01 Apr 1991

A Computer Simulation of the UMR Reactor

H. Allen Wilkins

Recommended Citation

Wilkins, H. Allen, "A Computer Simulation of the UMR Reactor" (1991). *Opportunities for Undergraduate Research Experience Program (OURE)*. 158.
https://scholarsmine.mst.edu/oure/158

A COMPUTER SIMULATION OF THE UMR REACTOR

H. Allen Wilkins

Introduction

The Opportunities for Undergraduate Research project entitled, "A Computer Simulation of the UMR Reactor" had two goals. To produce a reactor simulation to be used in creating an artificial intelligence based reactor simulation for the UMR Nuclear Reactor and to produce a means of teaching students the fundamentals of reactor operations.

The primary purpose was to create a program which would simulate all the situations one would encounter in actual reactor operation. With the simulator the artificial intelligence system could be thoroughly tested before use with actual reactor data.

This same simulator would be used as a teaching aid for students to observe events which would not be allowed to occur with the actual reactor. The ability to get actual hands-on experience with a real time simulation of the reactor would permit a student to obtain a better understanding of the initial reactor physics courses by allowing the student to actually see the subject matter put to use.

Previous Work

The starting point for the simulator was a program written by a former graduate student which represented the physical processes which occurred within the reactor. There were several features of this program which made it an excellent base from which to work.

First, the program was written in Pascal. The Turbo Pascal version of this language, as published by Borland International, has a very efficient compiler which aids the programmer in finding errors in the code. Modifications in this code would be fairly straightforward due to the self-documenting capabilities of properly written Pascal code. This language also allowed the actual screen display to appear more realistic due to the number of graphics routines available.

Second, the graduate student solved the reactor kinetics problem using Hammings method for the solution of stiff equations. This method, when coupled with current reactor data, allows for up-to-date simulations of the reactor power response to a given transient condition.

Project Description

With the means of solving the reactor kinetics equations available, the main task was now to obtain the necessary input to enable the simulator to perform as the UMR reactor would in various situations. This would require the mating of physical equations to the reactor control systems.

In order to accomplish this, one must first understand how the reactor operates. The heart of the reactor is the core where fuel undergoes the fission process. The reactor is controlled from the control room. From there the reactor operator is able to see the current state of reactor operations with the various charts and gauges which are positioned on the control panel. Along the top of the panel is a series of multicolored lights which display the current status of all alarms. When the alarm is sounded, the light which corresponds to it will flash along with the alarm. The alarms are color coded to allow the severity of the problem to be ascertained at a glance. The alarm names on the red lights are major disturbances which require immediate automatic response. The alarm names on the blue lights are disturbances which need attention because they may lead to worse events. The alarms which are on the yellow lights are warnings which require attention but are not of extreme significance. Beneath this alarm board there is a strip chart which gives the recent history of the reactor operation. With this the operator can detect a trend and make a correction for it. The control room also uses a series of switches to scale one of the strip charts to certain powers. These power scales are 2 watts, 20 watts, 200 watts, 2000 watts, 20 kilowatts and 200 kilowatts. The operator then judges the current power of the reactor based on a certain percentage of the given scale.

Located beneath the strip chart recorders are the reactor controls. It is with these manual controls that the operator is able to control the reactor power by raising and lowering control rods. As these rods are withdrawn, the number of fission reactions increases, which causes the power to increase. Above the controls, there is a clock style gauge for each individual rod which will display the current height of the rods. Also, there are lights used to display whether or not the rods have been removed past a certain length, or shim range.

A reactor cannot be operated safely without a number of safety features in place. These features are designed to automatically warn the operator of trouble and, in extreme cases, take steps to correct the event. There are three responses which these safety features can implement. They are, in order of least importance,

A) **Rod Prohibits**: These relatively minor occurrences are listed on the alarm panel as the Period Less Than 30 Seconds alarm and as the Less Than 2 Counts Per Second alarm. These are both in the yellow section of the panel. The rod prohibits that are based on the current rod location are always in effect during startup so they are not considered alarming occurrences and do not set off the alarm. If they did the alarm would sound continuously during a normal startup.

B) **Rod Rundowns**: This is a more severe problem. The blue section of the alarm panel is reserved for these problems. They are listed as the Period Less Than 15 Seconds alarm, the 120% Full Power alarm, and the 120% demand rundown.

C) **Reactor Scrams** (or rod drops): This is an extremely severe occurrence. The alarms which have this safety response are the Period Less Than 5 Seconds alarm, the 150% Full Power alarm and the Manual Scram alarm. These alarms are located on the red areas of the alarm panel.

The alarm panel works in conjunction with these safety systems to allow the operator to understand what has happened and why.

This suggests that the simulator must include several procedures to make it perform all the safety checks and actions. The safety systems, or interlocks, which needed to be written included:

*1 **Shim Range Regulating Rod Lock**. This prevents the regulating rod from being raised unless all three control rods are raised above the shim range (approximately 12.5 inches).

*2 **Control Rod Lock Due to Extended Regulating Rod**. This prevents the control rods from being raised if the regulating rod is not fully inserted and at least one control rod is below shim range. This could occur if all three control rods were above shim range, allowing the regulating rod to move, and then one control rod were to be lowered below shim range.

*3 **Manual Scram.** This is a button which will force all the control rods to drop at once.

*4 **150% Full Power Scram.** This will cause the rods to drop if the reactor reaches 150% of its full power which is 300 kilowatts.

*5 **Period Less Than 5 Seconds Scram.** This scram will automatically occur if the time it takes for the reactor power to increase by a factor of 'e', is less than 5 seconds.

NOTE: All scrams prevent any further use of the reactor unless the scram reset button is depressed.

*6 **120% Demand Rundown.** This causes the control rods to automatically perform a controlled descent into the reactor if the power exceeds 120% of what the current power scale is.

*7 **120% Full Power Rundown.** This causes the control rods to rundown into the reactor if the power ever exceeds 120% of full reactor power which amounts to 240 kilowatts.

*8 **Period Less than 15 Seconds Rundown.** This rundown will occur if the time it takes for the reactor power to change by a factor of ,e, is less than 15 seconds.

NOTE: All rundowns require that the rundown reset button be pressed before the rods can be extended again.

*9 **Less Than Two Counts Per Second Rod Interrupt.** This feature prevents the control rods from being withdrawn any farther unless the situation is corrected. The user is prevented from using the reactor without a neutron source thanks to this system.

*10 **Period Less Than 30 Seconds Rod Interrupt.** This prevents the control rods from being raised any further unless the period returns to a value greater than 30 seconds.

Another set of features which had to be installed were the Board Acknowledge and the Board Reset buttons. The Board Acknowledge button allows the alarm to be acknowledged, which silences the alarm yet leaves a light corresponding to that alarm lit above the control console. The Board Reset button clears all alarm lights and allows the alarms which were previously acknowledged to sound.

The first level safety interlocks, or rod prohibits, can be bypassed. This is done when the senior reactor operator wishes to operate the reactor under conditions which would set off a specific, low danger, safety alarm. When the safety system is bypassed, the alarm will still sound but the control rods will not be prohibited from moving further. This allows the regulating rod to be tested without the regular control rods withdrawn. It also allows for faster power changes and low source tests. Implementing the bypass procedure would be very similar to a reactor safety system failure procedure.

In order to determine how these safety features worked together, the senior reactor operators needed to be asked questions concerning the types of systems present in the reactor system. Questions concerning the order of alarm precedence were asked most frequently. This allowed the simulator to model the portions of the standard operating procedures which were based on hardware requirements.

A number of other questions dealt with how the reactor would respond if the various safety interlocks were to fail. To simulate this on the program a procedure to deactivate a given safety interlock needed to written. This procedure would turn a particular safety system off when a particular sequence of keys was pressed.

The safety interlocks, alarms, and acknowledgements outlined above were all incorporated into the simulator with the exception of the Rod Prohibit Bypasses.

Rrecommendations for Future Work

The next step which needs to be implemented is a fission chamber. While the simulator works from an operational standpoint, in order for a true startup to be accomplished, the operator must have data which can only be made available from a log count meter and a linear power scale. This will require a series of measurements to be taken of the reactor fission chamber. These measurements must be taken over a short period of time since the exact counts from the fission chamber vary over the lifetime of the unit. Another area to look at would be the variance of the log power meter to take into account over or under compensation of the compensated ion chamber. A procedure to take the failure of magnetic current in the control rods could also be worked out. This would be similar to the current procedure for inducing a scram, only the reactivity would change by a smaller amount. From an operational standpoint, one could include a bridge radiation term in the readouts. This would make the inclusion of a nitrogen diffuser something worthwhile, instead of a set of lights and switches with no real purpose. The alarm board lights could also be made to fail in order to observe what the loss of one of one of the readout systems did to the ability of a student to diagnose what is happening inside.

In the future this program will be used in the evaluation of student performance under the stress of postulated accident scenarios. If some system fails while the reactor is being brought to a higher power, how will that student react? It will be necessary for these students to understand some sort of standard response to these situations. This is necessary since the real UMR reactor will never allow someone to do some of the things which can occur in the simulator.

Conclusions

In conclusion, this OURE project allowed me to gain insight into the workings of the UMR reactor safety system while also producing a program which is capable of being used in many projects. These projects can be as diverse as a room full of computers where an instructor gives students the basics of reactor operations, to a high powered computer which constantly presents solutions to current reactor problems after a set of simulation responses has been evaluated. This project will certainly aid the students as well as provide growth potential for future research efforts.