B&W/MMS User Group Newsletter

MMS: A COMPUTER PROGRAM DEVELOPED BY THE ELECTRIC POWER RESEARCH INSTITUTE

April 1987 **Vol.2 No.4**

THE PRESIDENT'S CORNER

Welcome to the beginning of our third year as the B&W/MMS User Group. Since our first meeting, hosted by B&W in Lynchburg, VA on March 12-13, 1985, we have witnessed a tremendous growth of MMS. Today, the MMS library is approximately twice the size of the initial release. In addition, personal computer enhancement tools have been developed by B&W and others which will prove to be an important asset. The power of today's PCs is at a point where these tools can be used very effectively.

I would like to take this opportunity to thank Charles Sayles for his efforts as president of the User Group the past two years. Charles has worked hard and we all should give him a "round of applause". I would also like to thank Phil Bartells of B&W who has done an outstanding job promoting the User Group.

Over the last two years, our membership has grown to include our friends in Spain and Japan. Membership now stands at 15 companies of which 10 are USA utilities. A goal for all of us, over the next two years, is to assist B&W in increasing our membership further. Lastly, I would like to thank you, the users of MMS, for your vote of confidence.

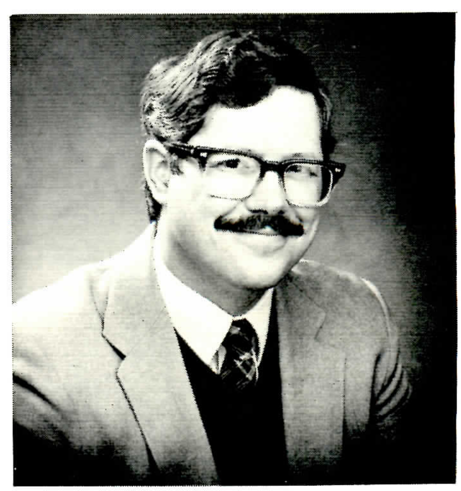
The User Group would like to extend a warm welcome to Chiyoda Chemical Engineering & Construction Company of Yokohama, Japan. Two representatives from Chiyoda Chemical attended our fifth meeting which was held at Southern California Edison's offices in Rosemead, California. In all, seven member organizations were represented at the meeting along with representatives from B&W and EPRI. Special thanks goes to SCE for hosting this meeting.

After reviewing my meeting notes, it is apparent that the users of MMS are having fewer problems with code use than before. We are also using the MMS for some applications that the original developers had not intended. As a result, we now can concentrate on optimizing the code and expanding its range of applications even further.

As I finish writing my first "President's Corner" message, I would like to invite all of you to be a part of this newsletter. It is very important that the newsletter represent you, the MMS user. To do this effectively, Phil needs your input in the way of short articles, helpful tips on using MMS, or any other notes-of-interest. Send your articles to Phil or to me.

The slate of officers that was nominated and listed in the January newsletter was elected and have assumed office.

The next meeting will be hosted by Detroit Edison in mid-September.



DAVE WEBER
PRESIDENT
April 7, 1987

USE OF THE MMS TO TEACH TRANSIENT ANALYSIS AT THE PENNSYLVANIA STATE UNIVERSITY

The Modular Modeling System (MMS-02) was recently used in a Systems Interaction course given by the Nuclear Engineering Department at the Pennsylvania State University. Ten students (seniors and graduate students) took the semester-long course. The fifteen week course consisted of two 50 minute lectures and one 100 minute computer laboratory session each week. The objectives of the course were to teach the students (1) how the pressurized water reactor primary system components are modeled, (2) how changes in various parameters affect the entire primary system, and (3) how a reactor system transient is analyzed.

The majority of the lecture time was spent in understanding the equations used in the development of the primary system modules. The computer laboratory was spent using individual modules and later connecting the modules to form a primary system. Whenever possible, default values built into the code were used since the system to be studied was a TMI Unit 1.

The first module studied was the pressurizer (PRESZR). This was modeled with heaters and spray as well as a surge junction. Then the reactor module (RX3), the steam generator (OTSGEM) and finally the primary pump (PUMP4Q) were studied. Each component was first studied individually and initialized with individual boundary conditions until a steady state was reached. The reactor and pressurizer were then joined together and initialized so that a steady state was reached. The steam generator was added and finally the primary pumps. Once the primary system was modeled, small power changes (+ or - 10%) were run. The final project was to run a turbine trip and compare the results with those of Ron Dixon (ref 1) who used a pre-release version of MMS. Results were also compared to experimentally obtained plant data (ref 1).

Overall, the course successfully accomplished its objectives. Student response to the course was very positive. It is planned to give the course again next fall. It is hoped by then that a simplified secondary system will be available. Two graduate students, who took the course this past fall, are planning to work on modeling the secondary system for a summer project.

1) Bechtel Group, Inc.

Modular Modeling System Validation:

"Transients in Fossil and Nuclear Power Plants" (March 1983) EPRI CS/NP-2945

DR. GORDON ROBINSON
PENNSYLVANIA STATE UNIVERSITY

PHILADELPHIA ELECTRIC LOOKS AT WATERHAMMER IN FEEDWATER SYSTEMS

At Philadelphia Electric Company, a study is being performed on the water hammer effect exhibited in some feedwater systems. MSS was reviewed to see if it could be used for this type of transient.

Piping system water hammer is an inertial effect. It is therefore critical that the model of the feedwater system adequately treat momentum transfer. The MMS PIPESR, PIPER, and PIPERS modules account for momentum transfer by incorporating a momentum conservation equation in the model formulation. The CONNI module, needed to connect two resistive components in series, does not conserve momentum in the general case. Therefore a new module was developed to study the water hammer problem.

A new module, HEADI, was written to connect two resistive components in series. The module differs from the CONNI in two key aspects. First, in addition to a mass balance, a momentum balance was written around the module. The balance is a steady state balance requiring that the momentum of the fluid entering the module equal the momentum of the fluid leaving the module. Secondly, there is a volume and cross sectional area associated with the model. The volume and area enable the model to be related to a physical component, for example the piping run between two valves.

In order to allow ACSL to sort properly, the HEADI module must be located immediately downstream of a module which has the exit flow as a state. As an example, HEADI can be placed downstream of a PIPESR module with the inertial flag turned

(See WATER, page 3)

- MMS TECHNICAL NOTE -
FINDING STEADY STATE FOR LARGE MODELS

Finding a steady state operating point for a large MMS model of a power plant can be a difficult task. One reason for this is that the steam/water flows and enthalpies are highly coupled in a typical power plant. For example, the enthalpy of steam produced from a fossil boiler or a nuclear steam generator may vary depending on the feedwater enthalpy. The feedwater enthalpy will, in turn, depend on the main steam enthalpy through the enthalpies of the extraction steam fed into the shell side of the feedwater heaters. The flow steams are, therefore, coupled by various intertwining mechanisms. Assembling an entire model, parameterizing it, guessing a steady state operating point and then just letting the (EASY5 or ACSL) steady state finder rip, will rarely lead to success. For large models, a more systematic approach should be taken.

We have recently built an MMS model of the balance of plant (BOP) for Unit 2 of the Diablo Canyon Nuclear Power Plant (DCPP). DCPP has two units and Westinghouse was the vendor. This note reports some of the techniques we used in finding the 100% power steady state operating point for the Unit 2 BOP. The hints and techniques contained in this note do not constitute the only way to reach the steady state operating point, rather, they offer a tested route for a MMS user to follow. Although PGandE uses the EASY5 simulation language to drive MMS, the techniques described in this note should still be applicable to ACSL.

DCPP has a rather typical nuclear plant BOP. The main steam first drives the high pressure turbines, it is then superheated in the moisture-separator-reheaters, then it drives low pressure turbines and it finally exhausts into the condenser. Steam is extracted from the turbines and the extraction steam is used to heat the feedwater in six stages of feedwater heating.

Figure 1 is a schematic of the BOP and is for purposes of illustration only; the actual MMS model schematic contains many more components. Figure 1 shows a steam generator (SG), high and low pressure turbines (HPT and LPT), the condenser (COND) and the high and low pressure feedwater heaters (HPFWH and LPFWH). The box labelled "COOL" represents miscellaneous coolers and even though the coolers provide only about 1% of the feedwater heating, they must be modeled if a full BOP model is being built.

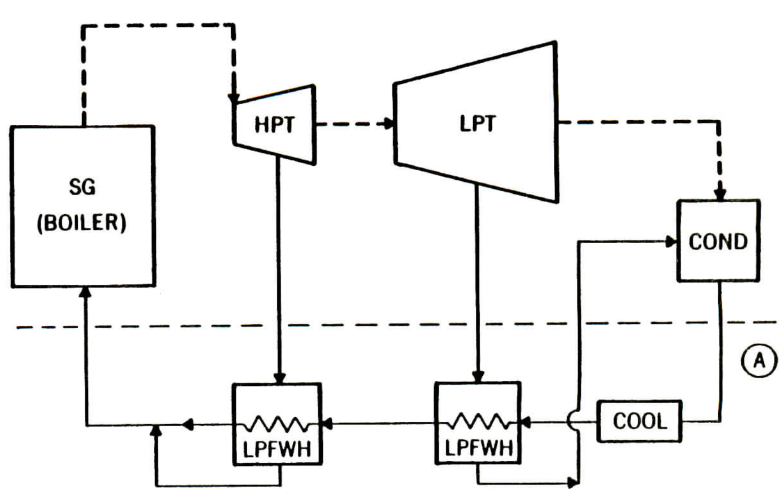
The basic strategy is two-fold. First, divide in order to conquer. By this, we simply mean that some reasonable split-up of the model should be defined right from the start and the various submodels should be brought to steady state in isolation in a consistent manner before they are all joined. The second aspect of the strategy is to use control techniques to force steam and water flows to meet target values throughout the model. The two elements of the strategy will hopefully be made more clear through the following comments and hints.

1. Lump components wherever possible. For example, three parallel feedwater heaters can be represented by one feedwater heater, three times as big. Lumping keeps the size of the model down. As part of simplifying the model, do not explicitly model the minor, miscellaneous house load steam flows but account for any effect they have on feedwater heating in a simple manner.

2. Obtain a steady state for each and every component in isolation using the proper stand-alone boundary conditions. We have found it useful to use controllers to automatically vary conductances so that flows are forced to match some target value of fluid flow. Flows in the MMS modules are usually computed using the orifice equation:

(See NOTE, on back)

Figure 1: Balance of Plant Schematic



NOTE - cont. from front

$$w = K \sqrt{\rho \cdot \Delta P}$$

where the flow (W) depends on the conductance (K) and the square root of the product of the fluid density (ρ) and a pressure difference (ΔP). We let the conductance, K, be a fictitious state of the system obeying the differential equation:

$$(dK/dt) = G(w_{ref} - w)$$

where G is a constant gain term, w is the flow computed via the orifice equation and w_{ref} is the target or desired value of flow. In EASY5, the equation for (dK/dt) can be represented using a "GA" (general controller) model. In steady state searches, the fictitious conductance state is left active. Experience has shown that the gain term (G) should be set equal to about K_{est}/w_{ref} where K_{est} is an approximation to the conductance. For example, for a flow of ten million lbm/hr and a K_{est} of 100,000, G should be set at about 0.01.

3. Once steady state operating points for isolated modules have been found, start assembling the entire model by first dividing it up into subsections and finding the steady state for each subsection. Allow the fictitious conductance states to be active during these steady state runs. For a BOP, a natural separation is forming a "feedwater" subsection and a "steam" subsection. The feedwater subsection contains the piping, pumps, tanks and feedwater heaters from the condenser outlet to the steam generator (or boiler) feedwater inlet. The steam subsection includes the steam generator (or boiler), steam piping, the turbines and the condenser. We included the extraction piping in the feedwater subsection although inclusion in the steam submodel will not affect the thrust of this method. In figure 1, the dotted line illustrates the dividing line, defining the two submodels. We also found it convenient to build up and get steady states for the subsections incrementally. For example, after reaching a steam generator steady state, we joined the downstream modules (high pressure turbines, moisture separator reheaters) one by one and got a new steady state after each additional component was introduced into the steam submodel.

4. Before assembling the final model, make sure the submodels are consistent. For example, make sure that the feedwater enthalpy computed at the feedwater train's discharge is close to the feedwater enthalpy assumed in the stand-alone steam submodel; the turbine extraction enthalpies should also be close to the enthalpies used as boundary conditions in the stand-alone water submodel. If the two submodels are inconsistent, then some iterative steady state calculations should be carried out to get consistency between the steam and water submodels.

5. At this point, join the two submodels. The joining should also be done in steps. For example, we first linked the two submodels at every point except at the feedwater exit at the condenser (the point labelled "A" in figure 1). A steady state was reached with the feedwater enthalpy at the entrance to the miscellaneous coolers imposed as a boundary condition. The model for the coolers, in turn, was as crude as possible: they were modeled as a heat addition to the feedwater: $\Delta h = Q/w$ where Δh is the enthalpy rise across the coolers, Q is the heat addition and w is the flow. In general, the feedwater enthalpy at the condenser exit will be nearly, but not exactly, equal to the feedwater enthalpy that was assumed for the full model unlinked at point "A". This slight mismatch can be corrected by an appropriate, slight modification of the heat input across the coolers (Q). In the final linking, we found it useful to accomplish this using control techniques similar to the ones described in item 2 (i.e., Q is a fictitious state, the value of which, is calculated to satisfy some target value of enthalpy at the exit to the coolers). In fact, our last steady state calculation consisted of letting Q be the only active state followed by a "PRINT" statement with all model states active to confirm that all rates were extremely small.

DAVE DION
PACIFIC GAS & ELECTRIC

MMS User Group Newsletter
Editors: Phil Bartells (804) 385-2637
Ross Schaack (804) 385-2584

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WATER - cont. from page 2

on. This gives a storage module which can be used between two valves.

In order to verify the formulation of the HEADI module, a simple system was examined. Figure 1(a) illustrates a system with 200 ft of pipe upstream of two open valves located 1 ft apart. This is followed by a 100 ft piping run. Figure 1(b) shows the MMS representation of this system. The 200 ft pipe is represented by two PIPESR modules, each with a length of 100 ft. Note that the space between the valves has been left blank. Three methods of modeling this region are now presented.

In the first case a CONNI module is inserted between the two VALVEI modules. The system is then perturbed by stepping the exit pressure of the system from 18.5 psia to 50 psia at a time of 100 seconds into the simulation. The response of the pressure at the entrance of the first valve is shown in Figure 2.

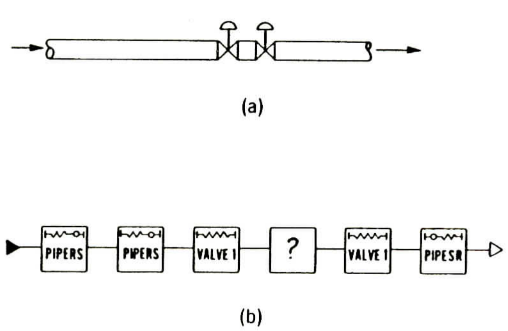
In the second case the space between the two valves has a PIPESR module, with the inertial flag turned on, followed by a HEADI module. This system then underwent the same perturbation as the first case. The response of the first valve inlet pressure is illustrated in Figure 3. Note that while the peak pressure is almost the same between the two cases, the second case, clearly, has a much higher frequency content.

A verification of this high frequency content is obtained by modeling the system as a single valve having a conductance equivalent to the two valves in series. In this case, no CONNI or HEADI modules are required. The valve inlet pressure response of this case, for the same perturbation, is shown in Figure 4. The frequency content is very similar to that of the case with the PIPESR-HEADI combination.

In conclusion, we see that the HEADI module adequately represents momentum transfer between two series resistive elements. This module can be used in conjunction with a PIPESR module to model systems where inertia plays an important role. By using this module to model resistive components in series, Philadelphia Electric Co. hopes to analyze the water hammer phenomena for specific operating conditions.

DAVE DIMENSTEIN
PHILADELPHIA ELECTRIC

Figure 1. Schematic and Causality Diagram of System Being Modeled



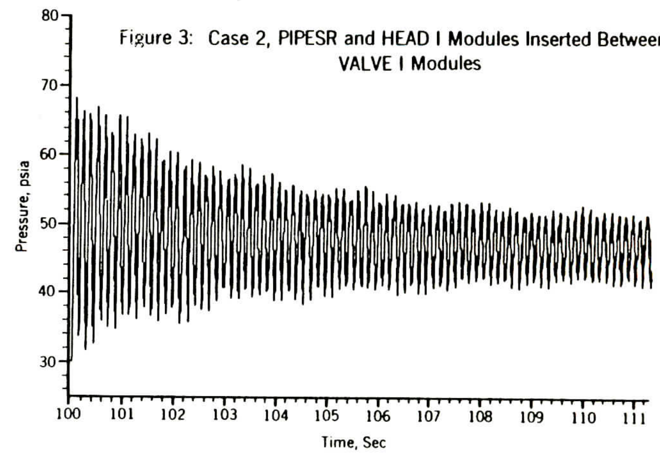


Figure 3: Case 2, PIPESR and HEAD I Modules Inserted Between VALVE I Modules

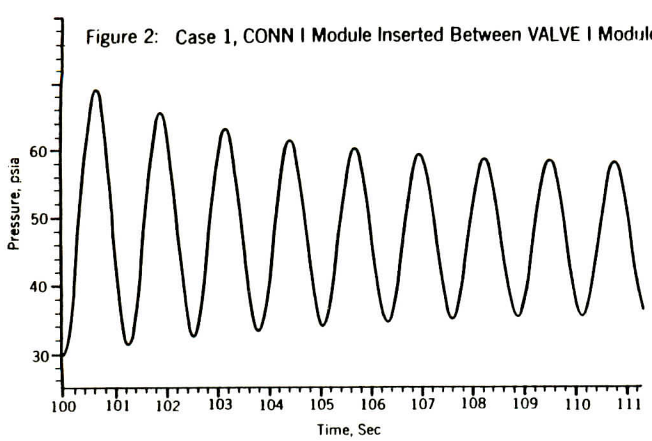


Figure 2: Case 1, CONN I Module Inserted Between VALVE I Modules

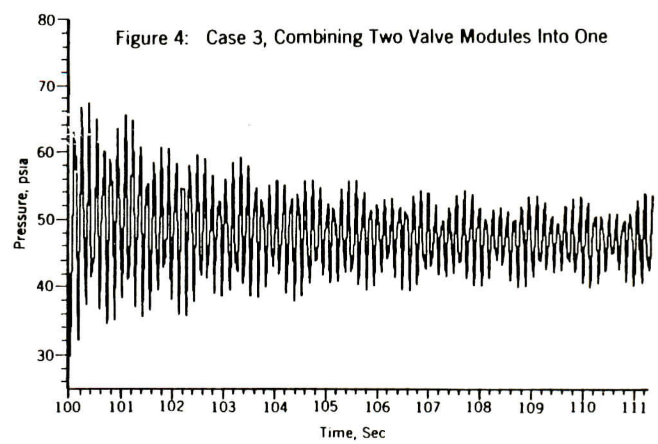


Figure 4: Case 3, Combining Two Valve Modules Into One

MMS MODEL OF B&W NUCLEAR PLANT COMPLETED

Development of a MMS model of a Babcock and Wilcox 177 Fuel Assembly Nuclear Steam Supply System (177FA NSSS) has been completed, and the resulting simulation will be used by B&W in support of the operating B&W nuclear plants. It is anticipated that this model will be used to analyze actual and postulated operating transients and to perform scoping studies for safety analysis. In addition, the lessons learned during the development program will be put to use in enhancing the MMS library.

The MMS two-phase modules were used for the Reactor Coolant System (RCS), the single-phase modules were used for the feedwater system, a set of customized controls modules were developed to simulate the Bailey Controls Integrated Control System (ICS), and the coding for the steam line model was taken from a previously developed ACSL model and incorporated in the RCS loop model.

The first step in the development was to review the formulation of the MMS two-phase modules to determine their feasibility for use in this project. To accomplish this, the two-phase once-through steam generator module (OTSGTP) was evaluated in detail (see article in January 1987 Vol.2 No.3).

The next step was to construct the model of the RCS (Figure 1 shows the model layout). This was done as a three part process; the reactor core was modeled first and brought to steady-state, then each loop was modeled and brought to steady-state. The feedwater system was modeled and brought to steady-state next. Finally, all four models were combined and brought to a steady-state. No difficulties were experienced with this structured approach to finding a steady-state (Note that this technique is essentially identical to that described by Dave Dion in the Technical Note accompanying this Newsletter). The final "bare plant" model (without controls) contains fifty macros.

Concurrently, a model of the Bailey ICS was developed and tested using MMS. The ICS was modeled at the control component level using about 200 individual macros of controllers, auctioneers, signal monitors and other analog control components. Some of these macros are enhanced versions of the existing controls macros. They include the capability to fail the component to a preset level or to limit the output. The failure mode option is particularly useful in model debugging. These modules are candidates for later inclusion in the MMS library after completion of verification testing and documentation.

The final step was to combine the ICS and the bare plant model. The final model has approximately 250 macro calls, 140 state variables and 4000 variable names.

The model was benchmarked to the Davis-Besse (note: one of B&W's plants) station blackout event that occurred on November 29, 1977 with excellent results being obtained. Further benchmarking will be done, most probably using the data from the SMUD (note: another B&W plant) load rejection performance test conducted on March 18, 1975. This particular test data contains a lot of information on the ICS interaction with the plant.

The model has already been used to study the response of the ICS to a trip of one of the main feedwater pumps. In this analysis the model performed as expected and the results were used to provide boundary conditions for a Relap5 model. Several other applications are in the planning stage.

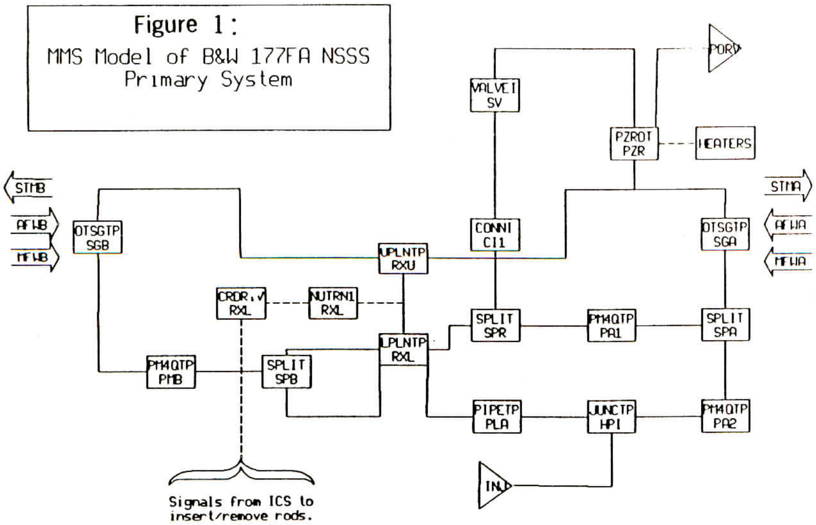


Figure 1:
MMS Model of B&W 177FA NSSS Primary System

ROSS SCHAACK
BOB BROWNELL
BABCOCK & WILCOX

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