Modular Modeling System User Group Newsletter

(A B&W Nuclear Service Company Software Bulletin)

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B&W HAS A NEW NAME

As you might have noticed from our logo above, we have changed our name. On November 1, 1989 Babcock & Wilcox and Framatome began a new partnership, the **B&W Nuclear Service Company (BWNS)**.

Framatome is a key participant in France's successful nuclear program and has manufactured 66 standardized pressurized water reactors.

We are looking forward to this new partnership and believe it will offer the MMS User Group new opportunities to expand its membership.

Insofar as current MMS license agreements are concerned, there will be no changes other than to transfer them to BWNS. The MMS will continue to grow, as in the past, and it is our intent to maintain and improve the MMS as directed by the User Group.

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CURRENT MMS USERS

The current register of organizations using the MMS includes:

- Nineteen (19) commercial members
- Ten (10) universities

(See **USERS**, page 6)

USER GROUP MEETING

Plans for our next MMS User Group meeting are close to being finalized.

The meeting will be held at the Hyatt Regency Chicago hotel on Thursday, April 26, 1990 in Chicago, Illinois following the American Power Conference which will be held at the Hyatt Regency in Chicago on April 23,24,25.

We will send you more detailed information on both meetings in the near future.

Information on available suites and their cost can be obtained by contacting the Hyatt Regency Chicago directly:

Hyatt Regency Chicago
Reservation Manager
151 East Wacker Drive
Chicago, IL 60601
(312) 565-1234, Ext. 1432

The American Power Conference covers electrical, mechanical, nuclear, industrial, cost, water technology, civil, hydro and education disciplines. We believe that many MMS users will be interested in attending the APC in conjunction with the MMS User Group meeting.

We anticipate an informative and productive User Group meeting and recommend that you make your plans to attend now.

NEWSLETTER RESTARTED

The last MMS newsletter was published in July, 1987. The main reason it was discontinued was that it became increasingly difficult to obtain articles from our members.

We think the newsletter is an excellent way for members to share their MMS experiences and we encourage each of you to send us articles for inclusion in future editions.

The newsletter will be published several times each year and we invite your comments as to what you would like to see included.

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FOSSIL PLANT MODEL AT DETROIT EDISON

The principal components of a 660MW B&W coal fired unit have been modeled at Detroit Edison using MMS. Initial work involved modeling the process and controls in five subsystems and tuning each independently. Three engineers have been involved about half time for a year. MMS-EASE+ was used for each subsystem setup. Most data was obtained from plant design drawings and documents but some data was available from a steady state model of the boiler.

The first subsystem was the superheaters and portions of the reheater with detailed multi-loop superheat attemperation control. The drum outlet and turbine inlet were boundary conditions. A portion of the reheat tube banks was included to connect the gas path. The 38 state subsystem was used independently to study and confirm the attemperation control stability during transition between valve banks and at the saturation point.

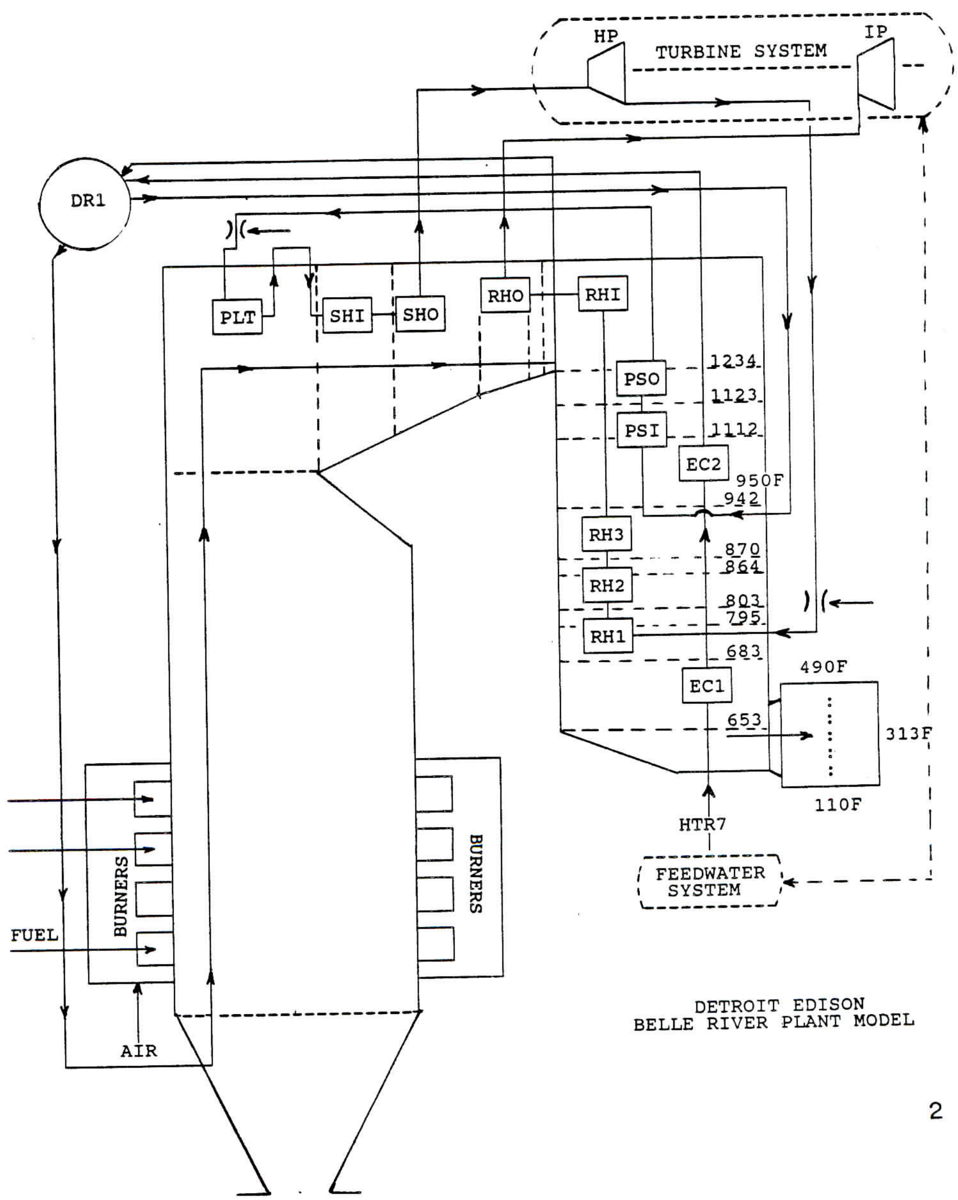
The drum and furnace submodel consisted of the DRUMNC module with pipes at the water inlet and steam outlet. A three element level-feedwater control was setup. Gains have not been available from the plant, therefore data from previous MMS papers and tuning experience were used to adjust the system. The model was calibrated using design data and compared favorably with exception of the gas outlet temperature. The model predicted a higher gas temperature than expected and measured in the plant. However this may be explained since the furnace module overlaps the platen superheater and does not use energy streams and therefore outlet gas must contain and transfer the energy to the platen.

The reheaters and economizers subsystem completed the gas flow path and enabled calibration of the five equivalent tube banks and tuning of the reheat temperature control. A significant problem encountered was an error in the heat transfer calculation for the economizer. Several iterations of coefficient adjustment resulted in good agreement with the inhouse steady state model. The PI temperature control included appropriate scaling of limits and was tuned for a step response resulting in slight overshoot.

The turbine system primarily programed by Zuwei He, a visiting Chinese professor, modeled the HP, IP, and LPturbines and condenser.

Since the HP turbine doesn't have impulse blading, TURBLP was used for modeling all the turbines. To make this subsystem independent a pipe with heat transfer was used to represent the reheat and functional relationships were used to represent the boundary conditions at the extracting line terminations. After fixing three small errors in the turbinecoding, excellent agreement was obtained between the model and design data down to 75 percent load. Turbine step response and condenser parameterization sensitivity studies were conducted.

(See **DETROIT**, page 5)



DETROIT EDISON
BELLE RIVER PLANT MODEL

PENN STATE'S USE OF MMS HELPS OBTAIN 2 MAJOR GRANTS

The Nuclear Engineering Department at Penn State has been using the MMS since 1985 for graduate research and undergraduate instruction. Six masters of science projects have been conducted with the MMS as the primary tool. In addition, the MMS has been adapted for real time simulation using the IBM Advanced Control System Software. This experience was an important factor in successfully obtaining two new major government research grants.

The two new grants, one from the National Science Foundation (NSF) and the other from the Department of Energy (DOE), are very much related and are being used to establish what we call Intelligent Distributed Controls research. The NSF grant was awarded in July (89) and will provide a state-of-the-art microprocessor based control system. The Bailey NETWORK 90 system will contain a 386 based Engineering Work Station which is used to configure and program controllers (see figure). The Bailey Multifunction controller (MFC) can accommodate 5000 lines of user defined C code for execution as part of a control strategy involving standard control blocks and the real-time executive module of the controller. The research using this equipment will explore the addition of expert systems technology and other Artificial Intelligence applications as part of control. A major activity will be to interface the microprocessor based control system with other computer networks at Penn State. These interfaces through the Bailey Computer Interface Units (CIUs) will permit the output of mainframe based simulations to drive the controllers. Access to controller operations will also be made available to higher level diagnostic and control functions executing in an ETHERNET network of UNIX based workstations. Delivery of the Bailey system is expected in January.

The 2nd new major grant will involve Penn State in the development of a prototype demonstration of Intelligent Distributed control at the Experimental Breeder Reactor in Idaho. The EBR-II plant is a small but complete power plant that supplies 20 MWe to the grid and the controls demonstration will be conducted on the EBR-II steam cycle power plant. The steam cycle at EBR-II is similar to most thermal power plant and in particular resembles a fossil fueled plant in that it has a natural circulation drum boiler and superheater system that supplies high quality steam to the turbine. Instead of a combustion furnace heating the water and steam, liquid sodium is the heat source. Despite most peoples' misgivings at using sodium in a steam generation system, EBR-II has successfully demonstrated this technology since the 1960s. Big pluses for the use of sodium are that it is not required to be pressurized because of its high boiling point and it is not corrosive to stainless steels. The EBR-II steam boiler also uses a double wall tube design with separate tubesheets for the water and sodium sides. The system is carefully monitored for leaks and special provisions for quickly draining the water are provided. Other features of the EBR-II steam system include a turbine, blowdown, condensate, and feedwater system.

There are three closed feedwater heaters and a deaerating heater. Most of the original analog control systems have already been replaced with Bailey NETWORK 90 controllers similar to those being obtained at Penn State through the NSF grant.

The DOE intelligent distributed controls demonstration is organized as a three year project and began in September of 1989. The first year's activities are: 1) develop a simulation of the EBR-II steam cycle power plant, 2) develop a diagnostic system for the steam cycle, and 3) test the diagnostic on a real-time simulation. The first year milestone is to demonstrate the diagnostic system operating in a SUN workstation interfaced to live plant data at EBR-II. The EBR-II steam cycle simulation is of course being developed using the MMS and is the masters degree project of David Ruhl. During the last spring semester, Dave completed a simulation of the EBR-II feedwater system using the standard modules available in the MMS library. Dave was fortunate enough to be hired as a summer student at EBR-II where he got to see the plant first-hand and collected data to complete the simulation project. Dave is now working on creating modules for the EBR-II steam generators which are being based on the corresponding MMS fossil library modules.

The development of a diagnostic system for the steam cycle will use DISYS[2], diagnostic and control guidance expert system. DISYS was originally developed at Westinghouse for DOE. The first year activity for the new DOE project is very similar to that performed in a Penn State DOE project recently completed in May of 1989[3]. That project converted DISYS to the C language and completed implementation of the

(See **PENN**, page 4)

(**PENN** - cont. from page 3)

diagnostic for the Argon Cooling System of fuel handling operations at EBR-II. That diagnostic system was also tested on a real-time simulation using the MMS and was the masters degree project of John Carper. Over the summer and continuing to the end of 1989, the DISYS development was extended to provide a graphical operator interface in the UNIX X-Windows environment of SUN computers (see slide). (As might be expected, the Bailey 386 based engineering workstation is also being equipped with UNIX and X-Windows software.)

The 2nd and 3rd years of the DOE program have been proposed and accepted in principle but continuation proposals are required for each year. The second year (beginning September 1990) will develop the implementation of the DISYS diagnostic system in a distributed computer system. The diagnostic system developed for operation in a single SUN computer at the end of the first year will be distributed between Bailey microprocessor-based controllers and the SUN computer network. Again, a major activity will be simulation testing of the distributed diagnostic system at Penn State using the equipment made available by the NSF grant. The 3rd year activity will examine closing the control loop to automatically effect changes in control based on the diagnosed state of the system, Intelligent Distributed Control.
Intelligent Distributed Controls research at Penn State is an interdisciplinary project involving Electrical, Mechanical, and Industrial Engineering, as well as Nuclear Engineering. Bob Edwards, who has attended many of the MMS user group meetings, is a full time research assistant and PhD candidate in Nuclear Engineering. Dr. Klevans, Nuclear Engineering Department head, is the principal investigator for the DOE project. Dr. Kenney, Professor of Nuclear Engineering, is the principal investigator for the NSF grant. Dr. Kenney teaches instrumentation laboratories and the reactor control course. M.A. Schultz, professor emeritus and author of the first book on reactor control, will be an active consultant to the DOE project. Schultz has campaigned heavily for distributed microprocessor-based control as a means to greatly simplify future power plant control rooms. Dr. Kwang Y. Lee of the Electrical Engineering department teaches power systems and the EE control sequence of courses including optimal control. Dr. Asok Ray of Mechanical Engineering conducts research in distributed computer and communication systems in manufacturing. Dr. Soundar Kumara of Industrial Engineering is involved with Artificial Intelligence applications in manufacturing with special interest in qualitative reasoning.

The MMS is an important power plant simulation tool that will be used in these new research projects. If you would like to learn more about Intelligent Controls Research and use of MMS at Penn. State, please contact Bob Edwards.

With the MMS experience that has been established at Penn State, the possibility of conducting a MMS short course for industry participants is under consideration. Penn State is best equipped to conduct courses for IBM mainframe computer users and the two weeks prior to Memorial day or the middle two weeks of August (between semesters) is the best time to guarantee availability of equipment and full attention of faculty instructors. It may also be possible to orient an MMS short course to a VAX computer environment if that would be the preference of industry participants. In order to schedule the necessary resources for a course in May, a definite decision will have to be made by Jan. 31, 1990. If you have an interest or any questions please contact Pete Cheatwood or Bob Edwards at Penn State.

References:

1) R.M. Edwards and G.E. Robinson, "Real-time Modeling and Controls Analysis Using the MMS and the IBM Advanced Control System (ACS)," EPRI 1988 Conference on Power Plant Training Simulators and Modeling, Charlotte, North Carolina, June 15-17, 1988.

2) R.M. Edwards, J.J. Carper, R.W. Lindsay, and G.E. Robinson, "Real-time Testing of a Diagnostic and Control Guidance Expert System", Proceedings of the Seventh Power Plant Dynamics, Control, and Testing Symposium, Knoxville, Tennessee, May 15-18, 1989.

3) Robert M. Edwards, John J. Carper, and Gordon Robinson, "Final Report, Testing and Installation of the DISYS Diagnostic System on the EBR-II Argon Cooling System," A project under DOE contract No. 31-109-ENG-38, June 30, 1989.

4) Robert M. Edwards, K.Y. Lee, S. Kumara, and S.H. Levine, "An Integrated Real-time Diagnostic Concept Using Expert Systems, Qualitative Reasoning and Quantitative Analysis," An invited paper and presentation at the U.S.-Korea Seminar on Application of Expert Systems to Power Systems and Industries, Seoul, Korea, August 13-18, 1989.

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(DETROIT, cont. from page 2)

The feedwater subsystem is the largest at 62 states. It includes seven equivalent banks of heaters with controls and four sets of pumps. The system has feedforward drains, that is a portion of heater drains is pumped into the condensate system by drains pumps. Because of limited design information and in the interest of time, three dummy controls were added to force some conductances and pump speeds to provide the design flow and pressure profiles. Design tuning parameters resulted in good level response for each heater.

Recently these submodels have been merged into two large models. One consists of all but the feedwater subsystem. This 88 state model represents the boiler from fuel input to the gas outlet at the air heaters plus the turbine system. After the initial merge, numerous computer runs were necessary to establish a steady state condition. Apparent interaction between the feedwater control and the superheat control systems has made the model surprisingly oscillatory. Although some complaints of oscillations were reported during plant startup, we have not been able to obtain data to confirm or compare against. The model has been calibrated against design and field test data and major parameters compared very favorably after slagging coefficients were adjusted. For mild transients the model runs efficiently.

A 4000 second model run requires only 20 seconds on an Amdhal computer. Presently the coordinated unit control scheme is being added to the model and data is being obtained to compare the model response to a ramp down field test which has been conducted.

The second large model consists of the merged feedwater and turbine submodels. This 85 state model ran to a steady state condition fairly easily considering the numerous common extraction lines involved, and compared closely with design data. Presently thismodel is being enhanced to include more detail in the condenser level control and cooling water dynamics. Plant engineers have requested a prediction of the speed of impact on the system to the loss of a circulation water pump and how much time an operator will have to startup another pump. During winter, operation with only one of three pumps is being considered. The ultimate goal is to combine the two larger models. Considering the mutual turbine, the complete model will have 150 states.

Regardless, we expect continued useof our fossil model and submodels to solve some of the nagging problems and questions at the plant and be an immediately available tool tosolve the emergency situations that invariably occur at operation plants.

Chuck Arndt / Terri Orloff
Detroit-Edison

The BWNS

MMS Team

Wishes for you

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Prosperous

and

Happy New Year

- TECH TIPS -
ALGEBRAIC LOOPS

Occasionally, when setting up simple control loops or dummy parameter adjustment loops, we unknowingly set up a subset of equations that form an algebraic loop, that is, a set that boils down to Y=f(y). ACSL cannot normally handle these because it sorts the input equations and "every value is assumed calculable on the outputs of the integrator: (and storage elements). ACSL tells us there are several methods to eliminate these loops, namely: 1) algebraically manipulate the equations so that the variable can be calculated directly, 2) use a Procedure block so the loop is not sorted, or 3) use the IMPL operator which separately used the Newton-Raphson method to numerically solve the loop during every iteration.

These could be good solutions, however we find that frequently in using MMS, more realistic models normally eliminate algebraic loops. For instance in simple control loops invariably an actuator and/or transducer is in the loop. Transducers are often represented by a REALPL which breaks the loop. Actuator response times range form seconds tominutes and transducer equivalent time constants range from fractions of a second or seconds for pressure transducers to several seconds for RTDs. Probably the temperature transducer well will be the most significant lag especially where it is massive to protect the element from abrasion eg. coal mill outlet (20 seconds). For attemperation, some recent spec we reviewed showed measuring time constants of 8 seconds.

Another encounter with the algebraic problem occurred with functional relationships for boundary conditions. In that case a REALPL was added to not only break the loop but also

(See **TIPS**, page 6)

(TIPS, cont. from page 5)

make the termination response more realistic since in the case sited, the pressure would not have instantly changed due to flow change. Since the response of the termination was not known, the time constant was temporarily set to a value smaller than that of the predominant ones in the model so as to not significantly influence the dynamics.

Dummy loops to initially adjust parameters for calibration are normally setup in our work to include a REALPL. Besides eliminating a possible algebraic loop, it slows the corrective action and more gradually forces the model into calibration preventing other possible numerical problems.

In general, we find more realistic models produce less problems. Evidently Mother Nature must have solved these problems long ago!!!

Chuck Arndt
Detroit Edison

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MMS TRAINING OFFER

BWNS is pleased to offer to any MMS User Group member organization, an economical two day training session on MMS.
We will send an MMS expert to **your** site to train your personnel on any aspect of MMS.
The only expense to you will be the travel and living expense of our instructor.

We are making this offer because we want to help you utilize the full capabilities of the MMS and because we believe the training can be made more effective by tailoring our courses to your unique requirements.

Contact H.C. Cheatwood to schedule this training for your personnel.

NEW PRODUCT

Power Master ™

BWNS has developed, and is marketing, a personal computer based dynamic simulation for B&W designed nuclear power plants and their control systems.

Power Master provides near real-time simulation, interactive graphics displays of the plant dynamic variables with the ability to easily modify the plant parameters on-line.

We used a B&W NSS 177 PWR as the plant model and the B&W Integrated Control System (ICS) as the control system model.

Power Master is being offered to MMS User Group members at a reduced price. If you would like to receive more information on **Power Master**, contact H.C. Cheatwood.

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(USERS, cont. from page 1)

1. Bechtel Power Corp.
2. Chiyoda Corporation, Ltd.
3. Chongqing University
4. Chubu Electric Power Co.
5. Cornell University
6. Delft University
7. Detroit Edison
8. Duke Power Co.
9. Empresarios Agrupados SA
10. Gent University
11. Iceland University
12. Karlstad University
13. Kema
14. Laborelec
15. Niagara Mohawk Power Corp.
16. Oak Ridge National Lab.
17. Philadelphia Electric Co.
18. Pennsylvania State Univ.
19. Public Service Elect. & Gas
20. San Diego Gas & Electric
21. Stork Boilers
22. Stuttgart University
23. Swedish State Power Board
24. Sydkraft AB
25. Southern Cal. Edison Corp.
26. Tennessee Technological Univ.
27. Texas University
28. Toledo Edison Co.
29. Tennessee Valley Authority

MMS UTILITIES

<u>SCAN</u> - On September 11, 1989, we sent all MMS installations a diskette containing our new SCAN pre-processor software that can be used to convert MMS/ACSL model and command files from SI units to US units (MMS uses US units).

We are integrating, into the MMS software, the ability to use either SI or US units. This project should be completed by the middle of 1990.

If you have not yet received a copy of SCAN, please contact the MMS coordinator for your company.

<u>SPLIT</u> - If you have ever received a Microsoft FORTRAN compiler message indicating that the ACSL translated FORTRAN file is too large, you should try the MMS utility program SPLIT. SPLIT will divide the ACSL generated ZZDERV.FOR subroutine into smaller subroutines which can be compiled and linked to generate an executable file.

<u>CRITER</u> - The CRITER program processes the Jacobians printed by ACSL and recommends error criteria appropriate to the precision of the floating point calculations of the host computer. MMS users have observed that some MMS models run more efficiently on computers which compute with more precision. For example, the BEXR MMS sample problem runs on the CDC mainframe (which has 60 bits of precision) but takes an excessive number of derivative evaluations on the IBM mainframe (which has only 32 bits of precision). CRITER is a program automating the procedure described in the report to MMS users, "Improving Numerical Efficiency of MMS on IBM Mainframes", May 1988. The procedure described in the report also applies to other 32-bit computer systems such as IBM PC compatibles. The procedure is experimental and has been demonstrated to work with several troublesome problems.