MODELING, IDENTIFICATION AND CONTROL, 1986, VOL. 6, NO. 4, 231–247
doi:10.4173/mic.1985.4.4

The application of simulation in large energy system analysis†

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Keywords: *power plant simulation, MMS, modeling, nuclear and fossil plant transients, dynamic analysis.*

The Modular Modeling System (MMS) developed by the Electric Power Research Institute (EPRI) provides an efficient, economical, and user friendly computer code to engineers involved in the analysis of nuclear and fossil power plants. MMS will complement existing codes in the areas of nuclear and fossil power plant systems simulation. This paper provides a synopsis of MMS code features, development objectives, usage and results of fossil and nuclear plant simulation.

The MMS code is truly modular, with the modularity followed and maintained at the component and simulation language levels. These carefully defined modularity principles allow modelers to choose and interconnect any set of modules to represent physically realistic arrangements of plant systems and subsystems and analyse them. Modeling time is reduced significantly. This large systems analysis package has been extensively tested at the development stage and is currently being used by 21 U.S. utilities to perform routine systems calculations.

1. Introduction

The emphasis for system code development in the nuclear industry has traditionally been on the need for emergency core cooling system (ECCS) and safety analyses, whereas heat rate improvements have been the primary focus for fossil power plants. The steady state codes such as PEPSE, THERM, and SYNTHA, all of which are proprietary, have to a great extent fulfilled the fossil power plant analysis requirements. None of the dynamic system analysis codes used in the fossil industry are publicly available, to the author's knowledge.

The early versions of nuclear system analyses codes in the U.S. like TRAC, RELAP (U.S. Nuclear Regulatory Commission, 1982) and RETRAN (Electric Power Research Institute, 1980) were often used primarily to address the licensing analysis of the power plant accident conditions. There are many applications of plant analysis which could be performed by less complex codes. The main reasons that have prevented the widespread use of dynamic modeling in fossil and nuclear industries, until recently, are (1) high cost, especially for engineering time, (2) specialized skills and experience required by the user, (3) long lead time required to produce a dynamic model, and (4) lack of confidence in the validity of the model. To be effective, an ideal dynamic modeling tool must be readily usable by both design engineers and professional modelers; therefore, it should be simple, flexible and modular, economical, and sufficiently accurate for the analysis of both operational and long term off-normal transients.

Received 20 November 1985.

† This paper was presented at the International Seminar on Modern Methods in Dynamics Simulation of Industrial Processes, Trondheim, Norway, May 1985.

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The Modular Modeling System (MMS) has been developed by the Electric Power Research Institute (EPRI) to fill the gap in the available library of power plant dynamic analysis codes and to directly address each of the problems which have inhibited wider use of dynamic simulation (Electric Power Research Institute, 1983b). In MMS,

(*a*) The cost in applied engineering time is reduced by pre-engineering the models of plant components, completely eliminating any required user component modeling. Computer costs are minimized by careful formulation and application of state-of-the-art numerical integration techniques geared for problems like power plant models.

(*b*) In addition, the user requirements are reduced by using high level simulation languages that contain the integration algorithms and convenient input/output features. This moves plant simulation from the realm of modeling specialists into that of utility engineers who are in the best position to utilize and apply the results.

(*c*) Model generation time is reduced to a period consistent with that available to study utility operating problems.

(*d*) Confidence in model validity is improved by extensive validation of each component model in the system, and by developing multiple versions of a component module varying in modeling complexity to suit different applications.

2. Modular modeling system (MMS)

Unlike other computer codes which use fluid volumes as basic elements, the MMS uses models of individual components as basic building blocks. Several papers and reports have been published on this dynamic simulation code in the last few years (Dixon and Toren 1981, Electric Power Research Institute 1981, 1983a, c, d). It is ideally suited for solving routine problems while providing options for those who wish to perform dynamic simulation of plant systems and sub-systems for analysing operational and long-term off-normal plant transients including two-phase phenomena. In particular, MMS was designed for (1) evaluation of plant design or retrofit alternatives by specifying, selecting, and integrating plant components, (2) design and checkout of control systems, (3) operational procedures development and review, (4) training simulator qualification, (5) diagnosis of plant performance and (6) retrospective analysis of plant transients and accidents.

To achieve these objectives, the physical behaviour of the parameters for each module in the MMS code is represented by appropriate ordinary differential and algebraic equations. Up-to-date algorithms are employed allowing fast and accurate model benchmarking. Built-in validity checks are flagged when the basic assumptions of the module are validated. Because of this, prime user modeling effort involves selecting appropriate modules representing the plant system or sub-system and parameterization of the component modules. In addition, the user is assured of modules that have undergone continued testing for various applications by a community of other users.

The MMS is built upon commercially available simulation languages: Advanced Continuous Simulation Language (ACSL) and Engineering Analysis System (EASY-5) (ACSL 1981, Burroughs 1981). These simulation packages themselves provide a modular framework incorporating steam tables, integration routines, analysis packages, and provide flexibility to add new blocks of coding.

The code is best described if the four elements that constitute MMS are explained separately (1) methodology, (2) library of modules, (3) simulation languages and (4) steam property routine.

2.1. Methodology

The methodology of MMS is the basic philosophical foundation of the code. Each component model (module) is fully self-contained. It contains all the relations required to define that component's dynamic performance when it is provided with only pressure, flow rate, enthalpy and dependent thermodynamic properties from interconnecting modules. As shown in Fig. 1, modules are typically characterized as

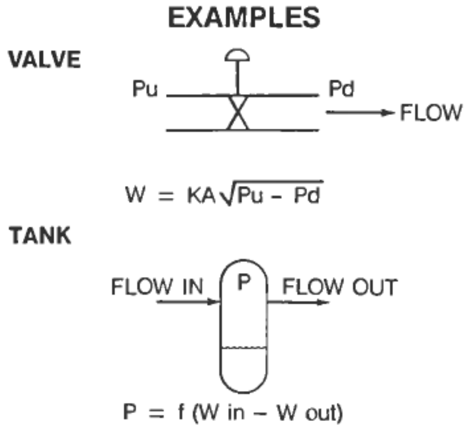


Figure 1(a). Example MMS module representations.

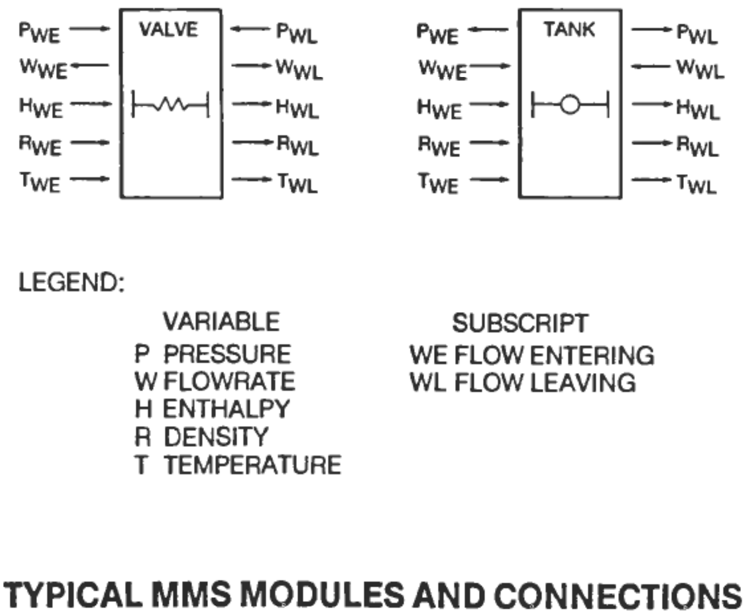


Figure 1(b). Typical MMS modules and corrections (value and tank module representations).

resistive, capacitive or combinations of them depending on which parameters are transmitted to the adjacent modules. Modules are described by the lumped parameter approach. Each module is represented by a set of first order non-linear ordinary differential equations expressing the rate of change of certain quantities called state variables. Algebraic equations are used where possible. Modules may be added or deleted in the model without affecting other modules; only the model response is affected. Maximum economy is provided by a clear and consistent set of specifications for module performance which, while retaining rigorous thermodynamic and constitutive relations, avoid simulation for simulation's sake. For example, quasi-steady state momentum relations are used consistently instead of carrying fluid momentum (or flow rate) as a state to minimize model order and to avoid the very lightly damped, difficult to integrate, eigenvalues that result from the solution of the dynamic momentum relation. Rather, fluid momentum is provided as an option for the modeler who requires it.

2.2. Library of modules

MMS includes a library of over 60 modules, given in Table 1, representing most components used in conventional fossil fueled and pressurized or boiling water reactor plants. Depending on the applications, the user can pick modules of desired complexity from the library. Further the user can improve any MMS plant model with state-of-the-art modeling techniques just by expanding the physics of a selected component as described.

Fossil modules	*Nuclear modules*
Spray attemperator	Once-through steam generators (3 versions)
Forced circulation drum boiler	U-tube steam generator (3 versions)
Natural circulation drum boiler	PWR reactor (12-node and 3-node)
Economizer	BWR modules (3 options)
Superheater/reheater	Wet steam turbine
Pulverizer/feeder	Moisture separator/reheater
Once-through fossil boilers	Equilibrium pressurizer
Flash tank	Non-equilibrium pressurizer
Regenerators	Critical flow module
Preheaters	Four quadrant pump
	Two phase splits, merges and pipes
BOP modules	Reactor vessel and plenum
Valve and actuator	
Water-to-water heat exchanger	*Interconnection modules*
Open feedwater heater	Connective module
Closed feedwater heater pipe	Flow divider
Motor-driven centrifugal pump	Flow junction
Steam-turbine-driven centrifugal pump	Surge junction
High-pressure steam turbine	
Intermediate/low-pressure steam turbine	*Control modules*
Valve(s)	On-off controller
Condenser	Proportional-integral controller
Variable speed motor-driven pump	
Speed variations in turbines	

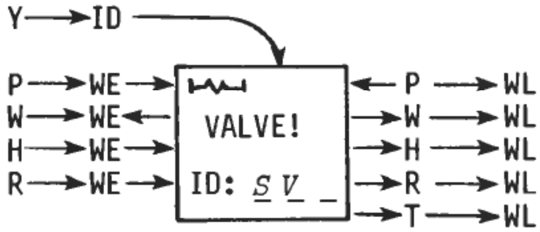
* In addition, ACSL and EASY have additional 50-75 control related modules.

Table 1. MMS modules library*

Each module has a separate parameterization worksheet identifying required parameter information which may readily be derived from component vendor design, heat balance sheets or plant data. A typical MMS user worksheet is given in Fig. 2 and a typical MMS plant model with the modules interconnected are shown in Fig. 3. Once the modules are connected and plant system is established with MMS modules, all equations are sorted and solved by the simulation language in MMS.

2.3. *Simulation language*

Advanced simulation languages such as ACSL or EASY-5 provide the user with considerable analytical support and versatility during problem setup and analysis. Thus, assembling and connecting the various components into a large system is performed through a sequence of elementary commands merely specifying the



MACRO Invocation

VALVE! *'S V _'*, *'E S V _'*, *'S P R A'*
ID WE WL

CONSTANT PARAMETERS: (All Parameters are Appended by ID)

Associated Pipe Conductance	______ :	KCP S V _ (ID) =	*2400.0*
Maximum Valve Conductance	pph/$\sqrt{\text{pcf. psi}}$) :	KCV S V _ (ID) =	*2400.0*
Valve Characteristic Constant	(Integer) :	KVA S V _ (ID) =	*2*

1 – Equal Percentage
2 – Linear
3 – Quick Open
4 – Square Root

NOTE! Valve and Actuator must have same ID.

VARIABLES:

H	WE	– Enthalpy Entering	(Btu/lbm)
H	WL	– Enthalpy Leaving	(Btu/lbm)
P	WE	– Pressure Entering	(psia)
P	WL	– Pressure Leaving	(psia)
R	WE	– Density Entering	(lbm/ft^3)
W	WE	– Flowrate Entering	(lbm/hr)
W	WL	– Flowrate Leaving	(lbm/hr)
Y	ID	– Valve Position	(fraction

Figure 2. Typical worksheet: (module: valve I).

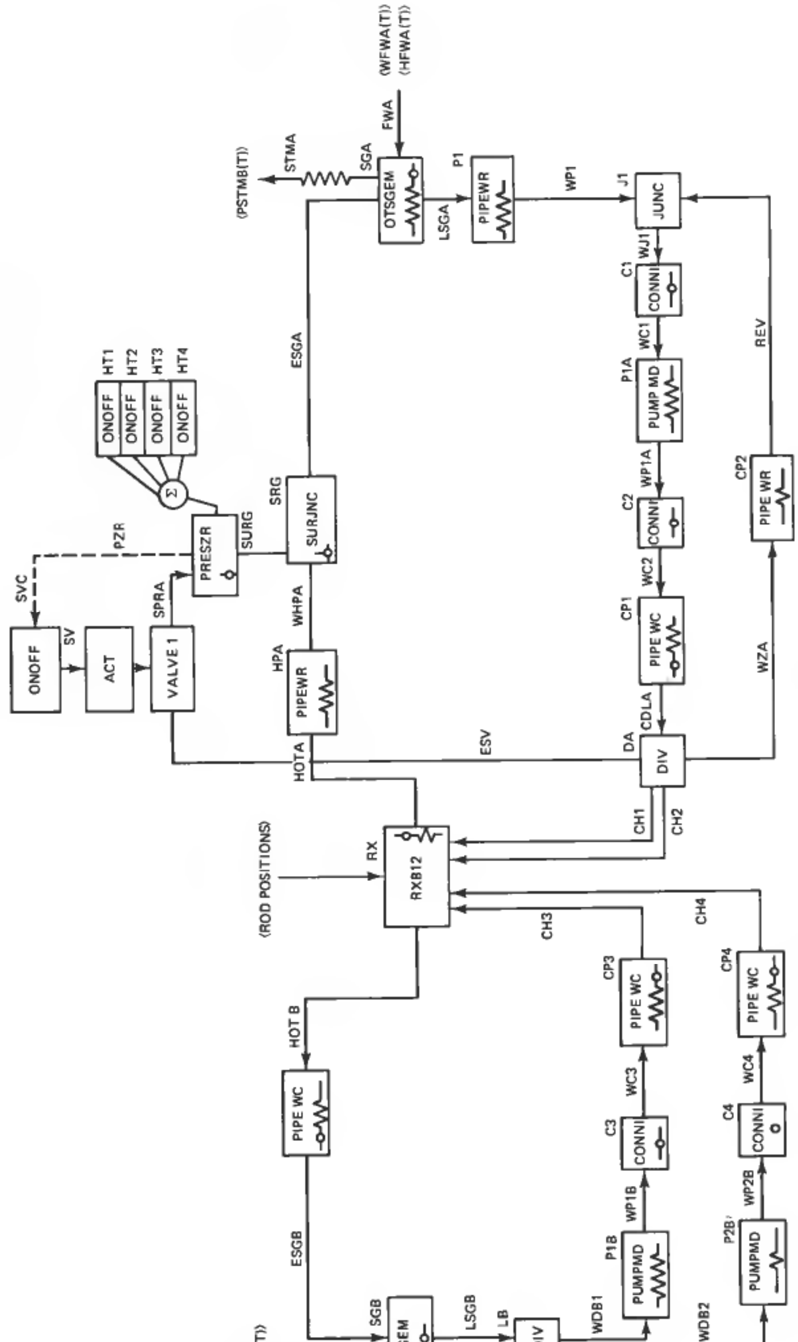


Figure 3. MMS interconnection schematic and plant model.

desired topological connections between modules. The language then, automatically translates these orders into equivalent FORTRAN statements and aligns a consistent set of variables names to all quantities transmitted from one module to another. The language organizes the order in which the equations are solved in order to satisfy causality. This is accomplished with the use of MACROS, which generalize the concept of SUBROUTINES. MACROS are essentially sub-routines divided into several blocks. These blocks of command cannot be internally shuffled by the main program, but they can be transferred from one sequential position of the overall program to another in order to optimize the solution procedure. This block manipulation is of course intimately related to the module connection scheme. The EASY-5 code also generates a map displaying the connections and the variables being transmitted across each connection. Figure 4 shows the MMS framework that includes the user's program or source code that is input to the ACSL/EASY-5 pre-compiler.

In addition to program optimization, the simulation language can perform many other tasks. The most interesting perhaps, from a user's standpoint, include:

(*a*) *Stability margin analysis* Nyquist, Bode, Root Locus analysis.

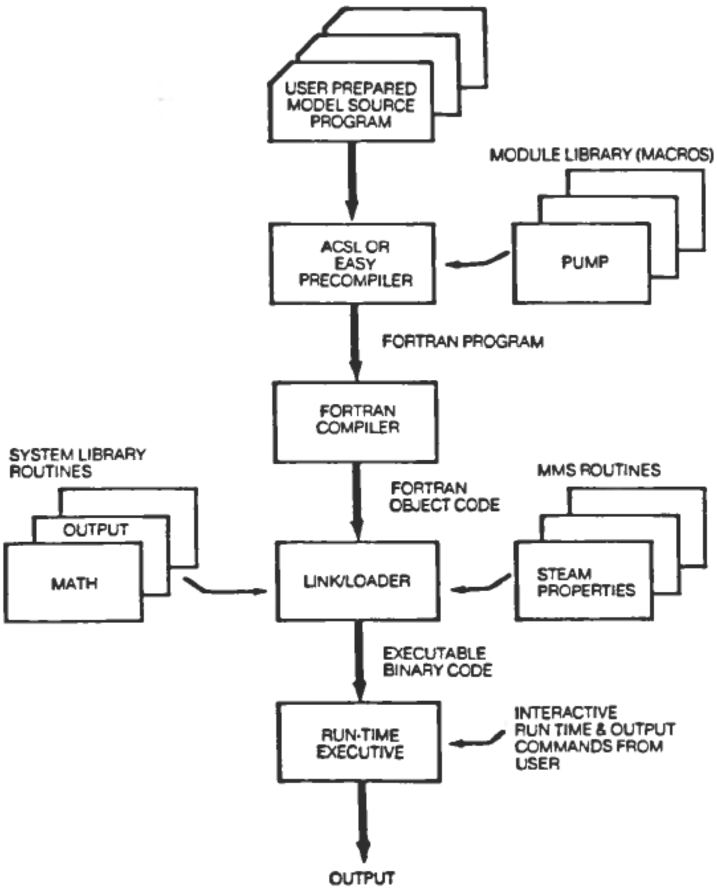


Figure 4. MMS structure.

(*b*) *Sensitivity analysis* determines the sensitivity of selected variables to specified parameters over a given range of parameter variation, with a single computer run.

(*c*) *Steady-state analysis* pseudo transients or TRIM functions.

(*d*) *Eigenvalue analysis* The set of eigenvalues of the system are listed. The user can reduce the order of the system, i.e., the number of ordinary differential equations, either by 'freezing' some time rates of change (usually for variables that vary very slowly) or by asking the code to combine two or more of the eigenvalues into a single complex number (usually for variables that vary very rapidly).

(*e*) *Optimal analysis* This feature enables the engineer to find the optimum value of his control parameters (gain, lags, etc.) of almost any control system.

(*f*) *Programming* In situations where the appropriate module does not exist in the library, the user can define his own FORTRAN module as part of the input. The module can then be connected to any other module provided it has the appropriate boundary conditions. The user only provides the equations and the numerical values of constants. The order in which the equations differ in his FORTRAN module or the numerical algorithm to solve them need not concern him.

(*g*) *Fluid of Metal Properties* The simulation languages allow access to steam, metal, air or any other properties external to the modules.

2.4. Steam property routines

MMS includes a large set of efficient, quarter per cent accurate steam property algorithms. These include both high order polynomial fits and table look-up routines.

2.5. Model construction with the code

From the user standpoint, the following ten steps are followed to develop and run a transient of interest using the MMS code.

Step	*Explanation*
(1) Draft model schematic	Line diagram separating the system under study from the rest of the plant.
(2) Draw interconnection schematic	Representation of above system with the modules in MMS Library.
(3) Parameterize model	Selection of boundary conditions and parameter values for each module.
(4) Model control system	Choice of modules to represent control system sufficiently.
(5) Fill out user worksheet	Defining input/output ports for each module and calculation of parameters indicated on each

Step	*Explanation*
	module worksheet using physical and operating data along the lines provided in the user manual.
(6) Code 'model'	Model program generation by copying lines from user worksheets (invocation of MACROS in ACSL and EASY-5).
(7) Generate command file	File consisting of choice of integration routines, output intervals and variables, and error criteria, etc.
(8) Generate executable program	Translation of model program using the simulation language. This automatically checks for syntax, generates FORTRAN source code, and compiles to generate a FORTRAN object code. The executable binary code is available at the end of this step.
(9) Initialization of model	Using a command file to reach a steady-state solution. The steady-state finders or the integration routines in ACSL and EASY-5 are used.
(10) Transient run	Using the run-time executive depart from steady state with a defined disturbance. Calculate at appropriate time intervals all parameters of interest.

3. Mathematical formulation

The conservation of mass, momentum and energy in fluid dynamics are usually expressed in the form of partial differential equations describing the local state of the pressure, velocity and enthalpy fields. In MMS these equations are transformed into ordinary differential equations specifying the rate of change of pressure, flow-rate and enthalpy. To achieve this, the partial differential equations are integrated spatially over finite control volumes. The size of these volumes vary and are generally large with lumped parameter approacn. In order to achieve good accuracy, the physical phenomena in MMS modules are described mathematically in sufficient detail. In each module, the set of ODEs is explicit in the sense that it can be written as:

$$A(x, y, t)\dot{x} = b(x, y, t)$$

where x is a n-dimensional vector of the state variables; $\dot{x}$ is its time derivatives vector; A is a non-singular matrix, and b is a vector. A and B contain the states (x) and the algebraic variables (y), but not the rates ($\dot{x}$).

The algebraic equations can be any set of non-linear equations. All equations are solved with consistent boundary conditions of flow, pressure and enthalpy, as the physical quantities are transported between the modules.

The total mass conservation equation, in a variable volume V is approximated by:

$$\frac{d\rho}{dt} = \frac{1}{V}(w_{\text{in}} - w_{\text{out}}) - \rho \frac{dV}{dt} \tag{1}$$

where w_{in} and w_{out} are the mass flowrates across the boundaries of V (i.e., flows relative to the motion of the boundaries). The corresponding energy equation is:

$$\frac{d}{dt}(\rho h V - PV) = (w_{\text{in}} h_{\text{in}} - w_{\text{out}} h_{\text{out}}) + Q = P\, dV + (\text{D.F. term}) \tag{2}$$

The second term on the r.h.s., Q, represents the energy source terms added within the volume.

$$Q = UA(T_{\text{wall}} - T_{\text{sat}}) \tag{3}$$

The overall heat transfer, U, which includes wall conductance, is an empirical function of flowrate, fluid properties and hydraulic diameter (determined by Dittus–Boelter, Thom, Nusselt correlations for subcooled, boiling and condensation conditions respectively).

The single-phase and two-phase equations are normally identical except for the presence of the drift flux terms (D.F. term) in the latter case. These terms express the fact that the steam and liquid can flow through the volume at different speeds ($V_{jg} \neq 0$) and that the distribution of liquid and vapor within the volume is not necessarily uniform ($C_0 \neq 1$). These terms are:

$$\begin{aligned}(\text{D.F. terms}) = {} & (C_0 - 1)[w_{\text{in}} \gamma_{\text{in}} - w_{\text{out}} \gamma_{\text{out}}] + AV_{jg} \\ & + AV_{jg}(\rho_{\text{in}} \gamma_{\text{in}} - \rho_{\text{out}} \gamma_{\text{out}})\end{aligned} \tag{4}$$

where

$$\gamma = \frac{\alpha h_{fg}}{\rho(1 - C_0) + \rho C_0} \frac{\rho_f \rho_g}{\rho} \tag{5}$$

Clearly, for single-phase flow or homogeneous flow ($C_0 = 1$ and $V_{jg} = 0$) these terms disappear and we recover the single-phase energy equation exactly.

The density term, in the two-phase flow case is identified as:

$$\rho = \alpha \rho_g + (1 - \alpha)\rho_f \tag{6}$$

where α is the average void fraction in the volume. In this case ρ_g and ρ_f are functions of pressure only but α is a complex function of pressure and enthalpy, defined by the Zuber–Findley relations:

$$\alpha = \frac{x}{C_0\left[x + (1 - x)\frac{\rho_g}{\rho_f}\right] + \frac{A\rho_g V_{jg}}{W}} \tag{7}$$

where the quality x is related to the average enthalpy by:

$$x = \frac{h - h_f}{h_{fg}} \tag{8}$$

In the single-flow case the partial derivatives of ρ are immediately computed from the water properties, whereas in the two-phase flow case they must be evaluated from Eqns. 6 and 7 as well as the phasic partial derivatives.

Equations 1, 2, and 10 are combined to yield expressions of dP/dt and dh/dt as a function of P, h and w. The momentum equation is handled somewhat separately. In general form it is approximated by

$$\frac{dw}{dt} = \frac{A}{L}\left[(P_{\text{in}} - P_{\text{out}}) - \rho g L - \frac{1}{K^2} W^2\right] + (\text{D.F. terms}) \tag{9}$$

The gravitational term is of course proportional to cos θ where θ is the angle of the volume axis with the vertical. The drift flux term (D.F.) is proportional to V_{jg}. In most cases, however, this term as well as the inertia term dw/dt are neglected, resulting in a simple 'orifice flow' formulation:

$$w = K[P_{\text{in}} - P_{\text{out}} - \rho g L] \tag{10}$$

The assumptions of neglecting the inertia term dw/dt is justified for most transients within the envisaged realm of application.

3.1. Neutronics

The neutronics model uses a nodal formulation with a maximum of four axial nodes and with either azimuthal symmetry or four azimuthal quadrants. Prompt and delayed neutronics in each node are represented by equations similar to those of point kinetics supplemented by leakage between neighbouring nodes:

$$\left(\beta + \sum_j D_{ij} - \rho_i\right)n_i - \sum_j D_{ij} n_j = \sum_j \Lambda \lambda_j C_{ji} \tag{11}$$

$$\frac{dC_{ji}}{dt} = \beta j \frac{n_i}{\Lambda} - \lambda_j C_{ji} \tag{12}$$

where n_i and C_i represent the nodal neutron density and delayed precursor concentration, D_{ij} is the nodal coupling coefficient, and ρ_i is the local reactivity. Reactivity can be introduced by local control rod motion, long term fuel exposure input, or by moderator density and temperature, and xenon concentration.

The above equations describe general formulation for all MMS modules. The following paragraph describe the boiling water reactor module to give a better feel for the formulation of a single module.

3.2. BWR module

As illustrated in Fig. 5, the Boiling Water Reactor (BWR) module of MMS consists of five interconnected engineering models

(*a*) A neutronics model computes transient neutronic behaviour and heat generation rate based upon reactivity input contributions.

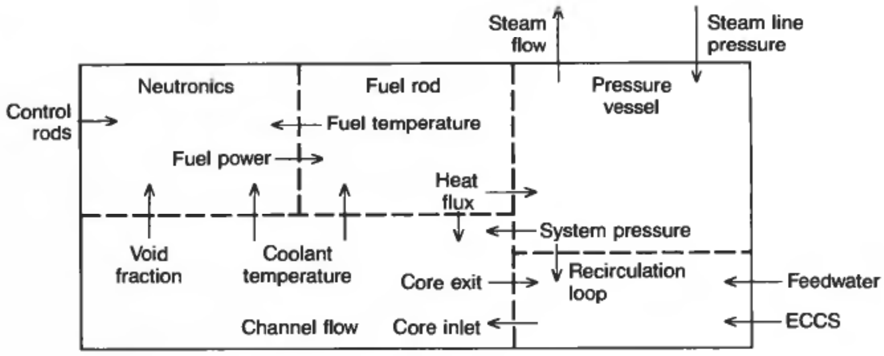


Figure 5. MMS/BWR model interaction.

The kinetics model used for the MMS/BWR module is based upon the approach used by the MMS model RX12 developed for PWR kinetics. New representations are used for the various feedback contributions in order to account for BWR voiding feedback and to facilitate connection between other submodules of MMS/BWR.

When the appropriate flag is set, the model performs steady-state initialization of the neutron kinetics with coupled thermal-hydraulic feedback. This solution requires iteration with respect to a multiplication factor for each node and is analogous to the eigenvalue problem of steady-state reactor physics. The transient calculation accounts for one or three groups of delayed neutrons in computing the reactor response to reactivity deviations from steady state.

(*b*) A fuel rod temperature model uses the heat generation rate to compute fuel cladding temperatures and heat transfer to the coolant.

A simple dynamic fuel temperature model is used by the core model to compute the proper transient relationship between core neutronics and core heat flux. Interrelated parameters are neutron flux, void fraction, and fuel temperature.

For each axial neutronic node, fuel temperature is modeled using three dynamic radial fuel nodes. The clad temperature is assumed to be in quasi-equilibrium with the fuel and coolant temperature. The fuel temperature derivatives are evaluated from transient conduction equations.

(*c*) A channel flow model calculates coolant thermal-hydraulic behaviour and void fraction, based upon input heat transfer from the fuel rod.

The core thermal-hydraulics model calculates axial dependence of void fraction in up to 4 quadrants and 12 axial nodes of the core. The model features a sub-cooled boiling treatment for direct input as a neutronic feedback contribution. Single-phase sub-cooled conditions apply when nodal enthalpy is less than an enthalpy h_d, corresponding to the sub-cooled Net Vapor Generation (NVG) point. The NVG enthalpy may be written in terms of the NVG quality $(xe)_d$.

$$h_d = h_f + (xe)_d h_{fg}$$

Note that h_d, which is less than h_f, is the enthalpy at which sub-cooled boiling begins. NVG quality $(xe)_d$ is determined from the Zuber–Saha correlation.

Channel calculations are performed with the nodal mixture enthalpy h as the state variable. This approach allows for solving the single-phase and two-phase nodes using a single set of conservative equations.

The two-phase module solves for the mixture enthalpy, liquid enthalpy, flow quality, void fraction and mass flux along the channel. All the variables are calculated by integrating only the state equation for the mixture enthalpy.

(*d*) A vessel pressure model (i) performs mass and energy balances to determine pressure response in the steam dome and (ii) solves the mass, energy, and momentum equations in the upper plenum to obtain the core pressure.

(*e*) A recirculation loop model solves loop momentum equations to determine flow and enthalpy at various points within the vessel and through the heat pump drive loop; transient pump speed and heat are computed for the recirculation pump.

These five 'submodules' or engineering models shown in Fig. 5 are included as distinct blocks within the BWR module of MMS. They are maintained together as a single module because (1) the coupling between neutronics, core thermal-hydraulics (especially void distribution) and recirculation flow is particularly tight for a BWR and (2) the utility user will ordinarily deal with this combination as a fixed unit, as he will not, for example, have the design freedom to respecify a recirculation pump.

4. Module validation and system simulation

The validation of the MMS code is performed using a two-step process. Initially, each module is validated individually with separate effects tests and benchmarked against other code results or plant data, where possible. Second step involves construction and qualification in a plant model, for which the plant data exists, using the validated set of modules.

An inherent advantage of this modular approach and sequential validation process is that it supports development and maintenance of a well-qualified set of plant component modules and an associated library of parameterization data from many different applications. This will reduce the art of modeling and improve the transfer of experience between users.

Extensive validation of the MMS code has been completed. A summary of the code validation conducted to date include the following applications by the U.S. utility engineers and in-house verification effort.

TMI-2 overcooling and turbine trip transient

Oconee-1 steamline break

Crystal River event analysis

TMI-2 accident analysis

Praire Island steam generator tube rupture analysis

W plant steamline break and SB LOCA analysis

LOFT L3-7 and SB-2 analysis

Sample analysis to verify *W* procedures

W plant control systems modeling

Wolf Creek plant feedwater control system modeling

South Texas project balance of plant system analysis
Grand Gulf plant analyses
Midland-2 reactor system evaluation
Fermi-2 plant simulation
SONGS-2 start-up analysis
Evaluation of new control strategies for Dunkirk fossil plant units
Evaluation of cycling strategies
Modeling of fossil units for control system evaluations
ANO-2 turbine trip evaluations
Peach Bottom unit turbine trip and natural circulation test evaluation
Load rejection test evaluations
Plant heat balance analysis
Inadvertent main steam isolation valve closure evaluation

The code is currently being used by several U.S. utilities and in essence, the code validation is continuing. The code validation results have been presented at numerous workshops in the last few years (Electric Power Research Institute 1983d, 1984). The most recent MMS workshop proceedings contain all the validation results conducted by EPRI and its contractors until September 1984.

Examples of code validation results are given in Figs. 6 and 7 for a steam generator tube rupture event, and the key system parameters such as the hot leg temperature and primary system pressure are compared with the plant data and RETRAN code. The BWR turbine trip simulation comparisons with the data are given in Fig. 8 and the PWR turbine trip simulation results are given in Fig. 9.

The utility industry is using the code for some new applications such as control systems evaluations in switching to digital systems and procedure evaluations. The

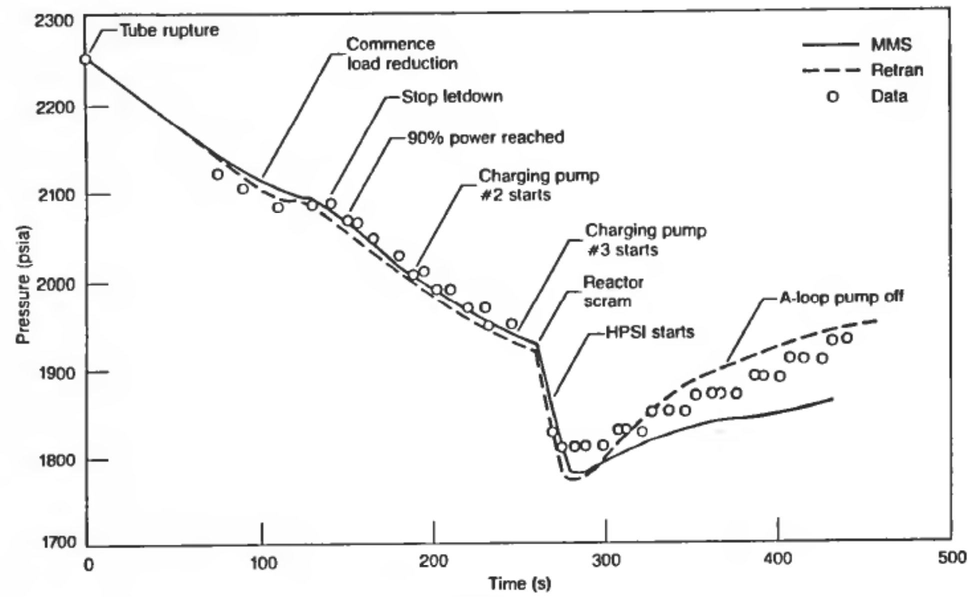


Figure 6. Praire Island SGTR event pressure vs. time.

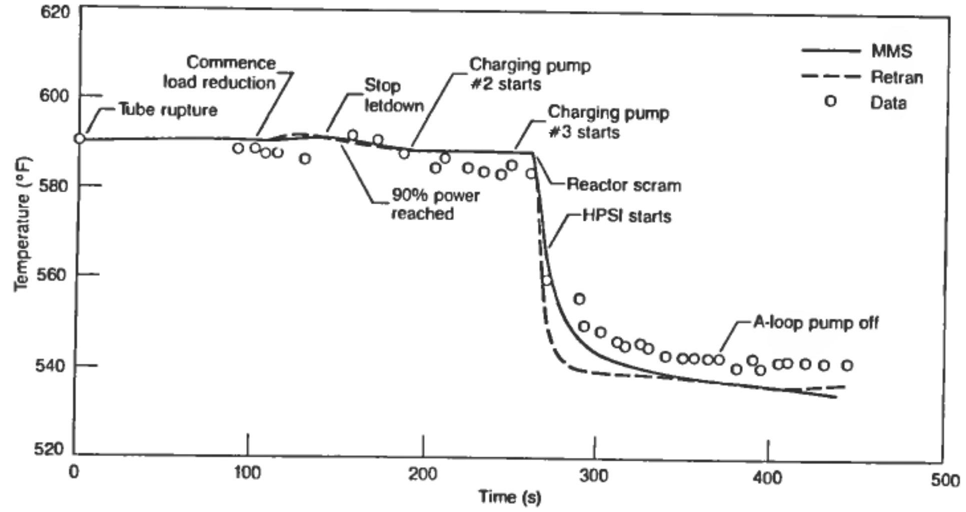


Figure 7. Praire Island SGTR event RSC temperature vs. time.

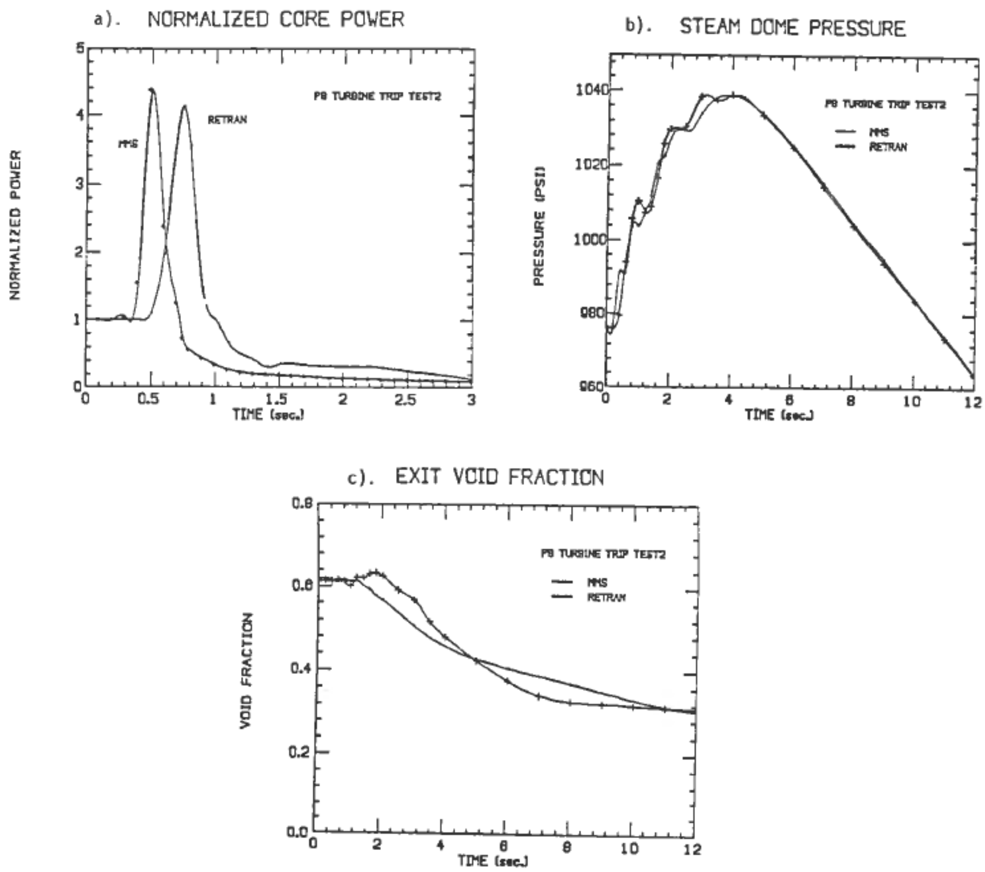


Figure 8. Peach Bottom turbine trip validation: (*a*) normalized core power, (*b*) steam dome pressure, (*c*) core exit void fraction.

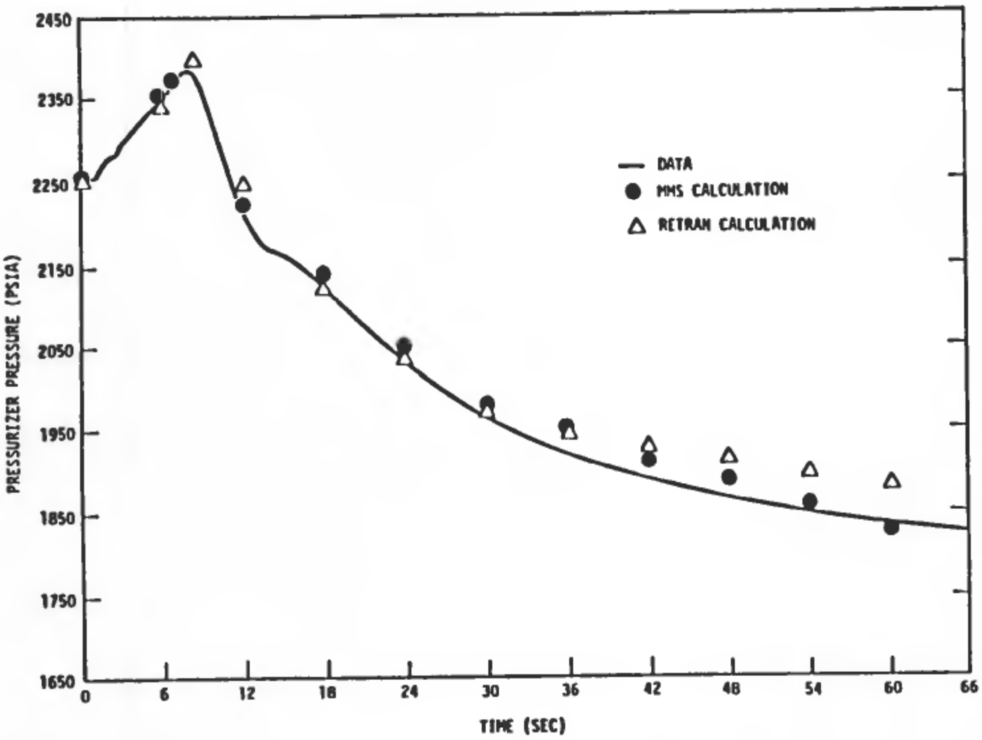


Figure 9. ANO-2 turbine trip test: pressurizer pressure.

largest model developed to date is by Middle South Services, consisting of 208 equation models for the Grand Gulf Services plant. The simplest model was developed by the Duke Power Company with a thirteen state MMS model of the feed-water heater drain system and evaluation of its control system.

5. Conclusions

Since the Three Mile Island accident, the United States nuclear industry has aggressively supported an extensive program to continually upgrade the base of technical knowledge that utility engineering and operations staff have about their plant performance. MMS code will facilitate this objective, as it will permit each utility to establish a central dynamic modeling base to be used by both engineering and operations personnel for a variety of applications. This will improve technical communications, enable a more efficient use of manpower, and encourage the growth of a well-qualified base of technical knowledge.

The flexibility offered by MMS can be used to validate the training simulator models, develop software for fundamental training simulators, perform off-line analyses for a wide variety of applications and evaluate new application areas such as plant cycling, use of digital controls in the power plants, and evaluate procedures.

EPRI is using this code in a wide variety of new applications. Evaluation of coal gasification plants and the development of power plant analysers are some examples, where MMS is serving as a foundation to conduct new research. The MMS code is well documented in form of theory, programmer, user and applications manuals, as well as a series of reports and code release workshop proceedings.

ACKNOWLEDGMENTS

The author, as one of the project managers, worked with Messrs. Frank Wong and Jean-Pierre Sursock (EPRI), Lance Smith (B & W), Will Shor (Bechtel Group), Randy May and Parveen Jain (S. Levy, Inc.), G. Duleba (BCS) and many others, during the course of MMS code development and wishes to thank them all. Much of the material presented here is a result of their valuable technical contributions.

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