set of "OR" gates to allow the insertion of all four rods in a bank when the select switch is in the "ALL" position and the master runback switch is asserted. The following narrative explains the logic.

If the manual switch is set to select rod 2 and the withdraw switch is then activated, then both inputs of gate WA2 will go low causing its output to go high. The output signal is buffered and delivered to a withdraw line. The information is passed, via the system back-plane buss, to the rod operation logic board for the rod selected.

The rod operation logic provides the interface between the rod select logic and the motor controllers or servo system. There is one board for every rod in the system which provides the following functions; it operates the rods via manual controls when no transient enable signal is present, it generates two separate assertions before rod motion is permitted, it prevents the withdrawal of more than one rod at a time, and it annunciates any attempt to withdraw more than one rod.

The circuit can be understood by examining figure 5. A set of "OR" gates is used to monitor the

withdraw command bus. a high on any line in this bus signifies a rod withdrawal command. Gate A4 is used to turn off the the withdraw command if a second withdraw command is detected. Gate A7 generates an alarm when this condition is detected.

If a simultaneous "INSERT" and "WITHDRAW" command is received due to some malfunction, gate A6 provides the alarm function. Gate A5 detects simultaneous "INSERT" and "WITHDRAW" commands at the motor starter and gate 04 generates the Control Rod Logic Fault alarm. In order to check out the fault detection features of the rod operation logic jumpers J1, J2, J3, and J4 are provided on the board. These jumpers allow fault conditions to be simulated for system checkout and verification of circuit integrity without compromising the actual circuit components.

The rod operation logic requires the following signals in order to function; a withdraw enable or insert enable from the rod select logic board, a transient not enabled signal from the reactor mode switch, and a manual enable command generated by the rod select logic.

Since two separate assertions must exist before rod motion is allowed two solid state relays must be active before the motor starter can be activated. There is one relay each for the insert and withdraw commands and a third relay which makes up the common leg of the motor starter. The Third relay is controlled by gate A8 and requires either an insert or withdraw enable signal, and a manual enable signal and a control rod motion request be present before activation.

The interlock system for the transient rod system is identical to that of the compensation and control rods except that no motor starter is used to control the rods. In place of the solid state relays there is an additional circuit card for each transient rod containing a transient rod drive generator which develops a voltage proportional to the position of the transient rod.

To generate this position information the output of the rod control logic "withdraw", "enable", and "insert" commands are used to gate a digital clock and deliver pulses to a 12 bit up/down binary counter. The digital outputs of the counter are connected to a 12 bit digital-to-analog converter. The output of the scaler is prevented from rolling over by a set of "exclusive or" gates which monitor the scaler output for all zero and all ones and gate off the proper clock when this condition is detected. In this manner analog rod position can be developed and delivered to the appropriate input on the transient rod controller. The output of the D-A converter is buffered and delivered to the Transient Rod Signal Interface for distribution to the Transient Rod servo systems.

Figure 6 is a flowchart diagram of the Transient rod interlock logic.

Transient Rod Signal Interface

The Transient Rod Signal Interface is the responsible device for controlling the demand input to the transient rod servo systems. To accomplish this signals from the monitor and control computers of the automatic reactor control system as well as the reactor mode switch are sampled. The "RSI monitors the "monitor computer ready", "control computer ready", "mode switch transient enable" and "monitor

computer rod stop" signals. Both computers must be "ready" for transient and the mode switch must be in "transient enable" position to transfer control from the manual system to the automatic reactor control system which generates the transient prescriptions. This function is generated by performing an AND operation. The circuit uses redundant AND gates with fault detection to provide protection against a false enable signal. If a fault is detected the control rod fault indicator is activated.

All digital and analog signals between the reactor control system are isolated using digital optical isolators and isolation amplifiers this prevents ground loops between the ARCS the MRCS and the rod control servo system.

Conclusion

The system is in the process of being installed in the TREAT reactor system. The complete system has been in an energized test mode for 8 months without experiencing any component failures. The author would like to acknowledge the following for their contributions: A. D. Valente, F. R. Lenkszus, G. T. Hicks and W. L. Doherty.

REFERENCE

W.C. Lipinski, W.K. Brookshier, D.R. Burrows, F.R. Lenkszus, W.P. McDowell, "TREAT Reactor Control and Protection System", Proceedings of the International ANS Topical Meeting on Computer Applications for Nuclear Power Plant Operations and Control, March 1985.

This work funded by the United States Department of Energy under contract No. W-31-109-ENG-38.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.