Building a Reactor Simulator as a Senior Project

By
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I. Introduction.

The Senior Design Project is intended to provide an “integrated educational experience” or capstone, for the engineering technology curriculum. As administered at the University of North Texas, the capstone “Senior Projects “ is a two credit hour, one semester course. The course concludes with a presentation of the students’ projects in which faculty, family members, business leaders, and other interested parties are invited to attend.

II. The Students.

The students in this project ranged in age from their early twenties to “fifty something”. Three majored in Nuclear Engineering Technology and five majored in Electronics Engineering technology. Their occupations ranged from general technician at the Creation Evidence Museum to Shift Supervisor at the Comanche Peak Steam Electric Station. Another student was the plant switchyard supervisor. The rest were high level technicians and operators at the plant.

Three of this group graduated immediately upon completion of the course. Two of the three graduated with honors. The remaining students are expected to graduate by August 2005.

III. Project Support Resources.

The utility company contributed $4,500 for the materials and equipment used in this project. The utility also contributed a surplus cabinet and permitted use of the company shops for drilling and fabrication efforts on the project. One of the company technicians also volunteered time to guide the selection and use of Allen Bradley controls in the project.

Simulation of step changes of reactivity were performed in the Simulink program of Matlab (from Mathworks) as a check on the expected outputs of the simulator. This work was done by students jointly enrolled in the Differential Equations course being offered in the same semester.

Students took vacation time or days off to visit the AGN 201 for photography, data collection and conversation with the Reactor Operators at Texas A&M. They were given the software used to drive the monitor that displayed reactor power or count rates.

IV. The AGN 201 Training Reactor.
The AGN 201 reactors were made in the 50's and 60's as a training tool for universities to use in preparing the first crops of nuclear engineers. The reactor is unique in many respects. It is fueled with 20% enriched U235 in a polyethylene matrix. The core dimensions are roughly 10 inches in diameter and 10 inches high. The total fuel load is only 670 grams. Control is accomplished by inserting rods made of the same composition as the core into holes in the reactor core. There are a total of four rods; two safety rods each worth \$0.42 in reactivity; one course control rod of the same reactivity as one of the safety rods, and one fine control rod with an integral worth of \$0.14. The control rods drives include magnetic latches that must be engaged before movement and two speeds of drive movement.

The reactor is surrounded by a graphite reflector, a lead shield, and a tank of water that serves as a neutron reflector and additional shielding. Figure 1 shows the control console.

The maximum power of the reactor is 5.0 Watts, which indicates that thermal feedbacks need not be considered. The kinetics will be dictated by a the delayed neutron characteristics of U^{235}.

Figure 1
The Texas A&M AGN 201 Reactor Control Console

V. Data Collection.
The students studied the Texas A&M reactor operator's manual and contacted the University of New Mexico (Dr. Robert Busch) and Idaho State for more data related to control rod worth. Dr. The data for the reactor kinetics calculations were taken from Lamarsh[1] , Ott[2] and Duderstadt[3].

VI. Construction Details.

Figure 2 shows the construction of the finished simulator. The main components are the cabinet, two flat screen monitors, an Allen Bradley Programmable Logic Controller, and a Shuttle XPC computer with 533/800 MHz front side bus. The minor components are the 15 switches and four active panel meters. Four of the switches are "instructor only" functions that cause shutdown or refusal to initiate such as low shield water, low shield water temperature, earthquake, or high local radiation. Other minor panel displays include the neutron source in light, neutron source out light, and the magnet engaged lights for each control rod.

Figure 2
The Completed Simulator

One of the monitors is dedicated to service as the panel alarms, the other is a reasonable replica of the A&M power level and rod position indicators. These can be seen in Figures 3 and 4.

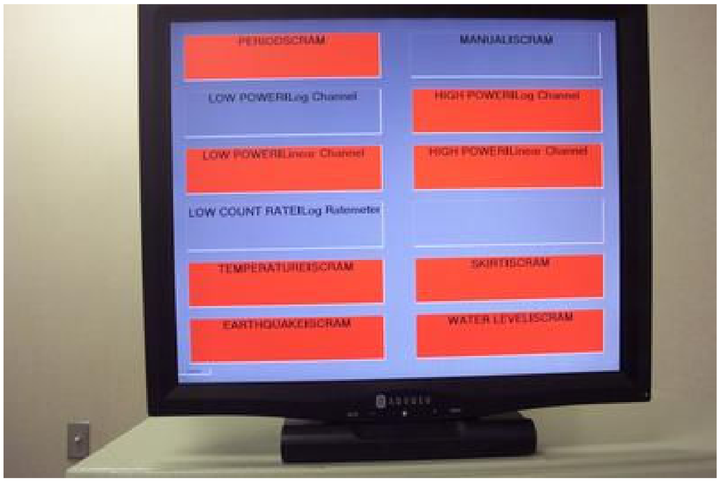

Figure 3
Panel Alarm Indicator Screen

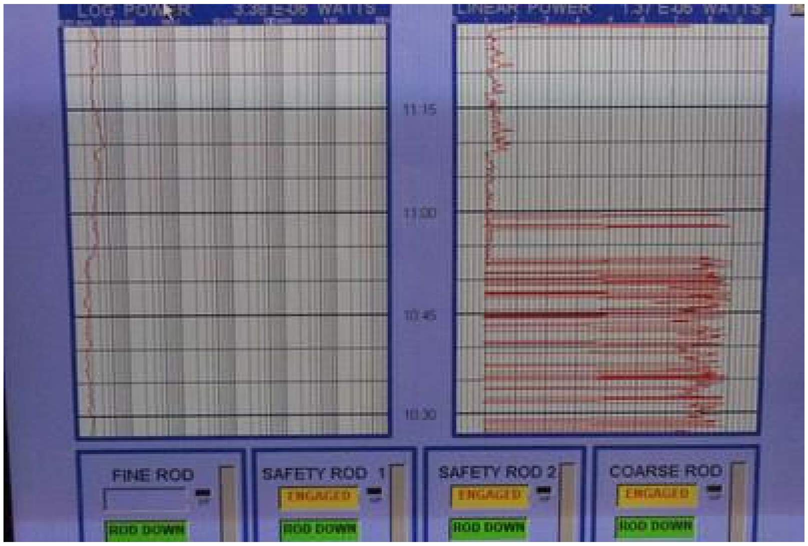

Figure 4
Power Level and Rod Position Indication Screen

The software construction was also considerable and included usage of Windows XP Professional, Virtual Basic, RS-Logic, RS-Links, and communication software for internet access. RS-Logic and RS-Links are the Allen Bradley control programs.

VII. Operational Aspects.

All switch functions accurately mimic the A&M AGN 201. The reactor kinetics are a reasonable facsimile of reality in that the power level behaves approximately like the zero power equation kinetics equations predicts. A substantial limitation of the Allen Bradley equipment that the students selected was that it could only use polynomials and not functions. That results in two difficulties. The first is that the exponential function has a McLauren expansion that converges only slowly with exponent. The second arises because the zero power equations fall into the category of “Stiff” differential equations because the time constants for the integrations range from 20 microseconds for the prompt neutrons and out to 80 seconds for the longest lived delayed neutron group.

VIII. Student Presentations.

The student presentations were held at 4:00 PM on the Thursday afternoon of the first full week of December. That time was selected to permit as much of the plant management and as many family members and coworkers to attend as possible. To assist in the grading, four faculty members from Engineering Technology were also present. The presentation was held in a small auditorium at the plant site.

Each student made a presentation of approximately 5-6 minutes on his contribution to the project. The utility also provided refreshments for the event. This part of the project called for two rehearsals and came off very professionally.

Figure 5 shows the students with the simulator.

Figure 5
Faculty Advisor, Students and Simulator

IX. Future work.

Future projects that will be based on these developments will be to improve the kinetics model. This might be best accomplished by migrating the calculation of the power levels to the computer and then relaying that data back to the PLC for output only.

A second class of improvements could be to reduce the simulator to a desk top operation using selected keys of the keyboard for the control switches. This would make the device into a very transportable training tool for students.

X. Acknowledgements.

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XI. References.

1. John R. Lamarsh. “Introduction to Nuclear Reactor Theory”, ISBN 020104120
2. Karl Ott and Robert Newhold, “Introduction to Nuclear Reactor Kinetics” ISBN 0894480294
3. James Duderstadt and L. J. Hamilton , “Nuclear Reactor Analysis”, ISBN 0471223638

Author Biographies.

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