

MODULAR MODELING SYSTEM MODEL BUILDER

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Abstract

The latest release of the Modular Modeling System (MMS) Model Builder adds still more time-saving features to an already powerful MMS dynamic-simulation tool set. The Model Builder takes advantage of 32-bit architecture within the Microsoft Windows 95/ NT™ Operating Systems to better integrate a mature library of power-plant components. In addition, the MMS Library of components can now be modified and extended with a new tool named MMS CompGen™.

The MMS Model Builder allows the user to quickly build a graphical schematic representation for a plant by selecting from a library of predefined power plant components to dynamically simulate their operation. In addition, each component has a calculation subroutine stored in a dynamic-link library (DLL), which facilitates the determination of a steady-state condition and performance of routine calculations for the component. These calculations, termed auto-parameterization, help avoid repetitive and often tedious hand calculations for model initialization.

Component connection is provided within the Model Builder based on connectivity rules defined for each component. The connection of components is intuitively implemented with mouse operations allowing only valid connections. The simulation code generator makes use of the graphically defined connections to automatically and analytically define fluid-flow paths, mechanical couples, or signal/logic flow paths within the simulation model.

Viewing features of the new Model Builder release have been enhanced significantly from earlier versions. Users can quickly zoom into a rectangle outlined by the mouse, to the previous zoom, to a zoom that results in all of the components being visible, or to pre-defined zoom levels. Multiple views of the same model are also supported, allowing the user to have the entire model in one window, while being zoomed into a specific region in another. By entering into the "Bubble Info" mode and moving the cursor to an object of interest, the user can obtain

context-sensitive data including module variable values, stream connection information, and port information. Groups of components can be defined into a rectangle called a hierarchical box that helps avoid clutter for large models containing many subsystems. The Model Builder's hierarchical groups are extremely flexible allowing unlimited hierarchical layers, easy control of the hierarchical views (windows), and easy external connection between components in different hierarchical windows.

In addition to the worksheet-like form used for each component's input variable list, the editing/maintenance capabilities have been extended to allow editing of more than one module at a time. A module "Diff" allows for quickly identifying the differences between two selected modules. Also, pressure distributions for an entire train of components can be quickly viewed and edited; likewise, for enthalpy, flow, and other port-associated parameters.

MMS CompGen™ is an Integrated Development Environment (IDE) for creating new modules: icon editing, connection information editor, module data worksheet editor, simulation code editor, and auto-parameterization code builder. By utilizing this IDE, the base library of MMS components has been created. Advanced users who wish to modify or add to the MMS library will make use of CompGen™.

In striving to meet the needs for large models and increase user productivity, the MMS Model Builder has been completely revamped to make power plant model creation and maintainability easier and more efficient.

Introduction

Plant design and operation personnel working to meet the challenges of today's highly technical environment need cost-effective analysis tools. Framatome Technologies' Modular Modeling System is just such a tool for dynamic simulation of power plant components and systems.

The MMS Library contains more than 160 pre-engineered mathematical models of most major nuclear and fossil power plant components. These modules can be interconnected, similar to actual power plant components, and are a powerful means of evaluating complex interactions between components. Through this modular approach to dynamic simulation, the MMS reduces the time required to simulate systems and increases the productivity of engineering personnel. Because the modules are pre-engineered, the user does not waste time formulating, coding, testing, and documenting each module.

In 1992 FTI introduced MMS for Windows. This tool provided a more flexible, easy-to-use method for building MMS models, utilizing common Microsoft Windows features. MMS for Windows added still more time-saving potential to the MMS product, when developing a simulation model.

Because of the popularity of MMS for Windows and the growing technology of the Microsoft operating systems, MMS for Windows was completely revamped for the Windows 95 and Windows NT operating systems. Many additional features were included in the latest version of MMS for Windows, now named MMS Model Builder. An additional tool, CompGen™, is also available to allow for the creation of modules or modification of MMS modules by the user. These modules can then be included in the model created within the Model Builder.

This paper discusses many of the time-saving features of the MMS, concentrating primarily on the latest version of the MMS Model Builder.

MMS Overview

The MMS was developed for designers and operators of power plants. Historically, the MMS has been used to analyze power plants, specify plant components, check out control systems, predict dynamic and steady-state performance, diagnose plant anomalies, perform what-if analyses, evaluate procedures, and instruct plant operators.

The MMS was designed to encourage wider use of dynamic simulation by offering these advantages:

- Reduced costs due to pre-engineering component models (or modules). Carefully formulated and implemented modules reduce applied engineering time and help achieve the most efficient computer evaluations.
- Quickly constructed plant models; this feature allows problems to be analyzed in a time frame consistent with plant operational requirements.

- Validation of each component module to improve overall confidence in results.
- Built-in numerical-analysis routines.
- Steam property algorithms to support the module formulations, eliminating the need for reference manuals.
- Automatic parameter calculations for all modules for steady-state initialization.
- Less effort for model documentation.
- Flexibility -- The MMS simulation models transfer to many computer platforms.
- Easy access to information on modules and user interface functionality through on-line help.
- Compatibility with System International System (SI) as well as U.S. engineering units.
- Support for the development of real-time applications, such as operator training simulators, through Real-Time Capable (RTC) modules.

Model Builder

The use of the MMS Model Builder provides many of the previously mentioned advantages of the MMS. It is a tool that vastly improves the ease and efficiency with which a simulation model is developed.

The Model Builder was designed to provide a model schematic and a simple means to enter component data via on-screen input forms. It enables the user to graphically "build" models by selecting plant components from a menu of modules, positioning them at a desired location on the computer screen, and inter-connecting them. Once completed, the schematic and component data represent a simulation model that can be run to dynamically analyze the plant performance.

Many of the features of the Model Builder enhance the efficiency and ease of model development. These features are discussed in greater detail below.

Full Microsoft Windows 95 Functionality

Windows 95 provides many advanced features that have been implemented in the Model Builder. These features make the Model Builder a user-friendly, common-feel application. Most of these features are designed to make the Model Builder easy and comfortable to use. The following list includes examples of such features.

- What-You-See-Is-What-You-Get (WYSIWYG) printing
- Multiple views of same worksheet
- Splitter windows
- Dockable toolbars with tool tips
- Context sensitive on-screen menus

- Hot keys for repetitive tasks
- Most-recently-used file list
- Drag and Drop from file manager

Viewing Models with the Model Builder

In addition to normal Windows viewing features, several advanced viewing features are available in the Model Builder. These features enable the user to easily manipulate the viewing of the model on the screen. Full zoom, pan, and scaling of a window is supported. With drag of a mouse, while holding the *Ctrl* key, the user can zoom-in on a specific portion of the model. Zooming is also provided to allow users to view the entire model, to revert to the previous zoom, and to select from pre-defined zoom ratios. Panning is provided with standard Windows 95 scroll bars, allowing users to move to any portion of the model at any zoom ratio.

Additional views of the same model are also possible with the model builder. Multiple views can be accomplished one of two ways. Standard Windows 95 splitter windows allow the user to instantly divide the window vertically and horizontally. In addition, new views can be created from the View/New menu item. This method actually creates a new window of the same model, allowing for independent zooming and scrolling. This feature allows a user to view the entire model in one window while zooming in on several specific portions of the model in other windows.

Graphically Building a Model

The MMS Model Builder allows graphical creation of a model, thus eliminating the need to manually develop a text input file representing a simulation model. The ability to graphically build a model radically reduces model development time. Several features are included in the Model Builder to aid in creating and presenting of the graphical model.

The Model Builder allows for two methods of inserting component modules within the model. The first method is to double-click with the mouse within the view. This action will prompt the user with a module open dialog box allowing the user to select the module to insert at the location in which the user double-clicked the mouse. The second method allows users to place multiple occurrences of the same module on the worksheet by clicking wherever that module is desired. When module insertion is complete, clicking the right mouse button will return the user to the normal select mode.

Once multiple component modules are inserted, connections can be made to allow for the representation of flow streams, control paths, and mechanical coupling within the model. In addition, these connections allow for variable passing between modules based on predefined port parameters. This ability allows initial conditions such as flow and pressure to be entered only one time and passed to any required module to which it is connected, thus avoiding tedious data entry.

Connections are added by double-clicking with the mouse on a module's port. Once a connection is started, the Model Builder highlights valid connection ports, eliminating much of the

uncertainty of where to connect. Valid connections are determined by rules defined for each module port and connection table. Once the valid connection port is determined, the path is drawn using mouse clicks to define a graphical path and finishing the connection at a valid port with a right mouse button click. Once a connection is established between two modules, the stream name is automatically generated based on the module names and user configurable naming rules. However, if the automatic naming is undesirable, the user may enter a user defined name for any stream, as necessary.

Copy, cut, and pasting features allow modules and groups of modules with internal connections to be replicated. The Model Builder automatically adjusts the names of the modules and streams based on user defined incrementation methods. Both numeric and alphanumeric values can be incremented when replicated. Copying groups of modules is convenient when a plant contains multiple parallel trains of equipment that are essentially equivalent with the exception of the component identifiers. Once replicated, each module can be independently modified to allow for individual component characteristics.

Annotations and Viewing Options

Once all modules have been inserted into the model and interconnected to represent the desired model, several Model Builder features allow enhanced viewing and printing of the model.

Text and graphical annotations can be added to the view to allow for visible grouping of modules, text notes, and visible captions. Module text such as ID, port names, stream names, and a note box each can be toggled between visible and invisible. In addition, the normal flow direction of all streams can be shown with an arrow on the connection, if desired. All text fonts are completely configurable. The typeface, size, color, and attributes can be modified for each annotation text boxes, as well as for module and stream texts. The graphical annotations (rectangles, ellipses, rounded-rectangles, and lines) may be individually configured for line style, line width, and fill color. These options allow for the display of detailed information and/or the creation of presentation quality schematics.

Graphical Manipulation of Modules and Objects

Modules and annotation objects can easily be manipulated by the user to allow additional flexibility and control of model creation. Several Model Builder features allow such activities.

When multiple objects are selected, these objects may be manipulated as a group. They may be moved, sized, copied and deleted as a group. In addition, groups of objects can be aligned with each other on any side or the by vertical or horizontal centerlines. All selected objects can be manipulated to be the same height, width, or both. They can also be spaced equally in the vertical or horizontal directions. These features help the user create a clean, professional looking model.

Objects, including modules, can also be flipped about either the horizontal or vertical centerline to create mirror images, or rotated in 90 degree increments. These features allow modules to

appear to flowing in the correct direction within the model if the direction is other than the direction displayed by the default module icon.

Lines and connections attributes, such as width and style, can be modified easily within the Model Builder. In addition, midpoints can be deleted by placing the cursor over the point and pressing the *Delete* key. Points can be added to the line by placing the cursor over the line and pressing the *Insert* key. Points can be moved by selecting the line or connection and clicking and dragging any of the handle boxes on a line joint. Finally, the entire line can be moved by click and dragging a line segment. Another useful feature for line and connection manipulation is automatic straightening, which converts all line segments to have right angles with connecting segments. As a group, the line and connection manipulation features give the user unlimited control of lines within the model.

Hierarchal Blocks

Another Model Builder feature to improve the look and manageability of a large model is hierarchal blocks. Hierarchal blocks allow the user to group several modules, connections, and annotation objects into a “box” that displays a text description. This box replaces and contains the previously selected objects. When the user double-clicks on the hierarchal block or box, a new view opens to display all of the objects that were included. This view responds the same as any main view and can contain any number of recursive hierarchal blocks. All external connections to the block are noted with the ports of the module modules highlighted in red. Using hierarchal blocks can effectively reduce the perceived complexity of large models. These blocks can be copied and pasted with the new block containing identical objects as the original with new names. In addition, they allow for faster scrolling and model manipulation within the main view. Figures 1 and 2 display the process of selecting objects to create a hierarchal block and the results after creation.

Figure 1

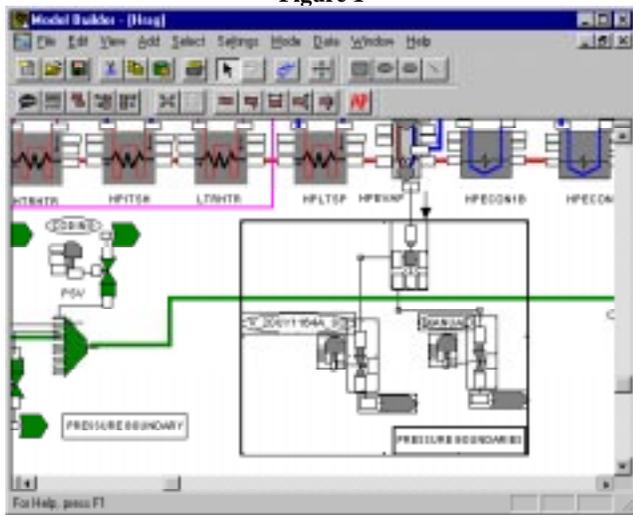
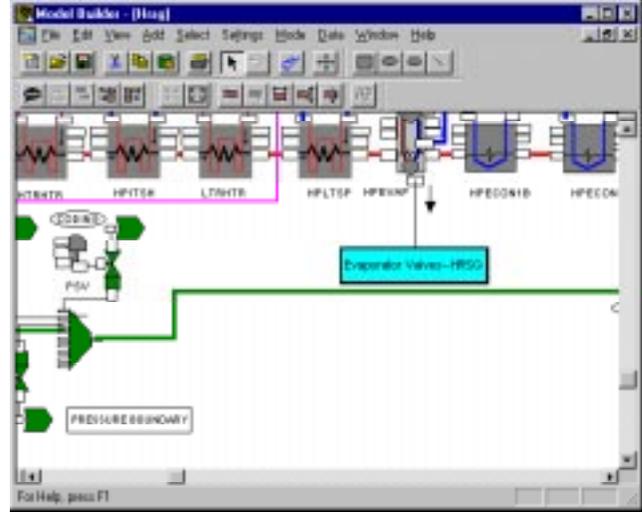


Figure 2



The hierarchal blocks can be expanded back into the main view or parent hierarchal block by selecting the block and choosing the “Hierarchal Restore” menu item or corresponding Toolbar button.

External connections may be made to and from a hierarchal view, by making two views visible simultaneously, double-clicking on a port in one view and connecting it to a valid port in another view. An external connection is created and the connected ports are highlighted in red.

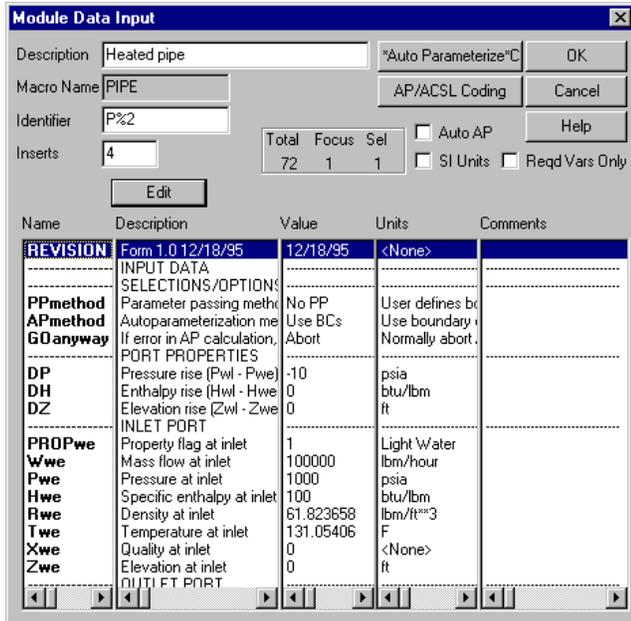
Module Data Input and Auto-Parameterization

After graphically inserting a module into the model worksheet, the data in the module is modified to represent the actual component’s attributes. For example, the diameter of a pipe or the heat-transfer area of a heat exchanger is entered.

Additional parameters used within the simulation can be automatically calculated from the input variables using pre-determined module specific methods. These methods are essentially functions that reside within a dynamic-link library. Each module type has its own parameterization function, dubbed the “auto-parameterization routine.” The auto-parameterization routine is written such that a module steady-state is achieved, meaning that if constant boundary conditions are applied to the module with the conditions entered by the user, the module calculational results would remain constant during simulation.

The module data sheet is the means to enter component information into the module variables. Each module type will contain a list of variables, shown in a spreadsheet-type format, that defines it’s characteristics. The module can contain variables with either S.I. or U.S. units. By toggling between the unit types, the current values are automatically converted to the corresponding value for the newly selected units. On-line help for each module type is available at the press of a button. The help file contains information on the use of the module as well as the module variables. Figure 3 displays a typical module data sheet.

Figure 3



Many variable types are supported, including: double precision real numbers, long integers, integers, floating point real numbers, tables, vectors (arrays), strings, delimiters, and methods. Delimiters are static text that separate groups of variables on the module data sheet to make the data easier to understand.

Methods are basically enumeration variables that assign text actions to an integer variable; a simple example would be a "True" or "False" method. The method variables also provide another function: multiple auto-parameterization (AP) methods. Each of these AP methods requires the model developer to select the desired option. Each method option is a list of required inputs for auto-parameterization. A check-box on the module data sheet allows the user to display only those inputs required for the AP methods currently selected. This reduces the number of variables visible to the user and eliminates all of the unneeded variables for the options chosen. An example use of an AP method would be to allow the user to enter one of two methods to determine pipe volume. One method might be to enter the length and cross-sectional area of the pipe. A second method might be to enter the length and inside diameter of the pipe. The input form would reflect the choice by only showing either length and area or length and inside diameter as required inputs. This feature makes entering the module characteristics more intuitive and efficient.

Auto-parameterization can be accomplished many ways. From within the module data sheet, the user can individually auto-parameterize the module being edited. From within any model worksheet view, a menu item allows the user to auto-parameterize all currently selected modules. In addition, a hot key and Toolbar button provide shortcuts to this function. Each module's auto-parameterization status (whether it has been auto-parameterized since the last data change within the module) is displayed both in the module data sheet and the graphical view. If this AP status viewing is enabled, a red "X" will cover the module in the view

indicating that the module needs to be auto-parameterized. This feature of the model builder clearly indicates which modules may not have an initial steady state, eliminating many hours of debugging steady-state initialization problems. A final AP method combines auto-parameterization with parameter passing and is discussed later.

Parameter Passing

Connected modules facilitate parameter passing via the connection stream. Each port has within its characteristics a list of associated variables. Each of these variables is assigned a type, for example "Pressure" or "Flow." When the port of one module is connected to another valid port, the port-associated variables are available for passing to the adjoining module based on variable types. Imagine that a Pump module contains an outlet (discharge) port that is connected to the inlet port of a Pipe module. The Pump outlet port has associated variables such as pressure leaving, PL, of type Pressure. The Pipe inlet port has an associated variable for pressure entering, PE, also of type "Pressure." If the parameters are passed from the Pump outlet port to the Pipe inlet port, the PE variable within the Pipe module will be set to the same value as the PL variable within the Pump module.

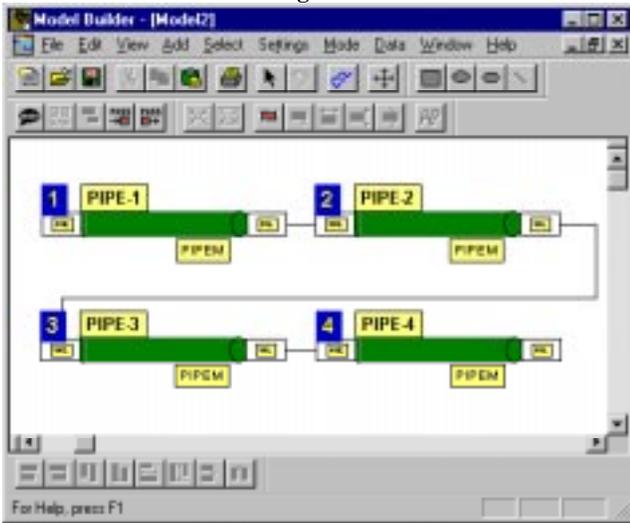
Variables may be passed in three ways. First, by changing the current mode to the "Pass Out" mode and clicking the mouse on a port. The associated variable values are sent from that module to the corresponding variables of the module that is connected to that particular port. The second method is the reverse. By changing the current mode to "Pass In" mode and clicking the mouse on a port, the variable values associated with that port are grabbed from the corresponding variables associated with the connected module's port. The third method is to individually get a specific variable's value from the connected module within the module data sheet input dialog box. Within this dialog box is an entry field to enter a value and a "Get from Connection" button along with the value from the connected module. By pressing this button, the value from the connected module is automatically entered into the entry field.

Parameter passing is an extremely powerful method of quickly initializing the port variables (boundary conditions) of the modules. This feature eliminates duplicate data entry.

Auto-Parameterization and Passing Parameters

Another extremely powerful, time-saving command combines auto-parameterization with parameter passing. To quickly draw up a scenario, suppose that all modules have the required inputs entered defining their physical characteristics. However, the boundary conditions have not been entered, with the exception of the first module, which happens to have these conditions known. First of all, the module order must be set. To do this, change to the "Set Module Order" mode. Double-click on the module that you wish to be the first module. Then, consecutively click on the adjoining modules to increment the count by one. Once the order has been set, see Figure 4, select the "AP/Pass Out" command from the menu. The command will walk through the order just specified and perform the following actions on each module.

Figure 4



- Auto-parameterize the module.
- Passport-associated variables through all outlet ports
- Increment to the next module according to the order and repeat

By following this procedure, the Model Builder can automatically define all boundary conditions for that selected train of modules, which could be the entire model if the order is set properly. The auto-parameterization can calculate pressure drops and flow splits within modules and pass the resulting outlet pressures and flows to the next module, thus defining the entire pressure and flow distribution with no user interaction.

Multiple Module Data Comparison Methods

The MMS Model Builder also contains several functions that allow for direct comparison of multiple module variables. The most useful of these functions are the “Selected Modules”, the “Diff on Mods”, and the “Selected Ports” commands from the “Data” menu.

Selected Modules Command.

The “Selected Modules” command displays all variables for all currently selected modules. These variables can be sorted by variable name or by module name. This allows for the comparison of more than two modules at the same time. Buttons at the top of the dialog box allow for the copying and pasting of values from and to any variable. In addition, another button allows the user to copy the selected variable’s value to all variables having the same name. Each variable may also be edited by normal value entry as well.

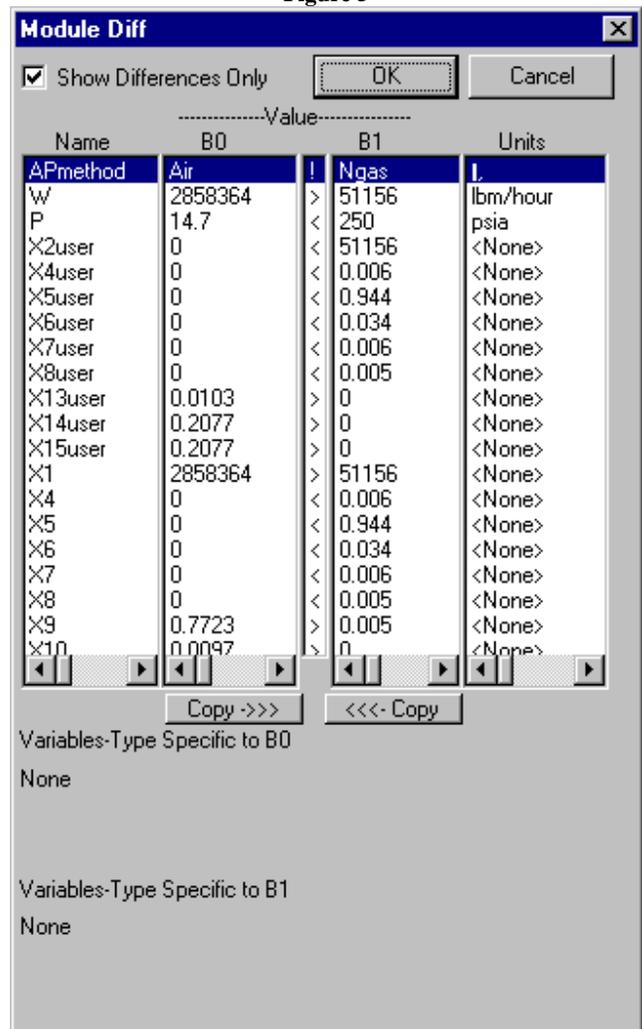
Diff on Mods Command.

The “Diff on Mods” command allows the user to select two modules and compare the values of variables with the same names within the two modules. See Figure 4, below, for an example of a “diff” on two modules. The center column of the dialog box will show the comparison result. The symbols are defined as follows:

- < Left Value “Less Than” Right Value
- > Left Value “Greater Than” Right Value
- = Left Value “Equal To” Right Value
- ! Left Value “Not Equal To” Right Value (used for Strings, Methods, Tables and Vectors).

A check-box at the top of the dialog box allows the user to display only those variables that are different. Two buttons facilitate the copying of the left value to the right variable or the right value to the left variable. A list of variables at the bottom of the dialog box displays variables that exist only in one or the other module. This area is blank if the two modules are of the same module type.

Figure 5



Selected Ports Command.

The “Selected Ports” command displays all variables for all selected port associated variables. These variables are listed in the order in which they were selected. Figure 5 is an example of viewing a pressure distribution of a pump train. The variables are displayed for only the selected type (i.e. Pressure or Flow). The type can be changed allowing the user to quickly examine the pressure or flow distribution for a flow path. Buttons at the top of the dialog box allow for the copying and pasting of values from and to any variable. In addition, another button allows the user to copy the selected variable’s value to all variables below that variable. Each variable may also be edited by normal value entry, as well. This command is invaluable when debugging the model and during initial model development.

capabilities of the MMS Model Builder. It provides several features to enable quick data entry and steady-state model initialization by eliminating many repetitive and tedious tasks.

A tool such as the MMS Model Builder can make the development of a plant model or plant simulator more attractive by reducing the overall development costs. Through this modular and graphical approach to dynamic simulation, the MMS reduces the time required to develop simulation systems and increases the productivity of engineering personnel. The MMS allows organizations that have, in the past, abandoned the idea of dynamic simulation to now develop cost-effective simulators for many purposes.

Figure 6

The screenshot shows a dialog box titled "Port Variables" with a dropdown menu set to "P - Pressure". Below the menu are buttons for "Copy to all Below", "Cancel", and "OK". The main area contains a table with the following data:

Module ID	Port Name	Variable	Value	Units
PIPE-1	WL	Pwl	14.7	psia
PUMP-1	WE	Pwe	14.7	psia
PUMP-1	WL	Pwl	500	psia
PIPE-2	WE	Pwe	500	psia
PIPE-2	WL	Pwl	500	psia
PUMP-2	WE	Pwe	500	psia
PUMP-2	WL	Pwl	700	psia
PIPE-3	WE	Pwe	700	psia
PIPE-3	WL	Pwl	700	psia
PUMP-3	WE	Pwe	700	psia
PUMP-3	WL	Pwl	900	psia
PIPE-4	WE	Pwe	900	psia

Context Sensitive Bubble Information

The final time-saving, convenient feature of the MMS Model Builder discussed within this paper is “Bubble Information” mode. This mode allows the user to place the cursor over an object and quickly view information on that object. By placing the cursor over a module, a box appears showing the current value of all variables within the module. Placing the cursor over a port will display the port type, name and all port associated variables. By placing the cursor over a stream, the names of the connected modules are shown along with the port names. Bubble information allows the user to quickly examine many items without much effort.

Conclusions

The MMS Model Builder has been totally revamped to include many time-saving, user-friendly features to make simulation model development easier and more enjoyable. It allows the user to quickly build a graphical schematic representation for a plant by selecting from a library of predefined power-plant components to dynamically simulate their operation. Figure 7, on the following page, displays the detail and quality of the modeling

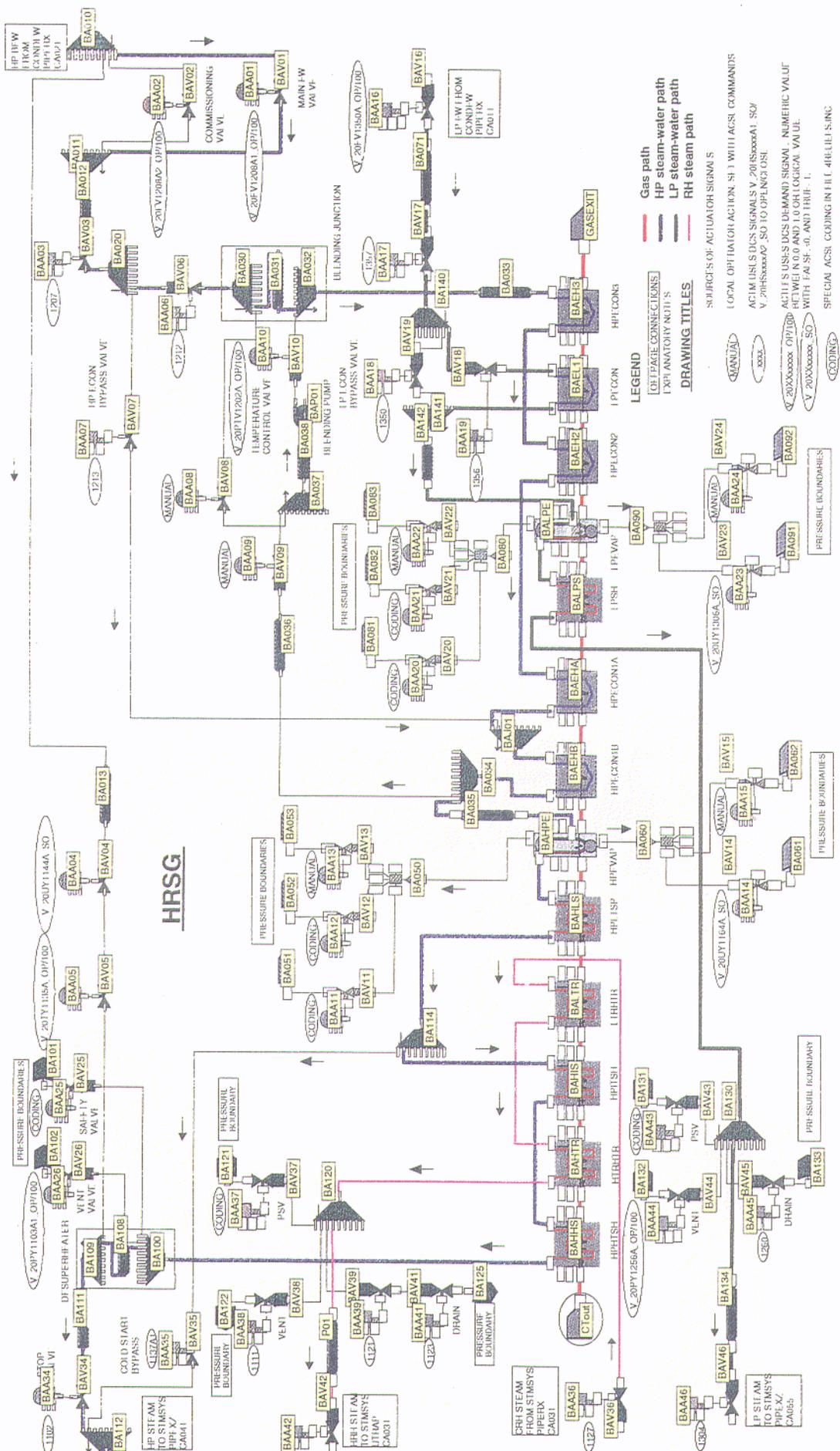


Figure 7