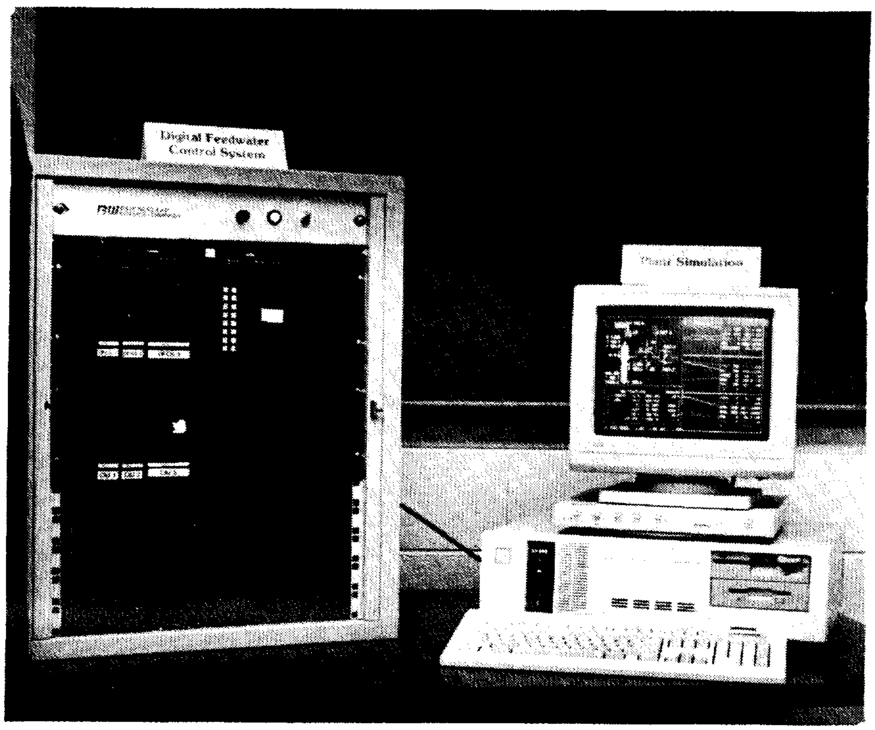
# IMPROVE PLANT OPERATION AND MAINTENANCE BY SIMULATION




by

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# Improve Plant Operation and Maintenance by Simulation

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## Introduction

Power plant operations and maintenance personnel frequently must make decisions about potential improvements in plant control system settings, plant setpoints and procedures, replacement of aging and obsolete equipment, etc., to keep on generating electricity safely and at minimum cost. To facilitate decision making, they need an inexpensive, quick, and risk-free way to evaluate the various options being considered. Since actual testing of the various alternatives is impractical, a power plant simulation is a valuable asset for supporting the final decision for a plant change.

Examples of plant improvements, applications of simulation, and simulation tools, services and procedure are discussed in this article.

## Examples of Plant Improvements

Analog control systems in many power plants are obsolete and costly to maintain due to scarcity of spare parts. Such systems are candidates for replacement with digital control systems and improved control algorithms. Many power plant monitoring systems and protection systems also fall into this category. Several utilities have replaced, or are planning to replace, existing analog feedwater control systems in their Pressurized Water Reactor plants (PWRs) and Boiling Water Reactor plants (BWRs) with Digital Feedwater Control Systems (DFCSs). Utilities with Babcock & Wilcox (B&W)-designed PWRs are planning to replace the analog Integrated Control System (ICS) with a digital Plant Control System (PCS).

Procedures for responding to failures in power plant equipment are periodically reviewed and improved.

With the need for operator training on the rise and training resources scarce, inexpensive alternatives for full-scope training simulators are of interest. Simulations are gaining popularity as the basis for personal computer (PC)-based compact simulators. These simulators offer an effective way to familiarize personnel with the characteristics and responses of a power plant.

## Applications of Simulation

To demonstrate the use of simulation for DFCS development, a conventional DFCS was recently implemented on Bailey NETWORK90 control system equipment and was debugged in closed loop with the PC-based simulation of a PWR via a Communications Interface Unit (CIU)[1]. The PWR simulation, like other simulations described in this paper, is driven by a dynamic plant model based on laws of conservation of mass, energy, momentum, neutron kinetics, fluid flow and heat transfer, and steam property calculations. The model parameters are initially calculated from plant design data and later fine-tuned to match the plant steady-state and dynamic response. The simulation features a "live" graphical user interface for monitoring a dynamically updated PWR schematic and trends of plant variables, and for initiating certain events by pressing preassigned keys from the keyboard while the simulation is running, for example, trip a feedwater pump by pressing the key "1". The plant response data can be saved for plotting and analysis later. Although the control hardware and simulation were linked over an RS-232 serial data highway, a connection using parallel data highway or analog and digital transmitters is also possible. This demonstration proves the feasibility of using simulation for minimizing the cost of testing and debugging equipment in the field and for minimizing plant downtime. Such simulations with hardware and operators in the loop are also effective for training I&C personnel in the use of control hardware and control panels. The stand-alone version of the PWR simulation includes the feedwater control algorithms. In this version, the user can also change the target power level and ramp rate, manually control the feedwater and steam throttle valves and feedwater pumps, and initiate swapping of the main and bypass feedwater valves during power increase and decrease by pressing preassigned keys.

To support the DFCS development and training for BWRs, a PC-based simulation of a BWR was developed. Various options, such as BWR type (Mark II through VI) and recirculation loops (1 or 2), for a specific BWR configuration can be included in the model. As with the PWR simulation, this simulation also

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## Plant Operation,
*Continued*

incorporates a live graphical user interface (Fig. 1). The user can change the target power level and ramp rate, and manually control the feedwater pump, control rods, recirculation valves, and steam throttle valve.

The digital Plant Control System (PCS) for B&W-designed PWRs is being implemented in Foxboro I/A series hardware and validated in closed loop with a B&W plant simulation. Called Power Master, this simulation program executes on a PC and has a live graphical user interface featuring mouse interaction. Power Master was used earlier to develop PCS algorithms. The link between the I/A system and Power Master is accomplished by a serial data transfer cable. A much faster ethernet-based link using a SUN workstation is also available. The PCS will be further tested in closed loop with a high fidelity simulator originally developed as a training simulator. The link between the I/A system and the training simulator will be accomplished by analog and digital transmitters.

To support improvements in procedures for responding to failures in power plant equipment, seven failure modes that can cause a reactor trip due to low pressurizer pressure in a 3-loop PWR were recently simulated to complement the conventional fault-tree analysis of failure-related transients.[2] The simulation is driven by a PWR model incorporating the reactor, pressurizer, and steam generator dynamics. The simulation has a graphical user interface for:

- selecting the failure modes and interlocks, and parameters to be included in the trends
- monitoring the transients via trends, dynamically updated schematic, and a dynamic display of sequence of events.

The simulation generates data on the relative timing of the onset of plant alarms and the actuation of system interlocks.

Although these applications relate to power plant operation and maintenance, simulations are also effective during the plant design phase. For example, the simulation of the New Production Reactor is being used to fine-tune the dynamic characteristics of the plant.[3] The dynamic responses of recirculating and once-through steam generators were recently compared in support of the design of next-generation light water reactors.[4]

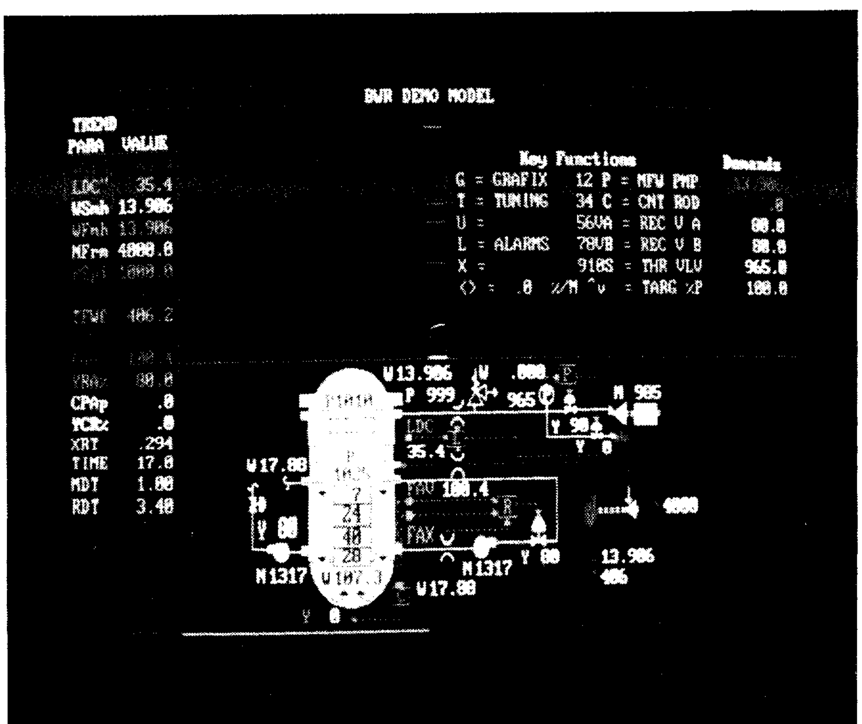


**Figure 1.**

## Simulation Tools, Services, & Procedure

Modeling tools, such as the Modular Modeling System (MMS)[5], and services are available for developing simulations. MMS includes modules for modeling PWRs, BWRs, and fossil power plants, and incorporates user-friendly features such as computer-aided design-(CAD)-like graphic model building, automatic parameter calculation, run-time interaction, graphical/keyboard/mouse user interface, and a choice of U.S. units and standard metric units.

A typical dynamic simulation model development starts with the use of MMS-EASE+ graphic pre-processor, which is an automated preprocessing system available on PCs. An interconnection diagram, showing the interrelationship of selected modules that represents the plant configuration to be modeled, is first prepared using a mouse to select, place, and interconnect appropriate "icons" on the screen. Icons are graphical elements that represent MMS modules. Each icon is associated with one or more data forms for entering physical and operating data for the represented module (and therefore the component that the module represents) and one or more data forms for parameter output. The forms include a description of each item and a space for entering a value. To automatically calculate the values of model parameters ("auto-parameterization"), values are entered in the input forms of the selected icons. The output forms then display the automatically calculated parameters.

After the preprocessing, MMS-EASE+ is again used to automatically generate the model source code in Advanced Continuous Simulation Language (ACSL)[6], a powerful high-level simulation language. The resulting code includes calls to module macros, the calculated parameters, custom ACSL coding, and custom Fortran subroutines included in model definition. The model code is then automatically translated to Fortran using the ACSL translator, compiled and linked to produce the executable model. The translator sorts the model calculations in the correct order; a great help in model building. The model developer needs only to focus on correctly specifying the process equations. Of course, most of this is already done in the pretested MMS modules. The modeling system has an open architecture for including custom Fortran and C routines, such as routines for graphical user interface and communication with other devices. Finally the model is debugged and fine-tuned by running various transients and evaluating the responses. ACSL provides a powerful runtime interaction facility featuring plotting, parameter adjustment, display of values of model variables, a runtime choice from several fixed- and variable- -timestep and -order numerical integration algorithms, control analysis (i.e., eigenvalues, linearized model, etc.), and design optimization.

A graphical user interface can be developed separately and later integrated with the dynamic model. The graphics and live interaction can be generated by using PC-based drawing and paint programs and graphical subroutines featuring EGA/VGA support and keyboard/ mouse interaction.

Applications involving man-machine interaction require the simulation to run in real time, i.e., the rate at which the simulation variables change to be the same as that at which actual plant variables change. The speed of the simulation depends upon the scope of the model, the level of detail included, the nature of equations required to describe the processes, and the computing power available for running the simulation (i.e., 386, 486, workstation, or minicomputer). Most power plant models have some fast dynamics (i.e., small time constants), such as pressure and flow dynamics, and some slow dynamics (i.e., large time constants), such as temperature dynamics. Fast dynamics need to be processed more frequently and take more computer time compared with slow dynamics. The fastest dynamics (i.e., smallest time constant) in the model governs the frequency of processing the model equations. Thus a conventional model usually requires some modifications to allow the simulation run in real time.

## Conclusion

The synergy between recent advances in simulation technology and the astronomical pace of continual increase in the performance/cost ratio of computer hardware and software has made power plant simulation a powerful, affordable and easily accessible tool for utility personnel. The cost savings possible through the use of simulation are many times the cost of developing the simulation. The cost of developing the simulation is insignificant relative to the large cost of typical power plant projects.

There is no reason for not having a simulation of your power plant on and by your side.

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