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A Desktop Simulator for Nuclear Engineering Education

[1]Larry R. Foulke, [1]Steven P. Levitan, [1]Samuel J. Dickerson, [1]Jesse Randall, [2]Anthony Pacella and [3]David Helling
[1]*University of Pittsburgh, Swanson School of Engineering*
[2]*Carnegie Mellon University, Mellon College of Science*
[3]*Westinghouse Electric Company*

INTRODUCTION

The Pitt Advanced Nuclear Training for Higher Education Reactor (PANTHER) desktop simulation system imbeds dynamic simulations of nuclear power plants into undergraduate and graduate nuclear engineering educational programs. This initiative specifically aims at: (1) development of a real-time, desktop simulation of an advanced Pressurized Water Reactor and (2) use of the desktop simulator in nuclear engineering courses at the University of Pittsburgh and at other universities. Knowledge of commercial nuclear plant operations is often cited by employers as one of the major missing competencies in new employees, and even experienced engineers. This desktop simulator will address this competency.

DESCRIPTION OF THE ACTUAL WORK

The mathematical models are being developed to provide dynamic simulation of a generic, advanced, pressurized water reactor with passive safety features. Model parameters are adjustable by students so the effect of reactor design changes on plant dynamic behavior can be analyzed.

The models are developed in MATLAB /Simulink and configured to run on a PC so that students could both see the underlying models and use the simulation program in laboratory-like sessions to study the effect of design changes and differing kinetics parameters on plant behavior. While the simulation model fidelity would be suitable for educational purposes, it would not be intended to replace or duplicate the high-fidelity dynamic simulation used in major accident analysis codes such as RELAP, TRAC, and TRACE. Rather, it would provide students with a desktop tool to realistically model and better understand reactor performance under various conditions.

The goals of the project are to give graduate students experience in developing simulation models and to give undergraduate students a desktop simulator that is a realistic interactive tool for education. The impact is expected to be improved education with a relatively low cost, interactive teaching tool. The project builds on an undergraduate certificate in nuclear engineering that began in the fall term of 2006. This program has grown with current enrollments of 150 students in the *Introduction to Nuclear Engineering* course, and 90 students in the *Nuclear Plant Technology* course. The undergraduate certificate program in nuclear engineering accommodates students from all engineering disciplines.

RESULTS

Interaction between the user and the PANTHER simulator is established via a combination of monitor displays, mouse, and keyboard. Figure 1(a) shows a primary system screen for PANTHER simulator showing the reactor core, control rods, two loop heat transfer coolant system, pressurizer, coolant pumps, and relief tank. Any three system variables associated with those components can be plotted at one time by clicking on the appropriate button on the *image* view. The display screens will have plant alarms and annunciators that indicate important status changes in plant parameters that may require operator action, and indicators showing major plant parameters such as reactor power, average fuel temperature, average coolant temperature, turbine generator output power, reactor pressure, core flow, reactor water level, steam flow to the turbine, and feedwater flow to the steam generator. Each monitored value on the display will also be available as a graph of value/time so that the operator can monitor the time history of a number of selected plant variables. The project also supports the *schematic view* native to MATLAB as shown in Figure 1(b).

Students are able to see the effect on reactor dynamics of using certain approximations, such as the delayed neutron precursor modeling. For example, as shown in Figure 2, a student could test differences in reactor behavior between using a six delayed-precursor group model and a one delayed-precursor group model both with and without reactivity feedback. In this example, one model uses a single effective delayed precursor group (in pink) compared to the standard six delayed precursor group (in yellow) without temperature feedback reactivity. The other model incorporates feedback reactivity. The parameters of the example are: steady state with reactivity equal to 0 from 0-5 seconds to confirm a steady state condition, followed by a ramp insertion of positive reactivity (rho dot = 0.002/sec) for 2 seconds, holding reactivity constant for 2 seconds and finally a ramp insertion of negative reactivity for 2 seconds. Figures 2(a)-2(c) are the comparisons of the two models with regard to Reactivity, Power, and Start Up Rate (SUR), respectively, without reactivity feedback. Figures 2(d)-(f) are the comparisons incorporating reactivity feedback. A key learning point here is the recognition that a one effective precursor group model predicts behavior well when reactivity feedback is present.

CONCLUSION

The project promotes course and curricula development by providing:

- A desktop simulator that is well suited to the classroom and a self - learning tool as complement to textbooks and manuals, and
- Knowledge of dynamic behavior, and system interfaces, integration and interactions.

The project promotes improvement in education / training by:

- Supplementing traditional education using textbook and classroom instruction that is inadequate for education in reactor operations,
- Using highly portable, standard PC platforms,
- Utilizing mathematical models that are easily configurable and provide flexibility of use, and,
- Using icons, control pop-ups, time trends for user interfaces instead of hardwired panels.
- Providing a cost-effective means for engineering education as contrasted with the use of a full scope training simulator.

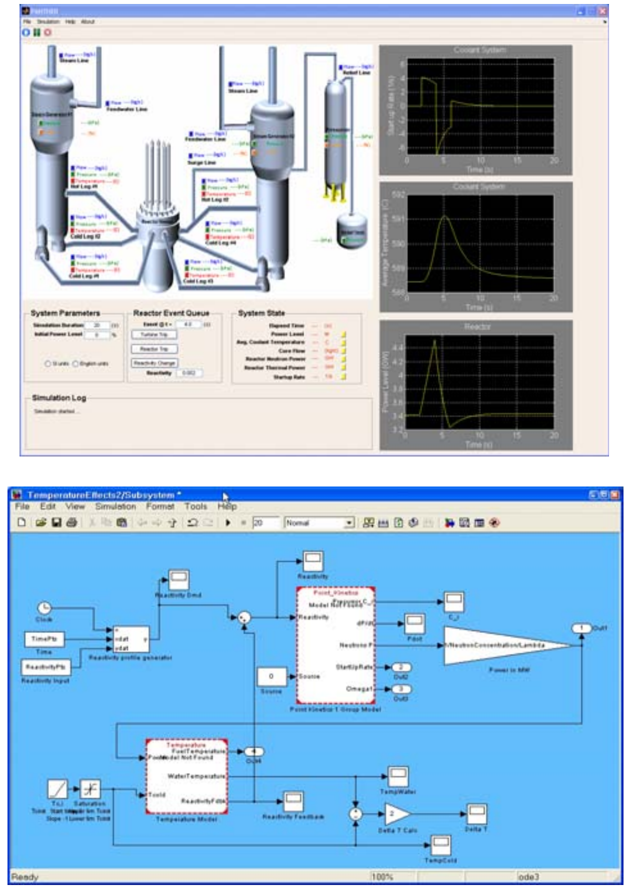

Fig. 1(a) Graphical user interface for PANTHER simulator (b) Schematic representation of coolant system

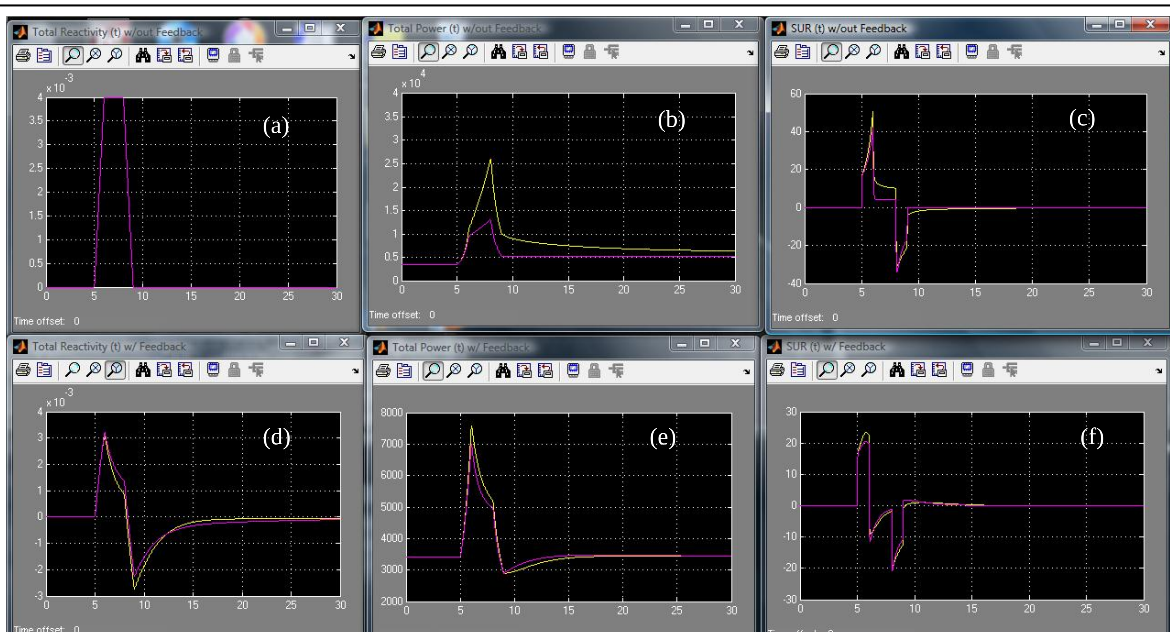

Fig 2. Simulations of reactor point kinetics with one-precursor group and six-precursor group models, with and without temperature feedback.