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1. Introduction

1.1 PowrSym4 Features

PowrSym4 is a multi-area, multi-fuel, chronological, production cost simulation model capable of detailed, short-term studies with high levels of optimization. It can also perform long-term system planning studies representing chronological system operating conditions. Multi-year system operation is simulated over sequential weekly optimization horizons with a time step of one hour. Real-time dispatch and transaction evaluations may use time steps of minutes and horizons of a few hours.

Accurate simulation of chronological operating conditions, unit commitment optimization, energy storage optimization, multiple fuel allocation, Monte Carlo outage method, and a multi-area transport model allow PowrSym4 to be used for short term optimization and operational planning studies. The same algorithms, optionally with lower optimization levels, are used to include dynamic system operating effects in long term system planning studies. PowrSym4 allows system planners to evaluate future system configurations from an operation viewpoint not possible with most planning models.

The computational requirements of a detailed chronological simulation model are satisfied by a combination of new efficient algorithms and faster computing hardware. It is no longer necessary for system planners to give up operational detail in long range studies.

The features of the PowrSym4 algorithms are:

- ~ Preservation of the chronological sequence of events
- ~ Accurate unit dispatch
- ~ Realistic unit commitment with dynamic optimization
- ~ Pumped hydro simulation with reservoir constraints
- ~ Hourly marginal and average cost calculations
- ~ Monte Carlo or derating options
- ~ Forced outage representation
- ~ Hydro including Cascade
- ~ Emission influenced commit and dispatch
- ~ Fuel contract model with optimization
- ~ Multi-area power transport model
- ~ Integrated reliability model
- ~ Integrated maintenance schedule
- ~ Co-generation heat model
- ~ Market influenced commitment
- ~ Flow based transmission using PTD factors

Input data may be prepared using a relational database, such as Microsoft ACCESS, and an on-line context sensitive help system. The data files may also be prepared or modified with an ASCII text editor, but this method gives up much of the user-friendly advantages of the database. The input data are in a standard ASCII sequential record file so that data files may be easily passed from desk-top machines to work station or main frame computers.

Output reports are available for any combination of hourly, daily, weekly, monthly, and annual time periods. In addition, an output report is available for a user-defined fiscal year. Results may be summarized in any combination of station, plant, station group, and area reports. Reports are available in print format and in spreadsheet or database compatible formats.

Some of the output report categories are:

- | | |
|---------------------------------|---|
| ~ System reliability | ~ Fuel costs |
| ~ Reserve margin | ~ Power plant emissions |
| ~ Capacity factors | ~ Purchase power requirements |
| ~ Energy generated | ~ Total costs |
| ~ Fuel consumption | ~ Inter-area flows and wheeling charges |
| ~ Number of starts | ~ Marginal cost |
| ~ Startup costs | ~ Cogeneration Heat reports |
| ~ Operation & maintenance costs | |

1.2 PowrSym4 Applications

PowrSym4 applications include:

- | | |
|--|---|
| ~ Generation system expansion studies | ~ Power exchange contracting strategies |
| ~ Optimization of pumped hydro design parameters | ~ Maintenance scheduling options |
| ~ Time-of-day pricing studies | ~ Plant retirement studies |
| ~ Revenue requirement studies | ~ Integrated resource planning |
| ~ Verification of less detailed models | ~ Near term operational studies |
| ~ Evaluation of demand side management options | ~ Real time resource scheduling |
| ~ Hydro power evaluations | ~ Real time power exchange evaluation |
| ~ Hourly marginal cost evaluations | ~ Fuel requirement studies, fuel budgeting and fuel contract evaluation |

1.3 Version History

PowrSym4 represents the cumulative algorithmic expertise of over twenty-five years of production cost simulations. PowrSym4 is the latest in a series of models which began with POWRSYM in 1973 and continued with new developments and spin-off versions which are in use throughout the industry.

PowrSym4 combines the best of previous Powrsym algorithms with a new unit commit and economic dispatch algorithm that simultaneously solves all chronological hours in each weekly horizon. This novel algorithm retains the same chronological detail of previous chronological models, while allowing optimal allocation of fixed energy constraints, such as energy limited fuels and emission caps. While previous chronological models could consider a small number of fixed weekly energy constraints by using a time consuming iterative method, PowrSym4 can directly solve multi-fuel, multi-station contracts. Each fuel may have hourly, daily, and weekly minimum and maximum requirements, all of which may vary with time. PowrSym4 achieves this solution with a network model directly integrated into the unit commit and dispatch algorithm.

1.4 Operation Simulation Associates

PowrSym4 was developed by Operation Simulation Associates, Inc. (OSA) of Ringgold, Georgia. OSA has supported the POWRSYM user group with continued model development, training, user group meetings, and consulting services since 1983. The OSA staff is led by Roger Babb, who has been active in production cost model development since 1969 and was a pioneer

in the development and application of both load duration curve and chronological models. The OSA staff is a combination of professionals with many years of electric utility experience and top young engineers with advanced degrees and relevant academic work in the most recent simulation methods.

The OSA staff was increased in 1994 and 1995 with the addition of four senior members with many years of utility experience. OSA staff members have the following types of power system experience:

- | | |
|--|---|
| ~ Power System Model Development | ~ Power Plant Construction and Operation |
| ~ Integrated Resource Planning Studies | ~ Staff Training Power Marketing and Exchange |
| ~ Manager of System Planning | ~ Transmission System Analysis |
| ~ Manager of Power Control Center | ~ Financial Modeling and Financial Studies |
| ~ Short Term Operational Studies | ~ Load Forecasting |
| ~ System Dispatch | |

The current resumes of OSA staff members will be provided on request or may be viewed on the Internet at: www.osa.comax.com

The OSA staff currently consists of professionals with varied electric utility experience and educational background. There is always someone available during normal office hours to field questions or otherwise support PowrSym4 users. A network of desktop computers and workstations support development and allow quick replication of client results when support is required.

OSA was formed in 1983 by Roger Babb after stepping down as head of the Tennessee Valley Authority's System Planning and Analysis Group. OSA participated with Energy & Control Consultants in the development of the POWRSYM-PLUS model. OSA also participated with The Simulation Group in the development of the PROSYM model. OSA and OSA staff members have supported operational planning, system planning, and integrated resource planning studies for a number of utilities in the U.S. and Europe.

Some of the services provided by OSA in support of PowrSym4 and related models are:

- | | |
|---|---|
| ~ Integrated Resource Planning | ~ Computer Software Evaluation |
| ~ Reliability Assessment | ~ Combined Heat and Power Generation Planning |
| ~ Demand Side Management Evaluations | ~ Utility Market Assessments |
| ~ Production Simulation Analysis | ~ Emissions Analysis and Economics |
| ~ Power Pooling Analysis | ~ Supply Resource Evaluation and Technical Assessment |
| ~ Multi-Area Production Simulation Analysis | ~ Project Benefit Analysis |

1.5 Documentation Manual Structure

This manual is written with two purposes in mind. One is to provide information to those who prepare data and analyze results for PowrSym4. The other is to provide algorithm information, logic description, and flow charts.

- Section 1** serves as an introduction to PowrSym4, its features, and history; to Operation Simulation Associates, Inc.; and to this manual.
- Section 2** is a general description of the model and the Input/Output organization.
- Section 3** provides a detailed description of all input data formats and the exact locations of different data items within the input files.
- Section 4** provides descriptions of the output data and reports provided by PowrSym4.
- Section 5** details PowrSym4's model theory.
- Section 6** provides definitions of the data variables used in PowrSym4.
- Section 7** lists and describes all input variables.
- Section 8** describes output variables
- Section 9** describes control of Input/Output files
- Section 10** describes Spot Market
- Section 11.** Margin Reliability Implications, and Marginal Cost.
- Section 12.** Power Contract Modeling (5x16)
- Section 13.** Power Purchase Contract Simulation

Please e-mail any corrections or suggestions for improvement to: tj@babb.com or rab@babb.com.

2. PowrSym4 Overview

2.1 Input Data Organization

Input data are presented to the model with three formats. Cost data and system operating parameters are input with an Alphanumeric Input Data (AID) format that is time dependent. This means the value set from the AID file stays effective until a new value is input or until the value is escalated. The hourly load data can be input with three user selectable formats. The maintenance data are also input with three user selectable formats.

PowrSym4 comes with a data analysis application based on Microsoft ACCESS (Analyzer). The Analyzer has forms for inputting and exporting all three data file formats. The AID file has the most extensive set of analysis tools. The maintenance files can be imported, schedules changed, and the modified data exported for use in a PowrSym4 simulation. The hourly loads have screens for importing and analyzing the data both tabular and graphically.

2.2 Output Data Organization

The output from PowrSym4 can be written into many output files that the user can print and review. Alternatively, the user may choose to have the output written into a spreadsheet or database format where it can be viewed and manipulated by commercial models for presentation. Section 4 has a detailed description of these files.

The output routines produce results for the following quantities by generating station:

- | | |
|--|--|
| ~ Capacity factor | ~ Emissions (five user defined categories) |
| ~ Fuel burn (Equivalent energy and physical units such as tons or barrels) | ~ Electric energy generated |
| ~ Costs (fuel; operation and maintenance, O&M; start up; emissions; total) | ~ Number of unit starts |
| ~ Operating hours | |

Results are summarized by fuel type and optionally may be summarized by station, plant, and area or power pool. Output reports, by default, summarize the above quantities by month and fiscal year with options for calendar year, weekly, and hourly reports. Optionally PowrSym4 can also produce hourly marginal cost reports.

An annual LOLP report lists for each year the following items by week:

- | | |
|--------------------------|---|
| ~ LOLP in hours | ~ Installed capacity before and after maintenance |
| ~ Peak and average loads | ~ Percent reserve before and after maintenance |
| ~ Load factor | ~ Capacity on maintenance |

The fuel contract report lists the quantity burned and purchase cost of each fuel. Any required fuel purchased that could not be utilized because of outages or other system constraints is listed also. An optional report shows the sources and amounts of fuel by station and the distribution to stations by fuel contracts.

The TRANSAREA report lists the load, generation, imports, and exports of each area. The link report lists the energy and maximum transfer over each link.

2.3 General Model Description

The purpose of this section is to give a brief overview of PowrSym4. The methodology used in the PowrSym4 modules will be discussed in more detail in Section 5.

The execution sequence of PowrSym4 is shown in Figure 2.3.1. There are two execution time horizons in PowrSym4: annual and weekly. The annual horizon is used for reliability calculations, adjusting expansion unit installation dates, and maintenance scheduling. The weekly horizon is used for production cost optimization. The basic operational time step is one hour with costs optimized over weekly horizons.

PowrSym⁴ Execution Flow

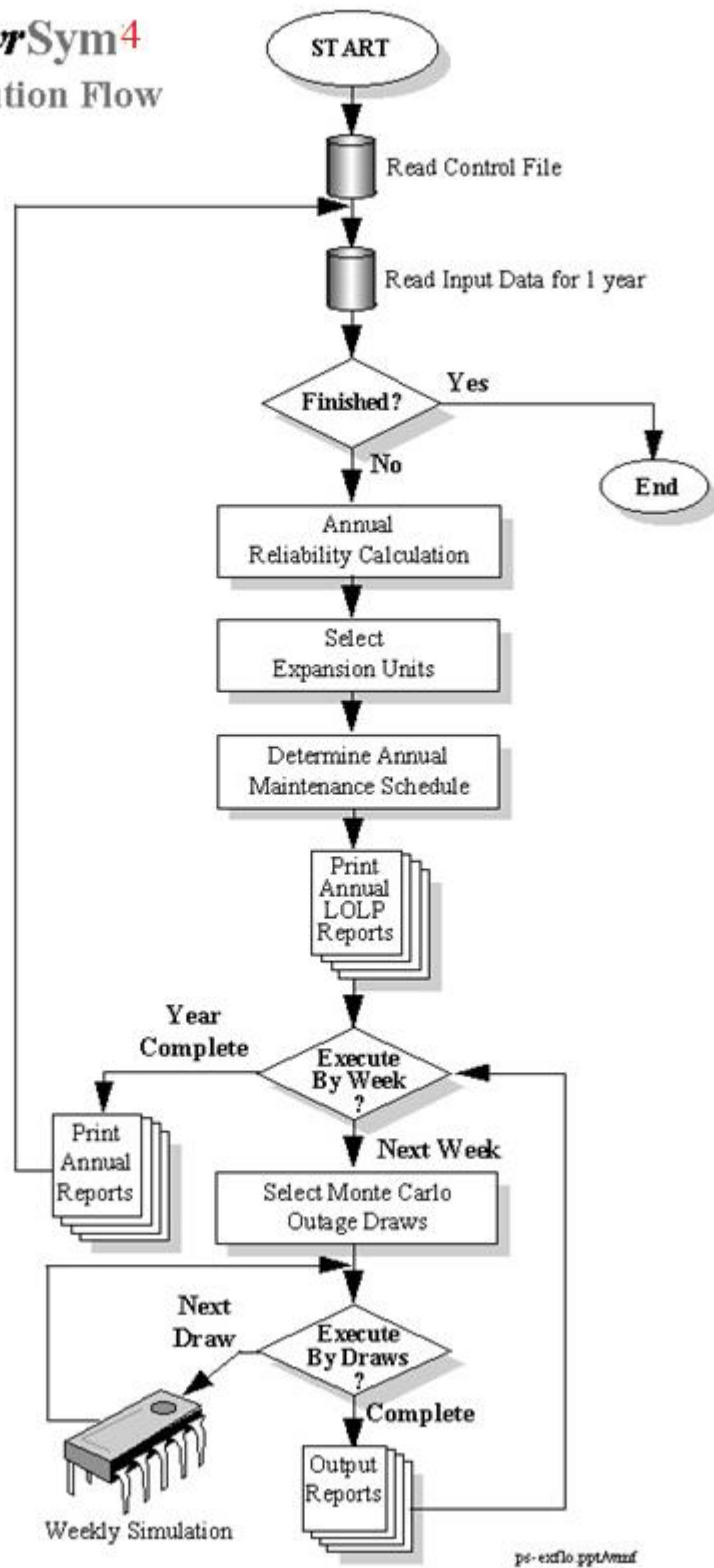


Figure 2.3.1

The control file links input and output files to specified file names. Input data are updated at the beginning of each execution year and may change on week boundaries. Additionally, many input items are allowed to change hourly.

The annual reliability model computes the annual loss of load probability (LOLP) in hours per year using the method of moments (or cumulants). Load carrying ability and capacity surplus/deficit and desired reserves are calculated relative to a specified reliability index.

The expansion module optionally schedules capacity additions to the system to satisfy capacity deficits. These additions may be made in a pre-determined sequence from an input list or the logic will choose from base load, intermediate load, or peaking options based on system energy requirements. This module is not a substitute for optimal system expansion studies, but allows PowrSym4 to schedule preselected expansion stations as needed to meet system reliability requirements.

The annual maintenance schedule can be determined in one of two ways. The schedule may be determined external to PowrSym4 and input through a file or the schedule may be determined by PowrSym4. In the internal schedule option, the scheduling objective function is to levelize weekly LOLP or minimize total system costs.

There is also a single-pass Monte Carlo outage draw method optionally implemented by the maintenance schedule module. This method, known as the semi-guided method, draws the expected amount of outage hours during the year for each station randomly selecting the hours, but using some guidance to distribute the total amount of outages evenly (within bounds) over each week of the year. This method, while not statistically converged, is very good for long range planning studies.

The first step in weekly execution is to determine the weekly random outage draws, unless predetermined by input data, the semi-guided method or deratings. The Monte Carlo logic, either by random draws or the “smart draw” method, selects the hourly station outage states for a specified number of iterations. The random method selects states driven by a random number generator. The “smart draw” method generates a number of iterations and then uses a very fast production cost approximation to select a sample set of iterations to represent the entire distribution.

Each iteration is then simulated, and the results averaged by day. The daily averages are sent to the output arrays. Both the expected value across all iterations and the value of each individual iteration are available for output in the daily output file.

The weekly simulation, shown in Figure 2.3.2, schedules the hourly operation of each resource over the weekly execution horizon. The hydro stations are scheduled first using a load leveling algorithm. Each hydro station is subject to a weekly energy constraint, hourly minimum and maximum generation levels, and ramp rates.

Conventional hydro may be represented in cascade.

PowrSym4

Weekly Simulation

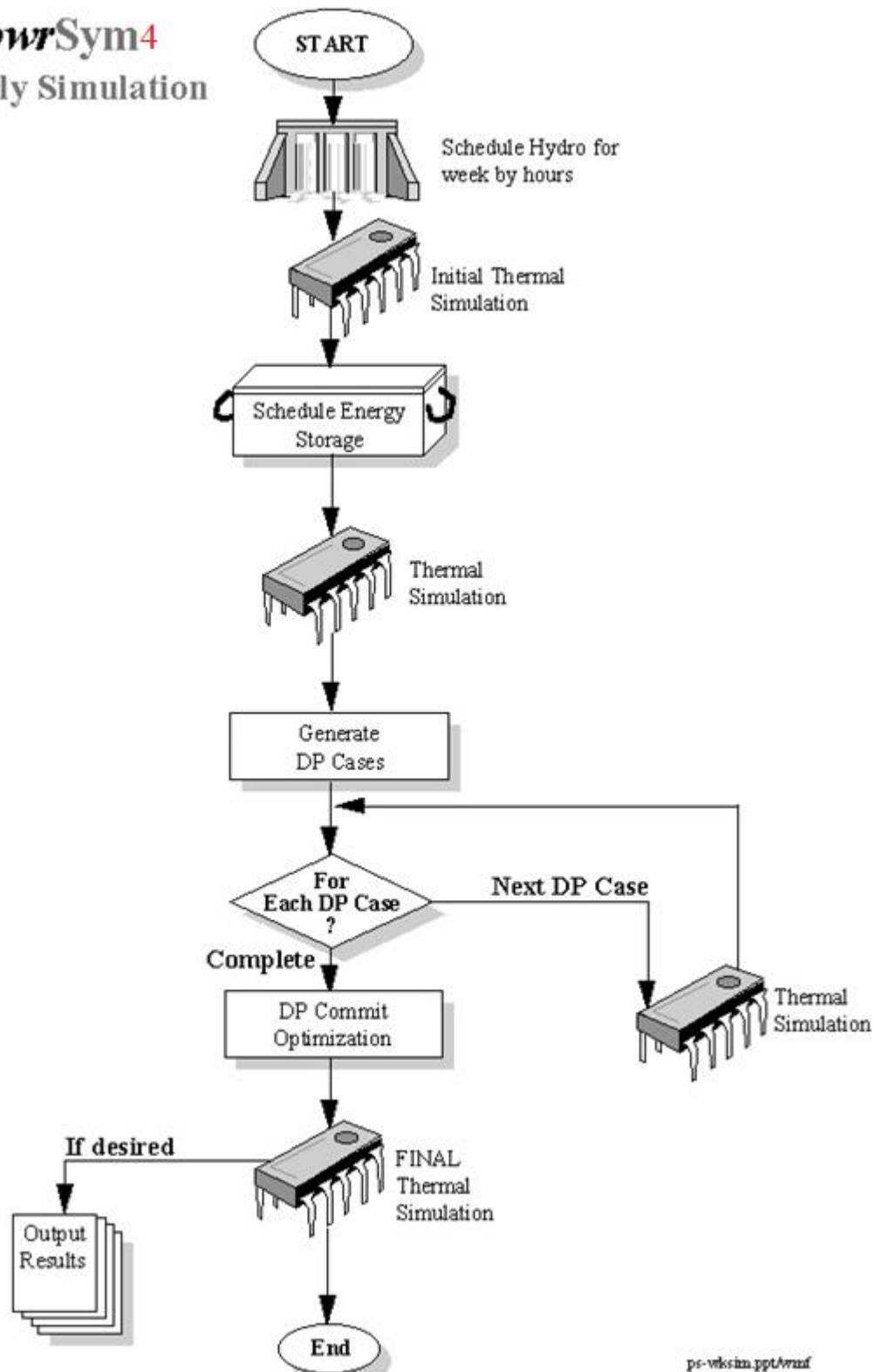


Figure 2.3.2

The thermal simulation schedules hourly thermal plant operation to meet electrical and heat loads. The initial thermal simulation is run without energy storage operation and creates a multi-step hourly marginal cost array. The marginal cost array is used as the objective function for scheduling hourly energy storage operation in the next step. The thermal simulation is then executed again with the given hourly energy storage schedule.

An expert system, driven by user input rules, is then used to generate a series of additional thermal simulations with variation in the thermal unit hourly commitment. A dynamic programming algorithm is used to select the hourly commitment from the available simulations with an objective function of minimizing total system cost over the weekly horizon. A final thermal simulation is then made using the unit commitment determined by the dynamic programming module.

PowrSym4 has two thermal station simulation methods available, the hourly sequential method and the All-hours Simulation Method (or concurrent method). The two methods are interchangeable except that the fuel contract logic is functional only with the All-hours method. The hourly sequential method has evolved over several years while the All-hours method is new and still rapidly evolving. It is expected that the computational advantages of the All-hour method will result in it becoming the method of choice.

2.3.1 Hourly Sequential Method

The hourly sequential thermal simulation method is shown in Figure 2.3.3. This method has evolved over several years and several versions of POWRSYM and PowrSym4 and is a robust chronological simulation. The first step in the simulation is a look-ahead algorithm that predicts the capacity requirements of future hours to aid in commit decisions. The simulation then solves the hours in sequence forcing chronological constraints relative to previous hours' results and the future hour look-ahead.

The hourly simulation begins with all the thermal stations committed and dispatched to the maximum allowed by constraints related to the previous hour's operation (minimum down time and ramp rate). The decremental dispatch cost and the decommit cost of each station are then computed. The decommit cost includes operating costs and start-up costs amortized over the predicted run time. The heat loads are then dispatched and the decremental costs are adjusted for heat production effects.

The next step is to determine the transarea with the highest incremental cost that can have its generation further reduced. A network flow transport algorithm is used to schedule flows between the areas and compute the decremental cost and potential surplus of each area. The area with the highest decremental cost and the station within that area with the highest decremental cost are then selected. If the selected station's decommit cost is higher than its decremental dispatch cost, it will be decommitted, otherwise its dispatch will be reduced by a decrement.

PowrSym4
Thermal Simulation
Hourly Sequential Method

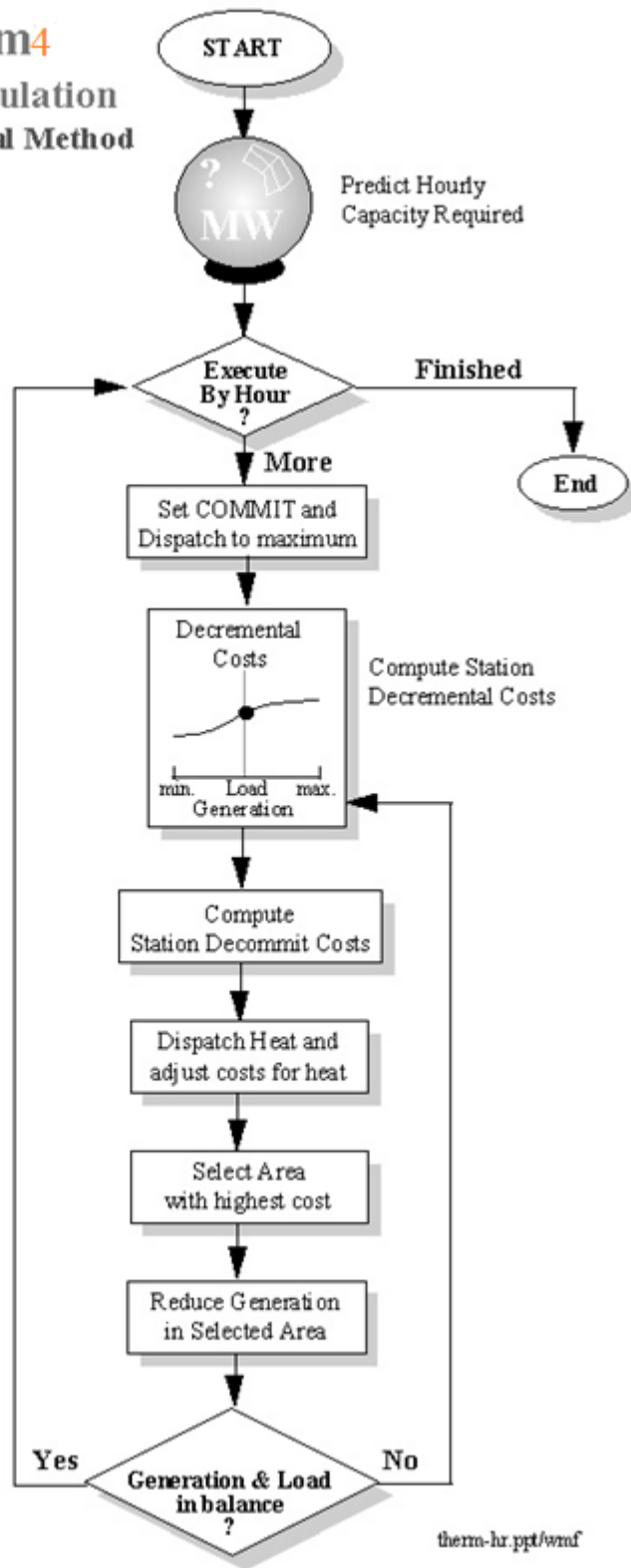


Figure 2.3.3

Decommit decisions are subject to spinning reserve requirements, operating reserve requirements, minimum down time constraints, minimum up time constraints, station minimum constraints, and heat load constraints. Dispatch decisions are subject to ramp rate constraints, unit minimum constraints, station minimum constraints, and heat load requirements.

After completion of the decrement, costs are recomputed and the process repeated until the generation and load are in balance. The repetitive process will bring marginal costs for all areas and all stations together at system lambda. This method is sometimes called the equal incremental cost method.

2.3.2 Concurrent Simulation Method

The concurrent simulation method, Figure 2.3.4, derives its name from its simultaneous solution of all hours in the optimization horizon (currently one week). This simulation method in a chronological format is new to PowrSym4 and, to our knowledge, is unique in the industry. It offers accuracy and speed improvements over the sequential method and allows optimal fuel allocation and fuel, energy, or emission limits to be simulated.

The simultaneous solution of all hours allows more optimal solution of events which span multiple hours. Examples of events which must be evaluated over a span of hours are unit commitment and energy limited fuel contracts.

The concurrent method will find more optimal unit commitment schedules for systems where commit decisions are strongly influenced by start costs or minimum up and down times. The commitment schedules developed by the concurrent method are comparable to those developed by dynamic programming optimization methods. The concurrent method uses dynamic programming techniques inside a network flow algorithm to produce results much faster than the dynamic programming optimization methods.

The fuel contract logic allows multiple fuels serving multiple stations. A station may have several fuel contracts plus spot fuel. A fuel contract may be shared by several stations. Each contract may have a station specific transportation cost and probabilistic derating. Each contract may have hourly, daily, and weekly minimum and maximum deliveries and storage with minimum and maximum levels which change by season. The concurrent method will optimize use of the fuel contracts to minimize total system weekly production costs.

PowrSym4
Thermal Simulation
Concurrent Method

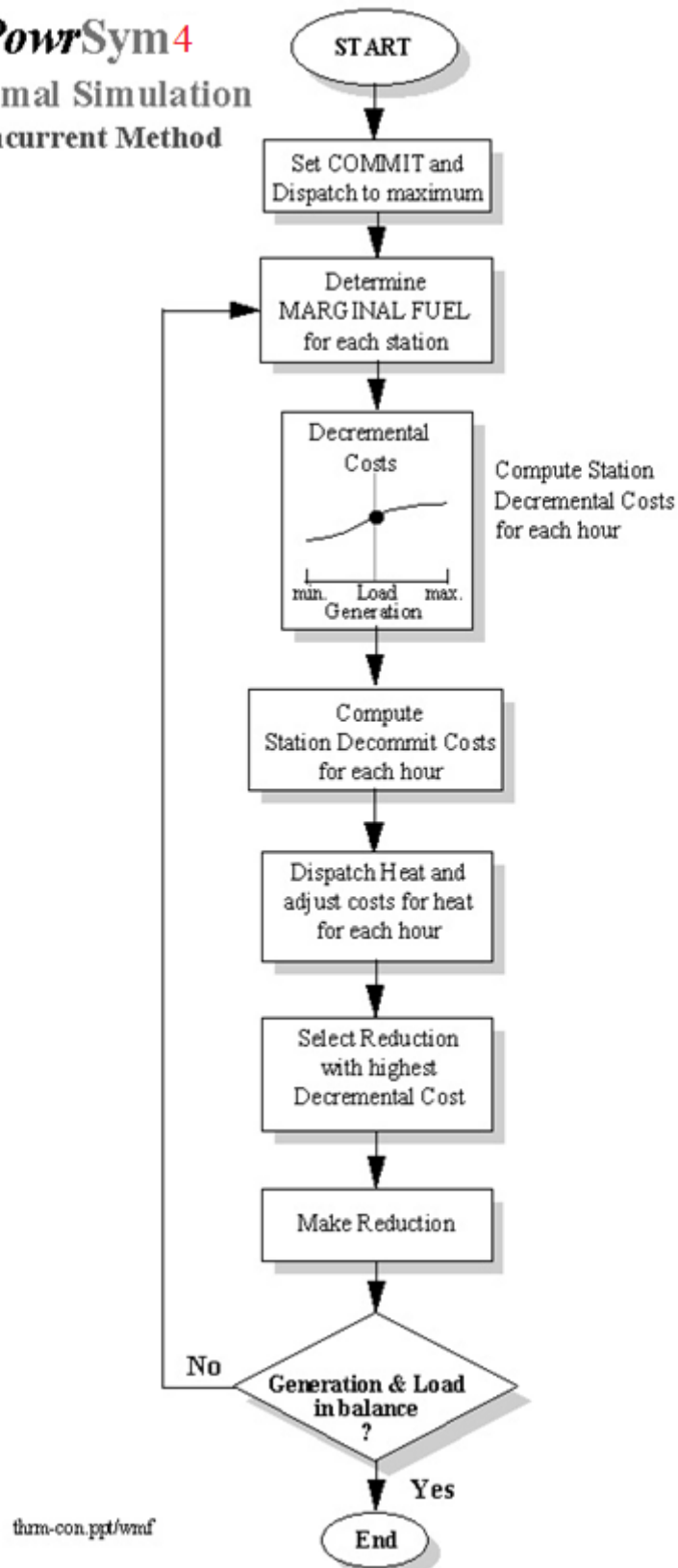


Figure 2.3.4

3. Data Input Preparation

3.1 Data Input Format

PowrSym4 is designed to accept data in a record format. The data are written to an ASCII file for portability to different computer platforms. This allows the user to edit data on one platform, copy the data to a different platform and execute the model, and copy the output files to the first platform for review and reporting.

The data can be created and maintained using a standard ASCII editor, a database, or a spreadsheet, allowing the data to be maintained in a user-defined form until a PowrSym4 run is needed. A Microsoft ACCESS database template is provided which reads and writes the direct data file and provides on-line help with predefined queries, forms, and macros.

3.2 Load Data

PowrSym4 has five formats for inputting the hourly electric loads. The model uses the **LOAD FORMAT** AID record to determine the appropriate load format as described in the Analyzer. **LOAD FORMAT** values of 0 and 1 are for obsolete formats that are maintained for backward compatibility.

If **LOAD FORMAT** equals 1, the loads format for each week follows:

First record	Year and week in an 8-column integer field (no decimals). The year is specified as a four-digit number and the week is specified as a one or two-digit number.
Next 21 records	8 loads in 9-column real number fields (decimals allowed).

The data should be right-justified in the fields.

If **LOAD FORMAT** equals 2, the loads format for each week follows:

Year	Columns 1:5
Week	Columns 6:8
Day of Week	Columns 9:9
Month	Columns 10:12
Day of Month	Columns 13:15
24 Hourly Loads	24 fields of 8 starting in Column 16

There are 24 loads on each record; the record has a year, week of year, day of week, month and day of month time stamp. For load records with week values greater than 51, the month value is checked; for these records if the month is less than 12, the calendar year is incremented.

PowrSym4 does not check the month and day of month fields for correct calendar dates. If the user wants the monthly reports to reflect some other time period, say quarters, all that is needed is to change the values in the month and day of month fields. Just remember PowrSym4 is checking weeks with values greater than 51. Quarter 1 should be a low number such as 1 while the fourth quarter should be a large number such as 14. The reports indicate the number of hours

simulated to help distinguish partial months and odd reporting periods.

The load data for individual transareas must be contained in separate files or be defined as a percentage of one of the defined load files. Each transarea must first be dispatched to meet its individual load before PowrSym4 solves the entire system. These load files are reported individually and summed to report a system load.

3.3 Maintenance Schedule

PowrSym4 uses three methods for simulating maintenance: an input schedule, a calculated schedule or a combination of an input schedule and calculating.

The input schedule is used to define specific periods that the unit is out for planned maintenance. These periods are defined by a beginning hour and week and an ending hour and week. For this period, the station is not considered in the commit and dispatch logic. However, any fixed costs associated with the station are included in the total system cost.

PowrSym4 can calculate a maintenance schedule using the maintenance scheduling routine. The planned outage rates for each station are used to determine the total hours of maintenance. These outage blocks are then scheduled on a yearly horizon using an objective function of levelizing the loss of load probability (LOLP) or minimizing total system costs.

3.4 PowrSym4 ANALYZER

The PowrSym4 Analyzer is designed to help users of the PowrSym4 production costing model edit their data in a user-friendly environment. It uses the powerful features of Microsoft ACCESS (version 97 or later). Users can read input data tables, edit the data, examine plots of various variables, combine data records from more than one table, and output the data for use by the production costing model.

The **Main Menu** and other self-explanatory forms make it easy for users to perform all the tasks described in the following sections. Experienced users of ACCESS can do any additional tasks that ACCESS supports.

The tasks that can be performed using the Analyzer fall into a number of categories. Each category consists of one or more related tasks as described in the **Main Menu** that opens automatically when the Analyzer is started. This manual contains a description of the Analyzer and how it is used.

3.4.1 Installing PowrSym4 Analyzer and Help Files

The PowrSym4 Analyzer package comes on a CD with these three directories: Manual, Aid and Database. There should be only one file in the Database directory; this is the ACCESS database file. This file can be copied for different studies or different users. The files in the Manual and Aid directories can be put in a central location so all of the copies of the database can access them. In this example a main directory, PowrSym4, has been created on the G: drive and the

three directories made subdirectories.



```
MS-DOS Command Prompt
G:\PowrSym3>dir
Volume in drive G has no label.
Volume Serial Number is 0455-7F41

Directory of G:\PowrSym3

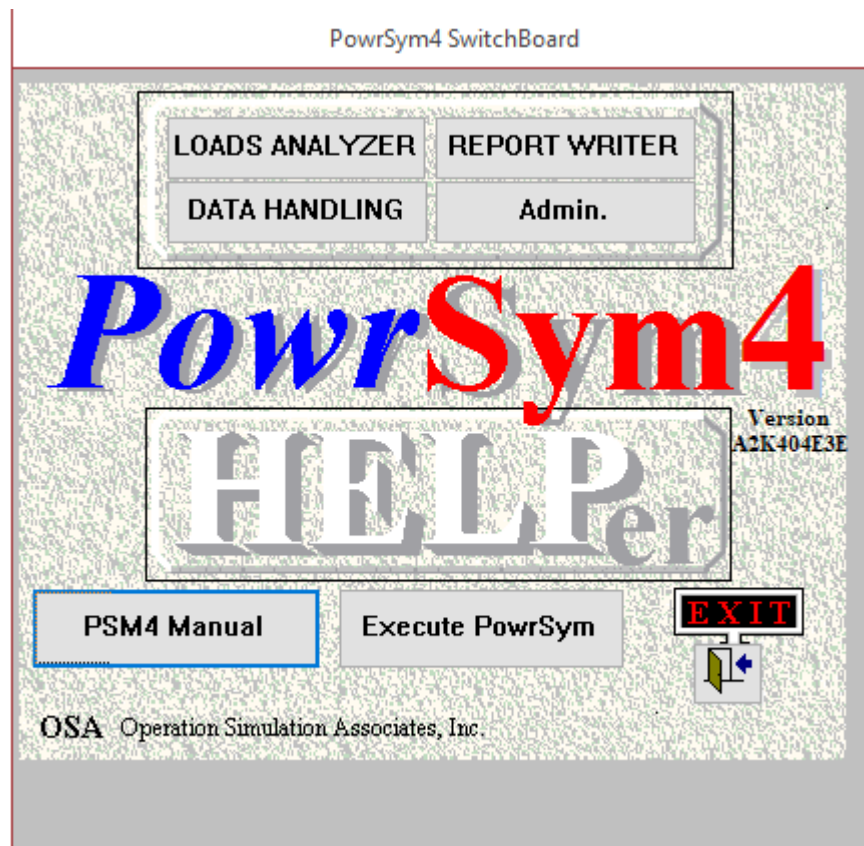
04/05/00  10:35a    <DIR>      .
04/05/00  10:35a    <DIR>      ..
04/05/00  10:42a    <DIR>      Aid
04/05/00  10:35a    <DIR>      Database
04/05/00  10:23a    <DIR>      Manual
               5 File(s)              0 bytes
               3,482,341,376 bytes free

G:\PowrSym3>_
```

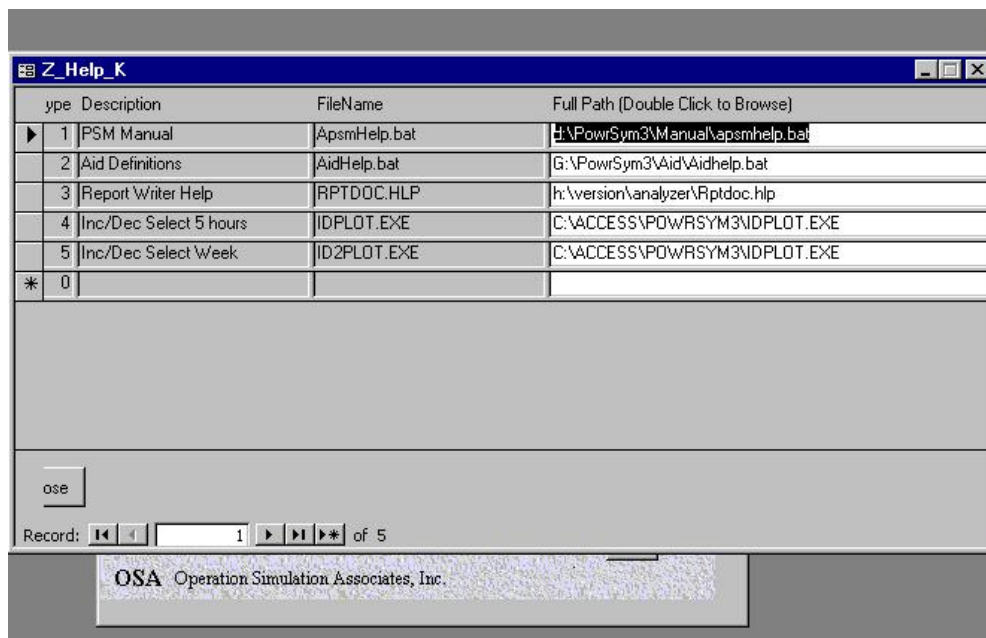
3.4.2 Making a Copy of The Database

Once the Analyzer is installed, it is time to save a copy of it using a different name. It is highly recommended that a copy of the database be saved after the first installation and have the original serve as a template. Copy **A97V350.MDB** to any disk or directory with a different name. However, the extensions **MUST** remain the same.

There are several ways to start the Analyzer. After you get ACCESS running open the Analyzer database file. Double clicking the file name will start ACCESS with the Analyzer. The Analyzer logo will be displayed as shown below from an older version 348. In the Analyzer control tables, queries, forms and reports all have names that start with Z; these objects should not be changed. The lower two action buttons open the user manual and the AID definition screens. These two documents are HTML files and are read with the default browser on the user's computer.



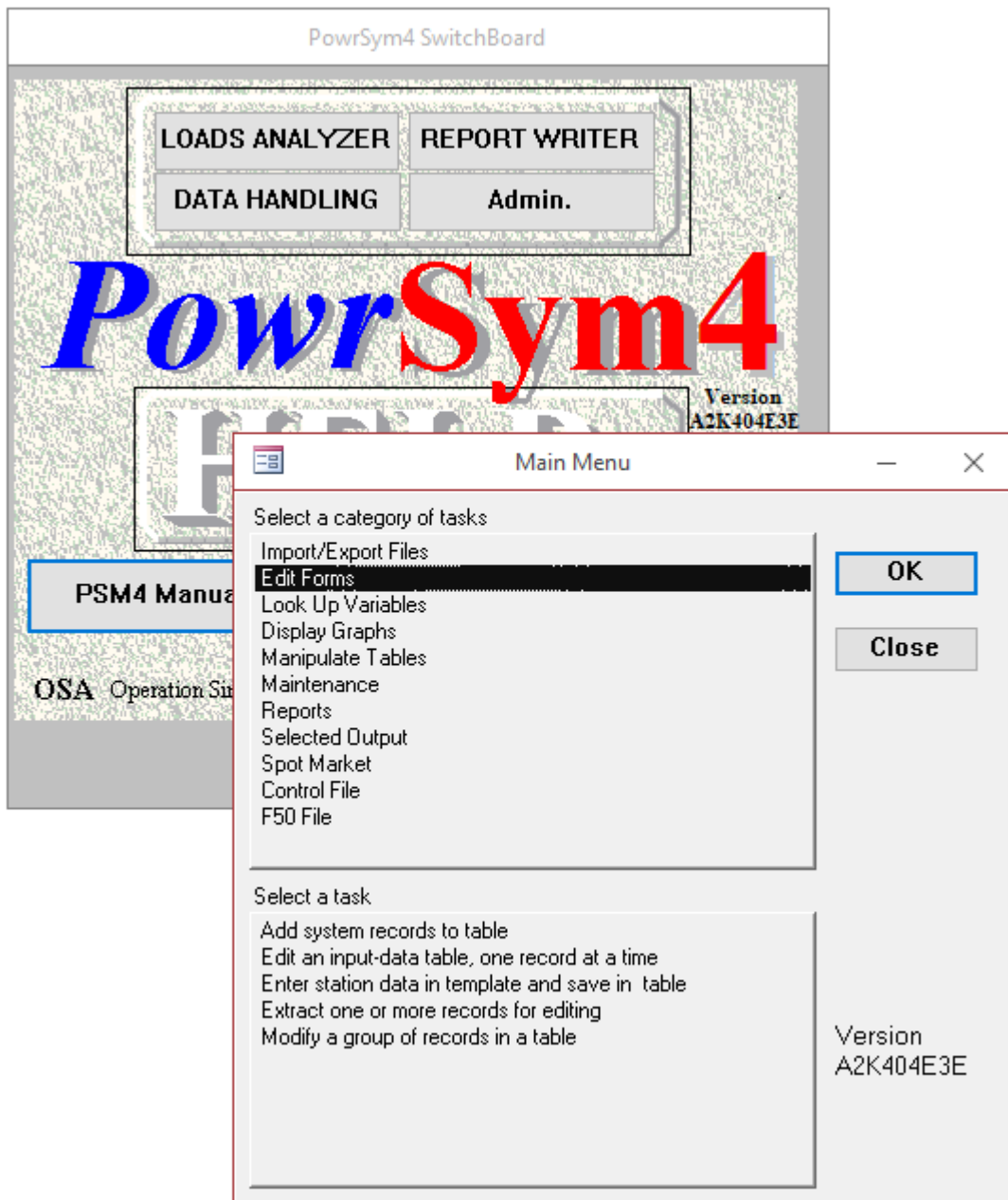
Making sure the manuals are installed is the first thing a user should do after coping and opening a database. When the **PSM4 Manual** button is clicked, the code will open a command window and open the manual files. If the file is not accessible, an error message is put on the screen. After the user clicks OK, the following form is opened. The **PowrSym4 Manual** button was clicked, and this is the file that needs to be located. The file name the user is looking for is in the gray column labeled FileName. If the file name in the white box is double clicked, screens are opened to allow the user to point and click the correct file name. Here the file name is correct, but the file is located on the G: drive not the D: drive.



Both the Aid Definition and PowrSym4 Manual files should be located before they are needed. The three buttons at the top of the logo screen open screens to help the user analyze both the input and output data from a PowrSym4 simulation. The first section to be discussed will be the input tools.

3.4.3 Categories and Tasks

The **Main Menu** contains categories with a list of tasks. To perform a particular task, use the **Main Menu** to first select the category under which the task falls and then the task itself. The table below lists the tasks in each category. The sections following the table describe the forms associated with each task, how to open a task from the **Main Menu**, and the results of each task. The **Main Menu** and all other forms together with this manual should provide enough information to start a new user working with the Analyzer. Users who are familiar with ACCESS can open these forms and their underlying tables and queries directly from the database window. The form names will be given with the form descriptions.



Category

Import/Export

Task

Export a file (fixed width)
Import File (fixed width)

Edit Forms

Add system records to a table
Edit an input-data table, one record at a time
Enter station data in template and save in table
Extract one or more records for editing
Modify a group of records in a table

Look Up

Show input variable definitions

Variables

Show output variable definitions

Display Graphs

Display graphs for yearly input data

Manipulate Tables

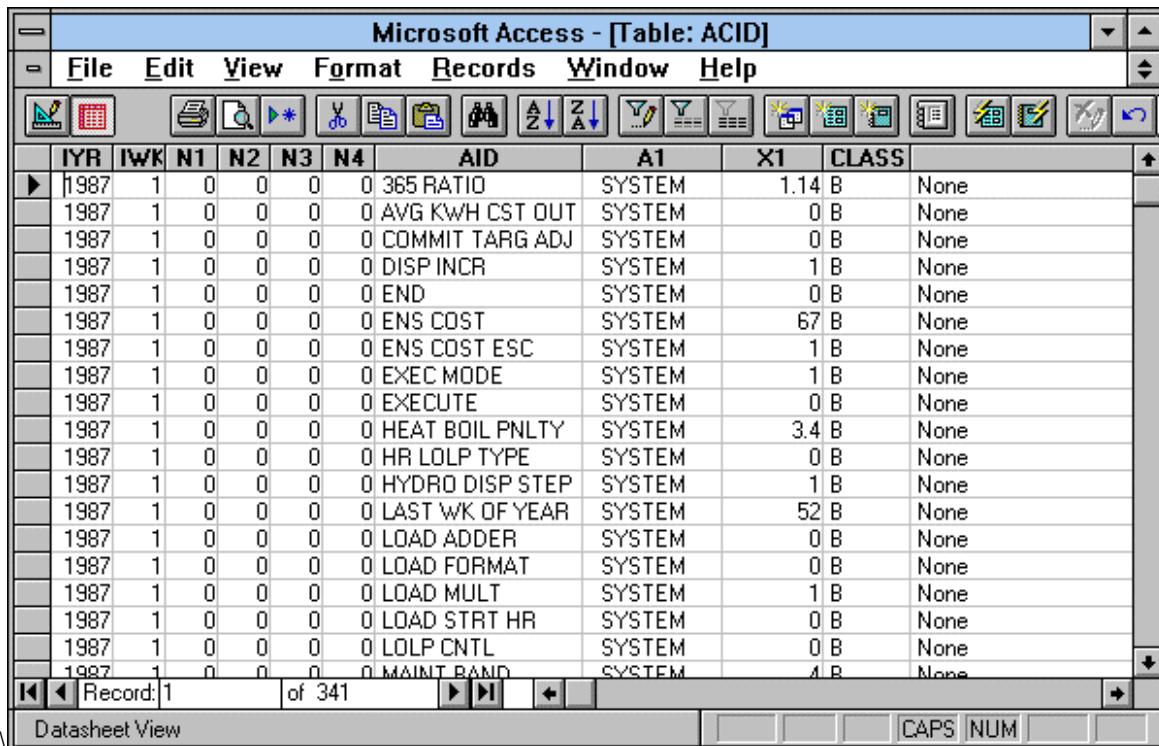
Find table's dates of creation and latest change
Merge two tables and export result as PSM4 input
Merge two tables (overlay)
Tabulate station variables per station per year
Verify values in the X1 field of a table

Reports

Print all variable-by-year station reports
View a station's data report by variable by year
View transarea link report

Table Format

To export any table using the Analyzer, the source table needs to be in the format illustrated below. Any data table that is sent in this package and any table that is later imported to the database using the Analyzer will be in the correct format.



IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS
1987	1	0	0	0	0	365 RATIO	SYSTEM	1.14 B	None
1987	1	0	0	0	0	AVG KWH CST OUT	SYSTEM	0 B	None
1987	1	0	0	0	0	COMMIT TARG ADJ	SYSTEM	0 B	None
1987	1	0	0	0	0	DISP INCR	SYSTEM	1 B	None
1987	1	0	0	0	0	END	SYSTEM	0 B	None
1987	1	0	0	0	0	ENS COST	SYSTEM	67 B	None
1987	1	0	0	0	0	ENS COST ESC	SYSTEM	1 B	None
1987	1	0	0	0	0	EXEC MODE	SYSTEM	1 B	None
1987	1	0	0	0	0	EXECUTE	SYSTEM	0 B	None
1987	1	0	0	0	0	HEAT BOIL PNLT	SYSTEM	3.4 B	None
1987	1	0	0	0	0	HR LOLP TYPE	SYSTEM	0 B	None
1987	1	0	0	0	0	HYDRO DISP STEP	SYSTEM	1 B	None
1987	1	0	0	0	0	LAST WK OF YEAR	SYSTEM	52 B	None
1987	1	0	0	0	0	LOAD ADDER	SYSTEM	0 B	None
1987	1	0	0	0	0	LOAD FORMAT	SYSTEM	0 B	None
1987	1	0	0	0	0	LOAD MULT	SYSTEM	1 B	None
1987	1	0	0	0	0	LOAD STRT HR	SYSTEM	0 B	None
1987	1	0	0	0	0	LOLP CNTL	SYSTEM	0 B	None
1987	1	0	0	0	0	MAINT BAND	SYSTEM	4 B	None

ASCII Data File Format

The Analyzer will structure the destination file in a format that can be read by PowrSym4. This

format is described in Section 9. It is not necessary to know this format to export a table using the Analyzer. The following steps export this file.

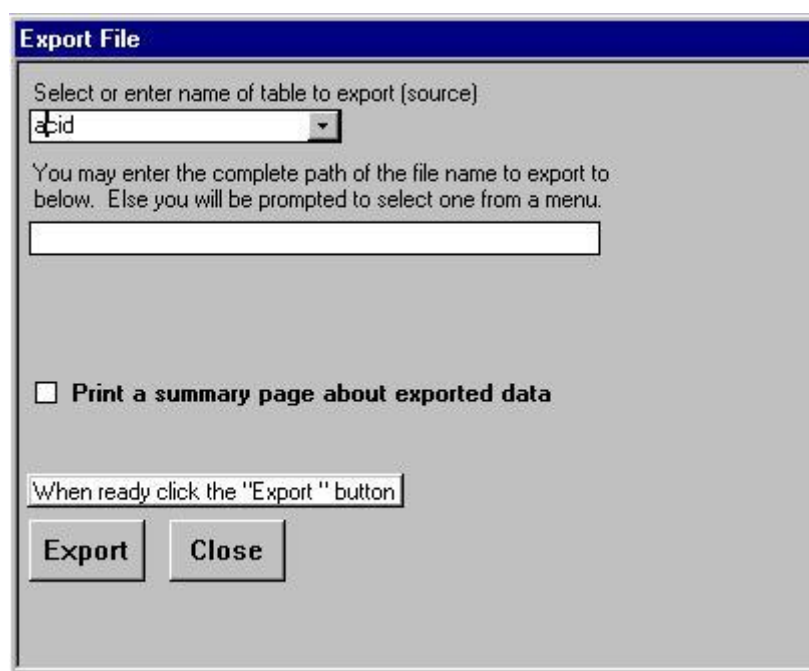
Steps

From the **Main Menu**, click the **Import/Export File** category.

Click the Export a file (fixed width) task.

Click the **OK** button. The **Export File** form opens.

Select the name of the table to export from the pull-down menu. If you check the **Print a summary page about exported data** box, a printed report is generated that describes the class fields and type of data exported. If desired, enter the complete path of the destination in the space provided. If a filename is not entered, a menu will prompt to specify one.



Click the **Export** button. Choose the **Close** button instead to close this form and cancel the export. If the complete path of the destination is not specified in step 5, a dialog box opens. Specify a file and click the **OK** button in the dialog box. The specified file may be existing or new.

The next screen to open will show all of the class fields in the selected table along with user supplied class descriptions. In this example the table only has records with B in the class field. However, when the user has a table with several simulation options, this is helpful in remembering which class fields should be exported. When the screen opens, the last export options will be marked Yes.

3.4.4 Importing a File

The Analyzer can also be used to import a file from outside the database into a table. You will most probably want to import a file containing the results of a PowrSym4 run to examine it or an input data file to edit it and prepare it for exporting. The source file needs to be of the same file format described above.

Steps

From the **Main Menu**, click the **Import/Export File** category.

Click the Import a file (fixed width) task.

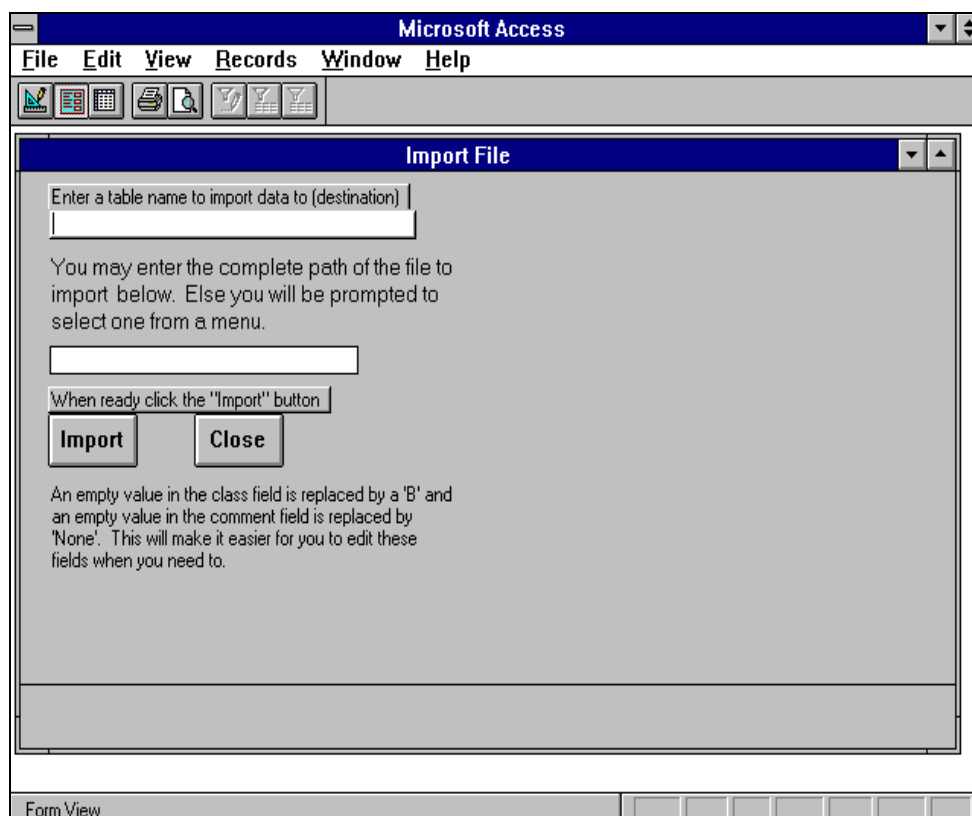
Click the **OK** button. The **Import File** form opens.

Enter the name of the table to export in the space provided on top of the form. The table should be one that exists in the database.

If desired, enter the complete path of the destination in the space provided. If a filename is not entered, a dialog box will prompt to specify one.

Click the **Import** button. Click the **Close** button instead to close this form and cancel the import.

If the complete path of the destination is not specified in step 5, a dialog box opens. Specify a file and click the **OK** button in the dialog box. The specified file may be existing or new.



Values of **B** and **None** will be used in place of any blanks in the CLASS field and COMMENT field, respectively. This will help in other functions needed later.

Note: To import a file where both the source file and the destination table are in databases or the source file or destination table is not of the same format as described in Section 7, use the Microsoft ACCESS Import function from the File menu. Do not use this if all the tables imported are PowrSym4 input files or output files formatted for the Analyzer.

3.4.5 Editing an Input Data Table

There are several ways you can edit a table. One way is to make changes to a table when it is opened in Datasheet view. Alternatively, you can edit a table with the help of the **Edit Table** form as described below.

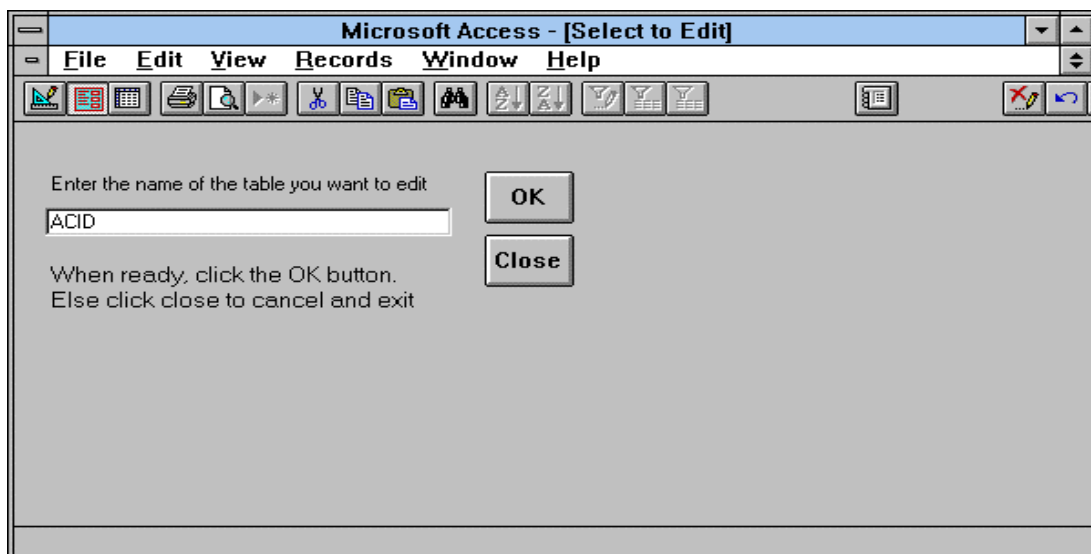
In the category box of the **Main Menu**, select the **Edit Forms** category by clicking it.

In the task box, select the **Edit an input-data table** task.

Click the **OK** button. The **Select to Edit** form opens.

Enter the name of the table you want to edit in the space provided on the form. This should be an existing table.

Click the **OK** button. The **Edit Table** form opens. You might choose to click the **Close** button instead to close this form and cancel the edit job.



Microsoft Access - [Edit Table]

File Edit View Records Window Help

Year Week N/A N/A 0 N/A Variable SYSTEM MW

1987 1 0 0 0 0 DISP INCR SYSTEM

SYSTEM Category

1 Minimum

100 Maximum

10 Default

This value determines the megawatt step size used in the thermal dispatch logic. It is dependent on the generating system size. For systems with 5000 megawatts or less, the value should be between 1 and 10 megawatts. For larger systems, values between 10 and 20 megawatts should be used. As this value decreases, the "smoothness" of the dispatch increases. As this value increases, the model execution time decreases. The value needs to be balanced between time constraints and the "smoothness" of the results.

COMMENT None

Close PSM3 Model Help

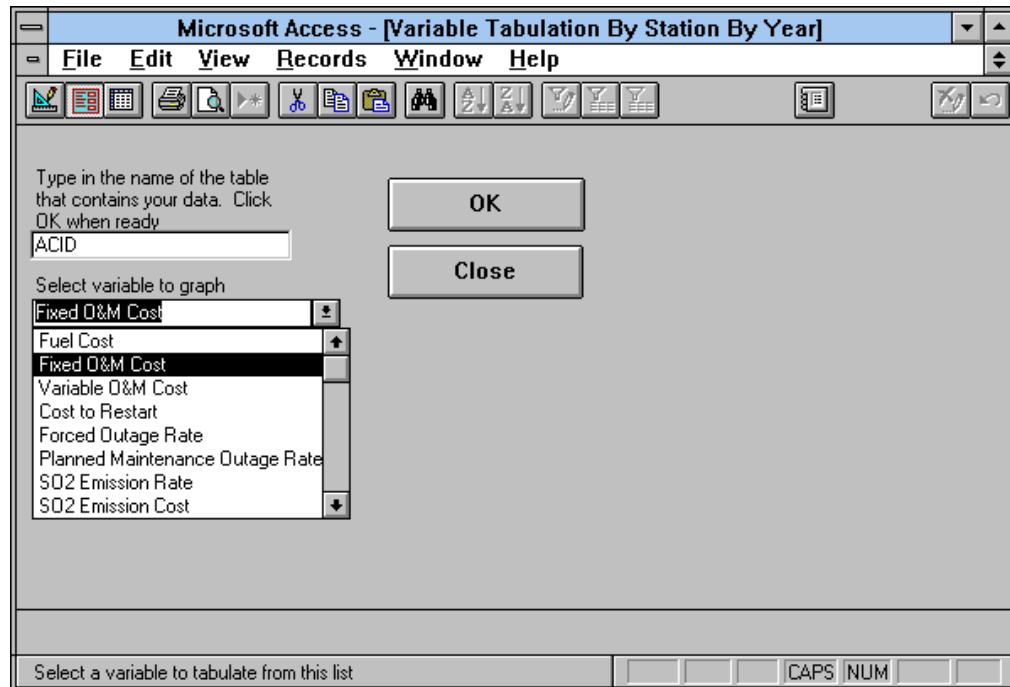
3.4.6 The Edit Table Form

This form is used to edit the table specified in the **Select to Edit** form. You can navigate through the records of the table, make changes to them, add new records, etc. Unlike the forms described so far, you work on this form yourself rather than providing parameters and clicking a button to activate a procedure. The form shows one record at a time of the underlying table. All the fields, except for the **COMMENT** field appear on the second row near the top of the form. Each cell on the first row briefly describes what you need to enter on the row below it. It also shows the definition of the data variable. You can use the record selector on the bottom of the form to select an existing record to view and/or edit or you can use it to move to an empty record at the end of all records and type in new record data. For thorough range checking, use the **Verify** form described later. Only input-type data tables are suited for use with this form. Note that you can edit any table directly without using this form by opening it and making your changes and additions.

For a detailed description of variables and other help items you can click the **PSM4 Model Help** button on this form. This will open the on-line help so that you can navigate using the mouse to select help items. The **Close** button will close the form and any changes you have made will be saved in the underlying table. On-line Help about PowrSym4 is accessible from the form in which you do most of the editing. A command button is provided for your convenience and you only have to click it to access help at any time. The definitions part of this form also appears as part of the **Edit Table** form, described in Section 11, so that you can always see the definition of the variable you are editing.

3.4.7 Displaying Input Graphs

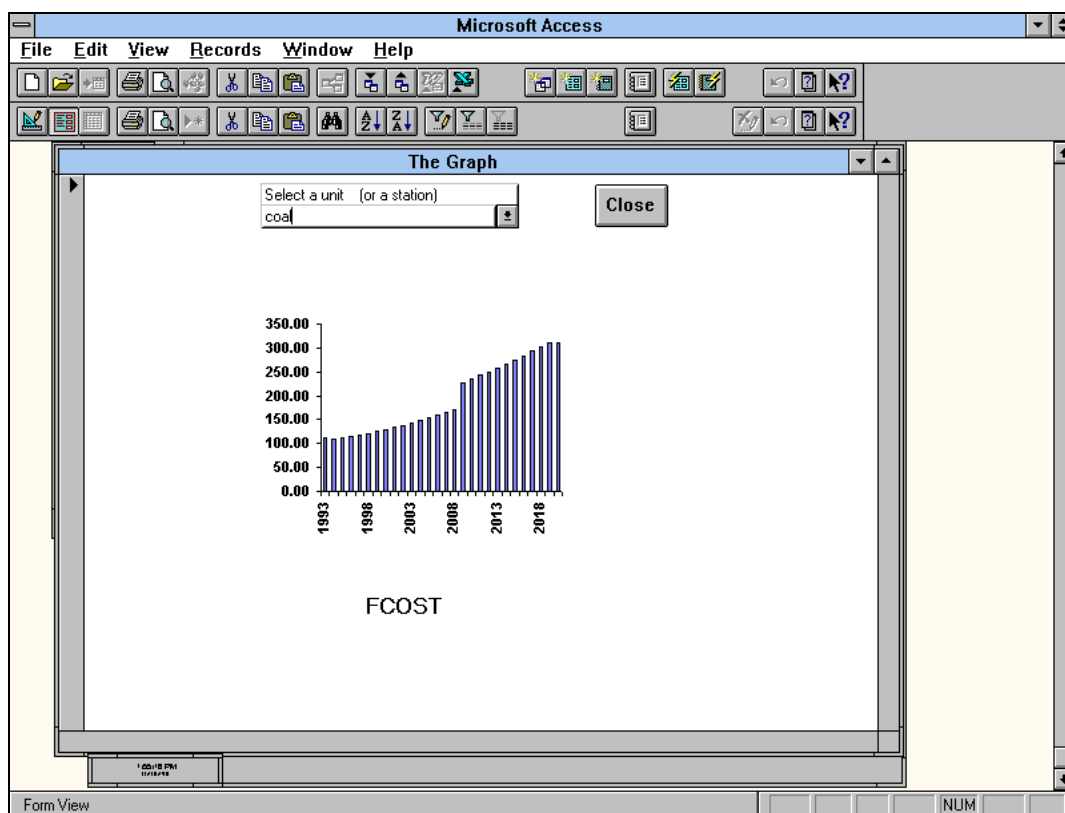
Two forms work together to help you display the change in certain input variables with time in graph form. These are the **Input Graphs** and **The Graph**.



Steps

1. In the category box of the **Main Menu**, select the **Display Graphs** category by clicking it.
2. In the task box, select the **Display graphs for input data** task.
3. Click the **OK** button. The **Input Graphs** form opens.
4. Select a variable from the list of available variables to be used in the graph.
5. Enter the name of the table containing the data to plot.
6. Click the **OK** button and **The Graph** form, screen 25B, opens. You might choose to click the **Close** button instead to close this form and cancel the job.
7. On **The Graph** form, select a station name from the list of available names. It takes some time for graphs to appear on the screen.
8. Repeat the step above for all the stations for which you want to examine the selected variable.
9. Click the **Close** button to close this form.

When you select a station from the pull-down list, the required data will be loaded and you will see the graph you asked for. While the form is open you can change your selection and view as many of the available stations as you want.



3.4.8 Overlaying Tables

The purpose of overlaying is to create a new table by combining two existing tables. This is most useful when you are performing a study requiring different cases from PowrSym4 using input data that differs slightly from a base case scenario. The following screen illustrates how to use the **Overlay** form.

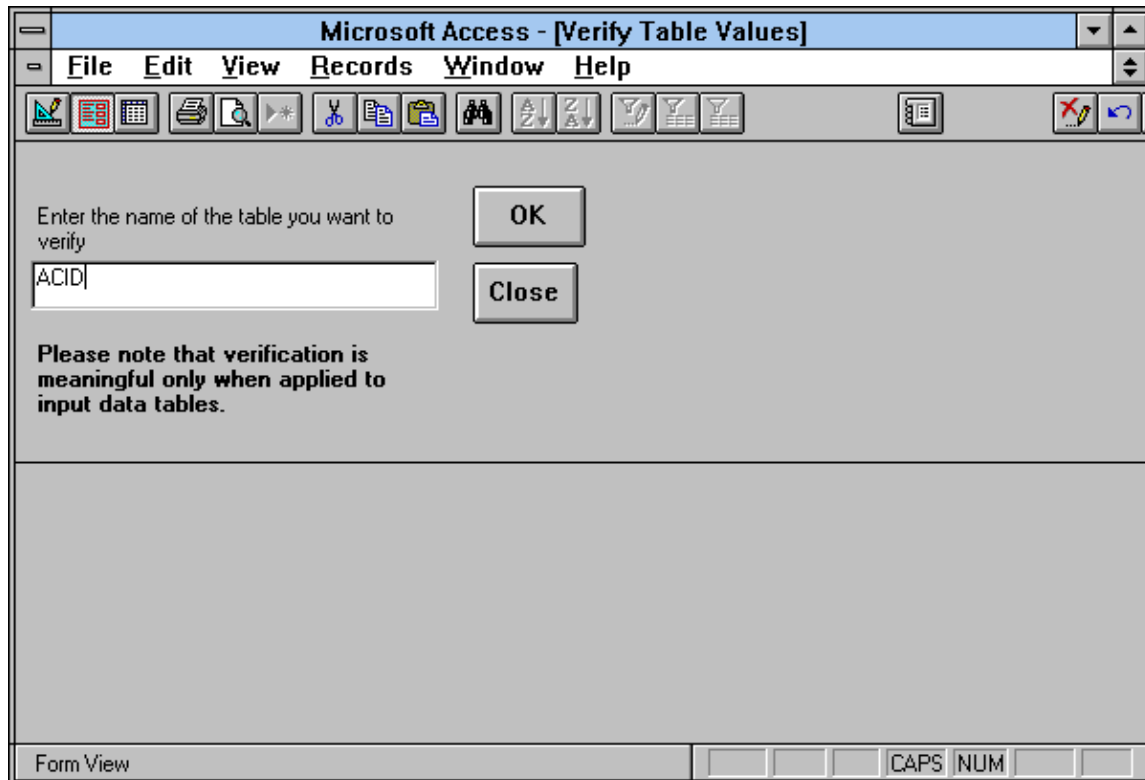
Steps

1. In the category box of the **Main Menu**, select the **Manipulate Tables** category by clicking it.
2. In the task box, select the **Merge two tables(overlay)** task.
3. Click the **OK** button. The **Overlay** form opens.
4. Enter the name of the base table to overlay changes
5. Enter the name of the table containing your changes.
6. Enter the name to give to the combined table.
7. Select one of three options on the bottom of this form by clicking the button next to it.
8. Click the **OK**. You might choose to click the **Close** button instead to close this form and cancel the job.

You can create the change table by first copying into it those records of the base table whose **X1** values need to be modified for a study case, modifying them, and then typing in any new records that belong only to the study case. If you choose the **Create combined table and retain it in data base** option, a combined table will be created and saved in the database. If you choose **Export combined table and retain a copy of it** or **Export the table and delete it from database**, you will be prompted for a destination to which the sorted table will be exported in for use by PowrSym4 and you will be notified of any resulting errors. The difference between the last two choices is that the former will retain a copy of the table with the name you selected in the database while the latter will delete the combined table after exporting a copy of it.

3.4.9 Verifying Values in a Table

The steps below show you how to check if the values in the **X1** field of an input data type table fall within an expected range. The following screen shows a picture of the **Verify Table Values** form.



Steps

1. In the category box of the **Main Menu**, select the **Manipulate Tables** category by clicking it.
2. In the task box, select the **Verify values in the X1 field of a table** task.
3. Click the **OK** button and the **Verify Table Values** form opens.
4. Enter the name of the table you want to verify.
5. Click the **OK** button. You might choose to click the **Close** button to close this form and cancel the job.

When you click the **OK** button, each **X1** value in your table will be compared with its minimum and maximum allowed values to verify that it falls within the range. You will then see on the screen one of two messages depending on the result of the comparison. **X1** values outside the expected range, if any, will be listed in an error table and the corresponding message will be displayed. The other message tells you that the verification was successful.

It is important to note that the range is determined by the minimum and maximum values given

for each variable in the definitions table and may not be correct for all users. If this is the case, the table will need to be edited to reflect the correct range.

Directly Modifying Source Table (Or a Copy of Source Table)

This function allows you to edit records extracted from the table specified in the **Extract Data For Editing** form. You can select one or more records from the source table, make changes to them, add new records, etc. and save the results in the specified result table. If the result table is the same as the source table, the changes will be reflected in the source table. Screen 28 through 29 illustrate this function.

The screenshot shows a Microsoft Access window titled "Microsoft Access - [Table To Modify]". The menu bar includes File, Edit, View, Records, Window, and Help. The toolbar contains various icons for database operations. The main area contains the following text and input fields:

Enter the name of the table you want to modify. This has to be an existing table.

MYTABLE

Enter the name of the table where you want results to be saved

MYTABLE2

When ready, click the OK button.

OK Close

Form View

CAPS NUM

Microsoft Access - [Find Records To Modify]

File Edit View Records Window Help

Enter/Select one or more values to search on:

Variable: Show Records

Station Name: Clear

Year: Close

Class:

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1987	1	0	0	3	0	STRT COST	OIL 1	6840	B	None
1987	1	0	0	4	0	STRT COST	OIL 2	741	B	None
1987	1	0	0	5	0	STRT COST	OIL 3	304	B	None
1987	1	0	0	6	0	STRT COST	OIL 4	494	B	None
1987	1	0	0	7	0	STRT COST	OIL 5	5320	B	None
1987	1	0	0	8	0	STRT COST	OIL 6	38	B	None
1987	1	0	0	9	0	STRT COST	STORAGE	0	B	None
*										

Customers. CAPS NUM

Steps

1. In the category box of the **Main Menu**, select the **Edit Forms** category by clicking it.
2. In the task box, select the **Modify a group of records in a table** task.
3. Click the **OK** button. The **Table To Modify** form opens.
4. Enter the name of the table to modify
5. Enter the name of the table where to save changed table (can be the table above.)
6. Click the **OK**. The **Find Records To Modify** form opens. You might choose to click the **Close** button instead to close this form and cancel the job.
7. If desired enter one or more values to search on, a variable name, a station name, a year or value in the CLASS field of the table.
8. Click the **Show Records** button, to see records that meet the specified search criteria. If no search values were entered, the whole table will be displayed.
9. Change any field in the selected records if desired.
10. At any point while this form is open, you may click the Clear button to clear the display and start over.
11. Click the **Close** button when satisfied with changes and the results will be saved in the table you specified.

Note that the Clear button does not undo changes, it only clears display so you can enter different search criteria for your next set of changes

Editing Specific Group of Records for Further Manipulation

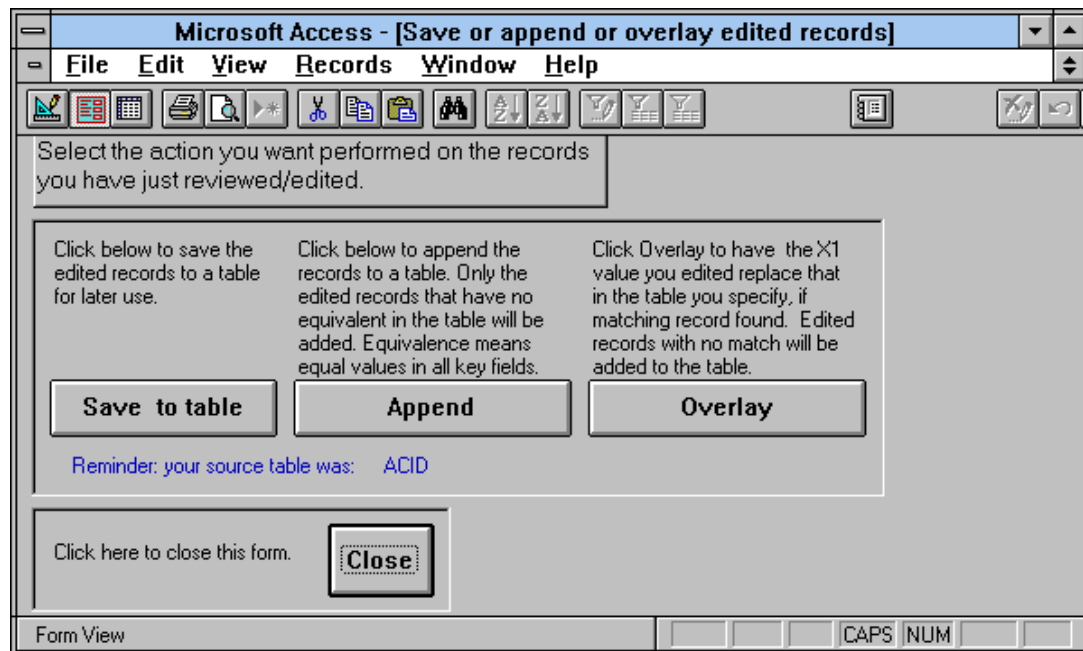
This function allows you to edit records extracted from the table specified in the **Extract Data For Editing** form. You can extract one or more records from the source table, make changes to them, add new records, etc. for use in a subsequent form. Screens 30 through 32 illustrate this function.

The screenshot shows a Microsoft Access window titled "Microsoft Access - [Extract Data for Editing]". The menu bar includes File, Edit, View, Records, Window, and Help. The toolbar contains various icons for file operations, editing, and viewing. The main area has a text box labeled "Enter the name of the table from which you want to extract data" with the text "ACID" entered. Below this is a message: "When ready, click the OK button. Else click Close to cancel and exit." At the bottom are two buttons: "OK" and "Close". The status bar at the bottom shows "Form View" and "CAPS NUM".

The screenshot shows a Microsoft Access window titled "Microsoft Access - [Find Records]". The menu bar includes File, Edit, View, Records, Window, and Help. The toolbar contains various icons for file operations, editing, and viewing. The main area has a cyan background with the text "Enter/Select one or more values to search on:". Below this are four search criteria: "Variable: STRT COST", "Station NAME:", "Year: 1987", and "Class:". To the right of these are three buttons: "Show Records", "Clear", and "Next" Below the search area is a table with the following data:

	IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
▶	1987	1	0	0	3	0	STRT COST	OIL 1	6840	B	None
	1987	1	0	0	4	0	STRT COST	OIL 2	741	B	None
	1987	1	0	0	5	0	STRT COST	OIL 3	304	B	None
	1987	1	0	0	6	0	STRT COST	OIL 4	494	B	None
	1987	1	0	0	7	0	STRT COST	OIL 5	5320	B	None
	1987	1	0	0	8	0	STRT COST	OIL 6	38	B	None
	1987	1	0	0	9	0	STRT COST	STORAGE	0	B	None

The status bar at the bottom shows "Records" and "CAPS NUM".



Steps

1. In the category box of the **Main Menu**, select the **Edit Forms** category by clicking it.
2. In the task box, select the **Extract one or more records for editing** task.
3. Click the **OK** button. The **Extract Data For Editing** form opens.
4. Enter the name of the table to extract records from.
5. Click the **OK**. The **Find Records** form opens. You might choose to click the **Close** button instead to close this form and cancel the job.
6. If desired enter one or more values to search on, a variable name, a station name, a year or value in the CLASS field of the table.
7. Click the **Show Records** button, to see records that meet the specified search criteria. If no search values were entered, the whole table will be displayed.
8. Change any field in the selected records if desired.
9. At any point while this form is open, you may click the Clear button to clear the display and start over.
10. Click the **Next** button when satisfied with your changes. The **Save or append or overlay edited records** form opens. The group of records just edited will be ready for use.

Note that the Clear button clears display so you can enter different search criteria for records to edit. Any previous changes will be discarded.

Next Steps

As mentioned above, the **Save or append or overlay edited records** form opens when you click the **Next** button in step 10 of section 3.4.17.2.1. This form allows you to choose one of four actions to perform on the set of records selected and edited above.

- To save the edited records in a table, click the **Save To Table** button. You will be asked for a table name and records will be saved under this name.
- To Append the edited records to an existing table, click the **Append** button. You will also be asked for a table name to append records to.
- To merge the edited records with an existing table, click the **Merge** button. Again you will be asked for a table name to merge records with.
- To close the form and do no further actions, click the **Close** button.

Appending Records To Existing Table:

The following steps describe how the Analyzer appends records to an existing table. The records will be referred to as the Change Table and the table to append to as the Base Table:

1. Find records in the Change Table, if any, that have equivalents in the Base Table and delete them. Equivalent records have the same values in all key fields; they carry duplicate information e.g. they may refer to the same variable for the same station for the same year.
2. Add all remaining records from the Change Table to the Base Table.

The result, which will be the Base Table, contains all unique records from both tables in addition to modified equivalent records. The values in the X1 field of equivalent records will be those of the Base Table.

Merging Records With Existing Table:

Merging is very much similar to appending as shown by the following steps that describe how the Analyzer merges records with an existing table. Again, the records will be referred to as the Change Table and the table to append to as the Base Table:

1. Find records in the Base Table, if any, that have equivalents in the Change Table and delete them. Equivalent records have the same values in all key fields; they carry duplicate information e.g. they may refer to the same variable for the same station for the same year.
2. Add all remaining records from the Change Table to the Base Table.

The result, which will be the Base Table, contains all unique records from both table in addition to modified equivalent records. The values in the X1 field of equivalent records will be those of the Change Table.

3.4.10 Merging Two Tables and Exporting Result as PSM4 Input

This function combines the merge function of section 17 with the export function of section. You will want to use this function when you are ready to make a run for which all required data reside in two tables, a Base Table and a Change Table. Using one form, the form of screen 33, you can merge the two tables, select which records you want for the scenario, and export the selected records.

Microsoft Access - [Merge two tables and export result as PSM3 input]

File Edit View Records Window Help

Enter name of base table
Base_Table

Enter name of change table
Change_Table

Export Close

You may enter, below, the complete path for the resulting PSM3 input-type data. Else you will be prompted to select one from a menu.
E:\PSM\NEWSTUDY\NEWFILE2

If desired, enter below selected class or classes to be included in the resulting file. The selected classes should spell exactly like they are in the class field of the tables specified above. If no class is entered, the whole resulting table will be exported. In case of duplicate information, the records with CLASS other than "B" will be used.

B ACD NSQ

Form View CAPS NUM

Steps

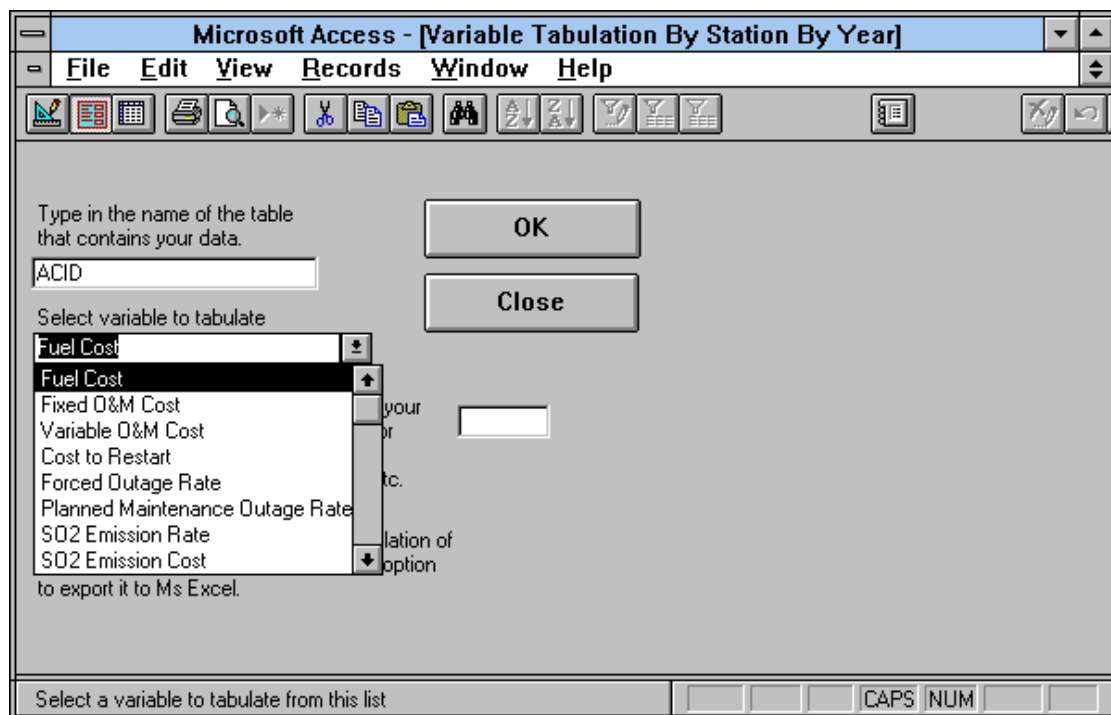
1. In the category box of the **Main Menu**, select the **Manipulate Tables** category by clicking it.
2. In the task box, select the **Merge two tables and export result as PSM4 input** task.
3. Click the **OK** button. The **Merge two tables and export result as a PSM4 file** form opens.
4. Enter the name of the base table.
5. Enter the name of the table containing your changes.
6. If desired, enter the complete path of the destination in the space provided. If you don't enter a file name, you will be prompted to specify one using a menu.
7. If desired, enter up to 6 classes to export a selected class of records of the specified table. If no classes are specified, only records where CLASS is 'B' or 'b' will be exported. Use of classes is explained in section 8.
8. Click the **Export** button. Choose the **Close** button instead to close this form and cancel the export. These are ignored when exporting an output type data.

9. If you chose not to specify the complete path of the destination in step 5, a dialog box opens at this point so that you can specify one. Specify a file and click the **OK** button on the dialog box. The specified file may be an existing or new file.

Following the last of the steps above, the tables you named will be merged, and the records with the specified CLASS values will be sorted and exported. Merging is done in the same manner as explained in section 19.2.2. If the exported file contains duplicate records, you will be notified of where to find a copy of these records. Duplicate records are records with equal values in all key fields except the CLASS field. Since PSM4 ignores the CLASS field, it will use only one of the duplicate records, namely the one that comes last after sorting. Your run will be affected if the X1 field is not the same in all duplicate records. You can check the duplicate record table and correct the problem before attempting to export a second time.

3.4.11 Tabulating Yearly Values of Station Variables

The purpose of this tabulation is to provide an easy way of viewing and documenting the station variables used in some database or for some run. Screens 34 through 36 illustrate how to achieve that.



Microsoft Access

File Edit View Format Records Window Help

Crosstab Query: Z_Fuel_Cost_Crosstab

A1	1993	1994	1995	1996	1997	1998
coal	112.10	109.60	112.30	114.60	117.40	121.00
HYDRO	0.00	0.00	0.00	0.00	0.00	0.00
STA 1	254.00	255.00	272.00	292.00	299.00	323.00
STA 2	254.00	255.00	272.00	292.00	299.00	323.00
STA 3	114.20	112.60	115.40	117.80	120.70	124.40
STA 4	41.50	42.50	43.60	44.69	45.81	46.95

Record: 1 of 129

Macro Module

Z_Append_Error_Table
Z_BadAids
Z_Category
Z_ClassOut
Z_Definitions

Datasheet View

Output To

File Name: z_fuel_c.xls

Directories: e:\psm\newstudy

e:\
psm
newstudy

List Files of Type: Microsoft Excel (*.xls)

Drives: e: compressed

OK
Cancel
Network...
☐ AutoStart

Steps

1. In the category box of the **Main Menu**, select the **Manipulate Tables** category by clicking it.
2. In the task box, select the **Tabulate station variables per station per year** task.
3. Click the **OK** button. The **Variable Tabulation By Station By Year** form opens.
4. Enter the name of the table containing your data.
5. Select a variable from the pull-down list.
6. Click the **OK** button. Choose the **Close** button instead to close this form and cancel the

tabulation function. A table will open with station names down the side and years across the top. You will also be prompted for a destination file name where the resulting table will be saved as a MS EXCEL spreadsheet.

7. If you wish to export the resulting table to EXCEL, select a destination. Otherwise select Cancel. You will still have the table on the screen.

3.4.12 Using Input Templates to Enter New Station Data in a Table

The purpose of input templates is to enable the user to add to a new or an existing table, all necessary records for a new unit. There are seven templates one for each of the seven unit types that can be modeled by the production costing model PowrSym4. These are Nuclear, Fossil, Gas/Combustion Turbines, Power Purchase Blocks, Hydro, Pumped Hydro and Combined Cycle/Co Generation. All templates, except that for hydro plants look much alike and are used in the same way. The Hydro template is different from all the rest, since hydro data are entered on weekly basis while all others are entered on yearly basis.

Selecting Unit Type, Name, Table And Dates

First a form, the **Preparation for template data entry** form, is used to enter general information about the unit, e.g. The table to save the unit's data after entering it. If this is an existing table, the form will search it for existing summary class names and transarea names in case you want the new unit to belong to an existing summary class or transarea. Summary classes are used to group different stations (units) in your table by a common attribute e.g. fuel type. Choosing an existing summary class name for the new unit means a record will be entered in the tables that assigns the unit to that summary class. Choosing a new summary name means two records will be entered, one defining the new summary name and one assigning the new unit to it.

Transarea names are used to define different transmission areas in a multi-area system. For a single area system, you need to have only one transarea name, e.g. the name of your utility, which you can enter for a table when first using it with templates and thereafter use it for all new units you add to the table. In a way similar to summary classes choosing an existing or a new transarea name means one or two records will be entered in the table. This form is also used to select unit type, nuclear, fossil, etc., the name to give to the new unit, the beginning and ending years of the period for which data will be entered and finally the starting week of each year of data. The starting week of the year is week 1 for calendar year based data. For fiscal year based data, its value depends on when the year starts. For a fiscal year starting October 1st, this is week 40, for July first this is week 27 etc.

Steps

1. In the category box of the **Main Menu**, select the **Edit Forms** category by clicking it.
2. In the task box, select the **Enter station data in template and save in table** task.
3. Click the **OK** button. The **Preparation for template data entry** form opens.
4. Select or enter the name of the table to save data in. Click the Tab key or the Enter key
5. Select the type of the unit you will be entering data for

6. Enter a name to give to the new station. Only 10 characters can be saved in table
7. Enter the years marking the start and end of the period the data covers
8. Enter the beginning week of each year of data.
9. Select or enter, if not already existing in table, the summary class the station belongs to
10. Select or enter, if not already existing in table, the transarea the station belongs to
11. Click the **OK** button (or choose the **Close** button instead to close this form and cancel this function).

Following step 11, **Entering xx plant data to be saved in a table - Page 1** form will open where xx is the selected unit type. Screen 38 gives you an idea of the layout of this form; use of this form is explained below. If the plant selected in step 5 is hydro, a different form will open.

Microsoft Access

File Edit View Records Window Help

Preparation for template data entry

Select or enter table name to save subsequent data in

Table To Save In

Select plant type:

☒ Nuclear plant

☐ Fossil plant

☐ Gas turbine

☐ Power purchase

☐ Hydro

☐ Pumped storage

☐ Combined Cycle

Enter the name of the plant the data is for. Only the 10 leftmost characters will be used.

NUCLEAR1

This plant's data is for the years from 1995 To 2009

The first week of the year for this data is 1

Enter or select a summary class name for this station, up to 10 characters. The listed names, if any, are the summary names found in your table

NUCLEAR

Enter or select a transarea name for this station, up to 10 characters. The listed names, if any, are the transarea names found in your table.

AREA1

OK Close

Form View

NUM

Microsoft Access

File Edit View Records Window Help

Nuclear Plant Data Unit Name Close

Number of Units = Precommercial Forced Outage Rate (%)

Minimum Up Time (HRS) Number of Precommercial Weeks

Minimum DownTime (HRS) B Coefficient for Maturity Curve

Year 1995 1996 1997 1998 -----

Equivalent Forced Outage Rate (%) -----

Planned and Maintenance Outage Rate (%) -----

Full Load Capacity(MW) -----

3rd Capacity Level (MW) -----

Fuel Heating Value -----

To enter more data, for 11th year and above, click the "More " button. Else click "Done"

More Done

Form View NUM

Entering Plant Data To Be Saved In A Table - Page 1 Form

According to the type of plant selected in step 1, one of seven forms will open when you click the OK button in step 11 above. Six of these forms, for all plant types except hydro, look and function similarly and will be described in this and the following two sections. The **Entering xx plant data to be saved in a table - Page 1** form is used to enter data for a unit of type xx for the first 10 years or less of the specified period. The top part of the form is for the unit's variables that do not change by year. An entry is required for each of these variables. Below this part you will see years across the top and variable names down the side. There is a box for data entry for each variable for each year. Entries are required for the first year for all variables. Any box left blank after the first year will be assumed to have the same value as the previous year. If a variable has the same value for years n , where $n > 1$, to m , you need only enter it for year n and leave years $n+1$ to m blank

At the bottom of the form, there are two buttons. One button, the **Done** button, allows you to save the 10 or less years' worth of data entered on the current form and exit. The second, the **More** button, allows the data to be saved and opens a second form to enter up to 10 more years of data provided that your start and end years of the desired period, on the **Preparation for template data entry** form indicate more than 10 years.

Steps

1. Fill in the top part of the form, values that do not change yearly.
2. Make sure the first year values for all variables are entered (first column).
3. For the second year and beyond you need only enter a variable's value if it differs from the previous value.
4. If you need to enter values for more than these 10 years click the **More** button, a second similar form opens.
5. If you are finished click the **Done** button, the data will be saved in the table and the form closes.
6. To cancel the procedure and close the form, click the **close** button on top of the form.

Entering Plant Data To Be Saved In A Table - Page 2 Form

To enter data for the 11th through the 20th years of data, you clicked the **More** button on the form which opens this form. You need only enter values in the boxes for years where the value is different from that of the previous year. This form also has **More** and **Done** buttons at the bottom that allow you to either save data and exit or to save data and open a third form provided that your start and end years of the desired period, on the **Preparation for template data entry** form cover more than 20 years.

1. For each variable enter only the values that differ from the latest entered value. The form remembers the values entered on the previous form.
2. If you need to enter values for more than the 10 years in this form, click the **More** button, a second similar form opens.
3. If you are finished click the **Done** button, the data will be saved in the table and the form closes.
4. To cancel the procedure and close the form, click the **close** button on top of the form. This does not undo the values entered on the previous form.

Entering Plant Data To Be Saved In A Table - Page 3 Form

To enter data for the 21st through the 30th years of data, you clicked the **More** button which opens this form. Again, you need only enter values in the boxes for years where the value is different from that of the previous year. This form does not have **More** button at the bottom. It only has a **Done** button, since only 30 years of data can be handled using the templates. When you click the **Done** button, the values on the form are entered in the table and the form closes. The Page 1 and Page 2 forms that were used for entering the first 20 years of data are also closed. If click the close button instead the values will be ignored; however, this does not undo the values entered using the previous two forms

Steps

1. For each variable enter only the values that differ from the latest entered value. The form remembers the values entered on the previous form.

2. If you are finished click the **Done** button, the data will be saved in the table and the form closes.
3. To cancel the procedure and close the form, click the **close** button on top of the form. This does not undo the values entered on the two previous forms.

Entering Hydro Plant Data To Be Saved In A Table

Entering hydro plant data are done on one form, rather than three forms as required by other plant types. To save data for a year and move on to edit the next year, you only need to click a button on the form.

There are three parts to this form. The top part is for station data that is not usually expected to vary with time, the number of units and the ramp rate. These have to be entered when the form first opens. They stay on the form for as long as it is open. The second part is for data that changes yearly. All values in this part are required entries. However, you don't need to retype them for each year of data since they stay on the form once you entered them. You only need to reenter a value for the year when it takes on a new value. The third part of the form is for hydro data that can change weekly. All values for the first week of the year being edited need to be entered on the form. Any value left blank from the second week on, will be assumed to equal the previous week's value. If a value is the same for weeks n , where $n > 1$, to m of a year, enter that value for week n only leaving weeks $n+1$ to m blank.

A click button at the bottom of the form allows you to save the current values on the form and gets the form ready for the next year's entries.

Steps

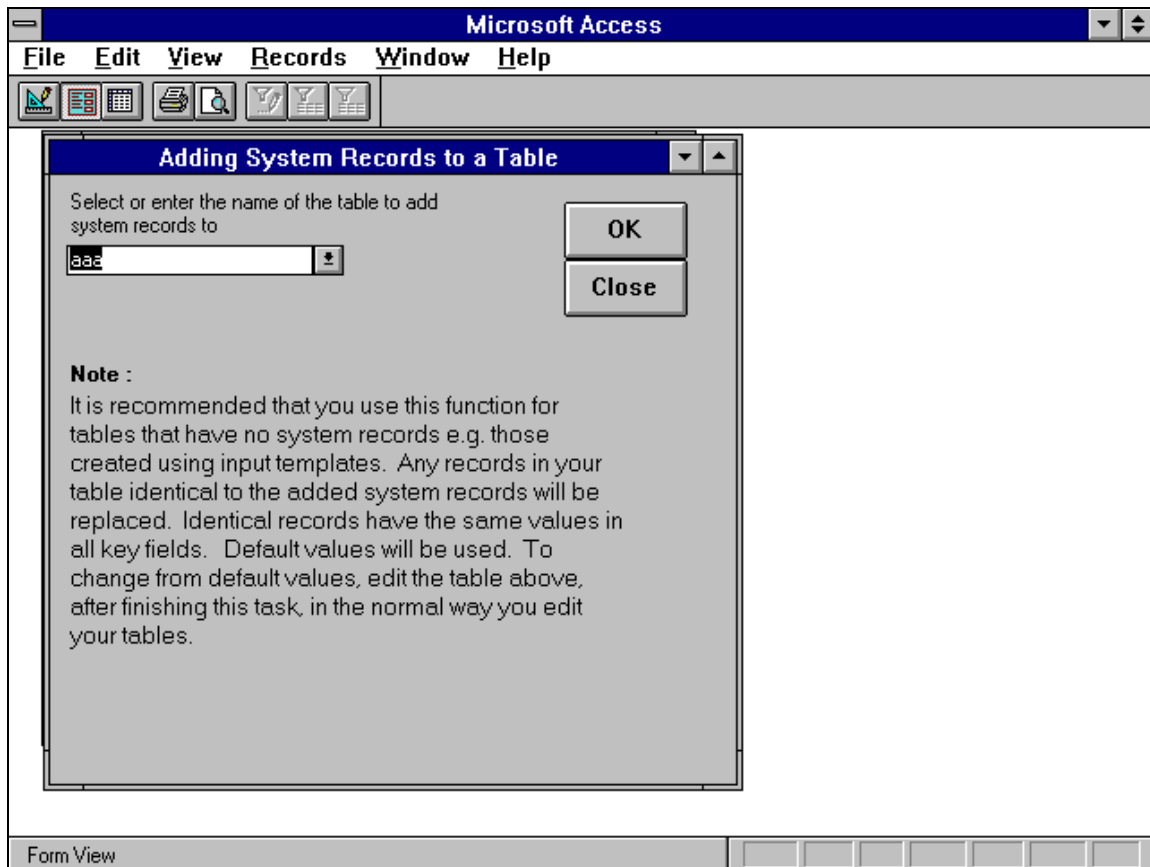
1. Fill in the top two parts of the form, constant and yearly values.
2. Make sure the first week values for all variables are entered (first row).
3. For the second week and beyond you need only enter a variable's value if it differs from the previous value.
4. Click the **Save To Table** button to save the current year values be ready to edit the next year. You can click the **Close** button instead to close the form and ignore the current values on the form. A note next to this button reminds you which year you are editing.
5. Enter or modify yearly and weekly values that differ from the previous year values.
6. Go to step 4.

3.4.13 Entering System Records In A Table

The templates explained above are used to enter station data only. If you have not entered system data by other means, e.g. copying from an existing table and pasting to your table, you may want to use the **Add System Records to a Table** form. This will provide you with all the system variables recognized and/or expected by PowrSym4 in their default values. You can then edit some or all of these records to the values suitable for your scenario.

Steps

1. In the category box of the **Main Menu**, select the **Edit Forms** category by clicking it.
2. In the task box, select the **Add system records to table missing them** task.
3. Click the **OK** button. The **Add system records to a table** form opens.
4. Select or enter the name of the table to add system records to.
5. Click the OK button (or the Cancel button to quit without adding the records)



3.4.14 The Analyzer Reports

The Analyzer can be used to summarize information from some table in a report format. Three reports are available. One report shows transarea (or Tarea) link data and the other two show unit data by year.

Transarea Link Report

This report is needed only if you have a multi-area system. If you have a multi-area system you still need to check that relevant data (e.g. Tarea names and link numbers) are in your table. This will ensure accurate reporting. This report summarizes link data available in a table. It shows

the link number, the transarea where the link originates and the transarea where it ends. It also shows the capacity of the link, the loss percentage and the wheeling charge. The same information is given for the reverse link.

Steps

1. In the category box of the **Main Menu**, select the **Reports** category by clicking it.
2. In the task box, select the **View transarea link report** task.
3. Click the **OK** button. The **Transarea link data** form opens.
4. Enter the name of the table that contains the transarea data
5. Click the **OK** button (or choose the **Close** button instead to close this form and cancel this function). The table will be searched for required data and the report will open.

Microsoft Access

File Edit View Records Window Help

Transarea Link Data

Select or enter the name of the table containing your data

CT_BASE

Click below to view a link data report for your transmission areas

View Report

Close

Form View

NUM

Link	Area	Transfer To				Reverse: Link		
		Area	Capacity	Losses	Wh Rate	Capacity	Losses	Wh
2	AREA2	AREA1	1,000	70.00%	\$0.20	1,000	50.00%	\$
4	AREA3	AREA2	10,000	54.00%	\$0.00	10,000	78.00%	\$
1	AREA1	AREA2	1,000	50.00%	\$0.10	1,000	70.00%	\$
3	AREA2	AREA3	10,000	78.00%	\$0.00	10,000	54.00%	\$

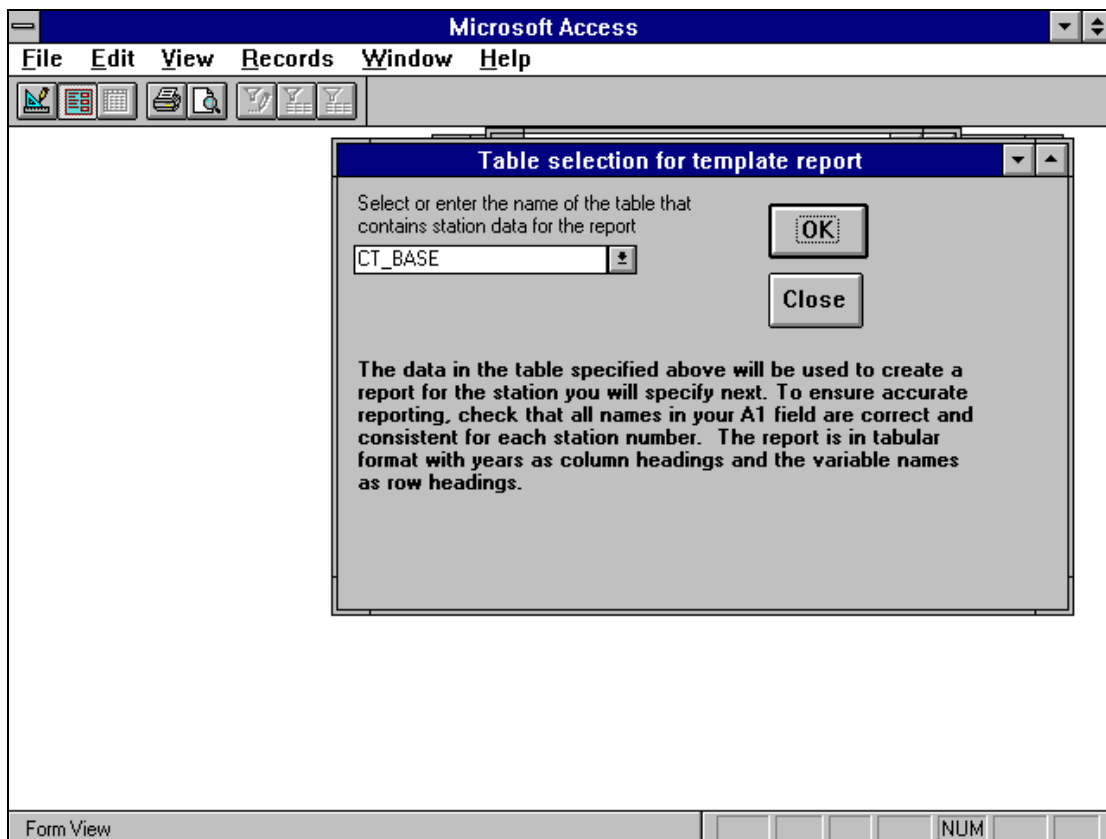
Station Data Report - One Unit At A Time

The Analyzer can also be used to summarize information about a specific unit from a table in a report format. The report format is similar to the templates of screen 38 that were used for entering unit data. It shows the unit's data by variable by year. If any value is the same as the previous year value, it is left blank. Two forms are needed to carry out this function. The first form is used to select the table where station data are stored. The second form is used to enter more specific data about the desired report, e.g. the particular station, its type, the report years to cover and optional titles.

Steps

1. In the category box of the **Main Menu**, select the **Reports** category by clicking it.
2. In the task box, select the **View station data report by variable by year** task.
3. Click the **OK** button. The **Table selection for template report** form of screen 43 opens.
4. Enter the name of the table that contains the unit data
5. Click the **OK** button (or choose the **Close** button instead to close this form and cancel this function). The table will be searched for available station data and a second form, screen 44, will open.
6. Select the type of the station that you want a report of.
7. Select the station itself from the pull-down list. For accurate reporting, make sure

- the station you select in this step is of the type selected in step 6 above; change your selections if necessary.
8. Enter two titles in the two text boxes provided. These are especially important if you are going to print the report since they will help you identify the reported data
 9. Enter the starting and ending years of the period you want the report to cover. A maximum of 30 years is allowed.
 10. To view a report of the selected station on the screen, click the **View Report** button. Up to 3 report pages, each covering 10 years' worth of data, will open on the screen dependent on the report period. Screen 45 is an example of such a report.
 11. To print a report of the selected station, click the **Print Report** button. Up to 3 report pages, dependent on the report period, each covering 10 years' worth of data, will be sent to the printer.
 12. To close the form and quit this task, click the **Close** button.



Microsoft Access

File Edit View Records Window Help

Patterned Report Elements

Select plant type

☐ Nuclear plant
☒ Fossil plant
☐ Gas turbine
☐ Power purchase block
☐ Hydro
☐ Pumped storage
☐ Combined Cycle

Select a station

coal

Enter an optional title (up to 55 characters to appear on report header.)

Station Report for Study X

Enter another optional title (up to 55 characters) to appear on report header.

Station 1 Coal

The report should cover the years between

1993 and 2000

Preview Report Print Report

Close

Enter the last year to include in the report

NUM

Microsoft Access

File Edit View Format Window Help

Fossil Plant Data - Page1

Station Report for Study X

Station 1 Coal

Number of Units =	1	Minimum DownTime (HRS)	96	
Minimum Up Time (HRS)	48	Ramp Rate (MWHR)	110	
Year/Week	1993-40	1994-40	1995-40	1996-40
Equivaient Forced Outage Rate (%)	0.127	0.08	0.077	0.0491
Planned and Maintenance Outage Rate (%)	0.153	0.1918	0	0.0981
Maximum Achievable Capacity Factor (%)	0.739431	0.743544	0.923	0.8576167
Full Load Capacity (MW)	467			
3rd Capacity Level (MW)	402			

Page: 1

Ready

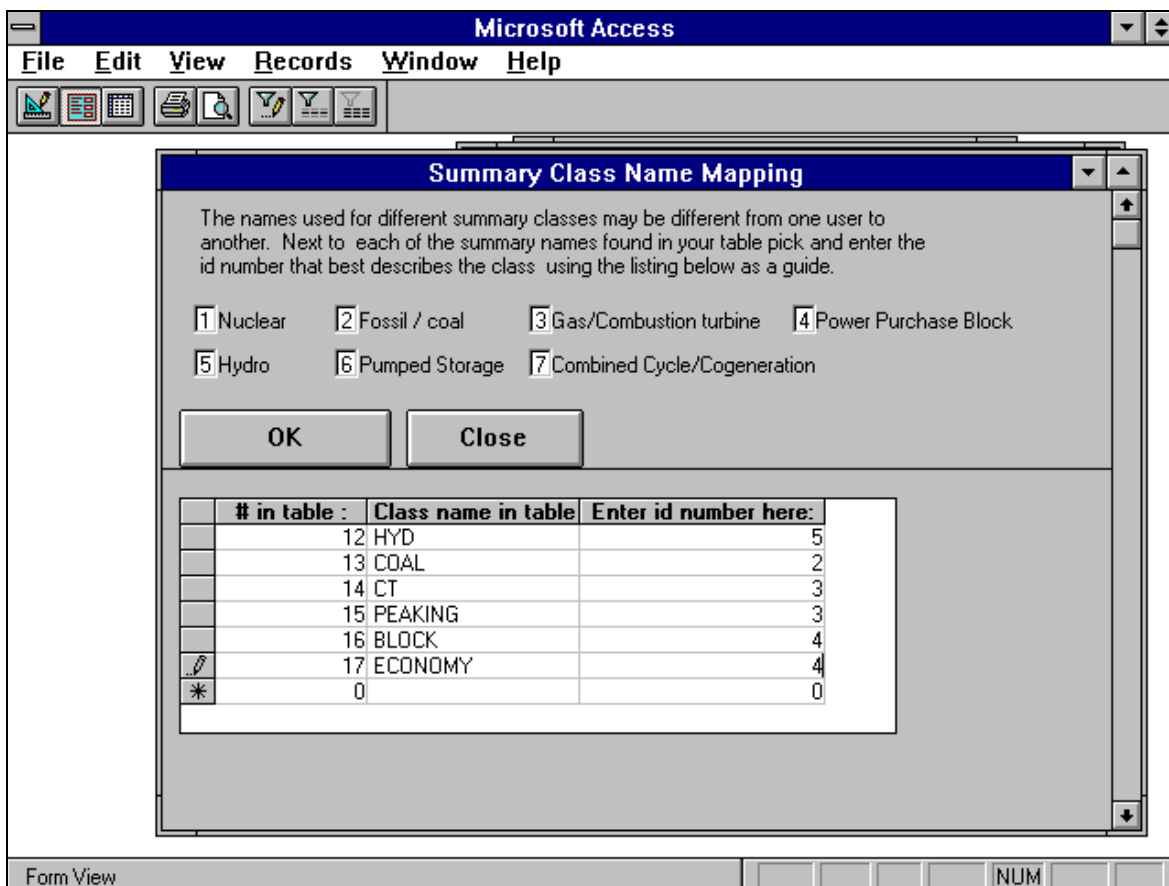
NUM

Station Data Report Printouts

The Analyzer can also be used to print out reports about all the stations grouped by summary class from a specific table. The report shows the unit's data by variable by year. If any value is the same as the previous year value, it is left blank. Two forms are needed to carry out this function. The first form is used to select the table where station data are stored. The second form is used to map the summary class names found in your table to ID numbers that tell the Analyzer the type of the plants in each summary class. If you have no summary classes in your table or if some of the stations in the table are not associated with any summary class, you will need to use the forms of section above to print the reports one station at a time.

Steps

1. In the category box of the **Main Menu**, select the **Reports** category by clicking it.
2. In the task box, select the **Print all variable-by-year station reports** task.
3. Click the **OK** button. The **Table selection for template report printing** form opens. This is similar to the one illustrated by screen 43.
4. Enter the name of the table that contains the unit data.
5. Click the **OK** button (or choose the **Close** button instead to close this form and cancel this function). The table will be searched for summary class information so that all units in your table can be grouped by summary classes for printing and the **Summary Class Name Mapping** form, screen 46, will open.
6. Next to each of the summary names found in your table pick and enter the id number, from the provided list, that best describes the class.
7. Click the **OK** button (or click the **Close** button instead to close the form and cancel this function). All units in your table that are associated with the first summary class will be sent to the printer followed by the units of the next class ... etc. until all available classes are covered.



3.4.15 Points to Remember

All internal tables, forms, and queries have names starting with **Z_**, **ZQ_** Or **ZW_** in either upper case, lower case or a combination. Do not delete them or use their names for your forms, queries, or tables.

It is strongly recommended that you compact your database regularly to save on disk space. The larger the size of your tables the larger your database is going to be. Table deletion does not free up all the space the table used to occupy; compacting does. To compact, close the database without exiting ACCESS. From File menu, select Compact Database. Following the dialog window, select the database to compact, say DBVXXX.MDB. Select a name to save the result, say DB1.MDB; you could also use the database itself (i.e., DBVXXX.MDB). You can then delete DBVXXX.MDB and rename DB1.MDB as DBVXXX.MDB.

3.5 Hourly Load Adjustment Algorithm

This algorithm will take a set of hourly loads that are continuous over time and modify the pattern such that a specified peak will be the maximum value in the new set of loads and the sum of all the new loads will equal a specified energy. This algorithm works well on load patterns where the average load is less than 80 percent of the peak load. It also works if the ratio of the

average load to the maximum load stays constant or changes by a small amount. The algorithm is:

$$X_i = (A_i/B)Y + [Z-(C/B)Y] [(1-(A_i/B)) / (N-(C/B))]$$

where

N = number of hours in time series.

A_i = old value for period I (The hourly load).

B = maximum A value (The old peak load in the period).

C = Sum of A_i as i goes from 1 to N (The sum of the old loads).

X_i = new value for period i (The new load for hour i).

Y = maximum X value (The new peak load).

Z = Sum of X_i as i goes from 1 to N (The sum of the new loads).

The algorithm mechanics can be divided into two components. One to set the new peak and the other to adjust the energy to the correct value. The first component $(A_i/B)Y$ sets the maximum value in the new series to the new peak. Since B is the maximum of all the A values, the term, A_i/B is equal to one at the hour of the peak, and one times the new peak equals the new peak. As other A_i values approach the size of B, the peak, the term, A_i/B , approaches one, and the new X_i values will be relatively close to the new peak. This term ratios the old pattern up or down by the ratio of the old peak to the new peak and does not necessarily yield the correct energy over the time period.

The second component is a little more complicated. This component takes the difference between the desired energy and the energy yielded by the first component and ratios it over the hours in the pattern. The term, $[Z-(C/B)Y]$, is the difference between the desired energy and the energy yielded by the first component. The term $(C/B)Y$ is the old energy ratioed by the old peak to the new peak; if this value is greater than the desired energy, the term will be negative and reduce the values from the first component. If the first component yields less than the desired energy, the term will be positive and will increase the values from the first component. The second term of this component allocates any energy adjustment to the various hours.

The term, $(1-(A_i/B))$, is the energy adjustment allocator. The term, $(N-(C/B))$, is the sum of all the $(1-(A_i/B))$ values in N periods. Consequently, the sum of all the values, $[(1-(A_i/B)) / (N-(C/B))]$, for N periods will equal one; and one times the adjustment will equal the adjustment. The energy adjustment allocator adjusts the values relative to the new peak. Since B is the maximum pattern value, A and B are equal at the peak and the term A/B equals one, and the adjustment at the hour of the peak is zero. For values of A that are near the peak load, the term, A/B near one and the adjustment is small. This algorithm fills or deepens the valleys in the calculated load pattern.

When this algorithm is used to adjust monthly loads in an annual load shape, there tends to be a discontinuity between the load for the last hour of one month and the load for the first hour of the next month. This happens because the months tend to end and start when the load is in a valley. The discontinuity is greatest between two months where energy is added to the pattern in one month and subtracted from the pattern of the other month. To minimize the discontinuity an end of the month adjustment is made. The values in the last five hours of the ending month and the first five hours of the following month are adjusted. The sum of the adjustments over the five hours is zero; therefore, the monthly energy remains at the desired value. The adjustments are defined as follows:

X_n is the value for the last hour of the month.
 Y_1 is the value for first hour of the following month.

Z is $X_n - Y_1$

$$\begin{aligned} X_n &= X_n - Z(3/9) \\ X_{n-1} &= X_{n-1} - Z(1/9) \\ X_{n-2} &= X_{n-2} + Z(1/9) \\ X_{n-3} &= X_{n-3} + Z(2/9) \\ X_{n-4} &= X_{n-4} + Z(1/9) \end{aligned}$$

$$\begin{aligned} y_1 &= y_1 + Z(3/9) \\ y_2 &= y_2 + Z(1/9) \\ y_3 &= y_3 - Z(1/9) \\ y_4 &= y_4 - Z(2/9) \\ y_5 &= y_5 - Z(1/9) \end{aligned}$$

This adjustment reduces the difference between X_n and Y_1 to one-third the original difference. The adjustment period may seem short, but this smoothes the floor of the valley and pushes the change to the shoulder where major changes in the load are expected.

This algorithm will be incorporated in PowrSym4 such that any flagged load input will be projected at the first week of the year with peaks, energies, and hours read in the first week of the year. The hours in each period are input once if they don't change. This algorithm will work for periods defined as weeks, months, quarters, or any division of the year as long as the periods are contiguous hours. The algorithm will be optimized for the computer by moving part of the computation outside the hourly do loop as follows:

$$X_i = (A_i/B)Y + [Z - (C/B)Y] [(1 - (A_i/B)) / (N - (C/B))] \text{ as } i \text{ goes from } 1 \text{ to } n$$

The terms $[Z - (C/B)Y]$ and $(N - (C/B))$ don't change hourly; therefore, they can be reduced to a constant inside the hourly do loop. The term:

$$W = [Z - (C/B)Y] / (N - (C/B))$$

$$X_i = (A_i/B)Y + (1 - (A_i/B))W \text{ as } i \text{ goes from } 1 \text{ to } n$$

3.5.1 Program Control

The load modification routine in PowrSym4 is controlled by the following four AID values:

TAREA LOAD CNTL	N3 value is the transarea load being modified, X1 controls the modification.
TAREA LOAD PEAK	N3 value is the transarea load being modified, N4 value is the forecast period, X1 value is the projected peak load.
TAREA LOAD ENGY	N3 value is the transarea load being modified, N4 value is the forecast period, X1 value is the projected energy for period.
TAREA LOAD HRS	N4 value is the forecast period, X1 value is the number of hours in forecast period.

The TAREA LOAD CNTL values are:

- 0 The default value; no load modification or forecasting takes place.
- 1 Hourly loads are read for a year. The first value is assumed to be the load for the first hour of the year, FY or CY.
- 10 The same as -1 and projected loads are output to a file.
- 1 As projected loads are used they are saved for pattern projections.
- 10 The same as 1 and projected loads are output to a file.

If TAREA LOAD CNTL is negative, the load modification routine reads a pattern set of loads to use for projecting the current and future years. If in a latter year of simulation a new TAREA LOAD CNTL value of -1 is input, another year of loads will be read from the input file and used as the pattern. If TAREA LOAD CNTL is a positive 1, the values of the projected hourly loads are saved and used as a pattern for projecting future years. A non-zero value for the first forecast period for TAREA LOAD ENG causes the program to stop reading hourly loads from the input file and to project them using the load modification routine.

4. Output Data Organization

4.1 Printed Reports

4.1.1 American Energy and Monetary Units

PowrSym4 allows user-defined flags to choose hourly, weekly, monthly, calendar year, and/or fiscal year output files. These files are written in an 80, column format to allow printing. In addition to station, output data can be aggregated by plant and three user-defined groupings. For each group of output, the model writes three reports containing operating characteristics, cost data, and emissions data by station. These reports contain the following information:

Operating Characteristics

~ Capacity factor in percent	~ Starts
~ Electrical energy in GWh	~ Operating hours
~ Heat produced in billions of BTUs	~ Fuel burn
~ Average heat rate in BTU per kWh	~ Operating cost in dollars per MWh

Cost Data

~ Fuel cost	in thousands of dollars
~ Start cost	in thousands of dollars
~ Fixed operation and maintenance cost	in thousands of dollars
~ Variable operation and maintenance cost	in thousands of dollars
~ Total operation and maintenance cost	in thousands of dollars
~ Dispatch cost	in dollars per MWh
~ Total cost without emissions	in thousands of dollars
~ Total cost with emissions	in thousands of dollars

Emissions Data

SO ₂	in tons	NO _x	in pounds per million BTUs
SO ₂ cost	in thousands of dollars	CO ₂	in tons
NO _x	in tons	CO ₂ cost	in thousands of dollars
NO _x cost	in thousands of dollars	Total Emission Cost	in thousands of dollars

In addition, data may be grouped in user-defined summary classes in two reports containing the following information:

Emissions Data

SO2	in tons	NOx	in pounds per million BTUs
SO2 cost	in thousands of dollars	CO2	in tons
NOx	in tons	CO2 cost	in thousands of dollars
NOx cost	in thousands of dollars	Total Emission Cost	in thousands of dollars

Operating Characteristics and Cost Data

Electrical energy	In GWh
Starts	
Fuel burn	
Fuel cost	in thousands of dollars
Total operating and maintenance cost	in thousands of dollars
Total cost without emissions	in dollars per MWh
Total cost with emissions	in thousands of dollars

There are also reports for the transareas and transmission links. They contain summary information of the activity in each area and on each link.

4.1.2 Metric Energy and Monetary Units

PowrSym4 allows user-defined flags to choose hourly, weekly, monthly, calendar year, and/or fiscal year output files. These files are written in a 132-column format to allow printing. In addition to station output, data can be aggregated by plant.

These reports contain the following information for each station:

Operating Characteristics

Capacity factor	In percent	Number of starts
Electric energy production	In gigawatthours	Hours of operation
District heat production	In TJ	Fuel consumption in TJ
Industrial heat production	In TJ	

Production Costs

Fuel cost	In thousands of dollars
Variable operation and maintenance cost	In thousands of dollars
Fixed operation and maintenance cost	In thousands of dollars
Start cost	In thousands of dollars
Operating cost	In cents per kilowatt-hour
Total cost	In cents per kilowatt-hour

The reports are summarized into the following categories:

System resources by cost, electric production, and heat production

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Total storage generation
 Energy not served by cost, electric production, and heat production
 Storage losses
 Dumped energy by cost, electric production, and heat production
 Energy not served
 Wheeling chargesin thousands of dollars
 Dumped energy
 Total system costin thousands of dollars
 Generation
 Total demand
 Transport losses
 Total storage load

4.2 ACCESS Report Writer

The PowrSym4 Report Writer generates reports using the output files from a PowrSym4 simulation. PowrSym4, with the proper flags set, will generate output files in the alphanumeric identification (AID) format for annual, monthly, and weekly data. The report layout in the Report Writer displays station data grouped by summary class on 8.5" by 11" paper in a landscape format. Thirteen annual or weekly periods are shown as column headings with station names as row headings. The monthly selection shows twelve months with an annual total. The station data can be grouped by the various reporting groups defined in the PowrSym4 simulation data. This Report Writer is a point and click screen driven tool that allows the user to import the PowrSym4 output files and generates reports in a user-friendly environment. Generating a report involves a number of general steps, some of which need to be done only once for each PowrSym4 output file. These steps are:

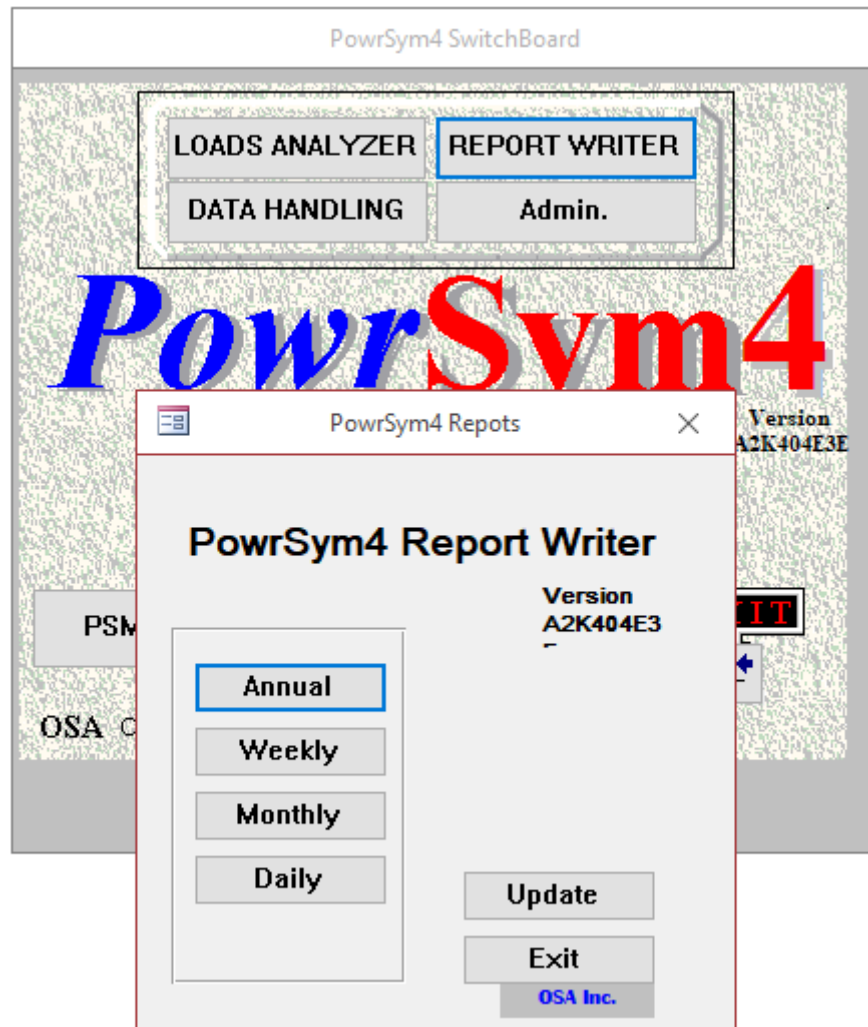
- ~ Updating station relations
- ~ Selecting a reporting period (annual, monthly, or weekly)
- ~ Selecting which statistics to extract from a PowrSym4 output file
- ~ Editing the titles that appear as a report's heading
- ~ Importing PowrSym4 data for a base case
- ~ Importing scenario data for comparison with the base case
- ~ Choosing between viewing data in report format or graphical format
- ~ Selecting starting and ending dates to display on the final report or graph
- ~ Viewing and/or printing the final report or graph

4.2.1 Base Data and Scenario Data

The Report Writer can be used to generate comparison reports using the results of two different runs of PowrSym4. The set of output reports (annual, monthly, or weekly) from one run is referred to as the base case and the set of reports from the other is referred to as the scenario. The user **MUST** compare base and scenario cases for the same time interval.

4.2.2 PowrSym4 Report Writer Main Form

The first form that opens when the Report Writer begins is titled **Select Time Period for Reporting**. It has five action buttons as illustrated by Screen 1. The **Annual**, **Monthly**, and **Weekly** buttons select the desired reporting period, defining which tables and forms are used. The **Exit Report Writer** button closes the main form when it is no longer needed. The function of the **Update Station Relations** button is described in Section 4.2.3.



Screen 1

4.2.3 Updating Station Relations

Updating station relations requires an output file from a PowrSym4 simulation to the Report Writer. This output file could be any of the AID format output files (annual, monthly, or weekly), since station information is included in all of them. The station information extracted from the imported file relates the operating unit statistics with the station names and identifies which reporting group(s) each station belongs to. This function **MUST** be performed the first

time the Report Writer is used after installation. Thereafter, it is only necessary if data are imported with results obtained using new stations added to the PowrSym4 input file or different station names and/or report grouping(s) used for any existing stations .

Steps

1. Click the **Update Station Relations** button on PowrSym4 Report Writer main form illustrated by Screen 1. A **File Selection** dialog box opens.
2. Select an output file and click **OK** to import the file or click **Cancel** to return to the main form without importing.

The file selection dialog box mentioned above allows the user to browse through the computer disk drives or across a network to find the correct file. Clicking **OK** in step 2 after selecting the correct file imports that file and extracts the station relations, storing them for use with any annual, monthly, or weekly reports. These relations will not change until the next time this function is performed.

4.2.4 Selecting a Reporting Period

The Report Writer needs to know which reporting period to consider before performing any function other than updating station relations. The period selected will determine which tables to use for input and which forms to open in response to the action buttons clicked.

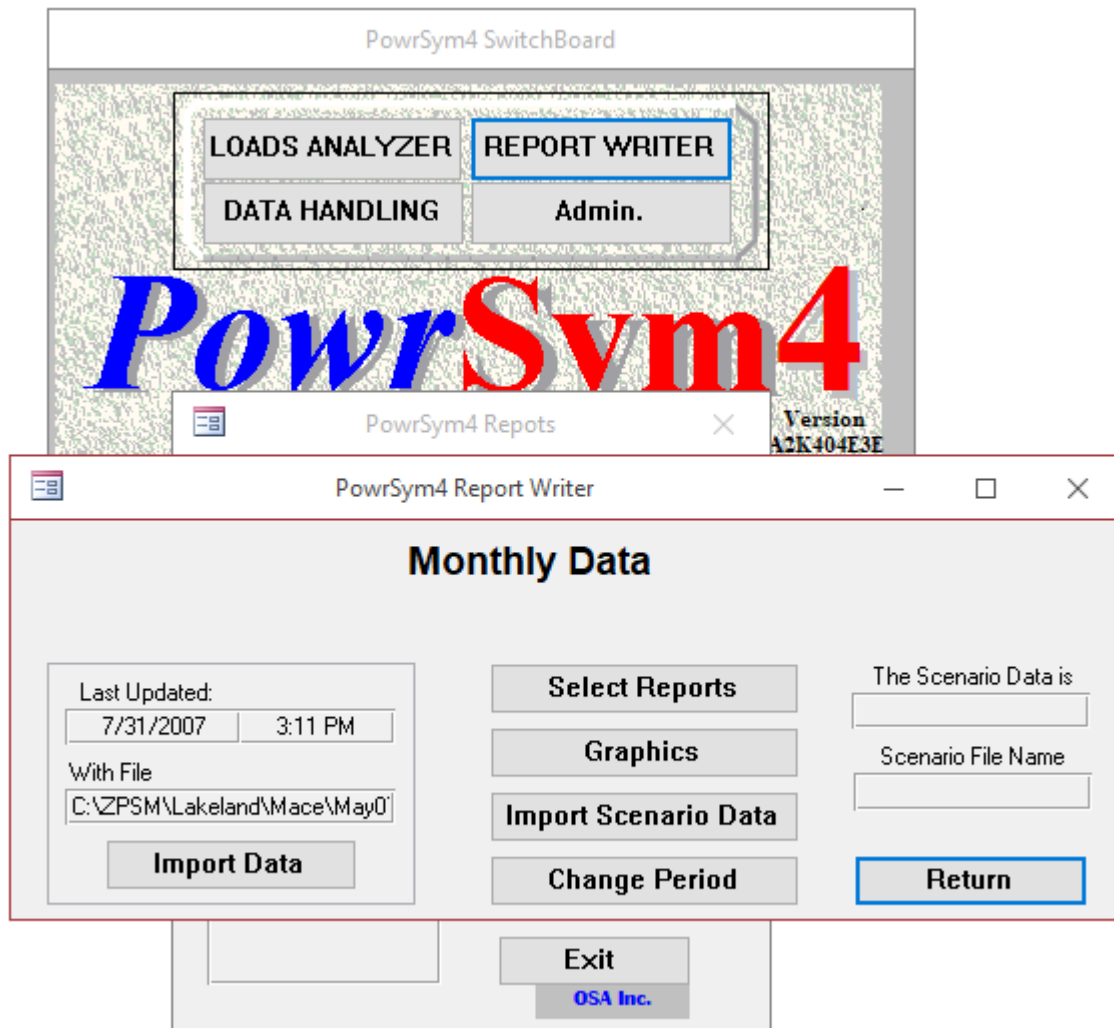
Steps

Only one step is needed to select a reporting period. On the Report Writer main form, click the button for the desired period (**Monthly**, for example). The form illustrated by Screen 2 opens. (Note: The title **Monthly Data** are replaced by **Annual Data** or **Weekly Data** if the **Annual** or the **Weekly** buttons are clicked instead of the **Monthly** button.)

Unless this form is used to change the reporting period, all reports and graphs generated and any related changes are for this period.

4.2.5 Importing PowrSym4 Data

As mentioned earlier, the Report Writer uses imported PowrSym4 output files to generate custom reports and graphs. The results of a particular PowrSym4 run only need to be imported once for each period (annual, monthly, or weekly). These results are stored and used for reporting until the user imports another output file for that period.

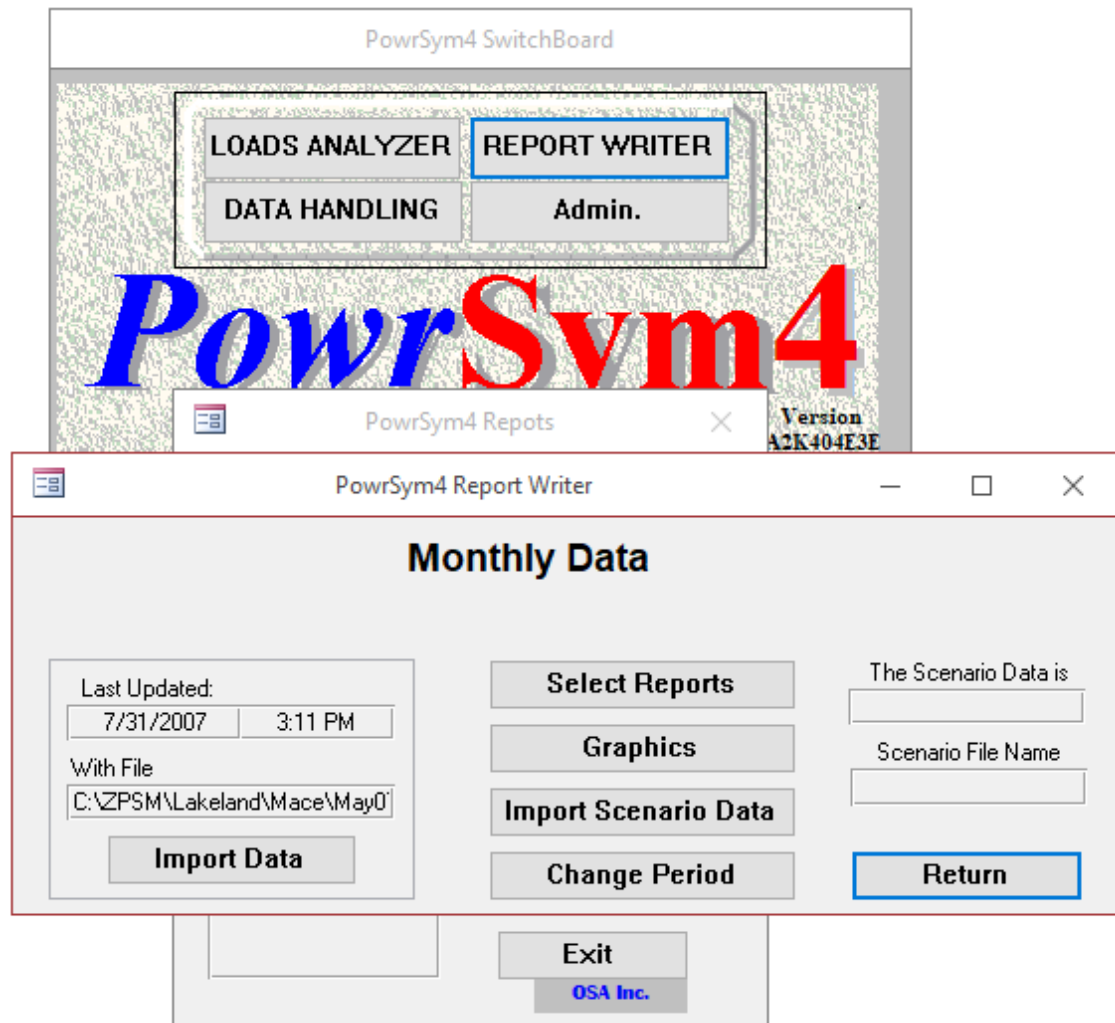


Screen 2

Summary of Steps

The following steps (each of which is explained in more detail in the following subsections) show the details involved in importing PowrSym4 data.

1. Click the **Import PowrSym4 Data** button on the form illustrated by Screen 2. This will open the form illustrated by Screen 3.
2. Click the **Import File** button. A **File Selection** dialog box opens. Select the file to import and click the **OK** button on the dialog box. Wait until importing finishes.
3. Click the **Edit Report Heading** button to change the default headings, if desired. This will open the form shown on screen 4 (see Section 4.2.5.3).



Screen 3

Selecting PowrSym4 Output Statistics

Step 1 of section 4.2.5 above opens Screen 3. The top portion of this form lists the existing selection of output statistics to extract (energy, heat, or fixed cost, for example). Each type of data (annual, monthly, and weekly) has its own selection list. After installation, the report writer retains the selections and data from a previous session. The selection lists show the PowrSym4 AID and a label that describes the data. This label is used as the generic header on the generated reports.

Importing PowrSym4 Data

Once the list of statistics is revised, a file name is needed to define the location of the output data to be imported.

Steps

1. On the form illustrated by Screen 3, click the **Import File** button. A dialog box will open prompting for the file to import.
2. Type the complete path or browse and select the correct file.
3. Click the **OK** button when ready and wait for importing to finish. Click **Cancel** to return without importing.

The file selection dialog box mentioned above allows the user to browse through the computer disk drives or across a network to find the correct file. Clicking **OK** in step 3 imports the base case data that will be used for reporting. The file name and the date and time of the action are saved to help identify the data in the tables. The specified data (annual, monthly, or weekly) is saved. The import action will bring the PowrSym4 data into ACCESS and extract the record types on the statistic selection list. All of this data are stored in a table.

Editing Report Headings

Unless report headings or titles are specified, the Report Writer will use the default titles or the latest edited titles. To review and/or change these headings, follow the steps below.

Steps

1. On the form illustrated by Screen 3, click the **Edit Report Heading** button. This opens the form illustrated by Screen 4.
2. Browse the records using the arrow keys or Page Up/Page Down keys and make any desired changes to the current titles.
3. When finished, click the **Previous Screen** button.

Screen 3 shows the statistics available for reporting (entitled PowrSym4 AID) and their headings for the period considered one record at a time. Only the heading portion of the record can be modified. The headings for the three types of data (annual, monthly, and weekly) are different and can be customized using up to 45 characters. The user moves through the various headings with the Page Up/Down keys or by clicking on the navigation arrows at the bottom of the form where the record number appears.

4.2.6 Importing Scenario Data

The Report Writer can be used to generate reports comparing the results of two PowrSym4 simulations. The set of output files (annual, monthly, or weekly) from one simulation are referred to as the base case and are imported as explained in section 4.2.5.3 above. The set of output files from the second simulation is referred to as the scenario. The steps below are used to import the scenario data for the period considered.

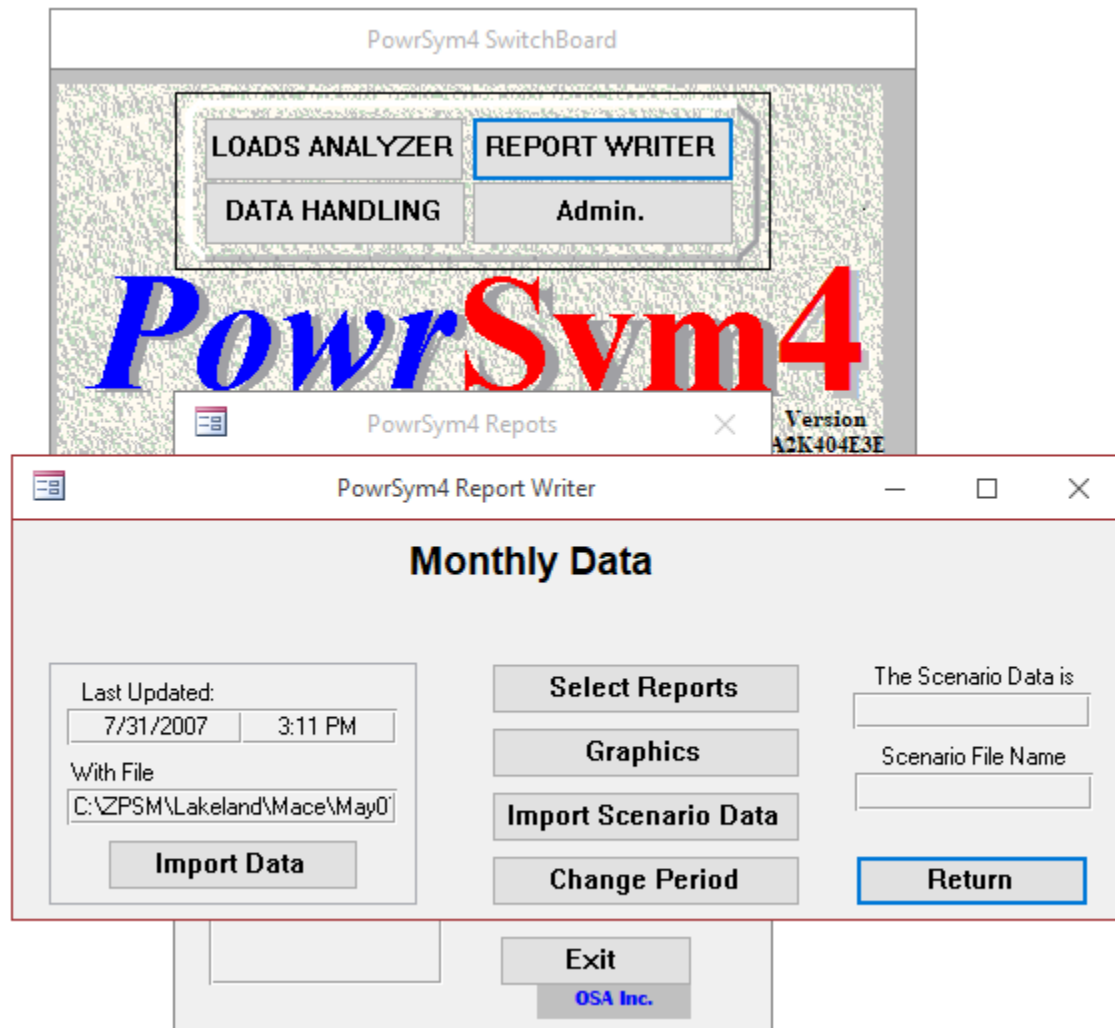
Steps

1. On the form illustrated by Screen 2, click the **Import Scenario Data** button. A dialog box will open prompting for the file to import.
2. Type the complete path or browse and select the correct file.
3. Click the **OK** button when ready and wait for importing to finish. Click **Cancel** to return without importing.
4. If **Cancel** is clicked in step 3 above, two information messages and a third message to continue will appear. Click **No**.

The dialog box that opens in step 1 above will allow the user to select a PowrSym4 output file from a simulation other than the base case. This action button imports the data file, extracts the selected statistics, aligns the data to the base case reporting periods, and creates the delta or difference table. After a scenario file has been imported, the Report Writer will generate reports for all of the statistics for that scenario. It will also generate reports of aggregate statistics for the difference between the base case and the scenario.

4.2.7 Selecting the Report Starting Date

At this point, a reporting period (annual, monthly, or weekly) has been selected. Suppose, for instance, that an annual output file with thirty years of data (1991 to 2020) is imported. The report writer can display reports twelve years at a time. Therefore, the starting year of each twelve-year period to view must be selected. For the file in this example, select the period beginning in 1991 (ending in 2002), 2003 (ending 2014), and 2015 (ending 2020).



Screen 4

Steps

1. On the form illustrated by Screen 2, click the **Change Reporting Period** button. The form illustrated by Screen 4 opens.
2. Select a starting date from the list.
3. Click the **Previous Screen** button when finished.

Clicking the **Change Reporting Period** button allows the user to change the periods. This action opens Screen 5 showing which periods are in the database. After selecting a starting period, the data are loaded in the report tables and the report headers are changed. If a scenario file has been imported, the reporting periods for the scenario and delta tables are kept in alignment with the base case data.

4.2.8 Selecting Which Report to Generate

Once the Report Writer has been initialized, a report is selected to view, print, or export to a spreadsheet or a text file. The statistics were selected from a PowrSym4 simulation output in section 4.2.5.2 and the report starting date in section 4.2.7. The available reports to view are based on these selections.

Steps

1. On the form illustrated by Screen 2, click the **Select Reports** button. This opens the form illustrated by Screen 6.
2. Optionally, type in a title to appear under the report heading in addition to the title edited in section 4.2.5.4. The default is no additional title.
3. Select the report to view from the pull-down list. The default is the first entry from the list.
4. Select a station grouping from the pull-down list. The default is the first entry from the list.
5. Select which case to report: the base case, the scenario, or the delta of the two. The default is the base case.
6. Select the number of decimal places to report.
7. To preview the report, click the **Preview Report** button. The report will open.
8. To send the report to the printer, click the **Print** button. Make sure the computer is connected to the correct printer.
9. To send the report to a spreadsheet or save it as a text file, click the **Report to File** button.

The default values will be used if steps 2 through 6 are skipped. The **Station Grouping** pull-down menu shows the various station groupings from the PowrSym4 simulation. It will always have at least two selections. The unit and plant station groupings are required for a PowrSym4 simulation. The station report grouping is an option that allows up to three additional groupings. The **Select Number of Decimals** pull-down menu allows the user to choose from zero to four decimal places used to display the reported data. The **Select Study to Report** pull-down menu allows the user to select the base case, the scenario, or the delta between the two. By clicking in the **Optional Title for Report** box, the user can enter a report header which is retained until changed by the user or until the **Return** button is activated. The **Return** button returns the user to the main report writer screen.

Screen 6

Station	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
HYDRO								
HYDRO	21	19	21	20	21	20	21	21
COAL								
COAL 1	12	12	11	10	10	9	12	11
COAL 2	10	10	11	12	14	9	9	11
COAL 3	41	41	43	41	18	24	39	38
COAL 4	39	40	22	16	38	37	32	30
COAL 5	81	78	50	31	74	84	79	86
COAL 6	142	127	127	38	0	118	126	124
COAL 7	223	202	223	182	220	214	222	221
COAL 8	142	125	184	168	29	102	174	164
COAL	689	635	672	497	402	596	695	686
CTURB								
GASTURB	1	9	2	1	1	0	1	0
OILTURB	0	4	0	0	0	0	1	0
CTURB	2	13	3	1	1	0	2	0

Screen 7

The **Preview Report** button in step 7 will generate and open the report on the screen. Screen 7 shows an example report. The report is larger than most screens requiring the user to scroll

across and down the page to see all of the report. The Page Up/Page Down keys move through multiple page reports. There are also arrows at the bottom of the screen with the current page number and the total number of pages. These arrows allow the user to move from page to page. The report screen can be closed by clicking the open door icon at the top left of the screen or by double clicking the minus box at the top left of the report.

The **Print** button in step 8 will send the report to the printer connected to Microsoft Windows. The user may need to return to the Windows Control Panel to change the printer destination before using this button.

The **Report to File** button in step 9 opens a dialog box to request the file name and format to export the file as a spreadsheet or as a text file.

4.2.9 Selecting Which Graph to Plot

Section 4.2.8 explained how to select and generate reports from the output of a PowrSym4 run. This section explains how to look at the same PowrSym4 output in graphical format.

Steps

1. On the form illustrated by Screen 2, click the **Graphics** button. This opens the form illustrated by Screen 8.
2. Choose the report from which the graph data will be taken.
3. Select a starting date from the pull-down list.
4. Select an ending date from the pull-down list.
5. Select the data to be used (**Station Data** or **Summary Class**) by clicking the correct option button. If **Summary Class** is selected, the screen will change as illustrated by Screen 9.
6. If **Station Data** are selected in step 6 above, use the two pull-down lists to select a station grouping and a station.
7. If **Summary Class** is selected in step 6 above, use the single pull-down list to select a summary class.
8. Click the **Plot Data** button. The graph will open.

Microsoft Access

File Edit View Records Window Help

PowrSym3 Report Writer

Monthly Data

Station Statistics

Monthly Data

Choose Report: GWh of Generation Starting Date: 1996-01 Ending Date:

Station Grouping: Plant

Choose Station:

Plot Data

Previous Screen

Previous Screen

Select Data to be Plotted

☒ Station data ☐ Summary Class

Form View

Screen 8

Microsoft Access

File Edit View Records Window Help

PowrSym3 Report Writer

Monthly Data

Station Statistics

Monthly Data

Choose Report: GWh of Generation Starting Date: 1996-01 Ending Date:

Station Grouping: Plant

Choose Station:

Plot Data

Select Summary Class

- HYDRO
- HYDRO
- COAL
- CTURB
- PKPUR
- XCHNG
- ECON
- PMPSTOR
- CCYCLE

Select Data to be Plotted

☐ Station data ☒ Summary Class

Form View

Screen 9

Clicking the **Graphics** button in step 1 opens Screen 9, allowing the user to select station data or summary class data. The default is station data. This causes the station grouping selection box and the station selection box to be shown on the screen. The starting period selection box will display all of the time periods that are in the database. The ending period selection box will display all of the time periods that follow the starting period that is selected. The plot button will generate a plot of the statistic selected. If the user selects to plot summary class data, the screen changes. The station group and station selection pull-down lists are replaced with a select summary class list. The screen works the same way for summary class as for station data.

5. PowrSym4 Model Theory

5.1 Chronology and Calendar Issues

PowrSym4 is an hourly chronological model with a weekly optimization horizon. When a Monte Carlo study is performed, all output statistical arrays are accumulated by day. The daily averages are reported as expected values. Within PowrSym4 there are three load format options.

Two of the load-format options tag the hourly loads with the year, week of the year and hour of the week. To report this data chronologically, PowrSym4 uses an internal calendar. With these load formats the year is modeled as 52 weeks of 168 hours, each which is one day short of a normal calendar year and two days short of a leap year. To make the adjustment for the missing day, the seventh day of the first day of the fiscal year is added twice. To determine which day is in which month, the internal calendar starts with day one of week one as January 1. The first day of the first week of the fiscal year is skipped; this day is skipped because this is where the extra day is added in to the monthly and annual data arrays. If the fiscal year end with week 52, then week one starts with January 2 since the first day is skipped. The January reports will show the data represent 744 hours of simulation.

With load format option 2, the hourly loads are tagged with the year, week of year, day of week, month and day of month. With this option, each record has 24 hourly loads for that day. Week one should always have only January loads. Weeks 52 and 53 should be the only months with mixed month and year records. These are the only weeks that are checked to see if the year needs to be changed with the month. Every so often week 52 will end on December 29 or 30, a week 53 is needed to adjust the calendar. This is a whole week adjustment of the leap year effect. PowrSym4 is not checking the month and day of month values in the load records. If the user wants the monthly reports to reflect quarterly totals, let the month values range from 1 to 4 and the daily values range from 1 to 90 or however many days are in each quarter. The report will indicate the number of hours aggregated for the statistics.

PowrSym4 operates on fiscal years and they may be defined by the user. The fiscal year defaults to begin on January 1 but may be specified to begin on any week boundary. Escalation rates are applied at the beginning of the fiscal year.

PowrSym4 Internal Calendar with Fiscal Year Starting on Week 40

<div>Note!</div>		PowrSym3 Internal Calendar						
		JANUARY						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
01	01	02	03	04	05	06	07	
02	08	09	10	11	12	13	14	
03	15	16	17	18	19	20	21	
04	22	23	24	25	26	27	28	
05	29	30	31					
		Note: PowrSym3's Jan. 1 is always a Monday.						
		JULY						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
26							01	
27	02	03	04	05	06	07	08	
28	09	10	11	12	13	14	15	
29	16	17	18	19	20	21	22	
30	23	24	25	26	27	28	29	
31	30	31						
		FEBRUARY						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
05				01	02	03	04	
06	05	06	07	08	09	10	11	
07	12	13	14	15	16	17	18	
08	19	20	21	22	23	24	25	
09	26	27	28					
		AUGUST						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
31			01	02	03	04	05	
32	06	07	08	09	10	11	12	
33	13	14	15	16	17	18	19	
34	20	21	22	23	24	25	26	
35	27	28	29	30	31			
		MARCH						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
09				01	02	03	04	
10	05	06	07	08	09	10	11	
11	12	13	14	15	16	17	18	
12	19	20	21	22	23	24	25	
13	26	27	28	29	30	31		
		SEPTEMBER						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
35						01	02	
36	03	04	05	06	07	08	09	
37	10	11	12	13	14	15	16	
38	17	18	19	20	21	22	23	
39	24	25	26	27	28	29	30	
		APRIL						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
13							01	
14	02	03	04	05	06	07	08	
15	09	10	11	12	13	14	15	
16	16	17	18	19	20	21	22	
17	23	24	25	26	27	28	29	
18	30							
		OCTOBER						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
40	02	03	04	05	06	07	08	
41	09	10	11	12	13	14	15	
42	16	17	18	19	20	21	22	
43	23	24	25	26	27	28	29	
44	30	31						
		Note: PowrSym3's October starts on the 2nd.						
		MAY						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
18		01	02	03	04	05	06	
19	07	08	09	10	11	12	13	
20	14	15	16	17	18	19	20	
21	21	22	23	24	25	26	27	
22	28	29	30	31				
		NOVEMBER						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
44			01	02	03	04	05	
45	06	07	08	09	10	11	12	
46	13	14	15	16	17	18	19	
47	20	21	22	23	24	25	26	
48	27	28	29	30				
		JUNE						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
22					01	02	03	
23	04	05	06	07	08	09	10	
24	11	12	13	14	15	16	17	
25	18	19	20	21	22	23	24	
26	25	26	27	28	29	30		
		DECEMBER						
Week	Mon	Tue	Wed	Thu	Fri	Sat	Sun	
48					01	02	03	
49	04	05	06	07	08	09	10	
50	11	12	13	14	15	16	17	
51	18	19	20	21	22	23	24	
52	25	26	27	28	29	30	31	

calendar.ppt/wmf

Table 5.1.1

The following flowcharts illustrate the simulation logic used in PowrSym4.

PowrSym⁴ **Execution Flow**

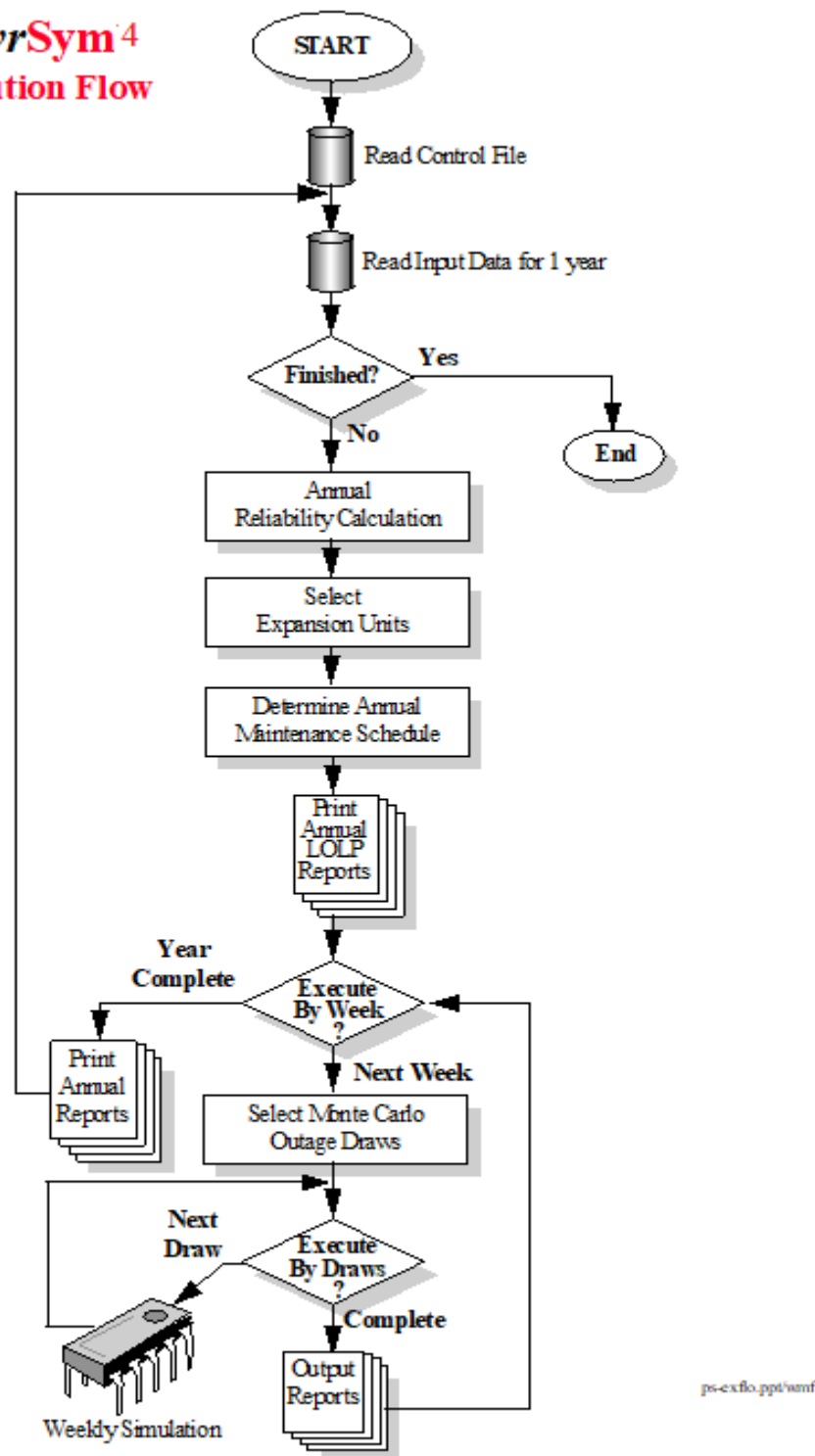


Figure 5.2.1

PowrSym⁴ **Weekly Simulation**

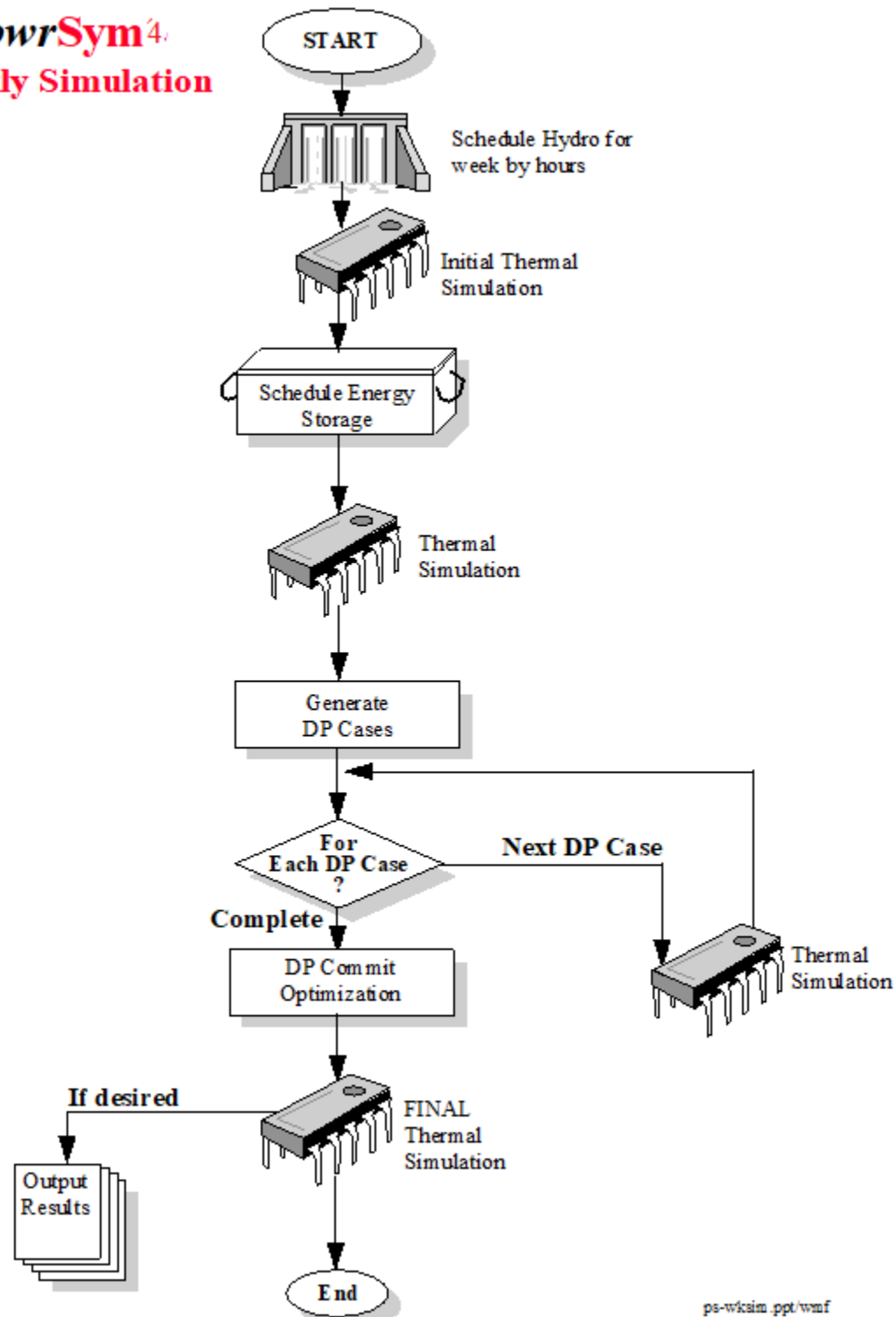


Figure 5.2.2

PowrSym⁴
Thermal Simulation
Hourly Sequential Method

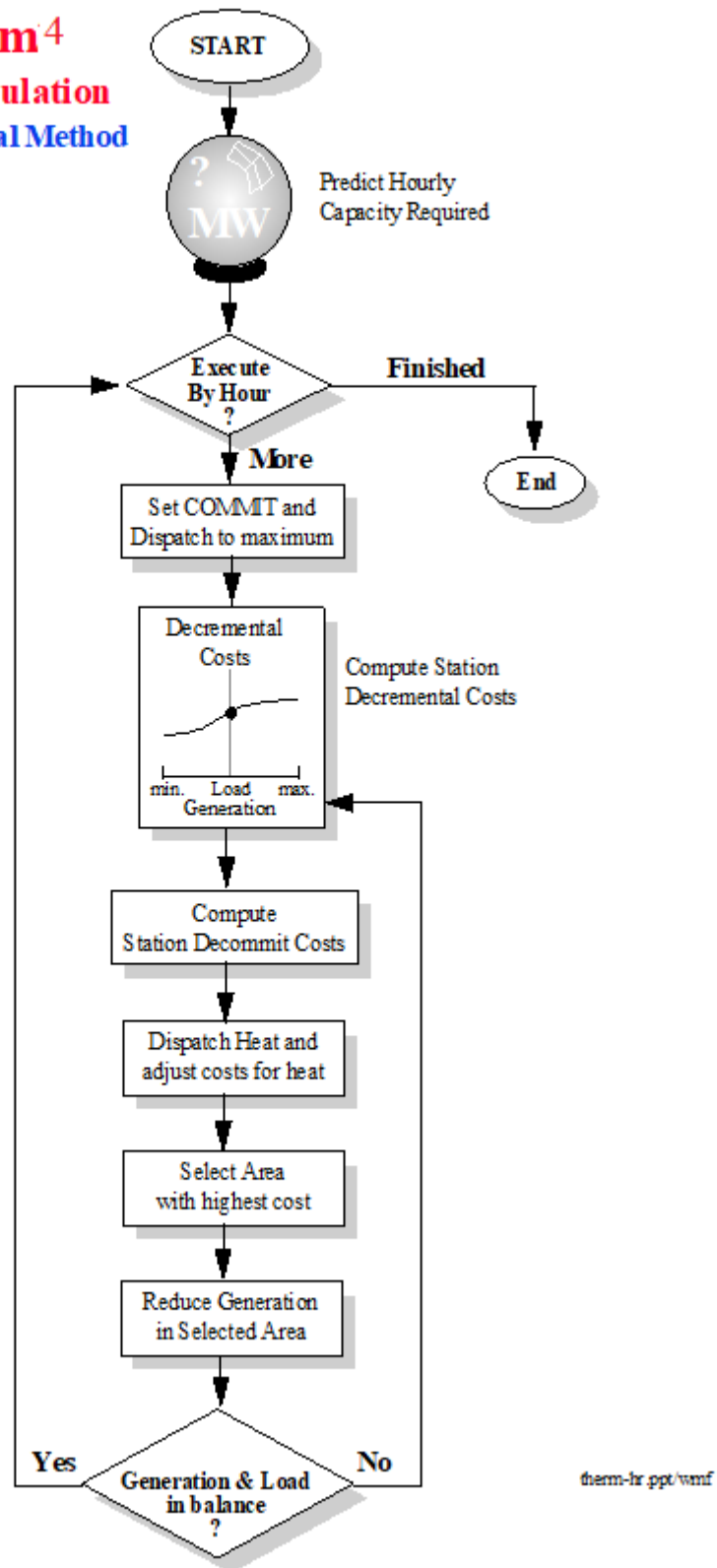
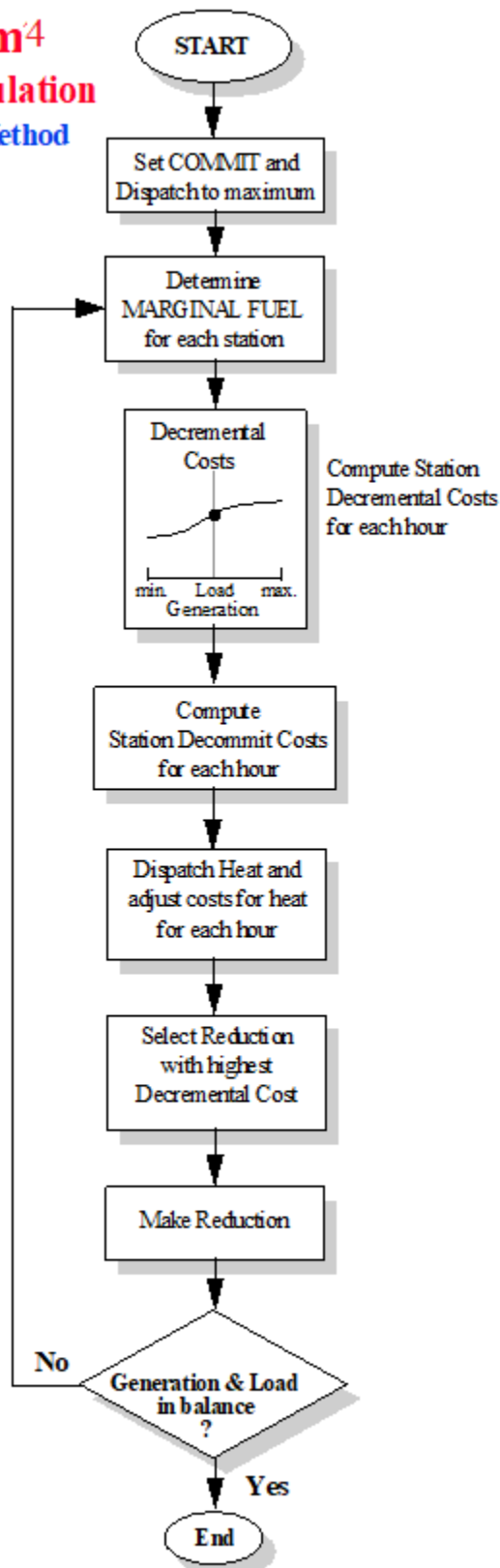


Figure 5.2.3

PowrSym⁴
Thermal Simulation
Concurrent Method



therm-al.ppt\wmf

Figure 5.2.4

5.3 Annual Reliability Model

PowrSym4 has an integrated loss of load probability algorithm which computes system reliability using probabilistic techniques. The actual reliability and the surplus or deficit of system capacity relative to a specified reliability index is computed. The model will optionally adjust the installation dates of new capacity additions in a specified sequence to meet system reliability requirements. Loss of load probability and expected unserved energy are computed hourly and summed by week, month and year. Capacity requirements may be computed relative to a weekly index, an annual index, or both.

5.4 Auto Expansion

The auto expansion option selects expansion units from base load, intermediate load, or peaking categories based on a combination of capacity needs and energy needs. The expansion units within each category are selected in a specified sequence.

5.5 Maintenance Schedule Model

5.5.1 Prescheduled Maintenance

The prescheduled maintenance is read from an input file, which is described in detail in Section 6.2.7. The file contains the number of generating units, which are to be scheduled out for each station and the amount of time these units are to be down for maintenance. Outage hours are divided by 168 to find the integer number of weeks to be scheduled for maintenance. The remaining x hours are chosen to be scheduled as the last x hours of the first week of maintenance period. A maintenance event may not cross a year boundary, which requires that all hours of maintenance for a certain year to be scheduled before the end of that year.

The maintenance schedule file may be prepared manually from an existing or planned schedule or may be prepared by an automated maintenance-scheduling model.

5.5.2 Combined Maintenance

It is possible to combine an external maintenance schedule and the calculated maintenance option. For each unit, any scheduled maintenance outages will be deducted from the calculated maintenance outage rate and the remainder, if any, will be scheduled.

5.5.3 Calculated Maintenance Schedule

PowrSym4 can specify a future maintenance schedule based either on levelizing the weekly loss of load probability or minimizing the effect of maintenance on annual production cost. In either case, the planned maintenance outage rate of each generating unit is translated into a single contiguous outage of the appropriate number of hours. Any prescheduled outage hours are deducted from this amount to determine the number of hours that PowrSym must schedule for that year.

To specify a reliability-based outage schedule the maintenance events are scheduled, large units first, with the objective function of levelizing the weekly loss of load probability and minimizing the annual loss of load probability.

Maintenance can also be scheduled to minimize the effect on annual production cost using a heuristic search scheme. This approach allows groups of units to be scheduled for maintenance while conforming to scheduling constraints. The cost objective function used for maintenance scheduling can reflect different values for fuel cost, energy not served, and loss of load hours than are used for production cost calculations.

5.5.4 LOLP Calculation

The reliability index (LOLP) is computed as the objective function for maintenance scheduling and is also included in the output reports. The index is computed as the expected hours per week of capacity deficiency. The index is computed for each hour of the week independently and summed for the week.

The computational method is based on a simplified version of the cumulant method and does not go to the level of detail of the reliability LOLP model. However, the results track with those of more detailed models, and the method serves quite well as an objective function for maintenance scheduling.

5.6 Forced Outage Model

The PowrSym4 chronological production costing model has six modes of simulation for forced outages. All of these modes can use the same data set. The six modes of simulation are:

- | | |
|--------------------------|-------------------------------|
| ~ Fixed outage schedule | ~ Random Monte Carlo |
| ~ Derating method | ~ Selected Sample Monte Carlo |
| ~ Gradient derate method | ~ Semi-guided Monte Carlo |

The representation of forced outages and forced deratings in chronological production costing models has been the subject of much research in recent years. The six methods available in PowrSym4 represent most of the methods available in the literature. Each of the methods has advantages and disadvantages for various types of studies. Unfortunately, the perfect solution awaits new methods or faster computers.

5.6.1 Fixed Outage Schedule

Forced outages and forced deratings may be input to PowrSym4 as a given input, and the model will assume all remaining resources to be available with certainty. This method is suitable for very short-term studies of specific scenarios. This method is fast because no iterations are required. The fixed outage schedule is often used for debugging and model comparisons in order to remove the fluctuations caused by varying outage scenarios.

5.6.2 Derating Method

The derating method reduces the capacity of each generating unit by the forced outage rate. For a large system, this is approximately the same as the statistical method used in older versions of POWRSYM. This method is fast because no iterations are required, but the operation of peaking resources such as pumped hydro and combustion turbines will not be accurate. This method tends to understate the use of pumped hydro. The amount of capacity on outage is always at the average condition. No extremes are observed.

5.6.3 Gradient Derate Method

The gradient derate method is a TVA specified method of derating for forced outages in the short term. It approaches the standard derating method over the long term.

Derating curve:

$$Y(t) = 1.0 - e^{-At} (1.0 + Kt^2)$$

$$\text{Capacity} = \text{Rated Capacity} (1 - e_{\text{for}} * Y(t))$$

Where A and K are constants and
e_{for} is equivalent forced outage rate.

5.6.4 Random Monte Carlo Method

The random Monte Carlo method is a brute force procedure to calculate expected system operation of the system by averaging a number of outage scenarios created by a random number generator. If enough iterations are used, this is the most accurate method of representing forced outage and forced derating events but is also the most time consuming. The extreme outage events, both good and bad, are represented and the operation of pumped hydro and combustion turbine peaking units is realistic.

The outage draw duration is an input to PowrSym4 and may be 168 hours or less. A new set of random draws will be made at the beginning of each duration period for the state of the units during the period. A unit is in or out for the duration of the period. With a duration of 168 hours, draws will be made once per week and with a duration of 12 hours, draws will be made 14 times per week. In a future version of PowrSym4, the draw duration will also be a random variable for each generating unit converting the model to frequency and duration mode Monte Carlo.

Reducing the draw duration introduces more random draws and speeds convergence with fewer iterations. However, reducing the duration to much less than the average system outage duration will increase the number of unit starts and stops above that which will actually occur on the system. A draw duration of 24 hours is a realistic compromise between accuracy and speed for most systems.

For a large power system such as TVA it has been found that 50 to 100 random draws are required for convergence. This means that only one iteration is needed for long range studies in which only the annual results are of interest, even with a 168-hour outage duration. With a daily

duration, seven to fifteen iterations are required for weekly convergence and two to four iterations for monthly convergence. With a 168-hour duration, 50 or more iterations are required for weekly convergence.

5.6.5 Selected Sample Monte Carlo

The selected sample Monte Carlo draw method uses a fast objective function to approximate the production cost results for each iteration. A large number of iterations, 100 up to 1000, are used to define the sample space, and the objective function results are sorted to create an objective function probability curve. This curve will not be normally distributed but will be skewed in the upward direction because of the increasing system lambda associated with higher outage draws. A smaller number of samples, usually five to eleven and always an odd number, are then chosen to represent the entire sample space in detailed production cost calculations. The samples are chosen by dividing the curve into equal areas.

This method insures that a small sample is not overly weighted by a “bad” draw and that the draws are uniformly selected to represent the entire sample space. A draw sample of one would use the sample nearest the mean of the distribution. The reason for using an odd number of samples is to force inclusion of the mean sample.

The strength of this method is that weekly production cost totals are usually very near the converged values with greatly reduced computation time. Generation by station type and fuel category is also well behaved. However, individual station results are not well converged and base load plants may not be operating at their expected capacity factors on an individual basis, although the average for the entire group of base load plants is likely to be near the expected values.

A special consideration for the selected sample method is the repeatability of the draw sample. When comparing model results, it is important that each run have the same random draws. Since the model is selecting the draws to be used in this method, it is necessary to save the draw sample file from the first run and force the following runs to use the draw sample file instead of creating new draws.

5.6.6 Semi-Guided Monte Carlo

The Semi-Guided Monte Carlo method is described in detail in a paper titled “Using a Semi-Guided Monte Carlo Method for Faster Simulation of Forced Outages of Generating Units” presented by Scully, et. al., at the Seventeenth PICA Conference. T. Jackson and C. Stansberry of TVA reviewed this paper. This method is used extensively in ABB Power Systems models.

This method produces statistically balanced forced outage schedules over an extended time period, usually one year. Results for shorter time periods within the year are not converged, but the annual results for both system totals and individual station results are very well behaved. The method is fast as only one iteration is required. This is the method of choice for medium and long range planning studies where only annual results are of interest.

5.7 Hydro Model

Hydro stations are scheduled to operate in such a manner as to levelize the load shape to be served by other stations. Hydro stations are scheduled sequentially over the weekly time horizon, subject to hourly constraints for minimum and maximum generation, and weekly constraints on ramp rates, and energy. Typically, hydro levelizes the overall system load; however, a hydro station can be scheduled to meet the load of a transmission or control area (e.g., when there are transmission constraints preventing the station from benefiting the system as a whole).

The station is first scheduled to operate at its hourly minimum for all hours, and the load for each hour is reduced by the amount of this generation. If this schedule is less than the available energy for the week from the station, the generation is increased by an increment for the hours with the highest adjusted loads. The loads for these hours are accordingly adjusted downward. Hourly constraints are enforced during the dispatch process. This process is continued until the total weekly generation for this station matches the available energy from the station. Interpolation is used on the last increment.

It is possible to specify the daily maximum and minimum energy to be used by a hydro station. If the sum of the daily maximums is less than the weekly energy allocation, a warning is issued, and all available energy is not used. If the sum of the daily minimums is greater than the weekly energy, a warning is issued, and hydro scheduling stops when all energy has been used.

Hydro can be simulated in cascade mode as well. See CHYD records in the Analyzer.

5.8 Simulation Methods

Simulation methods include sequential and concurrent. See 2.3 General Model Description.

5.9 Sequential Hourly Simulation

See 2.3.1

5.9.1 All-hours Simulation

See 2.3.1

5.10 Spinning and Operating Reserve

Most systems must carry sufficient operating reserves to cover the greatest contingency, often the largest generating unit on the system. For those systems operating under NERC guides, half the operating reserves should be spinning for regulation and instantaneous contingencies.

Spinning Reserve (the difference between the dispatched capacity and the sum of the full load capacity of all generating units) is expressed as a percentage of the hourly load plus a constant.

PowrSym4 features a detailed reserve specification. Spinning reserve is derived from firm-on-line units and firm transactions, while operating reserve additionally includes idle quick-start units. Each generating unit is specified as non-firm capacity, firm capacity, or quick-start capacity. Transactions may be either non-firm or firm. Non-firm capacity does not contribute to either spinning or operating reserve. Firm capacity contributes to both spinning and operating reserves when on-line. Quick-start capacity contributes to both spinning and operating reserves when on-line and to the operating reserve when off-line. An upper bound may be placed on the reserve contribution of each unit as well as a minimum required reserve contribution.

Both spinning and operating reserves may be specified for the system and for each area defined in the system or for user defined control area made up of separate areas.

An addition type of reserves, Back-up reserves, is also provided to allow the specification of availability of a slower response reserve requirement.

5.11 Multi-Area Model

PowrSym4 can be used in the multi-area mode to represent transmission areas within a system and/or to model interconnected systems. Each station is assigned to an area and each area may have a separate load file or a fraction of a total load file. Each area may be connected to any or all other areas through links. Each link has provision for a maximum transport capability, a transmission service charge, and a loss factor. The link data can be specified differently for each direction. Spinning reserve and operating reserve requirements may be specified for each area, or user defined control areas. PowrSym4 does not commit resources in one area to make up for reserve deficiencies in another area. To simulate this situation, a control area has to be defined that contains the two areas and carea reserves set.

Economy power flows between the areas are computed during the simulation process using a transport algorithm (not a load flow). It is assumed that all feasible economy transactions will be made.

PowrSym4 accommodates very large models involving potential transactions between many individual transareas. Run times for these large models can become quite long. One option for shortening run time is to reduce the level or precision in the model. PowrSym provides the ability to collapse all Tareas into a single new Tarea that matches the associated control area. Using this feature eliminates any limitations regarding transfers between Tareas, but preserves the linkage between the control area to other external areas.

5.12 Combined Heat and Power

Stations that produce heat and electricity, electricity only, and heat only can be simulated. See HEAT*records in the Analyzer.

5.13 Dynamic Programming Commit Optimization

Dynamic programming techniques have been used in power system operational models to obtain a ‘near-optimal’ answer to the unit commitment and dispatch problem but at a significant cost in computational requirements.

In PowrSym4 a dynamic programming enhancement is used to ‘fine-tune’ the result of the heuristic outcome. Because of the monotonic nature of the dispatch problem, PowrSym4 is able to quickly dispatch a period if the commitment is predetermined. Thus, the dynamic program is only used to search for a better commitment. Current algorithms of PowrSym4 are used in combination with user ‘expert’ inputs to produce several feasible commitments for each hour. After completing the dispatch of these commitments, each feasible hourly commitment is tagged with its production cost. The dynamic program module is then able to find the combination of these hourly commitments which yields the lowest cost (including startup) for the week.

In this phase of implementation, the ‘expert’ in the expert system component is simply a set of user inputs which force the heuristic algorithms of PowrSym4 to make commitment decisions it might have otherwise made differently. Currently these inputs are defined in terms of passes. Pass 1 is the heuristic pass. Other passes are defined by forcing units to be either on, off, or the same as in pass 1, and then re-running the heuristic pass with these additional constraints. For example, if the user thought that the heuristic pass turned a unit on that it should have left off, the user could have pass 2 force that unit to be off. It should be noted that the dynamic program does not select a particular pass - it selects the best commitment for each hour, given its input nodes. These hourly commitments are not restricted to come from a certain pass. The dynamic program checks minimum up and down constraints to make sure that its commitment combinations are feasible.

Reverse dynamic programming is used to determine the optimal commitment for a period of hours given an input array containing one or more possible commitments for each hour and the associated production costs. Because of the large size of the array, not all possibilities can be searched. However, if several ‘good’ possibilities for each hour are used, the dynamic program can generally find a better answer than the heuristic answer. If no better answer is found, the heuristic answer will be returned.

The output is simply the best path through the entire period (currently a week). PowrSym4 will then re-run dispatch, forcing this path to be taken. Also, output is a file, TABLE.OUT, that contains the number of units on at each station in every hour for this path, as well as some statistical results of the DP.

5.14 Electric Energy Storage Model (Pumped Hydro)

PowrSym4 provides the capability of simulating energy storage technologies. These simulations are based on concepts derived from the most commonly used energy storage technology, Pumped Hydroelectric generation, but lend themselves to broader applications as well.

In general, PowrSym starts with a specified amount of energy contained in an energy storage reservoir at the beginning of the week (i.e. 1:00 AM on Monday). Also specified is the amount of energy to be in storage at the end of the week. This allows the flexibility to alter the amount of energy in storage between weeks. It is generally preferable, however, to specify the ending point to be the same as the starting point to avoid potential distortions in the operating economics. PowrSym further constrains the operation of an energy storage unit to preclude overfilling the associated energy reservoir or draining it below empty. Within the operating constraints, PowrSym determines when generation and pumping should be performed to minimize the total system cost during the week.

Efficiencies associated with adding energy to the storage reservoir or with converting energy from the storage reservoir are included in the simulation. The simulation can also reflect differences in generating capability that result from changes in reservoir level (head). Combining energy storage simulation with generating station simulation allows representation of complex energy storage technologies such as compressed air energy storage (CAES).

5.15 Heat Storage Model

The model simulates heat storage. See HST*records in the Analyzer.

5.16 Emissions Influenced Operation

Emissions are computed based on the fuel consumption and emissions rate or on an equation for emissions of each unit for a variety of emission types. External costs may be assigned to emission types. These emission costs are included in the commit and dispatch logic such that the sum of generation costs plus emission costs is minimized.

5.17 Fuel Contract Method - Energy Limited Fuels (ELF)Module

5.17.1 Introduction To ELF Module

The Energy Limited Fuels Module, when used in conjunction with the Concurrent method, directly solves energy limited fuels allocation. This is accomplished by keeping the ELF fuel allocated optimally as units are dispatched down and decommitted. For a given commit, ELF allocation will be optimally solved.

The ELF allocation is solved using network flow programming. Fuel constraints and prices as well as station demand are modeled using a system of nodes interconnected by links. Each constraint has an associated set of nodes (i.e., weekly constraints for a fuel are assigned a node, daily constraints for that same fuel are assigned a set of 7 nodes, one per day, and hourly constraints for the fuel are assigned a set of 168 nodes.) Additional nodes are added to the network in order to represent stations, one node per hour per station. The last node assigned to the system represents both the source and the sink. All fuel flows through the system links from the source node to the sink node.

Links are used to interconnect the above set of nodes. Following the example started above, for the given fuel, the source is connected to the weekly fuel node (lelfwk), which is, in turn, connected to each daily node (lelfdy), which are then connected to their respective hourly nodes (lelfhr). Each hourly fuel node is connected with the hourly station node for all stations using this particular fuel (lstahr). Each hourly station node is then connected to the sink (ldemand) thereby completing the circuit. In addition to the links directly associated with a particular elf, there are spot links, which connect the source with each station hour (lspot), and dump links, which connect each elf hour with the source.

Each link, connecting a node U to a node V, has a mirror link, which connects node V to node U. Flow is scheduled on links, from source to sink, and unscheduled on mirror links, sink to source. Associated with each link are its cost (costl), flow (flowl), and potential flow (amntl). The cost for a link is determined by violation cost, which is the amount of fuel flowed with respect to the constraints for that link and fuel cost, which is the cost of flowing a unit of fuel on the link. The flow for a link is associated with the link only, not the mirror link, and represents the net amount of fuel that has passed from node U to node V. The potential flow for a link is the amount of fuel, which may be flowed before the cost of flowing that fuel changes. This potential flow is associated with both links and mirror links.

A Bellman-Ford shortest path algorithm is used to determine the shortest path between any two given nodes (a source and a sink). The algorithm consists of searching for the path from the source that minimizes the potential of a node through a relaxation process. The source always has zero potential, and all potentials and paths are referenced to it. The potential of a node V that is being potentialized from a node U across link (U, V) is calculated as the sum of the potential of node U and the cost of link (U, V). In relaxation a node is potentialized if the potential calculated is less than the current potential of the node. All nodes other than the source are initialized with an infinite potential.

The ELF network models fuel limits, fuel storage, and fuel costs for multi-fuel, multi-station systems. That is, each fuel may be consumed at one or more stations, and each station may consume one or more fuels. Weekly, daily, hourly, and station specific constraints are modeled in series as shown in Figure 5.16.1. In addition to fuel delivery, three levels of fuel inventory are modeled as shown in Figure 5.16.2.

ELF Constraint Hierarchy

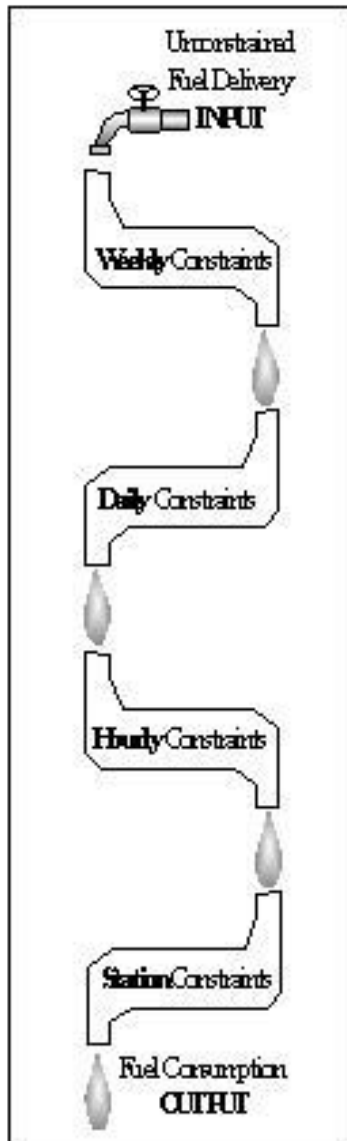


Figure 516.1

ELF Constraint Hierarchy Showing 3 Levels of Fuel Inventory

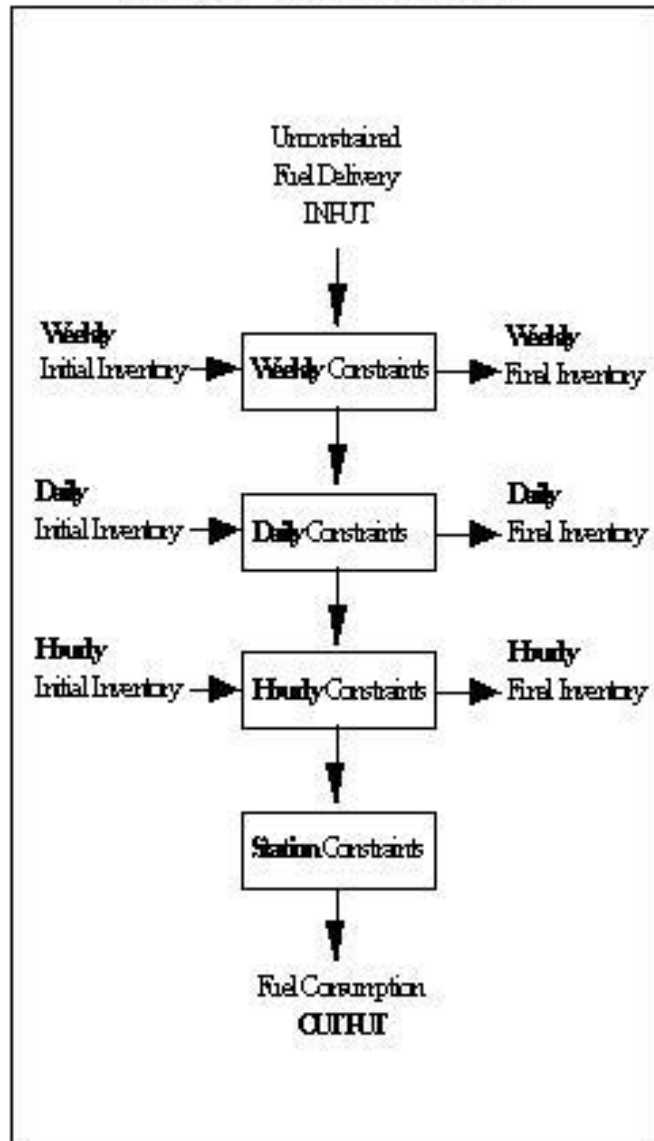


Figure 516.2

5.18 ELF Variables

The following constraints are used to describe each fuel:

ELF NAME	Fuel name	
ELF COST	Unconstrained fuel cost	
DAILY ELF HEAT VALUE	Heat value	(reporting purposes only)
ELF WEEKLY MIN	Weekly minimum delivery of a fuel	(may vary by week)
ELF WEEKLY MAX	Weekly maximum deliver of a fuel	(may vary by week)
ELF MIN	Daily minimum delivery of a fuel	(may vary by day)
ELF DAILY MAX	Daily maximum delivery of a fuel	(may vary by day)
ELF HOURLY MIN	Hourly minimum delivery of a fuel	(may vary by hour)
ELF HOURLY MAX	Hourly maximum deliver of a fuel	(may vary by hour)

The following constraints describe how stations may consume fuels:

FCOST	Unlimited spot fuel cost for all stations	(not variable)
STA ELF INDEX	Defines additional fuels a station may consume	(not variable)
STA ELF TMIN	Hourly minimum transport of a fuel to a station	(vary by hour)
STA ELF TMAX	Hourly maximum transport of a fuel to a station	(vary by hour)
STA ELF TCOST	Hourly transport of a fuel to a station	(vary by hour)

In addition, three sets of inventory related constraints are defined.

Weekly inventory:

ELF WEEKLY IINV	Initial inventory for current week	(may vary by week)
ELF WEEKLY FINV	Final inventory for current week	(may vary by week)

Daily inventory:

ELF DAILY IINV	Initial inventory for day 1	(may vary by week)
ELF DAILY FINV	Final inventory for day 7	(may vary by week)
ELF DAILY IMIN	Minimum inventory between days	(may vary by day)
ELF DAILY IMAX	Maximum inventory between days	(may vary by day)

Hourly inventory:

ELF HOURLY IINV	Initial inventory for hour 1	(may vary by week)
ELF HOURLY FINV	Final inventory for hour 168	(may vary by week)
ELF HOURLY IMIN	Minimum inventory between hours	(may vary by day)
ELF HOURLY IMAX	Maximum inventory between hours	(may vary by day)

These sets of constraints specify the allowable ranges of each fuel that may be consumed in each hour and at each station. In most cases, only a small set of constraints will be needed to model a particular fuel, and any unused paths (either zeroed or unconstrained) will not be included in the optimization network. Derating variables are listed in Section 5.16.6.

5.18.1 Detailed Network Representation

All ELF minimums, maximums, costs, and initial values are modeled in a standard network flow representation. In this representation, "nodes" are interconnected by constrained "links". Each node is a summation point and must observe the following continuity constraint:

The sum of the flows along links into a node must equal the sum of the flows along links out of a node

Due to limited floating point precision, the current model observes this constraint to within one one-thousandths (0.001) at each node.

Besides the continuity constraint, the only other information associated with a node is which links are connected to that node. All user constraints are assigned to network links. In general, each link has at most three constraints -- a minimum, a maximum, and a cost. Figures 5.16.3 and 5.16.4 show the relationship of the ELF and STA ELF variables to the links of the ELF network.

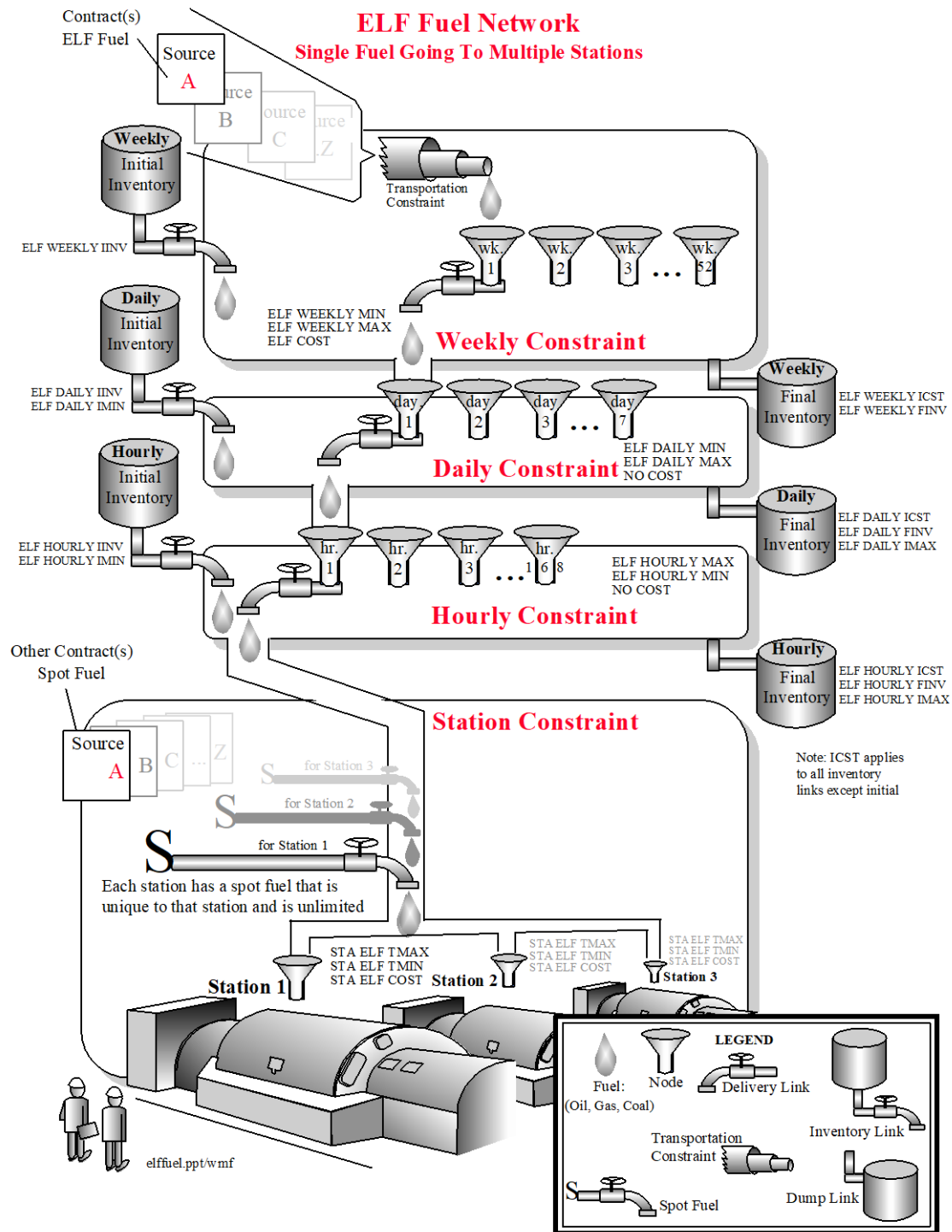


Figure 5.16.3

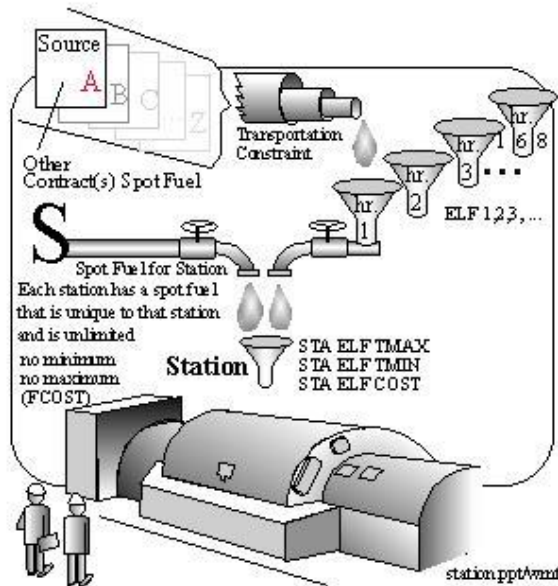


Figure 5.16.4

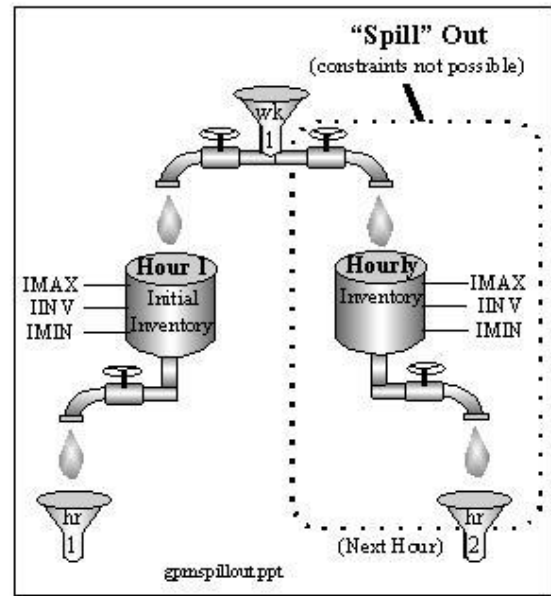


Figure 5.16.5

There are two types of links -- delivery links and inventory links. Delivery links flow from top to bottom and

are shown as this symbol (). Inventory links are shown as these symbols (), (), ().

For each ELF fuel, there is one week node, 7 day nodes, and 168 hour nodes shown as this symbol (). For each ELF station, there are 168 station-hour nodes. Thus, Figure 5.16.3 will be repeated for each fuel, and Figure 5.16.4 will be repeated for each ELF station. Constraints for each link type are labeled with the appropriate input variable. Note that all constraints are direct functions of input variables.

Figures 5.16.3 and 5.16.4 do not show additional weekly, daily, and hourly dump links flowing out of each ELF week, day, and hour node. Dump links allow fuel to "spill" out of week, day, and hour nodes if constraints are not possible to meet. For example, Figure 5.16.5, if there is a weekly minimum but all stations are forced out, then an amount equal to the weekly minimum will spill to the weekly dump link. The model will never violate maximum constraints, although it is possible to violate daily or hourly minimum constraints if weekly or daily maximums are too constraining.

5.18.2 Constraint Relationships

The ELF flow variables are:

Delivery:

Weekly	Fweek(fuel)
Daily	Fday(fuel, day)
Hourly	Fhour (fuel, hour)
Transport	Ftrans (station, fuel, hour)
Spot	Ftrans (station, 0, hour)

Inventory:

Daily	Fdayi (fuel, day)
Hourly	Fhouri (fuel, hour)

Dump:

Weekly	Fweekd (fuel)
Daily	Fdayd (fuel, day)
Hourly	Fhourd (fuel, hour)

Given inputs:

Initial Inventory:		Final Inventory:		Station Demand	
Weekly	Fweeki (fuel, 0)	Weekly	Fweeki (fuel, 1)	Station Demand	Fdemand (station, hour)
Daily	Fdayi (fuel, 0)	Daily	Fdayi (fuel, 7)		
Hourly	Fhouri (fuel, 0)	Hourly	Fhouri (fuel, 168)		

Given the detailed network diagrams, we can derive the relationship between ELF flow variables from the nodal continuity equations:

For each fuel:

Equation 1

$$Fweek(fuel) + Fweeki(fuel, 0) = \text{SUM}\{Fday(fuel, \text{day}=1..7)\} + Fweeki(fuel, 1) + Fweekd(fuel)$$

Equation 2

$$\begin{aligned} Fday(fuel, 1) + Fdayi(fuel, 0) &= \text{SUM}\{Fhour(fuel, \text{hour} = 1..24)\} + Fdayi(fuel, 1) + Fdayd(1) \\ &\vdots \\ Fday(fuel, 7) + Fdayi(fuel, 6) &= \text{SUM}\{Fhour(fuel, \text{hour} = 145..168)\} + Fdayi(fuel, 7) + Fdayd(7) \end{aligned}$$

Equation 3

$$\begin{aligned} Fhour(fuel, 1) + Fhouri(fuel, 0) &= \text{SUM}\{Ftrans(\text{station}=1..n, \text{fuel}, 1)\} + Fhouri(fuel, 1) + Fhourd(1) \\ &\vdots \\ Fhour(fuel, 168) + Fhouri(fuel, 168) &= \text{SUM}\{Ftrans(\text{station}=1..n, \text{fuel}, 1)\} + Fhouri(fuel, 168) + Fhourd(168) \end{aligned}$$

Where:

n is the indexed number of stations on the fuel

For each station:

Equation 4

$$\begin{aligned} \text{SUM}\{Ftrans(\text{station}, \text{fuel}=0..m, 1)\} &= Fdemand(\text{station}, 1) \\ &\vdots \\ \text{SUM}\{Ftrans(\text{station}, \text{fuel}=0..m, 168)\} &= Fdemand(\text{station}, 168) \end{aligned}$$

where

m is the indexed number of fuels serving the station.

An alternate measure, not given by the above nodal constraints, is to compute the total fuel consumed in a given week or day. These amounts are given by the following equations:

$$\begin{aligned} \text{Day 1 consumption} &= \text{SUM}\{Ftrans(\text{station}=1..n, \text{fuel}, 1..24)\} \\ &= Fday(fuel, 1) + Fdayi(fuel, 0) + Fhouri(fuel, 0) - Fdayi(fuel, 7) - Fhouri(fuel, 168) \end{aligned}$$

$$\begin{aligned} \text{Week consumption} &= \text{SUM}\{Ftrans(\text{station}=1..n, \text{fuel}, 1..168)\} \\ &= Fweek(fuel) + Fweeki(fuel, 0) + Fdayi(fuel, 0) + Fhouri(fuel, 0) - Fweeki(fuel, 1) - Fdayi(fuel, 7) - Fhouri(fuel, 168) \end{aligned}$$

These constraints are derived by considering a supernode, which consists of all the nodes in a day or week, respectively. Because all flows are additive, the sum of the flows into such a supernode must all observe the continuity constraint.

5.18.3 Interpretation and Discussion

To understand the basic mechanisms of the delivery and inventory model and their interactions, consider the following points:

- A. Weekly and daily deliveries are point functions. For example, if 100 units of fuel are delivered in a day, no information or constraints are given on when during the day that delivery takes place. If, on the other hand, the user wanted all daily deliveries to occur at the beginning of the day, this case could be specified with a varying hourly constraint and an hourly inventory. That is, hour 1 could have the entire minimum and maximum for day 1, and hours 2 through 24 could have a maximum of 0, with some non-zero hourly inventory on hours 1 to 23.
- B. Daily inventories are constraints on flows between days, not during days. Use the hourly inventory model for constraints during days.
- C. Weekly, daily, and hourly inventories are most easily visualized as three totally separate inventories. Imagine three separate stores, each sequentially delivering to the next level. In most cases, only one inventory model will be used. Simply choose the model with the finest granularity (week, day, or hour) that is required.
- D. When combining daily and hourly inventories to model a single inventory, note that there are actually two inventory links out each day. For example, in the first day, the hourly inventory from hour 24 to 25 is carrying fuel to the next day, in addition to the daily inventory link. The flows each contribute to the day's inventory, but possibly in different ways. If there are no hourly delivery constraints, then the total inventory is simply the sum of the daily inventory and the hourly inventory in the last hour of that day. Since hourly inventory is variable by hour, there is really no need to define a daily inventory in this case. Alternately, the hourly inventory at the end of each day (hours 24, 48, etc.) can be set to zero with a pattern.

However, if there are hourly delivery constraints, then the difference between hourly and daily inventory must carefully be considered. Fuel can be stored in the daily inventory without flowing through any hourly constraints, but not in the hourly inventory. To be stored in the hourly inventory, it must be delivered to the last hour or a previous hour, as well as not cause an overflow in the inventory between any previous hours and the last hour of the day.

- E. Be careful when combining inventories at one level and delivery constraints only at a higher level. For example, defining hourly inventories without hourly delivery constraints is questionable. Defining hourly inventory constraints without hourly or daily delivery

constraints is meaningless! (The initial and final values are still meaningful, but they could have just as easily been assigned at the weekly level.)

- F. Where are initial and final inventory levels assigned? What's the difference? Most likely initial and final inventories will only be assigned at one level when modeling a single inventory. As discussed in point D, the only difference is whether the fuel is required to meet the delivery constraints at a particular level before the storage occurs. For example, consider an initial inventory of 1000, a weekly minimum delivery of 1000, a final inventory of 2000, and an hourly delivery maximum of 1. If the initial and final inventory constraints are assigned weekly, everything is fine. However, if they are assigned as hourly constraints, it will not be possible to meet the final inventory. In fact, the maximum final hourly inventory in this case would be 1168, since only an additional 1 unit per hour could be stored.

5.18.4 Probabilistically Derated Deliveries

Each ELF delivery maximum may be probabilistically derated. To use this feature, the variable **ELF OUTAGE TYPE** must be set to 1. When it is 1, each ELF delivery maximum with a defined derating and probability will be drawn. If multiple Monte Carlo iterations are simulated, then these variables will be re-drawn each iteration. The following variables are used for deratings:

ELF WEEKLY DRAT	weekly maximum delivery derated values
ELF WEEKLY PROB	weekly maximum delivery cumulative probabilities
ELF DAILY DRAT	daily maximum delivery derated values
ELF DAILY PROB	daily maximum delivery cumulative probabilities
ELF HOURLY DRAT	hourly maximum delivery derated values
ELF HOURLY PROB	hourly maximum delivery cumulative probabilities
STA ELF TDRAT	transport maximum delivery derated values
STA ELF TPROB	transport maximum delivery cumulative probabilities

For example, if a particular fuel has a maximum of 100, then the following deratings may be specified (80, 60, 40, 20, 0) with cumulative probabilities (0.9, 0.8, 0.7, 0.6, 0.5), meaning that there is a 100% chance that the weekly delivery maximum will be 100 or lower, a 90% chance that it will be 80 or lower, etc., down to a 50% chance that the maximum will be zero. Note that the cumulative probabilities should all be in the range 0 to 1.0 and be descending. The derated values should also be in descending order.

For the daily maximum, draws will be made for each day. For the hourly and transport maximum, draws will be made each hour.

5.18.5 Bugs

There are no problems reported for Version 404 at this time. As bugs are reported, they will be corrected.

5.18.6 Future Development

The following features are under development:

- A. Smarter commitment optimization given ELF fuel constraints.
- B. Better integration of multi-area model with ELF model
- C. Use of ELF network for modeling pump storage
- D. Use of ELF network for modeling emission limits.

5.19 Fuel Blending

The ELF logic provides the capability to use a blended fuel at a station (i.e. fuel is drawn from more than one fuel source). PowrSym4 provides a similar capability outside of the ELF logic. In this logic, fuels are defined independently of the stations in which they are consumed. Each station points to one or more fuels to define its unique fuel source. A station can point to more than one fuel. If this is the case, the user specifies the percentage of each fuel (based on energy) that the station burns. An equivalent fuel cost is derived based on these percentages and used as the basis for dispatching the station. If the user defines a mix totaling less than 100%, the deficit will be made up by using the station's FCOST fuel.

Fuel-Type fuel costs are hourly pattern variables. This allows a fuel price to be represented by different costs for usage during different hours of the week. A separate fuel cost escalation rate is assigned to each fuel-type fuel, allowing each fuel to escalate at a different rate over the study period.

Fuel costs are transferred to stations that use the fuels by adding a transportation cost that depends on the fuel type and the station. This allows different stations that use the same fuel to have different effective fuel prices.

5.20 Emission Cap Method

Not available at this time.

5.21 Wind and Solar Generation Model

Wind and solar generation can be simulated using any number of such stations.

5.22 Marginal Cost Reporting

PowrSym4 calculates the hourly marginal costs by computing the decremental cost by a system redispatch with unit commitment, hydro, and pumped hydro frozen at the base solution. The marginal cost calculation is activated by setting the marginal cost flag and defining the desired megawatt decrement (-100 megawatts, for example). This information is output to file 2.

Using a positive marginal cost increment must be avoided. The correct way to compute a positive increment

is to increase all loads by the desired increment and then use the same increment as a negative marginal cost decrement.

The algorithm freezes the unit commitment, hydro, and pumped hydro for the marginal cost calculations because allowing these items to vary can create very large marginal costs in some hours and negative marginal costs in other hours. The costs associated with unit commitments or changes in the hydro and pumped hydro schedules cannot be allocated to single hour load changes.

5.23 Marginal Emissions Reporting

Not available at this time.

5.24 Hourly Load Adjustment Algorithm

This algorithm will take a set of hourly loads that are continuous over time and modify the pattern such that a specified peak will be the maximum value in the new set of loads and the sum of all the new loads will equal a specified energy. This algorithm works well on load patterns where the average load is less than 80 percent of the peak load. It also works if the ratio of the average load to the maximum load stays constant or changes by a small amount. The algorithm is:

$$X_i = (A_i/B)Y + [Z-(C/B)Y] [(1-(A_i/B))/(N-(C/B))]$$

where

N = number of hours in time series.

A_i = old value for period i (The hourly load).

B = maximum A value (The old peak load in the period).

C = Sum of A_i as i goes from 1 to N (The sum of the old loads).

X_i = new value for period i (The new load for hour i).

Y = maximum X value (The new peak load).

Z = Sum of X_i as i goes from 1 to N (The sum of the new loads).

The algorithm mechanics can be divided into two components. One to set the new peak and the other to adjust the energy to the correct value. The first component $(A_i/B)Y$ sets the maximum value in the new series to the new peak. Since B is the maximum of all the A values, the term, A_i/B is equal to one at the hour of the peak, and one times the new peak equals the new peak. As other A_i values approach the size of B, the peak, the term, A_i/B , approaches one, and the new X_i values will be relatively close to the new peak. This term ratios the old pattern up or down by the ratio of the old peak to the new peak and does not necessarily yield the correct energy over the time period.

The second component is a little more complicated. This component takes the difference between the desired energy and the energy yielded by the first component and ratios it over the hours in the pattern. The term, $[Z-(C/B)Y]$, is the difference between the desired energy and the energy yielded by the first component. The term $(C/B)Y$ is the old energy ratioed by the old peak

to the new peak; if this value is greater than the desired energy, the term will be negative and reduce the values from the first component. If the first component yields less than the desired energy, the term will be positive and will increase the values from the first component. The second term of this component allocates any energy adjustment to the various hours.

The term, $(1-(A_i/B))$, is the energy adjustment allocator. The term, $(N-(C/B))$, is the sum of all the $(1-(A_i/B))$ values in N periods. Consequently, the sum of all the values, $[(1-(A_i/B))/(N-(C/B))]$, for N periods will equal one; and one times the adjustment will equal the adjustment. The energy adjustment allocator adjusts the values relative to the new peak. Since B is the maximum pattern value, A and B are equal at the peak and the term A/B equals one, and the adjustment at the hour of the peak is zero. For values of A that are near the peak load, the term, A/B near one and the adjustment is small. This algorithm fills or deepens the valleys in the calculated load pattern.

When this algorithm is used to adjust monthly loads in an annual load shape, there tends to be a discontinuity between the load for the last hour of one month and the load for the first hour of the next month. This happens because the months tend to end and start when the load is in a valley. The discontinuity is greatest between two months where energy is added to the pattern in one month and subtracted from the pattern of the other month. To minimize the discontinuity an end of the month adjustment is made. The values in the last five hours of the ending month and the first five hours of the following month are adjusted. The sum of the adjustments over the five hours is zero; therefore, the monthly energy remains at the desired value.

The adjustments are defined as follows:

X_n	is the value for the last hour of the month.								
Y_1	is the value for first hour of the following month								
Z	is $X_n - Y_1$	X_n	=	X_n	-	$Z(3/9)$	y_1	=	y_1 + $Z(3/9)$
		X_{n-1}	=	X_{n-1}	-	$Z(1/9)$	y_2	=	y_2 + $Z(1/9)$
		X_{n-2}	=	X_{n-2}	+	$Z(1/9)$	Y_3	=	Y_3 - $Z(1/9)$
		X_{n-3}	=	X_{n-3}	+	$Z(2/9)$	Y_4	=	Y_4 - $Z(2/9)$
		X_{n-4}	=	X_{n-4}	+	$Z(1/9)$	Y_5	=	Y_5 - $Z(1/9)$

This adjustment reduces the difference between X_n and Y_1 to one third the original difference. The adjustment period may seem short, but this smoothes the floor of the valley and pushes the change to the shoulder where major changes in the load are expected.

This algorithm will be incorporated in PowrSym4 such that any flagged load input will be projected at the first week of the year with peaks, energies, and hours read in the first week of the year. The hours in each period are input once if they don't change. This algorithm will work for periods defined as weeks, months, quarters, or any division of the year as long as the periods are contiguous hours. The algorithm will be optimized for the computer by moving part of the computation outside the hourly do loop as follows:

$$X_i = (A_i/B)Y + [Z-(C/B)Y] [(1-(A_i/B))/(N-(C/B))] \quad \text{as } i \text{ goes from } 1 \text{ to } n$$

The terms $[Z-(C/B)Y]$ and $(N-(C/B))$ don't change hourly; therefore, they can be

reduced to a constant inside the hourly do loop.

$$W = [Z-(C/B)Y] / (N-(C/B))$$

$$X_i = (A_i/B)Y + (1-(A_i/B))W \quad \text{as } i \text{ goes from } 1 \text{ to } n$$

5.24.1 Program Control

The load modification routine in PowrSym4 is controlled by the following four AID values:

TAREA LOAD CNTL	N3 value is the transarea load being modified X1 controls the modification.
TAREA LOAD PEAK	N3 value is the transarea load being modified N4 value is the forecast period X1 value is the projected peak load
TAREA LOAD ENGY	N3 value is the transarea load being modified N4 value is the forecast period X1 value is the projected energy for period
TAREA LOAD HRS	N4 value is the forecast period X1 value is the number of hours in forecast period

The TAREA LOAD CNTL values are:

- 0 The default value; no load modification or forecasting takes place
- 1 Hourly loads are read for a year. The first value is assumed to be the load for the first hour of the year, FY or CY
- 10 The same as -1 and projected loads are output to a file
- 1 As projected loads are used they are saved for pattern projections
- 10 The same as 1 and projected loads are output to a file

If TAREA LOAD CNTL is negative, the load modification routine reads a pattern set of loads to use for projecting the current and future years. If in a latter year of simulation, a new TAREA LOAD CNTL value of -1 is input, another year of loads will be read from the input file and used as the pattern. If TAREA LOAD CNTL is a positive 1, the values of the projected hourly loads are saved and used as a pattern for projecting future years. A non-zero value for the first forecast period for TAREA LOAD ENG causes the program to stop reading hourly loads from the input file and to project them using the load modification routine. For this routine, all load areas are divided into the same forecast time periods. Only one set of **TAREA LOAD HRS** records need be input to the model.

6. PowrSym4 Data Definition

6.1 Execution Control

The execution control selects the time periods to be simulated and the simulation options to be used. It defines the parameters for a specific execution.

WEEKS TO SIM defines the number of weeks to run when the next **EXECUTE** record is input. The year and week that define the beginning of the period are defined by **EXECUTE**. For example, if the year and week on the **EXECUTE** record are 1995 and 14, respectively, and the **WEEKS TO SIM** is 4, PowrSym4 will execute weeks 14 through 17 of 1995. However, if **SKIP EXEC** is 1, the data that has been input will be processed and updated, but execution of the period specified will not occur. Since all weeks of a year must be defined in a **WEEKS TO SIM** and **EXECUTE** combination, **SKIP EXEC** allows the execution of a single week, selected single or multiple weeks, or realignment to the desired beginning week for execution in a multiple year data file.

WEEKS TO SIM and **SKIP EXEC** retain the same value that was last entered. It is not necessary to enter these records for each **EXECUTE** unless the values will need to be changed. However, the year and week defined on the **EXECUTE** record **MUST** be sequential and should accurately reflect the beginning of the execution period.

Once the last desired execution period has been processed, an **END** record terminates data input and stops execution. It may be placed after any **EXECUTE** record, even when additional data follows.

PowrSym4 can execute on a calendar year (beginning the first week of January), a fiscal year (beginning in a user-defined week), or both. **LAST WK OF YEAR** defines the last week of the fiscal year. If a fiscal year is not defined or will not be needed for this execution, **LAST WK OF YEAR** should be set to 52. See Section 6.2.4 for an explanation of annual output options.

Variable list:

END	Terminates execution
EXECUTE	Begins execution for currently defined data for this period
LAST WK OF YEAR	Last week of fiscal year
SKIP EXEC	Stores current data and skips execution for this period
WEEKS TO SIM	Number of weeks included in this execution period

6.1.1 Miscellaneous Execution Parameters

PowrSym4 has user-defined controls to define the behavior of certain algorithms, align files, and initialize values. This section defines these controls.

COMMIT TARG ADJ is used to determine if the commitment target can be readjusted after a unit fails to be decommitted because of a minimum up time, minimum down time, or station minimum generation constraint. This allows the simulation to continue toward a solution instead of being trapped in an endless loop.

HEAT BOIL PNLTY is the penalty cost in cents per kWh incurred for heat boiler operation as back-up for cogeneration plants.

SEED INIT aligns the random number seeds by the number of iterations requested and the week that execution begins. Since the random number seeds are an internal function, this number should not be altered by the user.

PowrSym4 calculates the hourly loss of load probability (LOLP) both for reporting purposes and levelizing the maintenance scheduled by its internal algorithm. **LOLP CNTL** is used to define the execution steps taken when an **EXECUTE** record is input. Execution can include data input only; data input and maintenance scheduling; data input, maintenance scheduling, and LOLP calculation; or data input, maintenance scheduling, LOLP calculation, and production cost calculation.

HR LOLP TYPE defines the method used to calculate the hourly LOLP. PowrSym4 can use the convolution method to calculate the LOLP or the cumulant method to approximate the LOLP. The cumulant method is less accurate, but the execution time is significantly less. When the cumulant method is used, **STD DEV OF LOAD** defines the standard deviation of the hourly load used as the second term in the two cumulant calculation.

REALTIME COMMIT will cause unit operating characteristics to be carried over the week boundary. This option is used in near-term studies. PowrSym4 loses its replicability feature. Hours a unit has been up or down and the dispatch level is carried over.

Variable list:

COMMIT TARG ADJ	Adjust commitment target after failed decommit
EXECUTE	Begins execution for currently defined data for this period
HEAT BOIL PNLTY	Penalty cost for heat boiler operation in cents per kWh
HR LOLP TYPE	Hourly LOLP calculation type
LOLP CNTL	Execution simulation and LOLP status
REALTIME COMMIT	Simulate real time commit
SEED INIT	Random number seed alignment
STD DEV OF LOAD	Standard deviation of load used for reliability calculations
STRT APPROX	Approximate starts occurring in first hour of week

6.2 System Data

The input data file provides control over modeling assumptions and parameters affecting the power system as a whole. Section 7 contains a reference table for all variables used. The meaning and use of key system variables is discussed below.

6.2.1 Initialization Parameters

PowrSym4 can be adjusted to fit the size of the system being modeled. **DISP INCR** is used as the step size by the thermal dispatch logic. Its value should equal approximately 1% of the total system capacity. This affects the “smoothness” of the dispatch logic. A “smoother” dispatch curve yields more consistent marginal costs and provides a more uniform pumping/charging and generation patterns for storage stations. However, the execution time increases as the step size decreases. The suggested approximation of 1% provides a reasonable execution time for most systems with a relatively “smooth” dispatch curve.

For dispatching the storage units on the system, PowrSym4 uses an internal marginal cost array. Half of this cost array is above the load for any hour and half is below the load. For example, if the array has a total of 250 steps, the array extends 125 steps above and below the load. The combination of half the array size and the step size must cover the total storage capacity. If the system has two 375 megawatt units, the range is 750 megawatts. Taking 750 megawatts and dividing by the step size of 125 megawatts, a minimum step size of 6 megawatts is obtained. This means that **PHYD DISP STEP** should be in the range of 10 to 15 megawatts.

For systems with storage capacity, **DISP INCR** must be equal to or smaller than **PHYD DISP STEP**. To avoid the increased execution time caused by interpolation, **DISP INCR** should divide evenly into **PHYD DISP STEP**. For example, if **PHYD DISP STEP** is 10 megawatts, **DISP INCR** should be 1, 2, 5, or 10 megawatts.

If a system has hydro generation, **HYDRO DISP STEP** is used to set the “smoothness” of the hydro dispatch. PowrSym4 uses a load-leveling technique to schedule the hydro. As the step size decreases, the “smoothness” of the chronological load fit increases. However, the execution time increases as the step size decreases. A **HYDRO DISP STEP** size equal to approximately 3% provides a reasonable execution time for most systems with a relatively “smooth” load fit.

When PowrSym4 is installed for a new system, there are four calibration controls to set the solution parameters to the size of the power system. Also, five control switches allow changes to different execution parameters. These will be set during the installation process and should only be changed when recommended by OSA.

CALB CNTL 1 adjusts the tolerance for determining the number of starts for individual stations considering the length of their economic up time. **CALB CNTL 2** also adjusts the number of starts, but considers the replacement value of the unit if it were decommitted. **CALB CNTL 3** adjusts the tolerance for meeting all reserve criterion. **CALB CNTL 4** adjusts the tolerance for reducing the number of minimum station generation violations.

CONTROL 1 indicates how the commit schedule will be created. It can be calculated by PowrSym4, calculated and saved to a file, or read from a file that was previously created. **CONTROL 2** indicates unit commitment when using the dynamic programming logic. **CONTROL 3** also indicates unit commitment for the dynamic programming logic. **CONTROL 4** indicates if the commitment and dispatch of stations will be interleaved. **CONTROL 5** indicates if the commit logic can redispatch a decommitted station in a transarea. This produces possibly better results with a significant increase in execution time.

Variable list:

CALB CNTL 1	Calibrate starts as a function of economic up time
CALB CNTL 2	Calibrate starts as a function of the replacement value of the station
CALB CNTL 3	Calibrate reserve criterion violation tolerance
CALB CNTL 4	Calibrate minimum station generation violation tolerance
CONTROL 1	Commitment schedule created or input
CONTROL 2	Unit commitment for dynamic programming
CONTROL 3	Unit commitment for dynamic programming
CONTROL 4	Interleaved commitment and dispatch of stations
CONTROL 5	Redispatch decommitted stations in a transarea
DISP INCR	Thermal dispatch step in megawatts
HYDRO DISP STEP	Hydro dispatch step in megawatts
PHYD DISP STEP	Storage dispatch step in megawatts (pumped hydro, CAES, heat, etc.)

6.2.2 User-definable System Size Parameters

PowrSym4 is dimensioned to accommodate the requirements of an individual system. However, these dimensions reflect the maximum size of a particular parameter and need to be adjusted for a particular execution.

NUM STA HR OUT indicates the number of stations that have been selected for user-defined hourly printed output. It is not the actual station numbers that have been selected, but the number of stations that will be printed in a particular hour.

Variable list:

NUM STA HR OUT - Number of stations selected for user-defined hourly printed output

6.2.3 Energy Not Served and Dump Power

Energy not served refers to load that cannot be met by the resources of the system or available purchases. This situation can occur when the available dispatched capacity cannot meet the load for a particular hour because of small ramp rates, long minimum down times, excessive load swing, too much capacity on scheduled maintenance, unreliable capacity (too much capacity forced out of service), a system with insufficient installed capacity to meet the projected load, or an excessive load adjustment increase with **LOAD ADDER** or **LOAD MULT**. Energy not served typically has a high cost associated with it to reflect an emergency situation. **ENS COST** is used to price the gigawatthours that are reported as energy not served. It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value. If no value is entered at the beginning of a year and **ENS COST ESC** has a value greater than 1, the model will escalate the cost of energy not served using its current value and the escalator. This value will be used for the entire year or until a weekly value overrides the calculated value. **ENS COST** applies to the entire system.

Dump power refers to generation in excess of system requirements. This would be power that is generated by the system in a particular hour that must be dumped into the transmission system (causing system instability) or a power block that must be sold at a cost considerably below the system lambda. It usually occurs during off-peak periods and can be caused by small ramp rates, long minimum up times, excessive mandatory minimum station generation requirements, excessive load swing, too much capacity designated as base-loaded, large power level steps associated with the heat rate curve levels, or an excessive load adjustment decrease with **LOAD ADDER** or **LOAD MULT**. Dump power typically has a low sale price associated with it, since it reflects low load and/or surplus generation situations.

DUMP COST is used to price the gigawatthours that are reported as dump power on an annual basis. It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value. Since a dump power cost that exceeded the cost for the system to produce energy would cause artificial sales that are not realistic, it is not escalated. The user must enter any cost changes as they occur.

DUMP COST applies to the entire system.

Variable list:

DUMP COST	Sale price in \$/MWh for dumped power
ENS COST	Cost in \$/MWh for energy not served
ENS COST	Escalator for energy not served entered as 1 plus the percent
ESC	increase
LOAD ADDER	Constant megawatt adjustment to all system hourly loads
LOAD MULT	Percent adjustment to all system hourly loads

6.2.4 Output Parameters

PowrSym4 allows the user to define the type of output necessary for each execution. The output is divided into printed files and output files.

Printed files present the output data in a tabular format designed for viewing on a screen or for direct output to a printer. These files include hourly, weekly, monthly, and annual output data for each of the user-defined groups.

Output files are designed for use by the PowrSym4 Analyzer and PowrSym4 Report Writer. These files contain data in a record format similar to the input data format. The Analyzer and Report Writer read these files to obtain the hourly, weekly, monthly, and annual data.

The annual output data can be calendar year (beginning in January) or a user-defined fiscal year. File 39 is used for calendar year print. File 40 is used for fiscal year print.

YEAR PRINT CNTL indicates if the annual output is for a fiscal year, calendar year, or both. Since a year is executed as 52 weeks, only 364 days are simulated in any one year. **LOAD FORMAT** can be used to adjust the number of days to equal 365 days in a year (or 366 days in a leap year). The first week of the year is week 1 if only a calendar year is defined. Otherwise, week 1 is the first week defined for the fiscal year. The weekly and monthly output data are not affected. **CY OUT FILE** indicates if the output file for the calendar year is written to file 36.

FY OUT FILE indicates if the output file for the fiscal year is written to file 37.

PERIOD PRINT indicates if there will be no additional print; monthly print; monthly and weekly print; or monthly, weekly, and hourly print. File 14 is used for hourly print. File 8 is used for weekly print. File 38 is used for monthly print. **HR OUT FILE** indicates if the output file for the hourly data are written to file 33. **WEEK OUT FILE** indicates if the output file for the weekly data are written to file 34. **MONTH OUT FILE** indicates if the output file for the monthly data are written to file 35.

Hourly print files and hourly output files require significant disk space. To minimize these files, the user can get the greatest level of hourly detail by using **DEBUG HRLY PRT** to print specific weeks for a detailed review.

The user can group together stations defined in the input data. These groups are only used for output. No internal calculations use any grouping other than stations. If a group is selected for print, it is printed to all period and annual files.

A commitment report can be produced in either of two formats as defined by **COMMIT REPORT**. The station format produces a table of commitment schedule for each station for each week (provided the station is committed for at least one hour in that week). The hourly format produces a table of stations and the associated actions for each hour in which a commitment action occurs (i.e. either the station is committed or decommitted at that time). Either, neither, or both reports can be generated.

STA PRINT indicates that the station data will be printed. **PLANT PRINT** indicates that groups of stations that have been designated as plants will be printed. **GROUP RPT NAME** defines the names of each group report and **GROUP PRINT FLG** indicates which groups will be printed. **SUMMARY NAME** defines the names of the summary classes printed on the summary report. If defined, these classes will be printed on the summary page of all printed reports. Summary classes can be grouped by fuel type, by geographic area, or any other grouping that will assist the user in reporting.

PowrSym4 can use both American and European monetary and heat units on printed files. Monetary units are American dollars or the currency of the European customer, and heat units are in British thermal units or gigajoules. **PRT UNITS FLAG** indicates if the printed report headers use American or European units.

PowrSym4 will simulate any number of wind power stations during an execution. **WIND POWER FILE** indicates that this data contains a wind power station. **WIND STA NUM** indicates which station is designated as the wind power station. The data for the generation of this station is input from file 24.

Several files have been designed for specific customers. **AVG KWH CST OUT** indicates that the hourly mean variable cost in cents per kilowatt-hour will be printed to file 30 with Dutch

report headers. **MIDAS FLAG** indicates that the interface data necessary to run the MIDAS Gold financial model will be output to files 47 and 48. **TVA FIN FLAG** indicates that generation data necessary for the Tennessee Valley Authority's financial model will be output to file 46.

In addition, binary files used to report selected hourly output were designed for the Dutch utility, Sep. **UNFORMATTED OUT** indicates which files from 26 through 29 will be used for output. **VAR TIME FLAG** indicates which variable time reports for the selected hours will be output. **VAR TIME RPTS** indicates the maximum number of variable time reports that will be output. **VAR TIME SPEC** defines which hours will be included in the variable time reports.

Variable list:

AVG KWH CST OUT	Print hourly mean variable cost in cents per kilowatt-hour in Dutch (File 30).
COMMIT REPORT	Defines the format of the Commitment Report (File 01)
CY OUT FILE	Calendar year output file for Analyzer (File 36).
DEBUG HRLY PRT	Hourly debug printed output for specified weeks (File 10).
FY OUT FILE	Fiscal year output file for Analyzer (File 37).
GROUP PRINT FLG	Define if reporting group will appear in printed output.
GROUP RPT NAME	Name used to identify reporting group on printed output
HR OUT FILE	Hourly output file for Analyzer (File 33).
MIDAS FLAG	Output MIDAS interface files (Files 47 and 48).
MONTH OUT FILE	Monthly output file for Analyzer (File 35).
PERIOD PRINT	Indicator for printed output other than annual
PLANT PRINT	Printed output for plant groupings
PRT UNITS FLAG	Indicator for American or European monetary and heat units
STA PRINT	Printed output for station groupings
SUMMARY NAME	Name used to identify summary group on printed output
TVA FIN FLAG	Financial output file designed for the Tennessee Valley Authority (File 46).
UNFORMATTED OUT	Unformatted output files for the Dutch utility, Sep (Files 26 through 29).
VAR TIME FLAG	Variable time period output files for specified hours
VAR TIME RPTS	Maximum number of variable time period output files
VAR TIME SPEC	Hours to be included in variable time period output files
WIND POWER FILE	Indicator for existence of wind generation station
WIND STA NUM	Station number for wind generation station
YEAR PRINT CNTL	Indicator for annual printed output.

6.2.5 Model Solution Parameters

PowrSym4 uses different modeling techniques to simulate production cost. A simple execution would have a fixed outage schedule, a predefined maintenance schedule, and use the simplified sequential derating algorithm. A complex execution would calculate an outage schedule determined by one of three Monte Carlo random draw algorithms, a maintenance schedule determined by a loss of load minimization algorithm, and use the concurrent weekly simulation with dynamic programming logic and a network flow algorithm. Using these techniques, PowrSym4's diversity ranges from a one week system operations simulation to a 30 year planning study.

The weekly solution uses a sequential execution, a concurrent execution, or a combination of the two methods. **EXEC MODE** indicates which execution method or combination will be used.

The sequential execution method is the traditional chronological algorithm. The thermal solution for a week is computed by calculating the least cost alternative for each hour of the week, given that only one hour is solved at a time. The algorithm uses its knowledge of the rest of the week to minimize the production cost for the entire week, but it cannot return to a previous hour once a solution is reached.

In contrast, the concurrent execution method solves all hours for an entire week. It uses the knowledge gained by each commitment and dispatch decision to alter any other hour in the week, including an hour previous to the present hour. This method will minimize the production cost for the entire week.

Both solution methods use one of six simulation options to calculate the forced outage for each station. **OUTAGE TYPE** indicates which of the simulation options will be chosen for this execution. Once a simulation option is chosen, it cannot be changed for the remainder of the current execution.

OUTAGE TYPE zero is the fixed outage schedule. Forced outages and forced deratings are entered from an input file and the execution method assumes all remaining resources to be available with certainty. This option is suitable for short term studies of specific scenarios. It is fast because no Monte Carlo iterations are required. The fixed outage schedule is often used for debugging and scenario comparisons in order to remove the fluctuations caused by varying outages.

OUTAGE TYPE one is the traditional derating method. It reduces the capacity of each generating unit by the forced outage rate. For a large system, this approximation will approach the answer given by a more sophisticated outage method because of the law of large numbers. It is also fast because no Monte Carlo iterations are required, but the operation of peaking resources such as pumped hydro and combustion turbines will not be accurate. This option tends to understate the use of pumped hydro. Since the amount of capacity on outage is always at the average condition, no extreme outage situations will occur.

OUTAGE TYPE two is the gradient derating method. It is used by the Tennessee Valley Authority to adjust the short term part of the derating curve. It approaches the traditional derating method over the long term. The derating curve equations are:

$$\begin{aligned} Y(t) &= 1.0 - e^{(-At)} * (1.0 + Kt^2) \\ \text{Capacity} &= \text{Rated capacity} * (1.0 - \text{EFOR} * Y(t)) \end{aligned}$$

where

A, K = Input coefficients
 EFOR = Equivalent forced outage rate (0.05 is a 5% outage rate).
 Rated capacity = Normal full load capacity as input

OUTAGE TYPE three is the random Monte Carlo method. It is a brute force simulation to calculate the expected system operation by averaging a number of outage scenarios created by a random number generator. If enough iterations are used, this is the most accurate option for

representing forced outage and forced derating events. However, it is also the most time-consuming option. The extreme outage events, both good and bad, are represented, and the operation of pumped hydro and combustion turbine peaking units is realistic.

The outage draw duration is an input and may be 168 hours or less. A new set of random draws will be made at the beginning of each duration period to ascertain the state of each unit during the period. With a duration of 168 hours, draws will be made once per week. With a duration of 12 hours, draws will be made 14 times a week.

Reducing the draw duration introduces more random draws and speeds the convergence with fewer iterations. However, reducing the duration to less than the average system outage duration will increase the number of unit starts and stops above that which will actually occur on the system. A draw duration of 24 hours is a realistic compromise between accuracy and speed for most systems.

MCARLO ITER is the number of Monte Carlo iterations to be used in this execution. For large power systems, it has been found that 50 to 100 iterations are required for convergence. This means that only one iteration is needed for long range studies in which only the annual results are of interest, even with a 168 hour outage duration. With daily duration, seven to fifteen iterations are required for weekly convergence and two to four iterations for monthly convergence. With a 168 hour outage duration, 50 or more iterations are required for weekly convergence.

OUTAGE TYPE four is the selected sample Monte Carlo method. It uses a fast objective function to approximate the production cost results for each iteration. A large number of iterations (100 to 1000) are used to define the sample space and the objective function results are sorted to create an objective function probability curve. This curve will not be normally distributed, but will be skewed in the upward direction because of the increasing system lambda associated with higher outage draws. **SMART MC SAMPLE** is used to input the number of samples (usually five to eleven and always an odd number) chosen to represent the entire sample space in detailed production cost calculations. The samples are chosen by dividing the curve into equal areas.

This option insures that a small sample is not overly weighted by a “bad” draw, and that the draws are uniformly selected to represent the entire sample space. A draw sample of one would use the sample nearest the mean of the distribution. The reason for using an odd number of samples is to force the inclusion of the mean sample.

The strength of this option is that weekly production cost totals are usually very near the converged values with greatly reduced computation time. Generation by station type and fuel category is also well behaved. However, individual station results are not well converged and base loaded plants may not be operating at their expected capacity factors, although the average for the entire group of base loaded plants is likely to be near the expected values.

A special consideration for the selected sample Monte Carlo method is the repeatability of the draw sample. When comparing scenario results, it is important that each run have the same number of iterations. Since the simulation is selecting the draws to be used, it is necessary to save the draw sample file from the first run and force the following runs to use the draw sample file instead of creating new draws.

OUTAGE TYPE five is the semi-guided Monte Carlo method. It is described in detail in a paper entitled Using a Semi-Guided Monte Carlo Method for Faster Simulation of Forced Outages of Generating Units presented by Scully, et. al., at the Seventeenth PICA Conference. This paper was reviewed by T. Jackson and C. Stansberry of the Tennessee Valley Authority. This option is used extensively in ABB Power Systems' models.

This option produces statistically balanced forced outage schedules over an extended time period, usually one year. Results for shorter time periods are not converged, but the annual results for both system totals and individual station results are very well behaved. It is fast as only one iteration is required. This is the option of choice for medium and long range planning studies where only annual results are of interest.

Variable list:

EXEC MODE	Indicates the weekly solution method to be used
MCARLO ITER	Number of Monte Carlo iterations to be simulated
OUTAGE TYPE	Indicates the forced outage calculation to be used.
SMART MC SAMPLE	Number of samples for the smart Monte Carlo method

6.2.6 Load Modification During Execution

PowrSym4 uses file 4 to input the system loads for an execution. A load file must contain at least one year of data (52 weeks). If additional load data are necessary, it must be entered as complete years. The maintenance scheduling logic uses the loads to determine the loss of load probability (LOLP) as the objective function to be minimized. Since the maintenance scheduler has a one year planning horizon, it requires an entire year's load input for each year to be executed.

PowrSym4 currently allows two load formats: a daily load format and an hourly load format. **LOAD FORMAT** indicates which load format is used for an execution. It cannot be changed during the execution. Since the loads must be aligned with the PowrSym4 calendar, the weekly loads in an input file may not begin on a Monday. **LOAD START HR** indicates the number of hours to shift the loads so that the weekly simulation begins on Monday. For example, if the hourly loads begin on a Wednesday in the input file, **LOAD START HR** should be set to 48 to move the input of the loads to hour 49 (Wednesday at 1:00 am). The last 48 hours of the week in the input file would be placed in the first 48 hours of the simulation week. This would apply to all weeks of an execution.

The daily load format uses the week from the PowrSym4 calendar and the last two digits of the year to identify each record. For each week (168 hours), there are fourteen records with twelve loads on each record in fields that are six digits in length. There are no blank records allowed in the file. All fields on the records should be right-justified. The following format is for a single record in the daily load format.

Columns	Field Description	Columns	Field Description
1-2	Last two digits of year	33-38	Hourly load in decimal form
3	Blank	39-44	Hourly load in decimal form
4-5	PowrSym4 calendar week	45-50	Hourly load in decimal form
6-8	Blank	51-56	Hourly load in decimal form
9-14	Hourly load in decimal form	57-62	Hourly load in decimal form
15-20	Hourly load in decimal form	63-68	Hourly load in decimal form
21-26	Hourly load in decimal form	69-74	Hourly load in decimal form
27-32	Hourly load in decimal form	75-80	Hourly load in decimal form

The hourly load format defines the year and PowrSym4 calendar week on the first record for each week in fields that are eight digits in length. The next 21 records have eight loads per record in fields that are nine digits in length. These records define the 168 hourly loads for the week identified by the first record. There are no blank records allowed in the file. All fields on the records should be right-justified. The following format is for a set of records to define a week in the hourly load format.

Record	Column	Field Description
	s	
1	1-8	Four-digit year
1	9-16	PowrSym4 calendar week
2	1-9	Hourly load in decimal format
2	10-18	Hourly load in decimal format
2	19-27	Hourly load in decimal format
2	28-36	Hourly load in decimal format
2	37-45	Hourly load in decimal format
2	44-54	Hourly load in decimal format
2	55-63	Hourly load in decimal format
2	64-72	Hourly load in decimal format

PowrSym4 permits limited user modification of the system load while executing. Since these load modifiers are applied to each hour of a year, they may only be changed at the beginning of the year.

LOAD ADDER defines the constant megawatt adjustment for all hours. It may be positive (to increase the load) or negative (to reduce the load). **LOAD MULT** defines the percent adjustment to all hourly loads. It may also be positive or negative. If both variables are defined, the load is affected by both adjustments. The load is first adjusted by one plus **LOAD MULT** and then summed with **LOAD ADDER**.

In addition to load adjustments, PowrSym4 can calculate marginal cost as a third simulation during an execution. The marginal cost is the cost of the last block of generation. The generation and/or charging for hydro, pumped hydro, other storage, and energy-limited stations are locked at the same level calculated for the second simulation, and the commitment order from

the second simulation is frozen. Therefore, the only change allowed is the redispatch of the committed stations. This method helps smooth the marginal cost curve and limit the number of negative marginal costs that would occur if a station that had been generating was removed or the charging schedule for a storage station changed.

Using a positive marginal cost increment must be avoided. The correct way to compute a positive increment is to increase all loads by the desired increment and then use the same increment as a negative marginal cost decrement.

Suppose that a utility offers to sell a 50 megawatt block of energy for the next four hours. The price for this energy is 25 dollars per megawatt-hour. It is difficult to tell from the system lambda if this would be a beneficial purchase. However, if the cost of generating the last 50 megawatts on the system was 28 dollars per megawatt-hour, the answer is obvious. By accepting the sale, the system saves 50 megawatts times 3 dollars per megawatt-hour times four hours for a net total system cost savings of 600 dollars.

The same logic would apply if another utility wanted to purchase a block of energy. If the cost of generating the energy for the specified number of hours does not produce enough revenue to cover to cost of the generation and a moderate profit margin, the sale would not be made.

MCOST FLAG indicates if a third simulation is needed to calculate a marginal cost. If the marginal cost is needed, the data will be output to file 2. **MCOST STEP** defines the number of megawatts to vary the load for the marginal cost calculation. A negative value is used to calculate the cost of the last block of energy, while a positive value is used to calculate the cost of the next block of energy.

Variable list:

LOAD ADDER	Constant megawatt adjustment to all system hourly loads
LOAD FORMAT	Indicates load input format
LOAD MULT	Percent adjustment to all system hourly loads
LOAD START HR	Adjust hourly loads to align beginning of week (Monday).
MCOST FLAG	Indicates if hourly marginal costs will be calculated
MCOST STEP	Adjust hourly loads to calculate marginal cost

6.2.7 Maintenance Parameters

PowrSym4 can execute with no maintenance, a predefined maintenance schedule, or a calculated maintenance schedule. The maintenance file is input from file 3.

The maintenance scheduling logic can use a predefined maintenance schedule for selected stations and complete the maintenance schedule for the remaining stations. PowrSym4 uses either minimization of the loss of load probability (LOLP) for the year or minimization of annual

production cost as the objective function for scheduling maintenance. Since both of these functions are based on a year, a predefined schedule must include 52 weeks of input.

6.2.8 Scheduling Maintenance Based on Reliability

The scheduling logic calculates the number of weeks of maintenance required for each station using the station's planned and maintenance outage rate (**PMOR**). It multiplies this percentage times 52 weeks for each unit at a station. The logic then calculates the LOLP for each week without maintenance (or with the selected predefined maintenance). The outages are then ranked by considering the length of the outage and the number of megawatts that will be lost. They are sorted so that the hardest outage to schedule is first.

The logic chooses the weeks that have the lowest LOLP and fits the first outage to these weeks. With this outage in place, the logic recalculates the LOLP for each week. It then fits the second outage, recalculates LOLP, fits the third outage, recalculates LOLP, etc. When it is finished, the maintenance schedule for the entire year is output to a file. That file may be used as a predefined maintenance schedule for future sensitivity runs to prevent a change in maintenance that would influence the study.

6.2.9 Scheduling Maintenance Based on Cost

The scheduling logic to minimize cost is heuristically-based. A scheduling priority is established for each unit based on the station's production cost and the contribution of the station to reliability. Units are scheduled for maintenance one by one in the priority order. Each unit is scheduled at the time where minimum incremental cost has occurred, providing that this time meets all other scheduling constraints. The overall result is a leveled total system marginal or incremental cost and, therefore, a minimum total system cost.

When it is finished, the maintenance schedule for the entire year is output to a file. That file may be used as a predefined maintenance schedule for future sensitivity runs to prevent a change in maintenance that would influence the study.

6.2.10 Maintenance Scheduling Controls

MAINT CNTL indicates how the maintenance will be defined. It can be predefined input from a file or calculated using the scheduling logic. It can also be a combination of the two with selected, predefined station maintenance input, and the remainder of the maintenance calculated. If desired, no maintenance will be input or calculated. The **MAINT CNTL** is also used to specify the objective function to be used with the scheduling logic.

MAINT PART WEEK specifies whether PowrSym4 will schedule maintenance in partial week intervals. If activated, the partial week option allows PowrSym4 to schedule the exact number of hours of maintenance required by the **PMOR**. If left off, PowrSym4 will schedule round the amount of maintenance required to the nearest whole week. Using **MAINT PART WEEK** also

provides additional flexibility in recognizing typical utility practice in scheduling maintenance. **MAINT START HR** is used to specify the hour of the week for starting maintenance. For example, specifying a value of 120 will cause an outage to start on Friday evening. **MAX MAINT UNITS** is used with multi-unit stations to specify the maximum number of units that can be scheduled for maintenance for the period as defined by the user. In general, reasonably long periods should be defined to avoid unexpected results. A priority can also be assigned to this value which will allow the constraint to be relaxed if necessary to schedule the required maintenance.

Constraints can also be applied to groups of stations in scheduling units. **PRC GROUP NAME** is used to define procedure groups, that is, groups of stations to which maintenance planning constraints are applied. **STA PROC GROUP** is used to define the stations that are assigned to a procedure group. An individual station can be assigned to more than one STA PROC GROUP. **STA GRP ACTION** is used to define the constraint to be applied to the STA PROC GROUP. STA GRP ACTION also includes information that is used in PowrSym to determine how much to relax the constraint should this be necessary. Three constraints can be defined for each STA PROC GROUP:

1. The maximum number of units that can be on maintenance in a single hour;
2. The maximum number of megawatts that can be on maintenance in a single hour; and
3. The minimum number of hours between maintenance outages.

Additional controls allow the user to adjust the cost function that is used to schedule maintenance to reflect different scheduling priorities. **MAINT COST ADDER** allows the user to assign an additional cost to maintenance performed at the associated station during a specified period of time. This adder can be considered a cost penalty to reflect additional burdens associated with performing maintenance during a less desirable period. **MAINT FCOST** replaces the normal station fuel cost when scheduling maintenance. **MAINT ENS PEN** is a multiplicative factor that is used to adjust the cost of energy not served in determining the cost objective function for scheduling maintenance. Note that an ENS COST must be specified to use this adjustment (see section 6.2.3). **MAINT LOLH PEN** allows the user to assign a cost to the calculated number of hours for which load is determined not to be served (this is applied based on the number of hours only, MAINT ENS PEN is used to penalize the quantity of load not served). These costs are used in determining the least-cost maintenance schedule, but are not included in PowrSym's subsequent calculations of production cost.

There are three file formats that are used: a weekly format, AID format and a station format. There are no blank records allowed in the file. All fields on the records should be right-justified. The file must contain a complete year (52 weeks) for every year to be executed. **MAINT FILE FLAG** indicates which format is used.

The weekly format contains the year, the PowrSym4 calendar week, and the number of the last station with predefined maintenance on the first record. A second record contains the number of units on maintenance for each station. The following format is for a set of records to define a week in the weekly maintenance format, given N stations with a predefined maintenance schedule.

Record	Columns	Field Description
1	1-6	Four digit year
1	7-12	PowrSym4 calendar week
1	13-18	Number of stations with predefined maintenance (N)
2	1-2	Number of units on maintenance for station 1
2	3-4	Number of units on maintenance for station 1
2	5-6	Number of units on maintenance for station 1
:	:	:
:	:	:
:	:	:
2	(N*2) -1, N*2	Number of units on maintenance for station 1

The station format contains the last two digits of the year, the PowrSym4 calendar week, and the number of stations with predefined maintenance on the first record. A set of maintenance input records follows containing eight stations per record. The following format is for a set of records to define a week in the weekly maintenance format, given N stations with a predefined maintenance schedule.

Record	Columns	Field Description
1	1-2	Two-digit year
1	3	Blank
1	4-5	PowrSym4 calendar week
1	6	Blank
1	7-8	Number of stations with predefined maintenance
2	1-4	Station number with predefined maintenance
2	5-7	Number of units on maintenance for station
2	8-11	Beginning hour for maintenance in this week
2	12-15	Ending hour for maintenance in this week
2	16-16	Station number with predefined maintenance
2	20-22	Number of units on maintenance for station
2	23-26	Beginning hour for maintenance in this week
2	27-30	Ending hour for maintenance in this week

The AID format:

Record	Columns	Field Description
1	1-4	Year
1	5-8	Week
1	9-12	Beginning hour of maintenance for this week
1	13-16	Ending hour of maintenance for this week
1	17-20	Station number
1	21-40	Blank
1	41-50	Station name (optional)
1	51-65	Number of stations on maintenance this week

*Must be a record for each week any unit at this station is on discrete maintenance

Variable list:

MAINT CNTL	Indicates if scheduled maintenance will be input or calculated
MAINT COST ADD	Adds a cost penalty to scheduling maintenance for a specific station during the specified period (used in scheduling maintenance, only)
MAINT ENS PEN	Applies a multiplier to ENS cost (used in scheduling maintenance, only)
MAINT FCOST	Substitutes a different fuel cost for a station when scheduling maintenance (used in scheduling maintenance, only)
MAINT FILE FLAG	Indicates which maintenance file format is used
MAINT LOLH PEN	Applies a cost penalty to the number of hours for which load is not satisfied (used in scheduling maintenance, only)
MAINT PART WEEK	Indicates whether maintenance will be scheduled for partial weeks
MAINT START HR	Specifies hour of the week for beginning maintenance when used in conjunction with the MAINT PART WEEK
MAX MAINT UNITS	The maximum number of units for a single multi-unit station that can be on scheduled for maintenance during a specified period
PMOR	Planned and maintenance outage rate for a station
PROC GROUP NAME	Identifies each maintenance scheduling group in conjunction with STA PROC GROUP and PROC GRP ACTION
PROC GRP ACTION	Specifies the type of constraint to be applied in scheduling maintenance for a PROC GRP
STA PROC GROUP	Assigns an individual station to a procedure group

6.2.11 Spinning Reserve Requirements

PowrSym4 calculates both spinning and operating reserve requirements. Spinning reserve requirements include only stations that are currently dispatched. Operating reserve requirements include units that are currently dispatched and any stations that are considered quick-start (see SPIN STATUS in section 6.6.10). A quick-start unit is defined as a generator that can achieve its normal full load capacity in ten minutes or less. These units normally include storage capacity and certain combustion turbine designs.

Both spinning and operating reserve requirements are considered soft constraints. The logic will meet both constraints, if possible. However, if a generation shortage occurs, the logic will allow the simulation to violate these constraints to continue execution. The logic records the number of violations and the megawatt size of the violations when they occur, although this information is not included in any of the standard output reports.

SYS OR FLAG indicates that operating reserve requirements will be enforced at the system

level. **SYS SR FLAG** indicates that spinning reserve requirements will be enforced at the system level. Reserve requirements can be input as a constant megawatt level, a percentage of the unadjusted hourly load, or as the normal full load megawatt level of the largest unit dispatched on the system (largest unit contingency).

SYS OR MW defines the constant megawatts of operating reserve requirements.

SYS OR PCT defines the percentage of the unadjusted hourly load to be added to the operating reserve requirements. These numbers are summed to obtain the total system operating reserve requirements for each hour.

SYS SR MW defines the constant megawatts of spinning reserve requirements.

SYS SR PCT defines the percentage of the unadjusted hourly load to be added to the spinning reserve requirements. These numbers are summed to obtain the total system spinning reserve requirements for each hour.

SYS LG UN FLG indicates if the system operating reserve requirement will be calculated. The normal full load megawatt level of the largest unit dispatched on the system (largest unit contingency) for each hour is used as the system operating reserve requirement. **SYS LG UN MW** defines the megawatt adjustment to the largest unit contingency for each hour.

Another classification of reserves, similar to the operating reserves, can also be defined. These reserves, “back-up reserves”, are assumed to be available later than the operating reserves (after about 30 minutes). The required backup reserves are defined using either **SYS BK PCT** or **SYS BK MW**. **SYS BK PCT** is the backup reserve capacity defined as a percentage of operating load; **SYS BK MW** is a constant reserve requirement.

Variable list:

SEP RES RULE	Indicates if the Dutch utility, Sep, reserve rules are used
SYS BK MW	Constant megawatt level back-up reserve requirement for the system
SYS BK PCT	Percent of unadjusted hourly load used for back-up reserves
SYS LG UN FLG	Indicates if operating reserve requirements are input or calculated
SYS LG UN MW	Number of megawatts to adjust the largest unit contingency.
SYS OR FLAG	Indicates if operating reserve requirements enforced for the system
SYS OR MW	Constant megawatt level operating reserve requirements for the system
SYS OR PCT	Percent of unadjusted hourly load used for operating reserve requirements for the system
SYS RES RULES	Indicates if the Dutch utility, Sep, low reserve rules or high reserve rules are used
SYS SR FLAG	Indicates if spinning reserve requirements enforced for the system
SYS SR MW	Constant megawatt level spinning reserve requirements for the system
SYS SR PCT	Percent of unadjusted hourly load used for spinning reserve requirements for the system

6.2.12 Dynamic Programming Parameters

PowrSym4 uses heuristics (a set of rules) to determine production costs in a standard simulation. This provides a realistic answer with a reasonable execution time. If a simulation is required for a limited number of weeks with greater detail, PowrSym4 uses dynamic programming logic to refine the solution it has calculated using heuristics.

The dynamic programming (DP) logic uses different combinations of station commitment in an attempt to find the optimum production cost solution. Since the answer obtained by the heuristic solution pass is a good approximation of the optimum solution, DP logic uses this solution as its initial optimum. By varying the station commitment pattern, the DP logic can improve this solution by finding combinations that are not attempted by the rigid rules enforced by the heuristic solution.

For example, if a system has three units, there are 2^3 or eight possible commitment patterns:

	Solution Number							
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>	<u>8</u>
Unit 1	0	1	0	0	1	1	0	1
Unit 2	0	0	1	0	1	0	1	1
Unit 3	0	0	0	1	0	1	1	1

where

0 = Unit is not committed

1 = Unit is committed

The DP logic would simulate each of the eight patterns for each hour and compare the result with the hourly production cost from the heuristic simulation. If the simulated pattern for a specified period yields a better result for the simulation week, this commitment pattern is inserted into that period. The adjusted hourly commitment pattern for the week becomes the current solution and is used in comparisons with future DP solution possibilities.

In addition to entering station commitment patterns, PowrSym4 has other possible adjustments for the DP logic. **DP CASE OR ADJ** defines the operating reserve adjustment in megawatts for a particular DP case. **DP UPDN TIME** indicates if the minimum up time and minimum down time constraints should be enforced.

Variable list:

DP CASE OR ADJ	Defines operating reserve adjustment in megawatts for a particular dynamic programming case.
DP UPDN TIME	Indicate if minimum up time and minimum down time should be enforced for this dynamic programming case

6.3 Control Area Data

A control area is a group of transareas. It can be determined by geography, centralized dispatch, further definition of transmission constraints, etc. If control areas exist, they are subsets of the entire system in the simulation. **CAREA TAREA MAX** indicates the maximum number of transareas assigned to any control area. Each control area is not required to have the maximum number of transareas. **CAREA TAREAS** indicates a transarea that has been assigned to a controlarea.

Since control areas are subsets of the entire system, they can have individual reserve requirements that must be met. PowrSym4 must enforce the system reserves and the control area reserves.

CAREA OR FLAG indicates that operating reserve requirements will be enforced for the control area identified. **CAREA SR FLAG** indicates that spinning reserve requirements will be enforced for the control area identified. Reserve requirements can be input as a constant megawatt level, a percentage of the unadjusted hourly load, or as the normal full load megawatt level of the largest unit dispatched in the control area (largest unit contingency).

CAREA OR MW defines the constant megawatts of operating reserve requirements for the control area identified. **CAREA OR PCT** defines the percentage of the unadjusted hourly load for the control area identified to be added to its operating reserve requirements. These numbers are summed to obtain the total control area operating reserve requirements for each hour.

CAREA SR MW defines the constant megawatts of spinning reserve requirements for the control area identified. **CAREA SR PCT** defines the percentage of the unadjusted hourly load for the control area identified to be added to the spinning reserve requirements. These numbers are summed to obtain the total control area spinning reserve requirements for each hour.

CAREA LG UN FLG indicates if the operating reserve requirement for the control area identified will be calculated. The normal full load megawatt level of the largest unit dispatched in the control area (largest unit contingency) for each hour is used as the control area operating reserve requirement. **CAREA LG UN MW** defines the megawatt adjustment to the largest unit contingency for each hour for the control area identified.

PowrSym provides the capability of collapsing all of the transareas within a given control area into a single transarea matching the control area. This feature, while eliminating the detail regarding transactions within a CAREA, allows significant reduction of running times for very large models. To activate this feature, the **n4** field in the **CAREA NAME** is set to 1. The following occurs during the Carea collapse:

- * A single Tarea with the name of the carea and the number of the lowest numbered original Tarea in the control area is created.
- * All stations in all Tareas inside the control area are re-assigned to the single Tarea
- * All links between Tareas inside the control area are lost (i.e. all transport restrictions between the former Tareas are eliminated)

- * If duplicate links are produced as a result of the previous step, they are combined into a single link having the sum of the capacities of the duplicate links.
- * Wheeling charges and losses for the new links are equal to those of the lowest numbered duplicate link
- * Reserve requirements that were specified for the original Tareas are NOT enforced in the collapsed carea. However, reserve margin requirements originally specified for the carea continue to be enforced

Control areas that contain “reference areas” or “transaction areas” cannot be collapsed.

Variable list:

CAREA LG UN FLAG	Indicates if operating reserve requirements are input or calculated for a control area
CAREA LG UN MW	Number of megawatts to adjust the largest unit contingency for a control area
CAREA NAME	Name to identify a control area for reporting purposes and to specify if a CAREA is to be collapsed
CAREA OR FLAG	Indicates if operating reserve requirements enforced for a control area
CAREA OR MW	Constant megawatt level operating reserve requirements for a control area
CAREA OR PCT	Percent of unadjusted hourly load used for operating reserve requirements for a control area
CAREA SR FLAG	Indicates if spinning reserve requirements enforced for a control area
CAREA SR MW	Constant megawatt level spinning reserve requirements for a control area
CAREA SR PCT	Percent of unadjusted hourly load used for spinning reserve requirements for a control area
CAREA TAREA MAX	Maximum number of transareas allowed in any control area
CAREA TAREAS	Identifies a transarea assigned to a control area

6.4 Transport Area Data

PowrSym4 is a full multiple area production cost simulation using a network flow transportation algorithm. This algorithm assumes that network flows can be scheduled. This means that a flow scheduled along a link between two areas is assumed to flow only on that link and not distribute across the network as a load flow would indicate. The flows are calculated iteratively to levelize incremental costs among the areas using the Edmonds-Karp version of the Ford-Fulkerson maximum flow algorithm with Dijkstra’s shortest path algorithm. This algorithm will find the lowest cost flow solution for the total system within the network constraints. Thermal unit commit and dispatch schedules and pumped hydro schedules are determined by the full network simulation with the objective function of minimizing total system production cost subject to local area constraints.

The system includes all components of the simulation: control areas and transareas. The system load is the sum of all transarea loads.

The transarea is the basic simulation unit for the multiple area algorithm. Transareas are interconnected by links with hourly loads specified in separate input files for each transarea. Spinning and operating reserve constraints, unserved energy, and dumped power may optionally be imposed for each transarea. Transareas may also be used for reporting purposes. A transarea can have a load, generation, or both. The algorithm first solves each individual transarea, given its generation capability and its load. If a transarea has a load with no generation or inadequate generation capability, the unserved energy for that transarea is calculated.

Next, the algorithm examines each transarea with an unserved energy and simulates all possible link combinations to find the least cost alternative. If possible, all transareas with unserved energy are solved. When considering energy transfers, any link combination that increases unserved energy for any transarea will not be considered.

The final step attempts to make any economic transfers. Once again, the transfer combination cannot increase the unserved energy for any transarea. A transfer will not be accepted unless it decreases the total cost for the system.

Links connect transareas in a single direction. Each link must be paired with a reverse link to simulate the bi-directional characteristics of a physical transmission line. Only one pair of links may be specified between each transarea and each other transarea. A load flow model must provide the maximum simultaneous transfer capability for all transmission between the two transareas. Multiple link pairs between two areas conflicts with the network flow algorithm used to solve the multiple transareas.

There are no limits to the network topology. Transareas may be connected in radial, delta, or combined configurations. Long series connections require the most computation time as flows are often relayed from remote areas across intervening areas.

TAREA NAME identifies a transarea for reporting purposes only. Input data are specified using a transarea number. **TAREA LOAD ADJ** defines the constant megawatt adjustment to all hours for a transarea. It may be positive (to increase the load) or negative (to reduce the load).

TAREA SYS PORT defines the percent adjustment to all hourly loads. It may also be positive or negative. If both variables are defined, the load is affected by both adjustments. The load is first adjusted by one plus **TAREA SYS PORT** and then summed with **TAREA LOAD ADJ**.

TAREA LOAD FLAG indicates the load assigned to a transarea. A transarea can have a load input from its own load file or it can be assigned a portion of the first transarea's load. To define the load portion, **TAREA LOAD ADJ** is added to one plus **TAREA SYS PORT** times the first transarea's load.

TAREA ENS COST is used to price the gigawatthours that are reported as energy not served for a transarea. It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value.

TAREA DUMP COST is used to price the gigawatthours that are reported as dump power for a transarea. It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value.

TAREA GEN PORT defines the percentage of the load for a transarea that must be produced by the generation capability of that transarea. No energy transfers may be considered until this portion of the load is produced.

TAREA OR FLAG indicates that operating reserve requirements will be enforced for the transarea identified. **TAREA SR FLAG** indicates that spinning reserve requirements will be enforced for the transarea identified. Reserve requirements can be input as a constant megawatt level, a percentage of the unadjusted hourly load, or as the normal full load megawatt level of the largest unit dispatched in the transarea (largest unit contingency).

TAREA OR MW defines the constant megawatts of operating reserve requirements for the transarea identified. **TAREA OR PCT** defines the percentage of the unadjusted hourly load for the transarea identified to be added to its operating reserve requirements. These numbers are summed to obtain the total transarea operating reserve requirements for each hour.

TAREA SR MW defines the constant megawatts of spinning reserve requirements for the transarea identified. **TAREA SR PCT** defines the percentage of the unadjusted hourly load for the transarea identified to be added to the spinning reserve requirements. These numbers are summed to obtain the total transarea spinning reserve requirements for each hour.

TAREA LG UN FLG indicates if the operating reserve requirement for the transarea identified will be calculated. The normal full load megawatt level of the largest unit dispatched in the transarea (largest unit contingency) for each hour is used as the transarea operating reserve requirement. **TAREA LG UN MW** defines the megawatt adjustment to the largest unit contingency for each hour for the transarea identified.

A link is defined by the transarea where it originates (**TAREA FROM LINK**) and the transarea where it terminates (**TAREA TO LINK**). Each link must have a reverse link to specify which link is paired with the current link to simulate bi-directional capability. If this link is not capable of transferring energy in both directions, the reverse link will have a transfer capability of zero, but still must be defined. The links are paired internally by PowrSym4.

Each link has a maximum megawatt capacity per hour (**TAREA LINK CAP**) and a wheeling or handling charge in dollars per megawatt-hour (**TAREA WHEEL**). The wheeling charge is added to the cost of transferring energy along a link when making transaction decisions. It is not considered part of the commit or dispatch cost. However, the amount of revenue from the wheeling charge is reported on the link report.

TAREA LNKLOSS A is the percent of the link capacity that is lost during transmission. **TAREA LINK CONTG** defines a transmission contingency for a link in megawatts. It may be entered on a weekly basis. For example, a link has a maximum capacity of 300 megawatts during the fall, winter, and spring. During the summer, the maximum capacity is 250 megawatts. For this link, **TAREA LINK CAP** would be 300 megawatts and **TAREA LINK CONTG** would be 250 megawatts for the summer weeks.

Variable list:

TAREA DUMP COST	Sale price in \$/MWh for dumped power for a transarea
TAREA ENS COST	Cost in \$/MWh for energy not served for a transarea
TAREA FROM LINK	Transarea where link originates
TAREA GEN PORT	Percentage of unadjusted hourly load that must be generated inside a transarea
TAREA LG UN FLG	Indicates if operating reserve requirements are input or calculated for a transarea
TAREA LINK CAP	Maximum megawatts per hour that can be transmitted along a link
TAREA LINK CONTG	Transarea link contingency in megawatts for a link
TAREA LNKLOSS A	Transmission losses for a link as a percentage of link capa
TAREA LOAD ADJ	Constant megawatt adjustment to all transarea hourly loads
TAREA LOAD FLAG	Indicate how load for a transarea is defined
TAREA NAME	Name to identify a transarea for reporting purposes only
TAREA OR FLAG	Indicates if operating reserve requirements enforced for a transarea
TAREA OR MW	Constant megawatt level operating reserve requirements for a transarea
TAREA OR PCT	Percent of unadjusted hourly load used for operating reserve requirements for a transarea
TAREA SR FLAG	Indicates if spinning reserve requirements enforced for a transarea
TAREA SR MW	Constant megawatt level spinning reserve requirements for a transarea
TAREA SR PCT	Percent of unadjusted hourly load used for spinning reserve requirements for a transarea
TAREA SYS PORT	Percent adjustment to all transarea hourly loads
TAREA TO LINK	Transarea where link terminates
TAREA WHEEL	Wheeling charge in \$/MWh for a link

6.5 Heat Area Data

PowrSym4 simulates both electric and heat demands. This requires the ability to model a station which produces only electricity, a station which produces only heat, and a station which produces combined heat and electricity (CHP). Parallel to the existence of transareas which delineate electric demand and electric generating stations, heat areas are defined with a heat load, heat and CHP stations, or both.

HEAT AREA FLAG indicates if heat data are defined for a heat area. If data are defined, **HEAT AREA NAME** identifies a heat area for reporting purposes only. **HEAT AREA TYPE** is the heating type supplied by a heat area. The heating type can be for district heat or industrial heat. **HEAT INPUT FLAG** indicates if the heat load is input from the heat load file (file 7) or is constant for all hours of the week.

COST HEATNS is used to price the gigawatthours that are reported as energy not served for a heat area. It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value.

COST DUMP HEAT is used to price the gigawatthours that are reported as dump power for a heat area. It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value.

HEAT LOAD MULT is the percent adjustment to all hourly heat area loads. The adjustment can be greater than one (increase loads) or less than one (decrease loads). It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value.

Variable list:

COST DUMP HEAT	Sale price in \$/MWh for dumped power for a heat area
COST HEATNS	Cost in \$/MWh for energy not served for a heat area
HEAT AREA FLAG	Indicates if heat data are defined for a heat area
HEAT AREA NAME	Name to identify a heat area for reporting purposes only
HEAT AREA TYPE	Indicates which heating type is supplied by a heat area
HEAT INPUT FLAG	Indicates the method of entering the heat load for a heat area
HEAT LOAD MULT	Percent adjustment to all heat area hourly loads

6.6 Thermal Station Data

A thermal station is a group of identical thermal units which are dispatched together. Grouping identical units into a single station reduces computation time. Units within a station are committed individually, but all committed units at a station are dispatched as a group to the same generation level. The grouping for dispatch purposes may introduce some inaccuracy in certain situations.

Single unit stations provide greatest accuracy, but this increases run time. Sensitivity to station grouping should be investigated for each power system.

6.6.1 Operating Parameters

STA NAME identifies the station name used for reporting purposes on station reports. Stations are the single or multiple unit groupings that are used by PowrSym4 as the logical groupings for commit and dispatch decisions. All other groupings are user-definable and are for reporting purposes only. Any combination of these groupings may be used in a single execution.

PLANT NAME identifies groups of stations for reporting. The conventional use for this grouping combines stations that are located in a single geographic location. **STA PLANT NUM** indicates the plant number where a station will be grouped.

STA GROUP NAME reassigns the station names used for group reporting. These groups are defined by the user with **GROUP RPT NAME**. **STA GROUP NUM** indicates the group number for a reporting group for a station. A station will have a group number for each reporting group that has been defined.

STA TAREA NUM indicates a station's transarea. It will be considered a part of that transarea for all calculations and reporting. A station can only belong to one transarea.

SUMMARY CLASS indicates a station's summary group. One possible grouping would be by fuel type. Another would be geographic location. These groups are output on the station summary report.

The commitment type (**COMMIT TYPE**) characterizes a station as base loaded, high load factor, medium load factor, low load factor, peaking, pumped hydro and other storage, hydro, or energy-limited. The commitment order is determined by economics within each of these categories.

PowrSym4 first schedules all available hydro, storage capacity, and energy-limited capacity for the week. For each hour of the week, it commits all available stations. Beginning with the peaking category, it decommits stations in reverse economic order until (1) all stations are decommitted, (2) it reaches the adjusted hourly load, or (3) encounters a heuristic limitation. As necessary, it continues to decommit stations in the low load factor category and the medium load factor category until it reaches one of the three criterion. All stations must be decommitted in one category before continuing to the next.

If the logic reaches the high load factor category, it cannot decommit a station unless it will cause an excess amount of generation for that hour (dump power). All stations in the first three categories must be decommitted or have a constraint that requires the station to remain on-line. Therefore, the stations in the high load factor category are not decommitted even if it is economical. For this reason, stations placed in the high load factor category must have an actual history of high load factors or need to be held on in situations where economics would decommit them.

Base load factor category stations are not decommitted. The logic will adjust the dispatch level of these stations, but they will remain committed. If necessary, the excess energy will be

considered dump power for that hour. If a simulation is needed that alters the commitment pattern for an individual station without modifying that station's operating costs, **VOM COM MULT** specifies a percentage to adjust a station's variable operation and maintenance cost. When the economic commitment order is defined, the station's cost will be increased (value greater than one) or decreased (value less than one) by this amount. However, the actual cost to operate the station will not be affected.

When the input data contains cases defined for the dynamic programming logic, PowrSym4 simulates commitment patterns specified by the user. **DP COMMIT FLAG** determines how a station will be affected in these patterns. A station can be forced to be committed, forced to be decommitted, or forced to keep the commitment pattern from the initial simulation. The logic then simulates the different commitment patterns and keeps the most economic pattern for the entire system.

Once PowrSym4 has determined the commit order for an hour and decommitted the necessary stations, the stations are dispatched according to their dispatch type (**DISP TYPE**). The five categories are: base loaded, high load factor, medium load factor, low load factor, and peaking.

In the peaking, low load factor, and medium load factor categories, the logic dispatches each station by economics given the individual station constraints. But like the decommit logic, the high load factor category stations are not changed until the first three categories have been adjusted to their limits. The base loaded category stations are the last stations to be adjusted. Therefore, only the units in the first three categories are actually adjusted by economics.

If a simulation is needed that alters the dispatch pattern for an individual station without modifying that station's operating costs, **VOM DISP MULT** specifies a percentage to adjust a station's variable operation and maintenance cost. When the economic dispatch order is defined, the station's cost will be increased (value greater than one) or decreased (value less than one) by this amount. However, the actual cost to operate the station will not be affected.

Each individual station has a set of characteristics and constraints that define its operation. PowrSym4 uses these definitions to determine which stations will be committed and the dispatch level for each station to meet the hourly system load.

INSTALLED UNITS defines the number of units available for a station at the beginning of the simulation. It may be altered by additions, retirements, and mothballing during the simulation.

RAMP RATE is the maximum rate at which a unit can increase or decrease generation in megawatts per hour under normal operating conditions. It is used to determine the amount of adjustment allowed in the dispatch logic.

MIN DOWN TIME is the minimum number of hours for which a unit at this station will be taken off-line. **MIN UP TIME** is the minimum number of hours for which a unit will be placed on-line. These values should be based on operating policy rather than the physical limitations of a station.

STA MIN is the minimum station generation level for all hours for the sum of all units at any station. This constraint is enforced in both commitment and dispatch. Minimum station generation levels are usually specified for voltage control or other transmission system considerations. **STA MIN HOURS** is the minimum number of hours that the sum of the units at a station must be on-line for economic reasons. **STA BEGIN DOWN** indicates how many hours a station is assumed to be down (zero units committed) before the first hour of the week. **STA UNIT MIN** defines the minimum number of units that must be on-line at a station for all hours of the week. All of these constraints are subject to unit availability due to forced outages and planned maintenance.

If a thermal station is limited by energy instead of capacity, **STA ENERGY** defines the number of gigawatthours per week that station can generate. It will be scheduled to minimize the load served by the station.

PowrSym4 has two interface files with the integrated resource planning model MIDAS Gold. Three station variables are used to input data required for these files. They are not used in PowrSym4 for any other purpose. All three variables are output to file 47.

A&I CAP RATE is the capital additions and improvements as a capacity rate expressed as dollars used per kilowatt affected on an annual basis for a station. **A&I ENERGY RATE** is the capital additions and improvements as an energy rate expressed as dollars used per megawatt-hour affected for a station. **REMAIN DEP LIFE** is the number of years of remaining depreciable life for a station.

STA COM MULT defines the percentage to adjust the maximum power level for a station's reserve calculations. This variable is only used by the Dutch utility, Sep.

If additional information is needed for an individual station on an hourly basis, **SELECT HR OUT** indicates that a station has been chosen for hourly output. This indicator overrides the user-defined print and output options specified at the system parameter level.

Variable list:

A&I CAP RATE	Capacity additions and improvements in \$/kW annual for output to MIDAS Gold interface file only (file 47) for a station
A&I ENERGY RATE	Energy additions and improvements in \$/MWh annual for output to MIDAS Gold interface file only (file 47) for a station
COMMIT TYPE	Commitment type for a station
DISP TYPE	Dispatch type for a station
DP COMMIT FLAG	Determines the effect to the commitment order for a station for a dynamic programming case
GROUP RPT NAME	Name used to identify reporting group on printed output
INSTALLED UNITS	Number of installed units for a station at the beginning of an execution
MIN DOWN TIME	Minimum down time in hours for a station.

MIN UP TIME	Minimum up time in hours for a station.
PLANT NAME	Name to identify a plant for reporting purposes only.
RAMP RATE	Ramp up and down rate for a station in megawatts per hour
REMAIN DEP LIFE	Remaining depreciable life in years for output to MIDAS Gold interface file only (file 47) for a station
SELECT HR OUT	Indicates if a station is selected for hourly output
STA BEGIN DOWN	Number of hours a station is assumed to be down (zero units committed) before the first hour of the week.
STA COM MULT	Percent used to modify the maximum capacity level for a station in the reserve calculations for the Dutch utility, Sep
STA ENERGY	Weekly energy allocation in GWh for an energy-limited station
STA GROUP NAME	Station group name used for reporting only
STA GROUP NUM	Group number assigned to a station by reporting group for reporting purposes only
STA MIN	Minimum generation in megawatts for a station
STA MIN HOURS	Minimum hours a week a station must run for economic reasons
STA NAME	Name to identify a station for reporting purposes only
STA PLANT NUM	Plant number assigned to a station for reporting purposes only
STA TAREA NUM	Transarea number assigned to a station
STA UNIT MIN	Minimum number of units at a station required to run
SUMMARY CLASS	Summary class number assigned to a station for reporting purposes only
VOM COM MULT	Percent to artificially adjust the variable operating and maintenance cost during the commit logic
VOM DISP MULT	Percent to artificially adjust the variable operating and maintenance cost during the dispatch logic

6.6.2 Economic Parameters

Thermal station cost parameters include the daily expenses incurred, the cost to start a unit, and the cost to have a unit on-line. Each of these parameters is discussed in this section. The other component, fuel cost, is discussed in section 6.6.6.

FIXED COST represents the fixed operation and maintenance (O&M) cost which will be incurred at the station independent of the level of unit operation. It is entered on a dollars per week per unit basis. Therefore, as the number of units at a station increases, the amount of fixed O&M for that station increases and vice versa. Fixed O&M is accrued even when units are unavailable due to forced outage, planned maintenance, or mothballing.

STRT COST defines the cost of starting a unit at a station in dollars per start. This value may include cost for startup fuel and an allocation of operation and maintenance cost associated with unit startups. If a unit at a station is on-line the first hour of the week, no start cost is incurred. This value is for a constant cost to start a unit.

If desired, PowrSym4 can calculate the start cost for a unit based on the equation:

$$SCost = A + FCost * (B + C * (1 - e^{(-DTime / T)}))$$

where

A, B, C, and T	Input coefficients
DTime	Down time in hours
FCost	Fuel cost
SCost	Start cost in dollars for this unit for this start

STRT COST A is input coefficient A, **STRT COST B** is input coefficient B, **STRT COST C** is input coefficient C, and **STRT COST TAU** is input coefficient T. Down time is the number of hours since this unit was on-line.

VAR COST represents the variable operation and maintenance (O&M) cost of unit at a station and is directly proportional to unit operation. It is entered as dollars per megawatt-hour. If a unit at a station has no generation, its variable O&M cost is zero.

All three of these costs may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value. If no value is entered at the beginning of a year and **O&M ESC** has a value greater than 1, the model will escalate that cost using its current value and the escalator. This value will be used for the entire year or until a weekly value overrides the calculated value.

Variable list:

FIXED COST	Fixed operation and maintenance cost in \$/wk/unit for a station
O&M ESC	Annual percent escalation for start cost, fixed operation and maintenance cost, and variable operation and maintenance cost for a station.
STRT COST	Start cost in dollars per start for a station as a constant
STRT COST A	Start cost optimization coefficient A for a station
STRT COST B	Start cost optimization coefficient B for a station
STRT COST C	Start cost optimization coefficient C for a station
STRT COST TAU	Start cost optimization coefficient T for a station
VAR COST	Variable operation and maintenance cost in \$/MWh for a station

6.6.3 Emissions Data

Emissions data for each station is currently specified for SO₂, NO_x, and CO₂. These are the first, second, and third effluents, respectively, defined on the standard printed reports. For each effluent, **EMMR** defines the emission rate for each effluent in pounds per million Btu. **EMMC** defines the cost in dollars per ton. This value is multiplied by the tons of effluent emitted to get the emission cost in dollars.

Both variables may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value. If no cost value is entered at the beginning of a year and **EMMESC** has a value greater than 1, the model will escalate the cost using its current value and the escalator. This cost will be used for the entire year or until a weekly value overrides the calculated value.

Instead of a constant emission rate for NO_x specified by **EMMR**, PowrSym4 can use an equation to calculate the hourly NO_x rate as a function of the current generating level in megawatts. The equation is:

$$\text{Pounds NO}_x = A1 + A2 * MW + A3 * e^{(A4 * MW)}$$

where

A1, A2, A3, and A4

Input coefficients

MW

Current dispatch level in megawatts for a station

NOX A1 CONSTANT is input coefficient A1, **NOX A2 CONSTANT** is input coefficient A2, **NOX A3 CONSTANT** is input coefficient A3, and **NOX A4 CONSTANT** is input coefficient A4. **EM EQ FLAG** indicates if a station is using a constant NO_x emission rate or the NO_x equation.

PowrSym4 uses the cost of these effluents to determine the operating cost of a station. The following settings for **STA EM FLAG** determine the operating costs included in the calculation of the total operating cost for a station:

- 0 All three emission costs plus fuel cost and variable operation and maintenance cost
- 1 Only emission cost 1 (SO₂).
- 2 Only emission cost 2 (NO_x).
- 3 Only emission cost 3 (CO₂).
- 4 All three emission costs.
- 5 Fuel cost and variable operation and maintenance cost only
- 11 Emission cost 1 (SO₂) plus fuel cost and variable operation and maintenance cost
- 12 Emission cost 2 (NO_x) plus fuel cost and variable operation and maintenance cost
- 13 Emission cost 3 (CO₂) plus fuel cost and variable operation and maintenance cost

A special set of emission reports have been developed for the Dutch utility, Sep. The emission rate, cost, and designation are all user inputs. Reports can be printed for up to four groupings. Currently, PowrSym4 allows six (6) user-defined effluents for these reports.

For each effluent, **EM COEFF** defines the emission rate for each effluent in pounds per million Btu. **EM WEIGHT** defines the designation used for the cost. This value is multiplied by the tons of effluent emitted to get the emission cost in dollars. **EM WEIGHT** identifies the name of the reporting category for an effluent.

EM OUT FLAG indicates if the user-defined emission reports will be printed. If so, **EM OWN REPORT** indicates if the owner report for the user-defined emissions will be printed. **EM PLT REPORT** indicates if the plant report for the user-defined emissions will be printed.

EM STA REPORT indicates if the station report for the user-defined emissions will be printed.
EM SUM REPORT indicates if the summary report for the user-defined emissions will be printed. Any or all of these reports can be defined.

Variable list:

EM COEFF	Emission rate in pounds per million Btu for a station
EM EQ FLAG	Indicates how NO _x is calculated
EM NAME	Identifies the name of the reporting category for an effluent
EM OUT FLAG	Indicates if user-defined emission reports will be written
EM OWN REPORT	Indicates if user-defined emission reports will be printed by owner
EM PLT REPORT	Indicates if user-defined emission reports will be printed by plant
EM STA REPORT	Indicates if user-defined emission reports will be printed by station
EM SUM REPORT	Indicates if user-defined emission reports will be printed by summary class
EM WEIGHT	Identifies the name of the reported weight for a user-defined emission
EMMC	Defines cost of emission in dollars per ton
EMMESC	Defines annual percent escalation for cost of emission
EMMR	Defines emission rate in pounds per million Btu
NOX A1 CONSTANT	Defines A1 constant in NO _x equation
NOX A2 CONSTANT	Defines A2 constant in NO _x equation
NOX A3 CONSTANT	Defines A3 constant in NO _x equation
NOX A4 CONSTANT	Defines A4 constant in NO _x equation
STA EM FLAG	Defines the operating cost objective function for a station

6.6.4 Energy-limited Fuel Data

The Energy Limited Fuels Module (ELF), when used in conjunction with the concurrent solution method, directly solves energy-limited fuels allocation. This is accomplished by keeping the ELF allocated optimally as units are dispatched down and decommitted. For a given commit, the ELF allocation will be optimally solved.

The ELF allocation is solved using network flow programming. Fuel constraints and prices, as well as station demand, are modeled using a system of nodes interconnected by links. Each constraint has an associated set of nodes (i.e., weekly constraints for a fuel are assigned a node, daily constraints for that same fuel are assigned a set of seven nodes (one per day), and hourly constraints for the fuel are assigned a set of 168 nodes.) Additional nodes are added to the network in order to represent stations, one node per hour per station. The last node assigned to the system represents both the source and the sink. All fuel flows through the system links from the source node to the sink node.

Links are used to interconnect the above set of nodes. For the given fuel, the source is connected to the weekly fuel node, which is connected to each daily node, and then connected to their respective hourly nodes. Each hourly fuel node is connected with the hourly station node for all stations using this particular fuel. Each hourly station node is then connected to the sink which completes the circuit. In addition to the links directly associated with a particular ELF, there are spot links which connect the source with each station hour and dump links which connect each ELF hour with the source. An example network is shown in figure 6.6.4.1.

Each link, connecting a node U to a node V has a mirror link which connects node V to node U. Flow is scheduled on links, from source to sink, and unscheduled on mirror links, sink to source. Associated with each link is its cost, flow, and potential flow. The cost for a link is determined by the violation cost (the cost of flowing a unit of fuel on the link) using the amount of fuel flowed with respect to the constraints for that link and the fuel cost. The flow for a link is associated with the link only, not the mirror link, and represents the net amount of fuel that has passed from node U to node V. The potential flow for a link is the amount of fuel which may be flowed before the cost of flowing that fuel changes. This potential flow is associated with both links and mirror links.

A Bellman-Ford shortest path algorithm is used to determine the shortest path between any two given nodes (a source and a sink). The algorithm consists of searching for the path from the source that minimizes the potential of a node through a relaxation process. The source always has zero potential, and all potentials and paths are referenced to it. The potential of a node V that is being potentialized from a node U across link(U,V) is calculated as the sum of the potential of node U and the cost of link(U,V). In relaxation, a node is potentialized if the potential calculated is less than the current potential of the node. All nodes other than the source are initialized with an infinite potential.

An ELF is identified by its name (**ELF NAME**) for reporting purposes and has an associated fuel energy cost in dollars per fuel consumed (**ELF COST**) and a heat value in fuel consumed per unit of fuel (**ELF HEAT VALUE**).

Each ELF can have maximum and minimum available energy in megawatthours on an hourly, daily, weekly, and annual basis. Hourly constraints are **ELF HOURLY MIN** for the minimum and **ELF HOURLY MAX** for a maximum. Daily constraints are **ELF DAILY MIN** for the minimum and **ELF DAILY MAX** for a maximum. Weekly constraints are **ELF WEEKLY MIN** for the minimum and **ELF WEEKLY MAX** for a maximum. Annual constraints are **ELF YEARLY MIN** for the minimum and **ELF YEARLY MAX** for a maximum.

Variable list:

ELFNAME	Name of an energy-limited fuel
ELF COST	Fuel cost in \$/fuel consumed for an energy-limited fuel
ELF HEAT VALUE	Heat value in fuel consumed per unit of fuel for an energy-limited fuel
ELF DAILY MAX	Maximum available fuel to consume per day for an energy-limited fuel
ELF DAILY MIN	Minimum available fuel to consume per day for an energy-limited fuel
ELF HOURLY MAX	Maximum available fuel to consume per hour for an energy-limited fuel

ELF HOURLY MIN	Minimum available fuel to consume per hour for an energy-limited fuel
ELF WEEKLY MAX	Maximum available fuel to consume per week for an energy-limited fuel
ELF WEEKLY MIN	Minimum available fuel to consume per week for an energy-limited fuel
ELF YEARLY MAX	Maximum available fuel to consume per year for an energy-limited fuel
ELF YEARLY MIN	Minimum available fuel to consume per year for an energy-limited fuel
STA ELF INDEX	Assigns fuels to stations

6.6.5 Forced Outage Rate and Maintenance Data

PowrSym4 simulates to outage states for each station: forced outage and maintenance outage. Currently, it does not allow partial outages or deratings. These enhancements will be available in future releases.

Section 6.2.5 describes the different simulation methods to model forced outages. **FOR** is a station's equivalent forced outage rate expressed as a percent. Since generating unit forced deratings are not explicitly represented, the forced outage rate should be computed as an equivalent including an allowance for partial outages. If the gradient derating method is used, **EFOR A CONSTANT** defines the "A" coefficient for the derating equation and **EFOR K CONSTANT** defines the "K" coefficient for the derating equation.

Section 6.2.7 discusses the different planned and maintenance outage options available. **PMOR** defines the planned and maintenance outage rate for a station.

Variable list:

EFOR A CONSTANT	Defines "A" coefficient in the equivalent forced outage rate equation for a station
EFOR K CONSTANT	Defines "K" coefficient in the equivalent forced outage rate equation for a station
FOR	Defines equivalent forced outage rate for a station
PMOR	Defines planned and maintenance outage rate for a station

6.6.6 Fuel Data

PowrSym4 calculates the fuel cost for a station using the input heat calculated to generate its energy. **FCOST** defines the fuel cost for a station in cents per fuel consumed. It is converted to dollars per megawatt-hour internally to sum with the variable operation and maintenance cost and emission costs to obtain the total operating cost for the station. The total operating cost is used to rank the stations for the commit and dispatch logic.

Fuel cost may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value. If no cost

value is entered at the beginning of a year and **FCOST ESC** has a value greater than 1, the model will escalate the cost using its current value and the escalator. This cost will be used for the entire year or until a weekly value overrides the calculated value.

To calculate the amount of fuel burned, **HEAT VALUE** defines the heat content of the fuel in millions of Btus per unit of fuel. For example, the unit of fuel for coal would be a ton, and the desired units for fuel burned would be tons. Therefore, the heat content for coal would be expressed in millions of Btus per ton. Other units of fuel would be barrels for oil, thousands of cubic feet for natural gas, and pounds of yellow cake for nuclear.

If a simulation is needed that alters the commitment pattern for an individual station without modifying that station's fuel cost, **FCOST COM MULT** specifies a percentage to adjust a station's fuel cost. When the economic commitment order is defined, the station's cost will be increased (value greater than one) or decreased (value less than one) by this amount. However, the actual cost to operate the station will not be affected.

If a simulation is needed that alters the dispatch pattern for an individual station without modifying that station's fuel cost, **FCOST DISP MULT** specifies a percentage to adjust a station's fuel cost. When the economic dispatch order is defined, the station's cost will be increased (value greater than one) or decreased (value less than one) by this amount. However, the actual cost to operate the station will not be affected.

If a simulation includes stations which burn blast furnace gas fuel as a supplement to their regular fuel, PowrSym4 can calculate the total fuel cost for a station by combining these two costs. **ALT FCOST** defines the price for blast furnace gas fuel in dollars per gigajoule for a station. It may be entered on a weekly basis. If a new value is entered at the beginning of the year, it is used for that entire year or until a weekly value overrides the initial value. If no cost value is entered at the beginning of a year and **ALT FCOST ESC** has a value greater than 1, the model will escalate the cost using its current value and the escalator. This cost will be used for the entire year or until a weekly value overrides the calculated value.

To calculate the amount of fuel burned, **ALT HEAT VALUE** defines the heat content of the blast furnace gas fuel in millions of Btus per unit of fuel. This amount is summed with the fuel burn calculated for the regular fuel to obtain the total fuel burn.

Variable list:

ALT FCOST	Defines price for blast furnace gas fuel in dollars per gigajoule for a station
ALT FCOST ESC	Defines annual escalation factor for blast furnace gas fuel for a station
ALT HEAT VALUE	Defines heat content contained in blast furnace gas fuel in millions of Btus per unit of fuel for a station
FCOST	Defines fuel cost in cents per million Btu for a station
FCOST COM MULT	Defines factor to artificially adjust the fuel cost for a station during the commit logic
FCOST DISP MULT	Defines factor to artificially adjust the fuel cost for a station during the dispatch logic
FCOST ESC	Defines annual escalation factor for fuel cost for a station

HEAT VALUE	Defines heat content contained in the fuel in millions of Btus per unit of fuel for a station
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6.6.7 Fuel-Type Data

The previous section describes an approach in which fuel properties are associated with a generating station. PowrSym4 also provides the alternative to assign fuel properties to a fuel-type and then draw from these fuel-types to calculate the fuel properties used at a generating station.

FUEL NAME is used to define each fuel-type that will be used in this mode. The associated **FUEL COST** is used to define the base cost for a fuel-type. **FUEL COST ESCALATION** defines the rate of annual escalation that will be applied to the fuel-type during the study period. **FUEL HEAT VALUE** defines the heat content (MBTU/unit of fuel) for the fuel-type.

Each station can point to one or more of the defined fuel-types to reflect either consumption of either a single fuel or a fuel blended from two or more fuel-types. **STA FUEL MIXING** defines the percentage of fuel-type used by that station in a blended fuel. If the total percentages specified add up to less than 100%, the difference will be made up using data defined for the FCOST, FCOST ESC and HEAT VALUE that were defined for that station (see above). **STA FUEL TCOST** is used to assign a transportation cost for each fuel-type and station involved. STA FUEL TCOST is added to FUEL COST in calculating the effective fuel cost that is used for station commitment and dispatch decisions. No provision is made at the current time for escalating transportation cost. A maximum of 10 fuel-types can be blended at one station.

Variable list:

FUEL NAME	Identifies a fuel that can be used at one or more stations
FUEL HEAT VALUE	Defines heat content of the fuel type (MBTU/unit of fuel)
FUEL COST	Defines fuel cost for fuel-type (cents per MBTU).
FUEL COST ESC	Defines annual escalation factor for fuel cost for a fuel-type
STA FUEL MIXING	Defines the percentage of a stations energy is provided by a fuel-type
STA FUEL TCOST	Defines the additional transportation cost associated with delivering a fuel-type to the station

6.6.8 Heat Rate and Power Level Data

PowrSym4 uses two methods to calculate the input heat associated with a specified power level for a station. One method uses the single curve or double curves that define the heat rate levels. The other method specifies the heat rates that correspond to five power levels: the minimum generation, two intermediate levels, the normal full load, and the maximum generation level. **EFF CURVE TYPE** indicates which method will be used to calculate the heat rates for a station.

The first method can use a single curve that is valid for all power levels. It can also use a double curve that is divided at the maximum, valid power level for the first curve. The curve or curves are used to calculate the input heat for a given power level at a station.

Both equations have the form:

$$\text{Heat} = A + B * \text{PLevel} + C * \text{PLevel}^2 + Z * \text{Plevel}^3$$

where

- A, B, C and Z - Input coefficients
- PLevel - Current power level for a station
- Heat - Heat rate for this power level for a station

EFF EQ A1 is the “A” coefficient for the single curve or the first curve for a double curve, **EFF EQ B1** is the “B” coefficient for the single curve or the first curve for a double curve, and **EFF EQ C1** is the “C” coefficient for the single curve or the first curve for a double curve. If a double curve is needed, **EFF EQ A2** is the “A” coefficient for the second curve, **EFF EQ B2** is the “B” coefficient for the second curve, and **EFF EQ C2** is the “C” coefficient for the second curve. **EFF MW MAX** defines the maximum power level that is valid for the first curve.

The second method uses up to five levels to define a net heat rate curve at specified power levels. The first power level is the minimum generation at which a unit for a station will normally be operated. The fourth power level is the normal full load. The fifth power level is the maximum generation which can be obtained from the unit. Levels two and three should be defined as close to actual intermediate power levels as possible, since PowrSym4 must interpolate to obtain the heat rate for the plant operating at the system lambda.

HEAT RATE LVLS defines the five net heat rates in Btus per kilowatt-hour for a station. **POWER LEVELS** defines the five power levels in megawatts that are associated with the net heat rates for a station. **HEAT RATE MULT** adjusts the net heat rates by a multiplier for a station. These adjustments could include plant degradation, temporary equipment failure, or seasonal increase during warmer months.

Variable list:

EFF CURVE TYPE	Indicates type of heat rate calculation for a station.
EFF EQ A1	Defines “A” coefficient for single heat rate curve or first curve for a double heat rate curve for a station
EFF EQ A2	Defines “A” coefficient for second curve for a double heat rate curve for a station
EFF EQ B1	Defines “B” coefficient for single heat rate curve or first curve for a double heat

	rate curve for a station
EFF EQ B2	Defines “B” coefficient for second curve for a double heat rate curve for a station
EFF EQ C1	Defines “C” coefficient for single heat rate curve or first curve for a double heat rate curve for a station
EFF EQ C2	Defines “C” coefficient for second curve for a double heat rate curve for a station
EFF EQ Z1	Defines “Z” coefficient for single heat rate curve or first curve for a double heat rate curve for a station
EFF EQ Z2	Defines “Z” coefficient for second curve for a double heat rate curve for a station
EFF MW MAX	Defines maximum load in megawatts that first curve for a double heat rate curve is valid for a station
HEAT RATE LVLS	Defines net heat rate levels in Btus per kilowatt-hour
HEAT RATE MULT	Defines adjustment multiplier for all five heat rate levels specified by HEAT RATE LVLS for a station
POWER LEVELS	Defines the five power levels in megawatts to be used with HEAT RATE LVLS for a station

6.6.9 Heat Station Data

PowrSym4 simulates stations which produce only electric generation, stations which produce only heat generation, and stations that combine heat and electric generation (CHP). Stations with heat production capability are simulated with the electric generation stations and not as a separate simulation.

A heat station is paired with an electric station to identify common characteristics. These include commit type, dispatch type, power levels, electric portion of input heat curve, and any characteristics necessary to define the electric production portion of CHP station.

HEAT STA ELEC identifies the station number of the paired electric station for a heat station.

HEAT STA NUM defines a heat station that is using the characteristics of an electric station.

Each heat station is identified by the combination of electric and heat load that it serves.

HEAT STA TYPE indicates a heat station’s capabilities using the following types:

- 1 Combined heat and electric production for district heating
- 2 Auxiliary heat boiler for district heating
- 3 Heat storage for district heating
- 4 Combined heat and electric production for both district and industrial heating
- 5 Combined heat and electric production for industrial heating
- 6 Auxiliary heat boiler for industrial heating
- 7 Heat storage for industrial heating

Heat storage stations will be discussed in section 6.9. Auxiliary heat boiler stations produce heat only, and CHP units produce both heat and electric production.

HEAT STA AREA indicates the heat area that contains a heat station. Heat areas are used to

define which units are expected to serve a particular heat load. **HEAT STA MIN** defines the minimum heat production available in megawatts thermal for a heat station. **HEAT STA MAX** defines the maximum heat production available in megawatts thermal for a heat station. Heat stations providing industrial heat have two additional characteristics. **HEAT AREA INDUS** indicates the heat area to which a heat station supplies industrial heat. If this heat station does not supply industrial heat, this value must be zero. **INDUS HEAT EXT** defines the fixed industrial heat extraction in gigajoules for an industrial heat production station.

PowrSym4 uses a single input heat equation to define the characteristics of electric, heat, and CHP stations. The equation is:

$$\text{InputHeat} = A + B * \text{PLevel} + C * \text{PLevel}^2 + Z * \text{PLevel}^3 + D * \text{HLevel} + E * \text{HLevel}^2 + F * \text{PLevel} * \text{HLevel} + G * \text{Iheat}$$

where

A, B, C, Z, D, E, F, and G	Input coefficients
HLevel	Current district heat load for a heat station
IHeat	Current industrial heat load for a heat station
PLevel	Current electric load for a heat station
InputHeat	Total input heat for a heat station

EFF EQ A1 is the “A” coefficient	HEAT EQ PARAM D is the “D” coefficient
EFF EQ B1 is the “B” coefficient	HEAT EQ PARAM E is the “E” coefficient
EFF EQ C1 is the “C” coefficient	HEAT EQ PARAM F is the “F” coefficient
EFF EQ Z1 is the “Z” coefficient	HEAT EQ PARAM G is the “G” coefficient

Each heat station has heat borders that determine the amount of electric and heat load it can serve. As the heat load goes up, the electric load must decrease and vice versa. The curve to define this area is:

$$X * \text{ElecLoad} + Y * \text{HeatLoad} > Z$$

where

X, Y, and Z	Input coefficients
ElecLoad	Electric load being served at a heat station
HeatLoad	Heat load being served at a heat station

The number of lines that define heat borders is determined by the operating characteristics of the individual heat station. **HEAT STA BORDER** defines the number of border lines used to delineate the heat area for a heat station. **HEAT BORDER X** is the “X” coefficient, **HEAT BORDER Y** is the “Y” coefficient, and **HEAT BORDER Z** is the “Z” coefficient. Some heat stations have blast furnace gas available as a supplementary fuel. It is used in conjunction with rich gas as fuel for a heat station. **BF PLANT TYPE** indicates which heat stations have blast furnace gas fuel available. **BF PLANT NUM** identifies the blast furnace gas plant for a heat station. Plants are only used to group stations for reporting. **RICH BURN STA** indicates the number of the station at a blast furnace gas plant that can burn rich gas independent of the blast furnace gas amounts.

BF SIM MODE indicates the simulation mode for blast furnace gas at a heat station. The modes available are:

- 0 Constant blast furnace gas supply for all hours of the week as specified by data input.
- 1 Constant blast furnace gas supply for all hours of the week using the input data as the expected value of a random distribution
- 2 Blast furnace gas supply estimates and input values must be specified separately for all hours of the week

BF GAS MIN defines the minimum amount of blast furnace gas and rich gas that can be burned at a heat station in gigajoules per hour. It is the minimum amount of support fuel needed while burning blast furnace gas. **BF GAS MAX** defines the maximum amount of blast furnace gas and rich gas that can be burned at a heat station in gigajoules per hour. The sum of the blast furnace gas and rich gas is not allowed to be greater than this value. **BF GAS EFF** is the correction factor to account for the efficiency reduction due to blast furnace gas burn. It is assumed that rich gas does not alter this factor.

BF REAL GAS defines the constant amount of real blast furnace gas fuel available for a blast furnace gas plant in gigajoules per hour. **BF REAL GAS EST** is the amount of estimated blast furnace gas fuel for a blast furnace gas plant in gigajoules per hour. It is used as the expected value of a random distribution to select a constant blast furnace gas supply for all hours of a week. **BF UNIT MIN** indicates the calculation method for blast furnace gas plant unit minimum amounts (real input values or estimated input values).

RICH GAS REAL defines the constant amount of real rich gas fuel available for a blast furnace gas plant in gigajoules per hour. **RICH GAS EST** is the amount of estimated real gas fuel for a blast furnace gas plant in gigajoules per hour. It is used as the expected value of a random distribution to select a constant rich gas supply for all hours of a week.

WK FUEL PATT is the weekly fuel pattern number for a heat station. It is used to determine the amount of blast furnace gas plus rich gas burned at the minimum level for all units at the heat station.

Variable list:

BF GAS EFF	Correction factor accounting for efficiency reduction due to blast furnace gas burn for a heat station.
BF GAS MAX	Maximum amount of blast furnace gas and rich gas in gigajoules per hour that can be burned at a heat station
BF GAS MIN	Minimum amount of blast furnace gas and rich gas in gigajoules per hour that can be burned at a heat station.
BF PLANT NUM	Blast furnace gas plant number for a heat station
BF PLANT TYPE	Identifies blast furnace gas plants
BF REAL GAS	Amount of real blast furnace gas fuel in gigajoules per hour for a blast furnace gas plant used as a constant for all hours of a week.
BF REAL GAS EST	Amount of estimated blast furnace gas fuel in gigajoules per hour for a blast furnace gas plant used as the expected value of a random distribution to select a constant for all hours of a week.

BF SIM MODE	Indicates simulation mode for a blast furnace gas plant
BF UNIT MIN	Indicates calculation method for blast furnace gas plant unit minimum amounts
EFF EQ A1	Defines “A” coefficient for single heat rate curve or first curve for a double heat rate curve for a station
EFF EQ A2	Defines “A” coefficient for second curve for a double heat rate curve for a station
EFF EQ B1	Defines “B” coefficient for single heat rate curve or first curve for a double heat rate curve for a station
EFF EQ C1	Defines “C” coefficient for single heat rate curve or first curve for a double heat rate curve for a station
EFF EQ Z1	Defines “Z” coefficient for single heat rate curve or first curve for a double heat rate curve for a station
HEAT AREA INDUS	Defines heat area where a heat station supplies industrial heat
HEAT BORDER X	Defines “X” coefficient in heat border equation for a heat station
HEAT BORDER Y	Defines “Y” coefficient in heat border equation for a heat station
HEAT BORDER Z	Defines “Z” coefficient in heat border equation for a heat station
HEAT EQ PARAM D	Defines “D” coefficient in heat rate calculation for a heat station
HEAT EQ PARAM E	Defines “E” coefficient in heat rate calculation for a heat station
HEAT EQ PARAM F	Defines “F” coefficient in heat rate calculation for a heat station
HEAT EQ PARAM G	Defines “G” coefficient in heat rate calculation for a heat station
HEAT STA AREA	Defines heat area containing a heat station.
HEAT STA BORDER	Defines number of borders describing shape of electric/heat production area for a heat station
HEAT STA ELEC	Identifies electric station number paired with a heat station
HEAT STA MAX	Maximum heat production available in megawatts thermal for a heat station
HEAT STA MIN	Minimum heat production available in megawatts thermal for a heat station
HEAT STA NUM	Defines a heat station using production cost characteristics for an electric station
HEAT STA TYPE	Indicates heat station type for a heat station
INDUS HEAT EXT	Defines fixed industrial heat extraction in gigajoules per hour for an industrial heat production station
RICH BURN STA	Defines station number for a blast furnace gas plant that can burn rich gas independent of the blast furnace gas amounts
RICH GAS EST	Defines amount of estimated rich gas fuel in gigajoules per hour for a blast furnace gas plant used as the expected value of a random distribution to select a constant for all hours of a week
RICH GAS REAL	Defines amount of real rich gas fuel in gigajoules per hour for a blast furnace gas plant used as a constant for all hours of a week
WK FUEL PATT	Defines weekly fuel pattern number for a heat station used to determine the amount of blast furnace plus rich gas burned at the minimum level for all units

6.6.10 Maturity Curve

PowrSym4 simulates the maturity curve that exists for a new station. As the station is reaching its commercial operation date (COD), it generates power during its final testing stages. However, the power level it can achieve and the length of time it can remain on-line do not

reflect its normal operation. **PRECOM FOR** is the precommercial forced outage rate used to emulate the excessive unavailability of a station during this time. **WEEKS PRECOM** is the number of weeks of precommercial operation expected at a station.

A maturity curve is used to simulate the additional forced outage during the period immediately following the COD for nuclear stations. This equation is:

$$\text{AdditionalFOR} = B / (C^{\text{Year}})$$

where

B and C	Input coefficients
Year	Years of commercial operation
AdditionalFOR	Additional forced outage while maturing

Variable list:

MAT CURVE B	Defines “B” coefficient in nuclear maturity curve equation
MAT CURVE C	Defines “C” coefficient in nuclear maturity curve equation
PRECOM FOR	Defines forced outage rate during precommercial period
WEEKS PRECOM	Defines number of weeks in precommercial period

6.6.11 Operating Reserves Data

PowrSym4 calculates the operating reserve contribution of each dispatched unit at a station. For stations classified as quick-start, the generation considered to be quick-start also contributes to a station’s contribution. A quick-start unit is defined as a generator that can achieve its normal full load capacity in ten minutes or less. These units normally include storage capacity and certain combustion turbine designs.

SPIN STATUS indicates the reserve status for a station. A station can be considered quick-start, firm, or non-firm capacity. If available, quick-start stations contribute all undispatched capacity for uncommitted units and the delta between the normal full load capacity and the dispatched capacity for committed units. Firm stations contribute the delta between the normal full load capacity and the dispatched capacity for all committed units. Non-firm capacity cannot contribute to any reserve calculation.

Once the total reserve contributions have been summed, PowrSym4 compares the total with the required operating reserves. If the total does not meet the required reserves, additional stations must remain committed to meet the reserve requirement. This applies even though the economical solution would decommit the stations. There are user-definable limits for operating reserve contributions from a station. Each station can have a limited contribution to operating reserves or be required to reserve capacity for operating reserves. These values can be defined in megawatts or as a percentage of normal full load capacity at a station.

OR UNUSED MW is the maximum available capacity in megawatts for a station that can be used to meet the operating reserve requirements. A station cannot contribute more than this amount to the operating reserve requirements. For example, a 100 megawatt station has a maximum contribution of 25 megawatts. If the station is dispatched to 80 megawatts, it can contribute all 20 megawatts to meet the operating reserve requirements. However, if it is dispatched to 70 megawatts, it can only contribute 25 of the 30 megawatts available to the operating reserve requirements. **OR UNUSED PCT** is the percentage of the normal full load capacity for a station that can be used to meet the operating reserve requirements. The simulation will use the calculated percentage up to a maximum available megawatts specified (i.e., the megawatt specification (**OR UNUSED MW**) is the maximum for the percentage calculation (**OR UNUSED PCT**).

OR RESERVED MW is the capacity in megawatts at a station that must be reserved to meet operating reserve requirements. In effect, the normal full load capacity for a station is lowered by this amount for generation purposes. For example, the same 100 megawatt station has 15 megawatts that must be reserved. If the simulation requires 80 megawatts from this station, it can generate all 80 megawatts. However, if the simulation requires 90 megawatts, this station can only contribute 85 megawatts. The other 5 megawatts will have to be met by another resource. **OR RESERVED PCT** is the percentage of the normal full load capacity at a station that must be reserved to meet operating reserve requirements.

Variable list:

OR RESERVED MW	Defines capacity in megawatts at a station that must be reserved to meet operating reserve requirements
OR RESERVED PCT	Defines percentage of normal full load capacity at a station that must be reserved to meet operating reserve requirements
OR UNUSED MW	Defines maximum available capacity in megawatts at a station that can be used to meet the operating reserve requirements
OR UNUSED PCT	Defines percentage of normal full load capacity at a station that can be used to meet the operating reserve requirements
SPIN STATUS	Indicates reserve status for a station
STA OR MAX	Defines percentage of normal full load capacity at a station as its maximum operating reserve obligation using reserve rules for the Dutch utility, Sep
STA OR MIN	Defines percentage of normal full load capacity at a station as its minimum operating reserve obligation using reserve rules for the Dutch utility, Sep

6.6.12 Unit Additions and Retirements

PowrSym4 allows specification of unit expansion and retirement dates for individual thermal units at a station. These values adjust the number of installed units specified at the beginning of the simulation.

ADD UNITS identifies the commercial operation date for an expansion unit at a station. Up to six units may be added with separate records on the same or differing dates. Dates are entered in the format YYYYWW where:

YYYY - Year the expansion unit becomes commercial
 WW - Week the expansion unit becomes commercial

During the first year of commercial operation, a unit is not scheduled for planned maintenance. This applies even if a **PMOR** is defined for that year.

REM UNITS STRT1 and **REM UNITS END1** specify the beginning and ending dates of the first mothball period for a station, respectively. **REM UNITS NUM1** identifies the number of units at a station that are affected by the dates of the first mothball period. Using these values, the simulation reduces the number of units available at a station for the specified time period. However, the fixed operation and maintenance cost will still reflect the total number of installed units at a station including mothballed units. The ending date for the mothball period may extend beyond the specified simulation period.

Two mothballing periods may be specified for a station. **REM UNITS STRT2** and **REM UNITS END2** specify the beginning and ending dates of the second mothball period for a station, respectively. **REM UNITS NUM2** identifies the number of units at a station that are affected by the dates of the second mothball period.

Variable list:

ADD UNITS	Defines the commercial operation date for an expansion unit at a station
PMOR	Planned and maintenance outage rate for a station
REM UNITS END1	Defines the ending date of the first mothball period for a station
REM UNITS END2	Defines the ending date of the second mothball period for a station
REM UNITS NUM1	Defines the number of units that are affected by the dates of the first mothball period for a station.
REM UNITS NUM2	Defines the number of units that are affected by the dates of the second mothball period for a station
REM UNITS STRT1	Defines the beginning date of the first mothball period for a station
REM UNITS STRT2	Defines the beginning date of the second mothball period

6.6.13 Hydro Station Data

Hydro stations are scheduled to operate in such a manner as to levelize the load shape to be served by other stations. They are scheduled sequentially over the weekly time horizon, subject to hourly constraints for minimum and maximum generation, and weekly constraints on ramp rates and energy. Typically, hydro levelizes the overall system load; however, a hydro station can be scheduled to meet the load of a transmission or control area (e.g., when there are transmission constraints preventing the station from benefiting the system as a whole).

The station is first scheduled to operate at its hourly minimum for all hours, and the load for each hour is reduced by the amount of this generation. If this schedule is less than the available energy for the week from the station, the generation is increased by an increment for the hours with the highest adjusted loads. The loads for these hours are accordingly adjusted downward. Hourly constraints are enforced during the dispatch process. This process is continued until the total weekly generation for this station matches the available energy from the station. Interpolation is used on the last increment.

Hydro units can be aggregated into very large pseudo stations without significant loss of accuracy because of their extremely low forced outage rates and flexibility of operation.

The energy and capacity levels specified for the very large pseudo hydro stations should be based on system hydro totals and not the sum of the capacities of the individual stations. These values are usually determined by examination of historical hydro generation data for wet, dry, and typical years. Diversity in hydrological years can be represented in PowrSym4 by making individual studies using the wet, dry, and typical year hydro data and weighting the results of the studies by the probability of occurrence of the associated hydrological condition.

If large pseudo stations are used, some thermal characteristics should be reflected in the seasonal operating data. The forced outage rate should be specified as zero, and the capacity of the pseudo station derated. Maintenance, additions, and retirements should be reflected in the seasonal operating data. The fixed operation and maintenance cost for hydro stations is specified in dollars per week per unit in service. The variable operation and maintenance cost is in dollars per megawatt-hour of generation. Startup cost and fuel cost are not meaningful for hydro plants and may be omitted.

If the hydro stations are uniquely represented, forced outage rates, maintenance, additions, and retirements may be included. The cost data should also be specified.

Each hydro station is identified by a reservoir number (**RESERVOIR NUM**). This number is used to identify the energy and power levels associated with that hydro station. **HYDRO ENERGY** is the weekly energy allocation in gigawatthours for a hydro station. **HYDRO MIN** is the minimum power level in megawatts for a hydro station. **HYDRO MAX** is the maximum power level in megawatts for a hydro station. If the sum of the daily maximums is less than the weekly energy allocation or the sum of the daily minimums is greater than the weekly energy, a warning is issued, and the simulation is terminated.

Variable list:

HYDRO ENERGY	Defines weekly energy allocation in gigawatthours for a hydro station
HYDRO MAX	Defines weekly maximum power level in megawatts for a hydro station
HYDRO MIN	Defines weekly minimum power level in megawatts for a hydro station
RESERVOIR NUM	Identifies reservoir number associated with a hydro station

6.7 Electric Energy Storage Station Data

Pumped hydro, batteries, compressed air energy storage, some DSM programs, and flywheels may be represented as energy storage stations. Such a station is characterized by a reservoir (stored energy from which to draw and to which energy must be returned). It also has characteristics of its power production and of its pumping (energy return). Each station has a reservoir number (**RESERVOIR NUM**) to identify the reservoir providing energy for generation and receiving pumping for storage. **RESERVOIR NUM** used for energy storage units is not the same as the **RESERVOIR NUM** used for hydroelectric units described in section 6.7, above. The reservoir sequence used in energy storage is maintained separately from the reservoir sequence used for the hydroelectric system.

In essence, the station operates as follows: given a starting level of energy in its reservoir on Monday at hour ending 1:00 A.M., the resource attempts to balance generation and pumping in order to end the week with same net energy as it started, while choosing times to generate and return energy to minimize system cost.

The reservoir size is given in gigawatthours (**RESERVOIR SIZE**) including any generating efficiency losses (**PHYD GEN EFF**). For example, if the station has a 90% generating efficiency, and a reservoir size of 10 gigawatthours, then the energy generated by taking the reservoir from completely full to completely empty is 9 gigawatthours. During the week's operation, the reservoir may not be filled beyond its capacity nor drained below "empty".

There are also efficiency losses incurred when replacing the energy in the reservoir (**PHYD PUMP EFF**). Using the same example above, it would require 11.11 gigawatthours to fill the reservoir from "empty" to completely full (10 gigawatthours) with a replacement efficiency of 90%.

The reservoir's starting net position at 1:00 A.M. Monday is given as a fraction of the reservoir's size (**PHYD RES INIT**). In the example above, if this position is set to 0.8, then the reservoir contains 8 gigawatthours at the beginning of the week. (This would allow some pumping to occur in the early hours of Monday, before the energy is required at the peak.) It is assumed that, when no value is specified, the reservoir is full at 1:00 A.M. Monday.

The reservoir's final position at the end of the week is also given as a fraction of the reservoir's size (**PHYD RES FINAL**). It is recommended that this value be the same as the starting position. If the reservoir is allowed to vary from week to week, energy is gained or lost from one week to the next. This causes the generation reported for other resources to be artificially influenced by this energy. Simulations designed to value individual resources would reflect this artificial influence and could be mistaken as additional benefit or greater cost.

The generating capabilities for each unit of the resource are required (**POWER LEVELS**). The maximum hourly pumping capability per unit is also required input (**PHYD PUMP MW**). Pumped storage units can typically pump at only one level since they operate as synchronous motors with a fixed load. However, exchange contracts sometimes allow power to be returned between a minimum and maximum level. The minimum pumping power level is specified using

PHYD PUMP MIN. If no value is given, the minimum power level defaults to the maximum level. The cycle efficiency of the station is the product of the generating and pumping efficiencies. Some care should be exercised in selecting the minimum pumping level if this option is used. The input value is equivalent to the average pumping performed during a single hour. Since the pumps do not necessarily have to operate for an entire hour at a time, this number may be less than the minimum instantaneous operating level for the pump.

In operating a storage station, PowrSym4 attempts to determine an equivalent monetary value of energy at which generating (when system marginal cost is above this value) and pumping (when system marginal cost is below this value) balance, subject to efficiency losses. This value can vary hourly and appears on the printed reports. The objective function of the model for storage stations is to lower system production cost by levelizing system marginal cost. If there is no value of energy which results in lower system cost (e.g., if marginal cost differences across the week are not sufficient to justify the efficiency losses), the storage station will not be operated.

The marginal cost considered in computing the value of energy is that of the system as a whole. PowrSym4 permits scheduling the pumped storage station using the marginal cost of any transmission or control area.

The pumped storage reservoir may have natural inflow (**INFLOW**), expressed in gigwatthours per week. This energy must be generated in the course of the week in which it arrives, even if the storage station is not otherwise operated. It is possible for inflow to be returned in the case of interchange power.

PowrSym4 can also simulate pumped hydro stations with small reservoirs that require a variable head calculation to determine the amount of energy available. Storage generation varies with the height (head) of the water turning the turbine. For most storage facilities, the variation in the head pressure is insignificant because of the head height. Some utilities, such as the Dutch utility, Sep, have a flat landscape and cannot generate as much head height. For these situations, PowrSym4 simulates the variation in generation by calculating the current head level of the reservoir.

VAR HD IND identifies that a storage station has a variable head. **VAR HD GEN EFF** is the generating efficiency for a variable head storage station, and **VAR HD PUMP EFF** is the pumping efficiency for a variable head storage station. These values are used in the energy calculations the same as the efficiency example from earlier in this section.

The head height is calculated using the following equation:

$$\text{Head} = \text{SQRT} ((\text{ReservoirLevel} + B) / A)$$

where

A and B	Input coefficients
ReservoirLevel	Reservoir level in gigwatthours
SQRT	Square root function
Head	Head height in meters

VAR HD COEFF A is the "A" coefficient, and **VAR HD COEFF B** is the "B" coefficient. **VAR HD LEVEL** is the beginning and ending reservoir head level in meters for a variable head storage station. **VAR HD MAX** is the head level in meters when the reservoir is full.

VAR HD MIN is the minimum head level in meters corresponding with the minimum power output for a variable head storage station. **VAR HD MIN PWR** is that minimum power output level for the minimum head level at a variable head storage station.

The default assumption in PowrSym is that the pump and generator for an energy storage station are a single unit. The **PHYD PUMP FLAG** is used to relax this assumption when the number of pumps is different than the number of generators. In this case, it is necessary to also specify the number of pumps associated with the reservoir, **PHYD NUM PUMP**. All pumps are assumed to be identical with the pumping efficiency defined by **PHYD PUMP EFF** and the maximum and minimum pumping rates defined by **PHYD PUMP MW** and **PHYD PUMP MIN**, respectively. **PHYD FOR** can be used to define a forced outage rate for individual pumps.

Modeling an energy storage technology, such as compressed air energy storage (CAES), that entails generating power both from stored energy and the direct conversion of fuel requires modeling the station both as an energy storage unit and as a conventional generating station. In this case, a combination of heat rate and generating and pumping efficiencies are used to simulate the overall performance of the station.

Variable list:

INFLOW	Defines natural reservoir inflow in gigawatthours per week for a storage station
PHYD FOR	Defines the forced outage rate for energy storage pumps
PHYD GEN EFF	Defines generating efficiency for a storage station
PHYD NUM PUMP	Defines the number of pumps associated with each reservoir
PHYD PUMP EFF	Defines replacement efficiency for a storage station
PHYD PUMP FLAG	Used to specify if pumps and generators are disassociated
PHYD PUMP MW	Defines maximum replacement capacity in megawatts for a storage station
PHYD RES FINAL	- Defines final reservoir level at the end of the week in gigawatthours for a storage station
PHYD RES INIT	Defines initial reservoir level at the end of the week in gigawatthours for a storage station
POWER LEVELS	Defines the five power levels for a storage station
RESERVOIR NUM	Identifies reservoir number associated with a storage station
RESERVOIR SIZE	Defines reservoir size in gigawatthours for a storage station
VAR HD COEFF A	Defines "A" coefficient in the variable head energy equation for a storage station
VAR HD COEFF B	Defines "B" coefficient in the variable head energy equation for a storage station
VAR HD GEN EFF	Defines generating efficiency for a variable head storage station
VAR HD IND	Identifies that a storage station has a variable head

VAR HD LEVEL	Defines beginning and ending variable head level in meters for a storage station
VAR HD MAX	Defines maximum head level in meters when the reservoir is full for a variable head storage station.
VAR HD MIN	Defines minimum head level in meters corresponding to power output defined as minimum for a variable head storage station
VAR HD MIN PWR	Defines minimum power level corresponding to the minimum head level for a variable head storage station
VAR HD PUMPEFF	Defines replacement efficiency for a variable head storage station

6.8 Heat Energy Storage Station Data

PowrSym4 simulates heat energy storage capability as one of the features in the heat logic. This technology usually involves heating an insulated container filled with a fluid, such as oil, that retains heat. The heat is then harvested at a later time to supplement the heat station output. It is very similar to an electric storage station.

Each heat storage station has a reservoir number (**HST NUM**) to identify which reservoir is providing heat to meet the heat load and receiving heat for storage. The heat storage reservoir size is given in gigawatthours thermal (**HST RES SIZE**) including any generating efficiency losses (**HST GEN EFF**). For example, if the station has a 90% generating efficiency, and a reservoir size of 10 gigawatthours thermal, then the energy generated by taking the reservoir from completely full to completely empty is 9 gigawatthours thermal. During the week's operation, the heat storage reservoir may not be filled beyond its capacity nor drained below "empty".

The heat storage reservoir also incurs heat losses over time. These losses may be in constant megawatthours thermal per hour (**HST LOSS CONST**) or a percentage of the actual stored heat per hour (**HST LOSS PROP**).

There are also efficiency losses incurred when replacing the heat in the reservoir (**HST PUMP EFF**). Using the same example above, it would require 11.11 gigawatthours thermal to fill the reservoir from "empty" to completely full (10 gigawatthours thermal) with a replacement efficiency of 90%.

The reservoir's starting net position at 1:00 A.M. Monday is given as a fraction of the heat storage reservoir's size (**HST RES INIT**). In the example above, if this position is set to 0.8, then the heat storage reservoir contains 8 gigawatthours thermal at the beginning of the week. (This would allow some charging to occur in the early hours of Monday, before the heat is required at the peak.) It is assumed that, when no value is specified, the reservoir is full at 1:00 A.M. Monday.

The heat storage reservoir's final position at the end of the week is also given as a fraction of the heat storage reservoir's size (**HST RES FINAL**). It is recommended that this value be the same as the starting position. If the reservoir is allowed to vary from week to week, heat is gained or lost from one week to the next. This causes the generation reported for other resources to be artificially influenced by this heat. Simulations designed to value individual resources would

reflect this artificial influence and could be mistaken as additional benefit or greater cost.

The generating capabilities for each unit of the resource are required (**POWER LEVELS**). The maximum hourly charging capability per unit is also required input (**HST PUMP CAP**). Heat storage units can typically charge at only one level. If no value is given, the minimum power level defaults to the maximum level. The cycle efficiency of the station is the product of the generating and charging efficiencies.

In operating a heat storage station, PowrSym4 attempts to determine an equivalent monetary value of heat at which generating (when system marginal cost is above this value) and charging (when system marginal cost is below this value) balance, subject to efficiency losses. This value can vary hourly and appears on the printed reports. The objective function of the model for heat storage stations is to lower system production cost by levelizing system marginal cost. If there is no value of heat which results in lower system cost (e.g., if marginal cost differences across the week are not sufficient to justify the efficiency losses), the heat storage station will not be operated.

The marginal cost considered in computing the value of heat is that of the system as a whole. PowrSym4 permits scheduling the heat storage station using the marginal cost of any transmission or control area.

Variable list:

HST GEN EFF	Defines generating efficiency for a heat storage station
HST LOSS CONST	Defines constant storage reservoir losses in megawatthours thermal per hour for a heat storage station
HST LOSS PROP	Defines percentage of actual energy for a storage reservoir lost each hour for a heat storage station
HST NUM	Defines heat storage reservoir that uses a heat storage station
HST PUMP CAP	Defines maximum charging capacity for a heat storage station
HST PUMP EFF	Defines pumping efficiency for a heat storage station
HST RES FINAL	Defines final reservoir level at end of week in gigwatthours thermal for a heat storage reservoir
HST RES INIT	Defines initial reservoir level at end of week in gigwatthours thermal for a heat storage reservoir
HST RES SIZE	Defines reservoir size in gigwatthours thermal for a heat storage reservoir
POWER LEVELS	Defines the five power levels for a storage station

6.9 RELY Module Input Data

The RELY module simulates system reliability for a period of one to forty years. Its primary use is calculating system loss of load probability (LOLP) and unit expansion plans. This section identifies input variables that are unique to the RELY module.

Variable list:

CAP MULT INDEX	Index capacity multiplier patterns
EST COAL GEN	Estimated coal generation for expansion logic
EST FUT CT GEN	Estimated future coal generation for expansion logic
EST FUTCOAL GEN	Estimated future combustion turbine generation for expansion logic
EST HYDRO GEN	Estimated hydro generation for expansion logic
EST NUCLEAR GEN	Estimated nuclear generation for expansion logic
EST SYSTEM GEN	Estimated system generation for expansion logic
HYDRO	Hydro cumulants for representing hydro as a single unit
CUMULANTS	
RELY ANNUAL LCA	Annual load carrying ability calculation flag
RELY ANNUAL RPT	Flag for RELY annual report
RELY AUTO EXPN	Flag to enable expansion logic
RELY CAP MULT	Capacity multipliers by station indexed by CAP MULT INDEX
RELY DSM STA	Identifies demand side management (DSM) stations
RELY EXPN FILE	Flag for RELY expansion file output
RELY EXPN RPT	Flag for RELY expansion report
RELY FIX ORDER	Fixed expansion order for this station
RELY FIX UNITS	Number of units allowed for fixed expansion
RELY FUEL TYPE	RELY module fuel type
RELY LOLP MAX	Maximum annual LOLP allowed for expansion logic
RELY LOLP RANGE	Range allowed for maximum annual LOLP
RELY LOLP RPT	Flag for RELY LOLP report
RELY LOLP2 RPT	Flag for RELY second LOLP report
RELY MACRO STA	Flag to identify macro stations (not used by RELY)
RELY MARGIN RPT	Flag for RELY LOLP report
RELY MIX ORDER	Mix candidate expansion order for this station
RELY MIX UNITS	Number of units allowed for mixed candidate expansion
RELY MONTH RPT	Flag for RELY monthly report
RELY RES MW	Minimum desired reserve for RELY in megawatts
RELY RES PCT	Minimum desired reserve for RELY as a percent of peak load
RELY SEASON RPT	Flag for RELY seasonal report
RELY SEPA	Additional total system capacity such as a SEPA contract
RELY SUM BEGIN	Calendar week that summer begins
RELY SUM CAP	Summer dependable capacity in megawatts
RELY SUM END	Calendar week that summer ends
RELY SUM LD MOD	Summer peak load modification in megawatts
RELY SUMMER	Summer load carrying ability calculation flag
LCA	
RELY SYS GEN	Net system generation requirements in gigwatthours
RELY WIN BEGIN	Calendar week that winter begins
RELY WIN CAP	Winter dependable capacity in megawatts
RELY WIN END	Calendar week that winter ends

RELY WIN LD MOD	Winter peak load modification in megawatts
RELY WINTER LCA	Winter load carrying ability calculation flag
RESP VAR A	Parameter "A" for delta load response function
RESP VAR B	Parameter "B" for delta load response function
RESP VAR C	Parameter "C" for delta load response function
RESP VAR D	Parameter "D" for delta load response function
RESP VAR E	Parameter "E" for delta load response function
RESP VAR F	Parameter "F" for delta load response function
RESP VAR INDEX	Index for response function used during simulation
WEEKDAY PROB	Weekday probability for derated capacity levels
WEEKEND FOR	Weekend forced outage rate
WEEKEND PROB	Weekend probability for derated capacity levels

6.10 Spot Market Module Input Data

See Section 10.5

7. Input Variable Reference

This section defines elements of the Data Input Format (DIF) to assist in creating or modifying a DIF. An abbreviated example of the DIF is shown in Table 7A. It consists of 11 columns of data items. Table 7B lists the field headings, field location, and a description.

Table 7A

IYR	IW	N1	N2	N3	N4	AID	A1	X1	Clas	Comment
	K								s	
1993	1	0	0	0	0	365 RATIO		1.14	B	Base case data 2/95
							SYSTEM			
1993	1	0	0	0	0	CY OUT FILE		1	B	Base case data 2/95
							SYSTEM			
1993	1	0	0	0	0	FY OUT FILE		0	B	Base case data 2/95
							SYSTEM			

Table 7B

Field Heading	Field Location	Column Description
IYR	1-4	Calendar year for this record's data
IWK	5-7	Calendar week for this record's data
N1	8-11	Beginning of period

N2	12-15	End of period
N3	16-19	Primary data identifier
N4	20-23	Secondary data identifier
	24	Blank
AID	25-39	Alphanumeric record identifier
	40	Blank
A1	41-50	Name associated with data item
X1	51-65	Input data item for this record
	66	Blank
Class	67-69	Class identifier for record selection
	70	Blank
Comment	71-150	User comment about this record

7.1 Input Variable Table Description

7.1.1 Alphanumeric Identifier (AID) Field

Each data item input by PowrSym4 has an alphanumeric identification name (AID). All data for any one record of this file is associated with the input variable specified by the AID for that record. All AIDs are listed in section 7.3.

7.1.2 A1 Field

An input variable may belong to any of 13 variable categories. The value in the A1 field of section 7.3 is the category of the variable specified by the AID name explains what to enter in both the A1 and N3 columns of the DIF.

7.1.3 N1 and N2

These fields are used to specify beginning and ending time period values. For example, if weeks 30 to 40 inclusive are to have equal values for the minimum maintenance factor, then the WEEK MIN MAINT variable should have values of 30 and 40 in the N1 and N2 fields, respectively.

7.1.4 N3

The entry in this field is determined by the entry in the A1 field. For example, if **SYSTEM** is entered in the A1 field, then N3 is zero. If a station or plant name is entered in A1, then the station or plant number should be entered in N3. For a list of all entries, see section 7.3.

7.1.5 N4

The majority of input variables have only one value to be entered in the X1 field. However, some input variables, such as dates for expansion units, heat rates, or power levels, may have up to 6 allowed values. In these cases, the variable will occupy as many records as allowed values and each record will specify one of these values in the X1 field. For each record, the N4 field will have a unique number starting with 1 and ending with a number equal to the number of allowed values.

A variable needs to have a second ID number when one number is not sufficient to uniquely identify it. For example, the X1 field specifies the power level of a station when the AID field is POWER LEVELS, and the N3 field is the station number. Since each station has five power levels, the DIF will have five records with different N4 fields (1 to 5) and the value of the associated power level in megawatts in the X1 field.

7.2 Energy and Monetary Unit Conventions

PowrSym4 can read input or write output in American or European units for energy and currency. For simplicity, the input variables are described using American units. However, either convention can be used. **PRT UNITS FLAG** defines which convention is used. If it is zero, PowrSym4 uses the European units. If it is one, the American units are used.

As an example, the following units would be used to describe operating cost using the two conventions. Operating cost is reported in monetary units per unit of energy. In American units, it would be expressed as dollars per megawatt-hour. For the Dutch utility, Sep, it would be expressed as guilders per gigajoule.

7.3 Detailed Record Identifier Definitions

Aid definitions are available in the Analyzer under Reports.

8. Output Variable Description

The results of PowrSym4 production cost simulations are output to variables for presentation in several output reports. An output file, or report, is comprised of a main and a summary section. The output variables contained in the main section are listed for each station under three categories, operating characteristics, cost data, and emissions data. The same information is aggregated in the summary section by station, plant, or summary classes under two categories, emissions data and operating characteristics-and-cost data. Examples of summary class reports are those which report all nuclear stations, all peaking stations or all coal fired stations. Section 4.1 shows the variables in each category. Output data may also be defined through user defined groupings.

In the weekly output report, file8, the variables in each category are reported for each week of the simulation period. Similarly, the monthly report, file38, and the yearly reports list these

variables for each station and summary class by month and year respectively. There are two annual reports, calendar year report (file39) and fiscal year report (file40). Examples of output files are shown in Appendix A.

The first column of Table 8.1 lists the variables in alphabetical order from all three categories. The second column gives a definition of the variable and the units in which it is reported. Columns three through five contain the category of the variable and the output report(s) the variable appears in.

Two other output files are produced by the maintenance and reliability models. The maintenance schedule is in two files (OUTPUT and PRINTOUT), and the reliability calculations are printed to file99. The output variables in these two files are listed alphabetically in Table 8.2. The first column of the table contains a variable name. The second column contains its definition, and the third column shows the output file it appears in.

Table 8.1

Variable Name	Definition and Unit of Measurement	Report Category		Report(s)
		Main Section	Summary Section	
Average Hrate BTU/KWh	Average heat rate (a measure of a station's thermal efficiency) obtained by dividing the total Btu of fuel burned by the resulting Kilowatthour generation.	Operating Characteristics		File8 File38 File39 File40
Cap Factor %	The ratio of the energy production of a unit to its maximum production capability for the period, expressed as a percent.	Operating Characteristics		File8 File38 File39 File40
CO2 Tons	Tons of carbon dioxide emitted by the station.	Emission Data	Emission Data	File8 File38 File39 File40
CO2 \$1000	The cost in thousands of dollars for carbon dioxide emitted.	Emission Data	Emission Data	File8 File38 File39 File40
Disp Cost \$/MWh	The cost of dispatching a station in dollars per Megawatthour, including emission cost.	Cost Data		File8 File38 File39 File40
Energy GWh	Energy production in Gigawatthours of a station or plant.	Operating Characteristics	Operating Characteristics and Cost Data	File8 File38 File39 File40
Fixed O&M \$1000	Fixed operation and maintenance cost in thousands of dollars.	Cost Data		File8 File38 File39 File40
Fuel Burn	The amount of fuel burned by the station expressed in thousands of units of fuel (i.e. tons, cf, bbls)	Operating Characteristics		File8 File38 File39 File40
Fuel Cost \$1000	The cost of fuel burned in thousands of dollars.	Cost Data	Operating Characteristics and Cost Data	File8 File38 File39 File40

Table 8.1 (continued)

Variable Name	Definition and Unit of Measurement	Report Category		Report(s)
		Main Section	Summary Section	
Fuel	The amount of fuel burned by summary class expressed in thousands of units--tons, bbl, cf.		Operating Characteristics and Cost Data	File8 File38 File39 File40
Heat KMBTU (10**9)	The amount of heat generated in kilo million BTUs. (Heat input)	Operating Characteristics		File8 File38 File39 File40
Nox Tons	Tons of Nitrogen oxides emitted by the station.	Emission Data	Emission Data	File8 File38 File39 File40
Nox \$1000	Cost in thousands of dollars for emitted nitrogen oxides.	Emission Data	Emission Data	File8 File38 File39 File40
Nox Lbs per MMBTU	Pounds of Nitrogen oxide emitted per million BTU input.	Emission Data	Emission Data	File8 File38 File39 File40
Oper Hours	Number of hours a station operated within the period considered.	Operating Characteristics		File8 File38 File39 File40
Oper Cost \$/MWh	The operating cost in dollars per Megawatthour, not including cost of emissions.	Operating Characteristics		File8 File38 File39 File40
SO2 Tons	Tons of Sulfur dioxide emitted by the station.	Emission Data	Emission Data	File8 File38 File39 File40
SO2 \$1000	The penalty in thousands of dollars for emitted sulfur dioxide.	Emission Data	Emission Data	File8 File38 File39 File40
Start Cost \$1000	The cost in thousands of dollars for changing the status of the station from OFF to ON.	Cost Data	Operating Characteristics and Cost Data	File8 File38 File39 File40

Table 8.1 (continued)

Variable Name	Definition and Unit of Measurement	Report Category		Report(s)
		Main Section	Summary Section	
Starts	The number of times a station changed states from OFF to ON.	Operating Characteristics	Operating Characteristics and Cost Data	File8 File38 File39 File40
Total O&M \$1000	Total operation and maintenance cost (fixed + variable) in thousands of dollars.	Cost Data	Operating Characteristics and Cost Data	File8 File38 File39 File40
Total Cost			Operating	File8

Variable Name	Definition and Unit of Measurement	Report Category		Report(s)
		Main Section	Summary Section	
Without Emiss \$1000	The sum of all costs except emission costs (start cost + fuel cost + total O&M cost).	Cost Data	Characteristics and Cost Data	File38 File39 File40
Total Cost With Emiss \$1000	Total cost obtained by summing all costs including penalties for emissions.	Cost Data	Operating Characteristics and Cost Data	File8 File38 File39 File40
Total Emiss Cost \$1000	The sum of all emission penalties in thousands of dollars.	Emission Data	Emission Data	File8 File38 File39 File40
Var O&M \$1000	Variable operation and maintenance cost.	Cost Data		File8 File38 File39 File40

Table 8.2

Variable Name	Definition	File variable comes in:
Hours LOL	Number of hours this week in which loss of load occurred	PRINTOUT (maintenance output)
Maint Factor	The portion of maintenance allocated to this week using the distributed maintenance method.	PRINTOUT (maintenance output)
Peak Load(MW)	Peak load this week in Megawatts	PRINTOUT (maintenance output)
Minimum Load(MW)	Minimum load this week in Megawatts	PRINTOUT (maintenance output)
Load (GWh)	Total energy for year in Gigawatthours.	PRINTOUT (maintenance output)
Average Load(MW)	Total energy for year divided by the number of hours in the year.	PRINTOUT (maintenance output)
Load Factr(%)	Load factor as the ratio of average load to peak load in percent.	PRINTOUT (maintenance output)
Net Peak Cap (MW)	Capacity available this week in Megawatts.	PRINTOUT (maintenance output)
Reserve Cap (%)	Reserve capacity as a percentage of peak capacity for this week.	PRINTOUT (maintenance output)
Adj Peak Cap (MW)	Capacity remaining after maintenance in megawatts.	PRINTOUT (maintenance output)
Adjusted Reserv (%)	System percent reserve after maintenance.	PRINTOUT (maintenance output)
Discrete Maint(MW)	The calculated capacity to be on maintenance for the week in megawattweeks.	PRINTOUT (maintenance output)
MaintHours	The number of maintenance hours required for the station per year.	OUTPUT (maintenance output)
LOLP	Loss of load probability in hours.	File99 (reliability model output)
E.N.S	Energy not served in Gigawatthours.	File99 (reliability model output)

9. CONTROL File and System Records

This section will describe the CONTROL file and some of the system parameters that control the simulation performed by PowrSym4. An ASCII text file that must be named "CONTROL" and must be in the active directory from which PowrSym4 is executed.

9.1 CONTROL File

The control file has a specific structure that must be correct if PowrSym4 is to simulate system costs correctly. If a file is not needed for the current execution, a file name of "DUMMY" may be entered. The model will not open that file number and no data will be read or written to that file. However, if the file is necessary and the name DUMMY is given in the control file, the model will open an output file with the name of the unit number in the current directory. If the file should have contained input data, a data error will be reported and the program stopped. If weekly print was requested and record nine of the control file is DUMMY, a file named "8" will be created and contain the weekly print output.

9.1.1 CONTROL File Setup

The first record is read as the title for the printed reports. The program reads up to 80 characters for this title, and the title may contain blanks at the beginning. If this record or any other record is inadvertently missing, the control file is corrupt. PowrSym4 reads this file record by record. Each record has meaning; if the file name for the file containing the load data are not in record five, there is no way for PowrSym4 to find the correct data file.

The program requires that the **CONTROL** file contain the title, file definitions 1 through 54 file definitions 97 through 99, and the **END** record for a total of 59 records for a single area simulation. If the records are not in order or all of the records are not present, the file definitions will be scrambled, and the model becomes unpredictable.

Each file may contain a path in its file definition. The model reads each record in the CONTROL file until it encounters a blank space. This is interpreted as the end of the file name. Any characters after the first blank space are considered comments. Therefore, to enter a file name longer than the space allowed in the left column of the CONTROL file, insert additional space to allow for the file name (making sure that there is a blank space at the end) or delete the remainder of the record.

In a multi area mode with a LOAD FORMAT parameter of 1 or 2, the loads for area 2 through n follow record 60. For spot market input data, the file names are in records following a record with a "?" in column 1. Spot market record should follow the multi area load file records and preceded the END record. For RELY input output data, the file names are in records following a "~" in column one. Files to be created from the load modification routine are named following a record with a "!" in column one.

9.1.2 CONTROL File Definitions

I. Input files

- File 3 is the discrete maintenance file
- File 4 is the load file area one
- File 7 is the heat area input file
- File 18 is the random number seed file
- File 19 is the RELY maintenance data
- File 20 is the blast furnace initial values
- File 24 is the the wind or run of river input data
- File 42 is the commitment data
- File 50 is the station data
- File 101 is the load file for Tarea 2
- File xxx is the load file for Tarea xxx - 99

II. Output files

- File 1 is the station or hourly commitment report
- File 2 is the marginal cost output file
- File 8 is the weekly printed output file
- File 14 is the hourly printed output file
- File 15 is the daily printed output file
- File 16 is the LOLP report and program header page
- File 22 is the daily output file in Analyzer format
- File 33 is the week by hour output file in Analyzer format
- File 34 is the year by week output file in Analyzer format
- File 35 is the year by month output file in Analyzer format
- File 36 is the calendar year output file in Analyzer format
- File 37 is the fiscal year output file in Analyzer format
- File 38 is the monthly printed output file
- File 39 is the calendar year printed output file
- File 40 is the fiscal year printed output file

9.1.3 CONTROL File Definitions

File 1

File Type: Output

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File Switch: EXEC MODE or COMMIT REPORT
File Definition: Debug output for the dynamic module and concurrent method. If EXEC MODE is 1 or 2 (concurrent mode), this file contains an output table with the data from the dynamic programming iterations. If COMMIT REPORT is -1 or -2 an hourly report of station generation is produced.

File 2

File Type: Output
File Switch: MCOST FLAG and MCOST STEP
File Definition: Marginal cost output file. If MCOST FLAG is 1 and MCOST STEP is not zero, this file is a set of records containing the year, week, day of week, hour of day, marginal cost for specified step, native load, and the load adjusted for hydro and pumped hydro operation.

File 3

File Type: Input
File Switch: MAINT CNTL
File Definition: Prescheduled maintenance input file. If MAINT CNTL is 0, the maintenance is scheduled using this file only. If it is 2, the maintenance schedule in this file is used first, and the remainder of the maintenance is scheduled using the internal algorithm.

File 4

File Type: Input
File Switch: None
File Definition: Transarea 1 load file. If no transareas are specified, this file is used to input the system loads. If transareas are specified, this file is considered the loads for transarea 1.

File 5

File Type: None
File Switch: None
File Definition: This file handle is reserved for the **CONTROL** file.

File 6

File Type: Output
File Switch: None
File Definition: Constraint violation output file. This report is only generated in the European print mode (PRT UNITS FLAG is zero). Each record reports the constraint violation year, week, iteration, hour, code, and the associated megawatt level. The code for the violation is defined as follows:

- 0 - Maximum dispatch is less than load. Reports megawatt shortage.
- 1 - No violation.
- 2 - Violates wind generation constraint.
- 3 - Violates ramp rate constraint.
- 4 - Violates unit minimum constraint.
- 5 - Violates station minimum constraint.

File 7

File Type: Input
File Switch: NUM HEAT AREAS
File Definition: Heat demand input. If NUM HEAT AREAS is greater than zero, this file contains the heat loads for all heat areas.

File 8

File Type: Output
File Switch: PERIOD PRINT
File Definition: Weekly printed output. If PERIOD PRINT is 1 or 2, this file contains the printed weekly output reports. This file is a viewing file, not a PowrSym4 ANALYZER file. Weekly print may be obtained by setting PRINT OUTPUT to 100.

File 9

File Type: Output
File Switch: UNFORMATTED OUT
File Definition: Unformatted output file used only in the European print mode

(PRT UNITS FLAG is zero).

File 10

File Type: Output
File Switch: DEBUG HRLY PRNT
File Definition: Hourly debug output. Primarily used for debugging FORTRAN code. DEBUG HRLY PRNT defines the weeks to be printed in hourly format.

File 11

File Type: Output
File Switch: None
File Definition: Energy-limited fuel output. This file contains a simple output file for all energy-limited fuels. It is written if energy-limited fuels are specified.

File 12

File Type: Output
File Switch: None
File Definition: Unformatted hourly average cost file used only in the European print mode (PRT UNITS FLAG is zero).

File 13

File Type: Output
File Switch: NUM STA HR OUT
File Definition: Hourly station output for user-defined stations. If NUM STA HR OUT is greater than zero, the user-defined stations (SELECT HR OUT) are printed for the hours designated.

File 14

File Type: Output
File Switch: PERIOD PRINT
File Definition: Hourly printed output. If PERIOD PRINT is 2, this file contains the

printed hourly output reports. This file is a viewing file, not a PowrSym4 ANALYZER file. PRINT OUTPUT = 1.

File 15

File Type: Output
File Switch: PRINT OUTPUT
File Definition: Daily printed output. If PRINT OUTPUT value is set to 10, this file is written. This file is a viewing file, not a PowrSym4 ANALYZER file.

File 16

File Type: Output
File Switch: None
File Definition: LOLP report and header. This file contains the header information written by PowrSym4 and the loss of load probability table. The LOLP report shows LOLP, loads, reserves, installed capacity, and capacity on maintenance.

File 17

File Type: Output
File Switch: PERIOD PRINT
File Definition: Pumped hydro output. This file is used only in the European print mode (PRT UNITS FLAG is zero). If PERIOD PRINT is 2, this file contains hourly pumped hydro information.

File 18

File Type: Input
File Switch: None
File Definition: Random number starting seed input. If this file is defined, the number starting seeds will be read. Otherwise, PowrSym4 uses an internal file to pick these seeds.

File 19

File Type: Input
File Switch: MAINT CNTL
File Definition: Detailed output from RELY if RELY is on and Print ≥ 1

—

File 20

File Type: Input
File Switch: BF SIM MODE
File Definition: Initial blast furnace gas input. If BF SIM MODE is 2, the initial values for the blast furnace gas plants are contained in this file.

—

File 21

File Type: Output
File Switch: MCOST FLAG
File Definition: COMAX. The MCOST FLAG value of three causes this file to be created.

—

File 22

File Type: Output
File Switch: DAY OUT FILE
File Definition: Daily ANALYZER output file. If DAY OUT FILE is one, the ANALYZER format is used. If DAY OUT FILE is two, the flat file format is used.

—

File 23

File Type: Input
File Switch: N4 on the PRINT OUTPUT record
File Definition: For selected OFC output, file name “CheckOut.prn”. Not listed in the Control file.

—

File 24

File Type: Input
File Switch: WIND/SOLAR GENERATION
File Definition: Wind power generation input. There can only be any number of wind/solar stations per simulation.

—

File 25

File Type: Output
File Switch: None
File Definition: Debug output. Currently, none of the output is written. It is mostly contained in the logic for calculating blast furnace gas usage.

—

File 26

File Type: Output
File Switch: UNFORMATTED OUT, VAR TIME FLAG, VAR TIME SPEC
File Definition: User-defined unformatted output. This file is used only in the European print mode (PRT UNITS FLAG is zero). If UNFORMATTED OUT equal 2 and VAR TIME FLAG equal 1, this file contains the hourly data specified by VAR TIME SPEC specified for variable time report 1.

—

File 27

File Type: Output
File Switch: UNFORMATTED OUT, VAR TIME FLAG, VAR TIME SPEC
File Definition: User-defined unformatted output. This file is used only in the European print mode (PRT UNITS FLAG is zero). If UNFORMATTED OUT is 2 and VAR TIME FLAG is 1, this file contains the hourly data specified by VAR TIME SPEC specified for variable time report 2.

—

File 28

File Type: Output
File Switch: UNFORMATTED OUT, VAR TIME FLAG, VAR TIME SPEC
File Definition: User-defined unformatted output. This file is used only in the European print mode (PRT UNITS FLAG is zero). If UNFORMATTED OUT is 2 and VAR TIME FLAG is 1, this file contains the hourly data specified by VAR TIME SPEC specified for variable time report 3.

File 29

File Type: Output
File Switch: UNFORMATTED OUT, VAR TIME FLAG, VAR TIME SPEC
File Definition: User-defined unformatted output. This file is used only in the European print mode (PRT UNITS FLAG is zero). If UNFORMATTED OUT is 2 and VAR TIME FLAG is 1, this file contains the hourly data specified by VAR TIME SPEC specified for variable time report 4.

File 30

File Type: Output
File Switch: None
File Definition: Hourly mean variable cost. This file is used only in the European print mode (PRT UNITS FLAG is zero). The report is written in Dutch.

File 31

File Type: Input
File Switch: None
File Definition: NOT USED

File 32

File Type: Input
File Switch: None
File Definition: SELECTED OUTPUT

File 33

File Type: Output
File Switch: HR OUT FILE
File Definition: Hourly ANALYZER output file. If HR OUT FILE is 1, this file contains the hourly output file to be used by the PowrSym4 ANALYZER. If HR OUT FILE is 2, the output format is a flat file.

File 34

File Type: Output
File Switch: WEEK OUT FILE
File Definition: Weekly ANALYZER output file. If WEEK OUT FILE is 1, this file contains the weekly output file to be used by the PowrSym4 ANALYZER. If WEEK OUT FILE is 2, the output format is a flat file.

—

File 35

File Type: Output
File Switch: MONTH OUT FILE
File Definition: Monthly ANALYZER output file. If MONTH OUT FILE is 1, this file contains the monthly output file to be used by the PowrSym4 ANALYZER.

—

File 36

File Type: Output
File Switch: CY OUT FILE
File Definition: Calendar year ANALYZER output file. If CY OUT FILE is 1, this file contains the calendar year output file to be used by the PowrSym4 ANALYZER.

—

File 37

File Type: Output
File Switch: FY OUT FILE
File Definition: Fiscal year ANALYZER output file. If FY OUT FILE is 1, this file contains the fiscal year output file to be used by the PSM4 ANALYZER

—

File 38

File Type: Output
File Switch: PERIOD PRINT
File Definition: Monthly printed output. If PERIOD PRINT is 0, 1, or 2, this file contains the printed monthly output reports. This file is a viewing file, not a PowrSym4 ANALYZER file.

File 39

File Type: Output
File Switch: YEAR PRINT CNTL
File Definition: Calendar year printed output. If YEAR PRINT CNTL is 1 or 2, this file contains the printed calendar year output reports. This file is a viewing file, not a PowrSym4 ANALYZER file.

File 40

File Type: Output
File Switch: YEAR PRINT CNTL
File Definition: Fiscal year printed output. If YEAR PRINT CNTL is 1 or 2, this file contains the printed fiscal year output reports. This file is a viewing file, not a PowrSym4 ANALYZER file.

File 41

File Type: Input
File Switch: LOAD FORMAT, NUM TAREAS
File Definition: Transarea load input in Sep format. If LOAD FORMAT is 0 and NUM TAREAS is greater than 1, this file contains all transarea loads in the Sep input format.

File 42

File Type: Input
File Switch: CONTROL 1
File Definition: Commit data input file. If CONTROL 1 is 2, this file contains the commit order to be used for this simulation.

File 43

File Type: Output
File Switch: CONTROL 1

File Definition: Load, power level, reserves, minimum up time, and minimum down time output file. If CONTROL 1 is 1 or 2, this file is written.

—

File 44

File Type: Output

File Switch: None

File Definition: Reserved for TVA unformatted fiscal year output file.

—

File 45

File Type: Output

File Switch: None

File Definition: Reserved for TVA unformatted calendar year output file.

—

File 46

File Type: Output

File Switch: TVA FIN FLAG

File Definition: Reserved for TVA financial output file for System Integration (FINESSE) and hourly total system data. The total system data are written with the Flat Fin format.

—

File 47

File Type: Output

File Switch: MIDAS FLAG

File Definition: MIDAS interface station output file. If MIDAS FLAG is 1, this file contains the station output for the PowrSym4 to MIDAS interface for financial analysis.

—

File 48

File Type: Output

File Switch: MIDAS FLAG

File Definition: MIDAS interface annual output file. If MIDAS FLAG is 1, this file

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contains the annual output for the PowrSym4 to MIDAS interface for financial analysis.

—

File 49

File Type: Output
File Switch: Maintenance
File Definition: Result of maintenance schedule

—

File 50

File Type: Input/Output
File Switch: None
File Definition: Intermediate File Creator (IFC) output and PowrSym4 input. This file is the resulting output file from the IFC. It is also the data input file for PowrSym4.
This file may be input as a comma separated variable, csv, file.

—

File 51

File Type: Output
File Switch: None
File Definition: Data input log file. This file is reserved for log information during data input for the Intermediate File Creator (IFC) and PowrSym4.

—

File 52

File Type: Output
File Switch: None
File Definition: Data input error file. This file is reserved for errors during data input for the Intermediate File Creator (IFC) and PowrSym4.

—

File 53

File Type: Output

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File Switch: PHYD DISP STEP
File Definition: If N3 is a one, detail pump storage output is written.

—

File 54

File Type: Output
File Switch: PHYD DISP STEP
File Definition: If N3 is a one, detail pump storage output is written.

—

File 97

File Type: Output
File Switch: None
File Definition: Programmer debug and dump output file.

—

File 98

File Type: Output
File Switch: None
File Definition: Programmer debug and dump output file.

File 99

File Type: Output
File Switch: None
File Definition: Programmer debug and dump output file.

—

File 100

File Type: Output
File Switch: None
File Definition: This file is not currently used.

—

File 101

File Type:	Input
File Switch:	NUM TAREAS
File Definition:	Load input file for transarea 2. If NUM TAREAS is greater than 1, this file contains the area loads for transarea 2.

File 102

File Type:	Input
File Switch:	NUM TAREAS
File Definition:	Load input file for transarea 3. If NUM TAREAS is greater than 2, this file contains the area loads for transarea 3.

File 1XX

File Type:	Input
File Switch:	NUM TAREAS
File Definition:	Load input file for transarea XX+1. If NUM TAREAS is greater than XX, this file contains the area loads for transarea XX+1.

9.2 ANALYZER File Format

Field Heading	Field Location	Column Description
IYR	1-4	Calendar year for this record's data
IWK	5-7	Calendar week for this record's data
N1	8-11	Beginning of period
N2	12-15	End of period
N3	16-19	Primary data identifier
N4	20-23	Secondary data identifier
	24	Blank
AID	25-39	Alphanumeric record identifier
	40	Blank

A1	41-50	Name associated with data item
X1	51-65	Input data item for this record
	66	Blank
Class	67-69	Class identifier for record selection
	70	Blank
Comment	71-150	User comment about this record

9.3 Flat File Format

The flat file format is comma delimited in a fixed format. Bytes five, nine, thirteen, etc. always have a comma. Bytes 22:25 identify what data are in the records.

Data Output: Type = 0

Variable	Format	Start	Bytes	Description
Year	I4	1	4	Calendar year data simulates
Week	I3	6	3	Calendar week or month of year data simulates
Hour	I3	10	3	Day of week or hour of week
Iteration	I3	14	3	Iteration number of data; zero indicates average of all iterations.
Station N3	I3	18	3	Station number; zero value for system total data.
Type	I4	22	4	Data type flag; 0=total system, 1=station
Native Load	E12.6	27	12	Total native load for all transareas
Pump Load	E12.6	40	12	Total pumping load for Pump Storage Stations
Dump Power	E12.6	53	12	Generation required by unit minimums not needed by system
Energy Not Served	E12.6	66	12	Native load that exceeds system capacity
Dump Power Rev.	E12.6	79	12	Revenue from dumping power
ENS Cost	E12.6	92	12	Cost of energy not served
Hours	E12.6	105	12	Hours simulated in reporting period
Spin Viol.	E12.6	118	12	MWh of spinning reserve violation
Operating Viol.	E12.6	131	12	MWh of operating reserve violation
Backup Viol.	E12.6	144	12	MWh of back up reserve violation
Spin Viol. Cost	E12.6	118	12	Dollars of spinning reserve violation
Oper. Viol. Cost	E12.6	131	12	Dollars of operating reserve violation
Backup Viol. Cost	E12.6	144	12	Dollars of back up reserve violation

Station Data Output: Type=1

Variable	Format	Start	Bytes	Description
Year	I4	1	4	Calendar year data simulates
Week	I3	6	3	Calendar week or month of year data simulates
Hour	I3	10	3	Day of week or hour of week
Iteration	I3	14	3	Iteration number of data; zero indicates average of all iterations.
Station N3	I3	18	3	Station number; zero value for system total data.
Type	I4	22	4	Data type flag; 0=total system, 1=station
Capacity	E12.6	27	12	Number of units times maximum power level
Generation	E12.6	40	12	Station generation during reporting period
Heat input	E12.6	53	12	Heat used to produce generation BTU's or Joules
Starts	E12.6	66	12	Number of unit starts during this time period
Oper. Hours	E12.6	79	12	Number of unit hours station operated during this period
Fuel	E12.6	92	12	Fuel consumed at station during this period

Fuel Cost	E12.6	105	12	Cost of fuel consumed
Start Cost	E12.6	118	12	Cost associated with number of unit starts
Fix Cost	E12.6	131	12	The number of units times average fixed unit cost
Var. Cost	E12.6	144	12	Average variable cost times station generation
O&M Cost	E12.6	157	12	Su of Fix cost and Var. Cost
SO2	E12.6	170	12	SO2 emissions
SO2 Cost	E12.6	183	12	SO2 emission costs
NOx	E12.6	196	12	NOx emissions
NOx Cost	E12.6	209	12	NOx emissions costs
CO2	E12.6	222	12	CO2 emissions
CO2 Cost	E12.6	235	12	CO2 emission costs

9.4 Flat Fin Format

The flat fin format is comma delimited in a fixed format. Bytes five, nine, thirteen, etc. always have a comma. Bytes 22:25 identify what data are in the records.

Variable	Format	Start	Bytes	Description
Year	I4	1	4	Calendar year data simulates
Week	I3	6	3	Calendar week or month of year data simulates
Hour	I3	10	3	Day of week or hour of week
Iteration	I3	14	3	Iteration number of data; zero indicates average of all iterations.
Null	I3	18	3	This and following null is to keep format same as flat file.
Null	I4	22	4	
Total Cost	E12.6	27	12	Total System Cost
Fix Cost	E12.6	40	12	Total fixed cost
Var. Cost	E12.6	53	12	Total variable cost
Fuel Cost	E12.6	66	12	Total fuel cost
Start Cost	E12.6	79	12	Total start cost
SO2 Cost	E12.6	92	12	Total SO2 cost
NOx Cost	E12.6	105	12	Total NOx cost
CO2 Cost	E12.6	118	12	Total CO2 cost
ENS Cost	E12.6	131	12	Total energy not served cost
Dump Rev.	E12.6	144	12	Total dump power revenue
Pump	E12.6	157	12	Total pumping load
ENS	E12.6	170	12	Total energy not served
Dump	E12.6	183	12	Total dump power
Native Load	E12.6	196	12	Total native load simulated
Heat	E12.6	209	12	Total energy burned
Starts	E12.6	222	12	Total number of unit starts
SO2	E12.6	235	12	Total SO2 emission
NOx	E12.6	248	12	Total NOx emission
CO2	E12.6	261	12	Total CO2 emission

10. Spot Market

10.1 Introduction To Spot Market

Deregulation of the electric utility industry is radically changing the ways in which utilities interact with each other. Activity in the wholesale electric market has increased dramatically. Utilities no longer exchange power simply to satisfy their obligation to serve their native load, but are using the exchange market as a significant contributor to overall financial success. Consequently, the potential effect of the wholesale spot market needs to be carefully considered in making both short- and long-term operational decisions.

PowrSym4 provides the unique ability to simulate the wholesale power market as a dynamic trading partner. Dynamic market simulation integrates power purchases and sales into the power system simulation, allowing operating decisions to fully consider the economic benefits that can be extracted from market transactions. As power trading between utilities increases, accurate representation of market opportunities becomes increasingly critical.

An associated program, *SPOT97*, allows the user to define, adjust, or modify the market price estimates. The ability to easily adjust market cost estimates, enables PowrSym4 to examine the influence of market transactions and their effect on net system production cost probabilistically.

10.2 PowrSym4 Market Transaction Model

Wholesale power trading occurs primarily through prescheduled trades, but also includes opportunistic trading on the spot market. Load adjustments and must-run generating units are used to simulate prescheduled trades. The difficulty occurs, however, in predicting trading that will occur beyond those trades currently committed. While most future trades will materialize as prescheduled transactions, the net economic value of the trades should approximate equivalent spot market trading. Therefore, the effect of yet-to-be-defined trades on system economics can best be simulated by representing the wholesale market as an hourly spot market.

10.2.1 Characterizing Hourly Spot Market Prices & Trading Areas

PowrSym4 provides the unique ability to characterize production cost sensitivity for any specific system using an incremental / decremental cost curve (I/D Curve). The I/D Curve portrays the effect on a system's marginal production cost of producing more or less power than native load demand.

Similar curves can be used to define one or more geographical wholesale market segments. Characterized in this manner, the market segment can sell power to the simulated utility if its marginal cost after increasing load is less than the marginal cost of the simulated utility at the reduced load. A reversed approach covers the potential for selling to the market segment. Geographical market representation is used to allow transmission constraints and transaction costs to properly included in the analysis.

Up to four unique transaction areas can be defined. Figure 1 illustrates a two-segment spot market model. The central area being modeled is assumed to both sell to and purchase from both transaction areas if these transactions are economically beneficial. The transaction areas are not permitted to trade directly with each other; trading between transaction areas is accomplished only through a combination of sales and purchases by the central area.

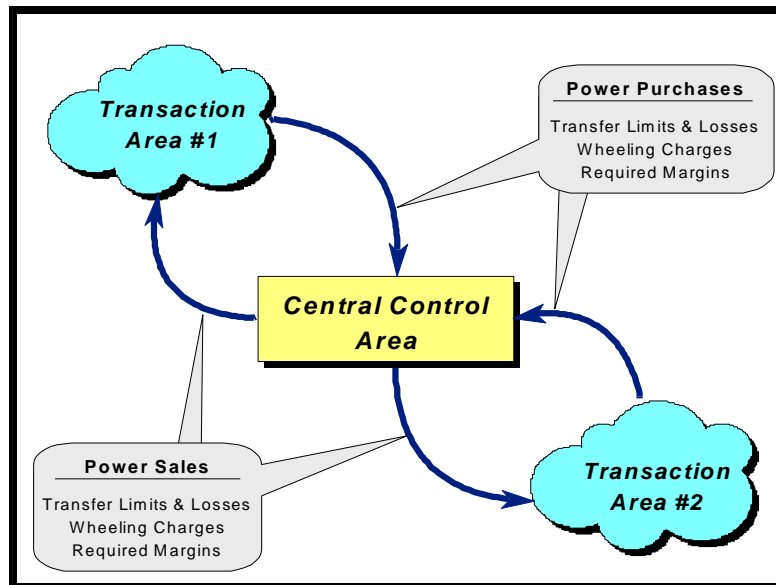


Figure 1: Two-Transaction Area Market Model

Transfer limits (analogous to transmission link capacities) constrain the maximum amount of power that can be transferred. Different limits can be set for purchases and sales. Different wheeling charges and losses can be applied to each transfer link. As described later, an additional limit can be set to preclude trades that do not satisfy a minimum threshold for economic benefit. PowrSym4 also limits trading to the range of market purchase and sales costs defined in the incremental / decremental input curve.

10.2.2 Predicting Economic Trading

PowrSym4 presumes the central area executes all economically beneficial trades provided all other constraints are satisfied. The central area may simultaneously purchase power from one transaction area while selling to another transaction area if both transactions are economically beneficial.

Transactions may be constrained by a number of limitations. Two of these constraints are treated by PowrSym4 as absolute; others may be violated in order to avoid incurring reserve violations, dump power, or energy-not-served. The two absolute constraints are:

1. Transactions can only take place up to the limit set by the transmission link capability. Different transmission limits can be set for purchases and sales.
2. Transactions can only occur up to the maximum range defined by the incremental / decremental cost curve

A transaction margin requirement can be used to limit economic transactions (but not to preclude transactions that avoid dump power, reserve violations, or energy-not-served). The margin defines the threshold benefit that a transaction must provide before it will be assumed to occur. The margin amount does not affect the price of the transaction, but only determines if the transaction will occur.

The price at which a transaction occurs includes the cost of wheeling and losses. PowrSym4 assumes wheeling charges are paid by the purchaser:

1. For sales to a transaction area, the price represented by the transaction area incremental-decremental cost curve includes the cost of the power, the wheeling cost, and an allowance for losses. The sale to the transaction area occurs if the purchase price component exceeds the central area's production cost plus margin.
2. For purchases from a transaction area, the price represented by the transaction area incremental-decremental cost curve is the price that the transaction area must receive for the power. Thus, the cost of wheeling and the allowance for losses must be added to this value to determine the price that the central area must pay. The purchase from the transaction area occurs if the total cost is less than the central area's production cost minus the margin.

PowrSym4 will make "uneconomical" transactions to avoid dump power, to meet reserve requirements, or to avoid energy-not-served. The spot market algorithm includes adjustments to assure that prices for these transactions reflect the generic dump power and energy-not-served costs.

"Dump power cost" defines the minimum price at which a sale to a market area will occur. As used elsewhere in PowrSym4, dump power is the revenue that is received by the utility in the event that it must dispose of power in order to satisfy operating constraints. Thus, dump power effectively represents a forced market transaction that may not be economically beneficial, and sets a floor value for sales to the transaction area.

Similarly, "energy-not-served cost" defines the maximum price that the central area will pay for power. As used elsewhere in PowrSym4, energy-not-served cost is used to introduce an economic penalty for failing to fully satisfy demand. The central area should buy power from the market to satisfy load, but only to the point where the total cost of the purchase falls below the cost of not serving the load. Thus, energy-not-served cost effectively represents a ceiling value for purchases from the transaction area.

PowrSym4 automatically limits transaction prices to reflect dump power and energy-not-served costs. Transactions will occur with the transaction area at either the dump power or energy-not-served price in preference to incurring "dump power" or "energy-not-served" if transfer constraints will permit these transactions. Dump power and energy-not-served costs include

wheeling costs and loss allowances. Margin requirements do not apply in these extreme events.

10.3 Preparing a Spot Market Analysis Case

The following section describes the process for modifying an existing single area PowrSym4 data set to simulate the effects of wholesale transactions with the external market.

10.3.1 PowrSym4 Spot Market Control File

Using the spot market feature of PowrSym requires that the control file specify the incremental / decremental cost data files for each transaction area. Since these files are not required for a normal single or multi-area PowrSym analysis, special control file provisions are made for their accommodation. Table 1 illustrates a PowrSym4 control file for a spot market case that uses four transaction areas. The question mark (?) record in the control file tells PowrSym4 that the following files are associated with transaction area incremental/decremental costs.

10.3.2 Single Transaction Area Data Requirements

Table 2 shows the data required to activate the market transaction calculation for a single transaction area. The transaction areas and associated pseudo-units must be defined in the first week of the study and cannot be changed during the course of the study. In addition, it is necessary to provide a characterization of the market price for each transaction area that is being simulated (described in the Data Preparation section below). If a single transaction area is used, the transaction area incremental / decremental cost data are assigned to File 191.

10.3.3 Multiple Transaction Area Data Requirements

The wholesale power market is characterized by up to four transaction areas. Each transaction area is assumed to be fully independent and can trade only with the central area being simulated. Table 3 shows the data that must be added to Table 2 to characterize a total of four transaction areas. Each transaction area is automatically associated with an Incremental / Decremental Cost Data file as follows:

Transaction Area	File
1	FUN 191
2	FUN 192
3	FUN 193
4	FUN 194

10.3.4 Transaction Area Incremental / Decremental Cost Data Preparation

PowrSym4 represents the wholesale spot market with a 250-point, hourly incremental / decremental cost curve. Each transaction area can be represented by a separate data set. Points above point 125 represent sales by the transaction area to the central area; points below point 125 represent purchases by the transaction area from the central area. Point 125 corresponds to zero sales and purchases. Each point above or below point 125 is the price that corresponds to successively greater trading amounts. The size of each step is specified in the incremental /

decremental cost curve. The maximum purchase or sale that can be made is limited to 125 x the step size (if not otherwise constrained).

For example, point 120 lists the price that the market would be expected to be willing to pay (not including wheeling charges and trading margins) after a trade of 5 MCOST STEPs. For the data illustrated in Table 4, this corresponds to a total exchange of 5x50, or 250MW. Using the incremental / decremental cost curve allows the effect of trading quantity on prices to be automatically reflected in the trading decision. The incremental / decremental cost curve must be increase monotonically, although values may be repeated. The model will function properly even if a single price is applied to all incremental / decremental values.

The points below point 125 represent the avoided cost of power in the transaction area. Since these are the costs for the marginal generation, they do not the cost of wheeling incurred in trades with the central area, allowances for losses, or any margin that is required to make the trade attractive. Conversely, the points above 125 represent the cost the transaction area would incur in supplying power. These costs also do not include wheeling, losses, or margins.

Files 191 through 194 provide the incremental / decremental cost data. Table 4 illustrates the format for these data files.

The transaction area data file must include an entry for the first hour for each week in the study period. This hours data will be repeated for all hours until another entry occurs in the data file.

Table 1: Example Control File

TVA ESO-d0598	SPOT MARKET TEST CASE spot_4A	
spot_4A.F01	Debug output for dynamic module	File 1
spot_4A.F02	Marginal cost output	File 2
TVAmain.f03	Maintenance schedule input	File 3
TVAload.f04	Loads input for central area	File 4
DUMMY	Reserved for CONTROL file	File 5
DUMMY	Constraint violation output	File 6
DUMMY	Heat demand input	File 7
spot_4A.F08	Weekly printed output AND HOURLY LOLP OUTPUT	File 8
DUMMY	Weekly station and marginal cost unformatted output	File 9
hrDEBUG	Hourly debug output	File 10
DUMMY	Energy limited fuel output	File 11
DUMMY	Hourly average cost output	File 12
HR0DUMMY.DMY	Hourly station output for user-defined stations	File 13
DUMMY	Hourly printed output	File 14
DUMMY	Not currently used	File 15
spot_4A.F16	LOLP report and header	File 16
DUMMY	Pumped hydro output	File 17
DUMMY	Random number starting seed input	File 18
DUMMY	Prespecified maintenance deratings input	File 19
DUMMY	Initial BF Gas input	File 20
DUMMY	RBE Marginal Cost	File 21
DUMMY	Data	File 22
DUMMY	RBE Maintenance	File 23
DUMMY	Wind power generation input	File 24
DUMMY	Debug output	File 25
DUMMY	User-defined unformatted output	File 26
DUMMY	User-defined unformatted output	File 27
DUMMY	User-defined unformatted output	File 28
DUMMY	User-defined unformatted output	File 29
DUMMY	KWHREP module output	File 30
DUMMY	SEP format input data for IFC	File 31
DUMMY	TVA format input data for IFC	File 32
DUMMY	Week by hour output file	File 33
spot_4A.F34	Year by week output file	File 34
spot_4A.F35	Year by month output file	File 35
spot_4A.F36	Study by calendar year output file	File 36
spot_4A.F37	Study by fiscal year output file	File 37
spot_4A.F38	Monthly printed output	File 38
spot_4A.F39	Calendar year printed output	File 39
spot_4A.F40	Fiscal year printed output	File 40
DUMMY	Transarea load input in SEP format	File 41
FT0DUMMY.dmy	FINANCIAL TEMP FILE	File 42
DUMMY	PSYM module output	File 43
DUMMY	TVA unformatted fiscal year output file	File 44
DUMMY	TVA unformatted calendar year output file	File 45
FI0dummy.dmy	TVA financial output file for Resource Planning	File 46
DUMMY	MIDAS interface station output file	File 47
DUMMY	MIDAS interface annual output file	File 48
DUMMY	Intermediate IFC input file	File 49
spot_4A.F50	IFC output data file, PSM4 input data file	File 50
spot_4A.F51	Data input log file	File 51
spot_4A.F52	Data input error file	File 52
DUMMY		File 53
DUMMY		File 54
DUMMY	Debug / dump output	File 97
fun98	Debug / dump output	File 98
fun99	Debug / dump output	File 99
DUMMY		File100
DUMMY	Tarea Load File	File101
?		
SPOT1.idc	Exchange Area 1 incremental/decremental cost	File191
SPOT2.idc	Exchange Area 2 incremental/decremental cost	File192
SPOT3.idc	Exchange Area 3 incremental/decremental cost	File193
SPOT4.idc	Exchange Area 4 incremental/decremental cost	File194
END		

*New Spot
Market
Records*

Table 2: Illustration of Spot Market PowrSym4 Input Data for a Single Transaction Area

YR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	
1996	1	0	0	0	0	SPOT MARKET FLG	SPOT MKT	0	B	Neglect All Market Areas if X1=1
1996	1	0	0	2	0	TRANS AREA	SPOT MKT 1	1	B	Name of Transaction (Market) Area
1996	1	0	0	2	0	TRANS AREA STA	SPOT MKT 1	95	B	Artificial station to represent market
1996	1	0	0	2	0	TRANS AREA MKUP	SPOT MKT 1	2	B	Transarea Cost Mark-up & Discount
1996	1	0	0	1	0	TRANS SALES MRG	CENTRAL	1	B	Margin req'd for sales to market
1996	1	0	0	1	0	TRANS PURCH MRG	CENTRAL	1	B	Margin req'd for purchases from market
1996	1	0	0	2	0	TRANS SALES MRG	SPOT MKT 1	1	B	Margin req'd for sales to Transarea
1996	1	0	0	2	0	TRANS PURCH MRG	SPOT MKT 1	1	B	Margin req'd for purch from Transarea
1996	1	0	0	1	0	TAREA FROM LINK	SPOT LNK 1	2	B	Central area purch link
1996	1	0	0	1	0	TAREA TO LINK	SPOT LNK 1	1	B	Central area purch link
1996	1	0	0	1	0	TAREA LINK CAP	SPOT LNK 1	1500	B	Central area purch link
1996	1	0	0	1	0	TAREA LNKLOSS A	SPOT LNK 1	0.02	B	Central area purch link
1996	1	1	168	1	0	TAREA WHEEL	SPOT LNK 1	2	B	Wheeling Charge (\$/MWh)
1996	1	0	0	2	0	TAREA FROM LINK	SPOT LNK 2	1	B	Central area sales link
1996	1	0	0	2	0	TAREA TO LINK	SPOT LNK 2	2	B	Central area sales link
1996	1	0	0	2	0	TAREA LINK CAP	SPOT LNK 2	1500	B	Central area sales link
1996	1	0	0	2	0	TAREA LNKLOSS A	SPOT LNK 2	0.02	B	Central area sales link
1996	1	1	168	2	0	TAREA WHEEL	SPOT LNK 2	2	B	Wheeling Charge (\$/MWh)

SPOT MARKET FLG		<i>X1 = 0 (default) : execute spot market transactions = 1 : do not execute spot market transactions</i>
TRANS AREA		<i>N3 = Transaction Area number (must be 2, 3, 4, or 5) A1 = name of transaction (market) area X1 = TAREA number to which Trans Area connects (must be 1) Must not duplicate a TAREA number; TAREA must not be assigned to a CAREA; Central area must be assigned TAREA 1</i>
TRANS AREA STA		<i>N3 = Transaction Area number X1 = Station number -- A station number must be assigned and cannot duplicate another station; No other station data are needed</i> Note: if non-firm purchases are used, central area system reserve requirements must be specified using TAREA or CAREA variables.
TRANS AREA MKUP	<i>\$/MWh</i>	<i>N3 = Transaction Area number X1 = Mark-up or discount that the transarea applies to transactions (i.e. the amount of benefit that they extract from each trade)</i> Note: the mark-up affects the transaction price and changes the revenues or costs associated with transactions
TRANS SALES MRG	<i>\$/MWh</i>	<i>N3 = TAREA number of transaction area for which these margins apply X1 = Minimum benefit that the central area must receive before a sale will be made to the transaction area (default = 0)</i>
TRANS PURCH MRG	<i>\$/MWh</i>	<i>N3 = TAREA number of transaction area for which these margins apply X1 = Minimum benefit that the central area must receive before a purchase will be made from the transaction area (default = 0)</i>
TAREA FROM LINK		<i>N3 = Link Number X1 = Transarea in which link originates</i>
TAREA TO LINK		<i>N3 = Link Number X1 = Transarea in which link terminates</i>
TAREA LINK CAP	<i>MW</i>	<i>N3 = Link Number X1 = Maximum Transfer Capacity (< 5000) (default = 0)</i>
TAREA LNKLOSS A		<i>N3 = Link Number X1 = Fraction of link flow lost during transfer (< 1.00) (default = 0)</i>

Table 3: Additional Records for Multi-Area Transaction Model

YR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	
1996	1	0	0	3	0	TRANS AREA	SPOT MKT 2	1	B	Name of Transaction (Market) Area
1996	1	0	0	3	0	TRANS AREA STA	SPOT MKT 2	96	B	Artificial station to represent market
1996	1	0	0	3	0	TRANS AREA MKUP	SPOT MKT 2	2	B	Mark-up & Discount for Transarea
1996	1	0	0	3	0	TRANS SALES MRG	SPOT MKT 2	1	B	Margin req'd for sales to Transarea
1996	1	0	0	3	0	TRANS PURCH MRG	SPOT MKT 2	1	B	Margin req'd for purch from Transarea
1996	1	0	0	3	0	TAREA FROM LINK	SPOT LNK 3	3	B	Central area purch link
1996	1	0	0	3	0	TAREA TO LINK	SPOT LNK 3	1	B	Central area purch link
1996	1	0	0	3	0	TAREA LINK CAP	SPOT LNK 3	1500	B	Central area purch link
1996	1	0	0	3	0	TAREA LNKLOSS A	SPOT LNK 3	0.02	B	Central area purch link
1996	1	1	168	3	0	TAREA WHEEL	SPOT LNK 3	2	B	Wheeling Charge (\$/MWh)
1996	1	0	0	4	0	TAREA FROM LINK	SPOT LNK 4	1	B	Central area sales link
1996	1	0	0	4	0	TAREA TO LINK	SPOT LNK 4	3	B	Central area sales link
1996	1	0	0	4	0	TAREA LINK CAP	SPOT LNK 4	1500	B	Central area sales link
1996	1	0	0	4	0	TAREA LNKLOSS A	SPOT LNK 4	0.02	B	Central area sales link
1996	1	1	168	4	0	TAREA WHEEL	SPOT LNK 4	2	B	Wheeling Charge (\$/MWh)
1996	1	0	0	4	0	TRANS AREA	SPOT MKT 3	1	B	Name of Transaction (Market) Area
1996	1	0	0	4	0	TRANS AREA STA	SPOT MKT 3	97	B	Artificial station to represent market
1996	1	0	0	4	0	TRANS AREA MKUP	SPOT MKT 2	2	B	Mark-up & Discount for Transarea
1996	1	0	0	4	0	TRANS SALES MRG	SPOT MKT 3	1	B	Margin req'd for sales to Transarea
1996	1	0	0	4	0	TRANS PURCH MRG	SPOT MKT 3	1	B	Margin req'd for purch from Transarea
1996	1	0	0	5	0	TAREA FROM LINK	SPOT LNK 5	2	B	Central area purch link
1996	1	0	0	5	0	TAREA TO LINK	SPOT LNK 5	4	B	Central area purch link
1996	1	0	0	5	0	TAREA LINK CAP	SPOT LNK 5	1500	B	Central area purch link
1996	1	0	0	5	0	TAREA LNKLOSS A	SPOT LNK 5	0.02	B	Central area purch link
1996	1	1	168	5	0	TAREA WHEEL	SPOT LNK 5	2	B	Wheeling Charge (\$/MWh)
1996	1	0	0	6	0	TAREA FROM LINK	SPOT LNK 6	1	B	Central area sales link
1996	1	0	0	6	0	TAREA TO LINK	SPOT LNK 6	4	B	Central area sales link
1996	1	0	0	6	0	TAREA LINK CAP	SPOT LNK 6	1500	B	Central area sales link
1996	1	0	0	6	0	TAREA LNKLOSS A	SPOT LNK 6	0.02	B	Central area sales link
1996	1	1	168	6	0	TAREA WHEEL	SPOT LNK 6	2	B	Wheeling Charge (\$/MWh)
1996	1	0	0	5	0	TRANS AREA	SPOT MKT 5	1	B	Name of Transaction (Market) Area
1996	1	0	0	5	0	TRANS AREA STA	SPOT MKT 5	98	B	Artificial station to represent market
1996	1	0	0	5	0	TRANS AREA MKUP	SPOT MKT 2	2	B	Mark-up & Discount for Transarea
1996	1	0	0	5	0	TRANS SALES MRG	SPOT MKT 5	1	B	Margin req'd for sales to Transarea
1996	1	0	0	5	0	TRANS PURCH MRG	SPOT MKT 5	1	B	Margin req'd for purch from Transarea
1996	1	0	0	7	0	TAREA FROM LINK	SPOT LNK 7	5	B	Central area purch link
1996	1	0	0	7	0	TAREA TO LINK	SPOT LNK 7	1	B	Central area purch link
1996	1	0	0	7	0	TAREA LINK CAP	SPOT LNK 7	1500	B	Central area purch link
1996	1	0	0	7	0	TAREA LNKLOSS A	SPOT LNK 7	0.02	B	Central area purch link
1996	1	1	168	7	0	TAREA WHEEL	SPOT LNK 7	2	B	Wheeling Charge (\$/MWh)
1996	1	0	0	8	0	TAREA FROM LINK	SPOT LNK 8	1	B	Central area sales link
1996	1	0	0	8	0	TAREA TO LINK	SPOT LNK 8	5	B	Central area sales link
1996	1	0	0	8	0	TAREA LINK CAP	SPOT LNK 8	1500	B	Central area sales link
1996	1	0	0	8	0	TAREA LNKLOSS A	SPOT LNK 8	0.02	B	Central area sales link
1996	1	1	168	8	0	TAREA WHEEL	SPOT LNK 8	2	B	Wheeling Charge (\$/MWh)

Table 4: Transaction Area Incremental/Decremental Cost File Format

Year	Week	Iteration	Hour	Load	# Sta Out	Step Size	Price					
							-124	-123		λ		+125
<i>Columns 1-4</i>	<i>Columns 5-7</i>	<i>Columns 8-10</i>	<i>Columns 11-14</i>	<i>Columns 15-20</i>	<i>Columns 21-23</i>	<i>Columns 24-26</i>	<i>Columns 27-30</i>	<i>Columns 31-34</i>		<i>Columns 523-526</i>		<i>Columns 1023-1026</i>
1998	1	1	1	18000	0	50	70	70	...	224	...	9900
1998	1	1	2	18340	0	50	70	70	...	226	...	9900
1998	1	1	3	18870	0	50	70	71	...	229	...	9900
1998	1	1	4	19340	0	50	70	71	...	235	...	9900
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

		<i>PowrSym4 simulation year</i>
<i>Week</i>		<i>PowrSym4 simulation week</i>
<i>Iteration</i>		<i>Not used for Spot Market (use default value of 1)</i>
<i>Hour</i>		<i>PowrSym4 simulation hour</i>
<i>Load</i>	<i>MW</i>	<i>Market Region Simulated Load at Lambda (Used only by SPOT97)</i>
<i># Sta Out</i>		<i>Not used for Spot Market (use default value of 0)</i>
<i>Step Size</i>	<i>MW</i>	<i>Size of each incremental / decremental step</i>
<i>Price</i>	<i>\$/MWh x 10</i>	<i>Price of Power after Transaction (must be <10000)</i>

10.4 Interpreting Market Transaction Output Results

10.4.1 Print Reports

While *SPOT97* can be used to produce summary reports, spot market results are also captured in the PowrSym4's F08 output file. A sample output for a single area case is illustrated in figure 2.

Operating Characteristics and Cost Data								07/14/98	
Summary Class Report			Year 1998		Week 2				
TVA ESO-d0598			SPOT MARKET TEST -- CASE spot23						
					Fuel	Start	Total	Total	Total
					Cost	Cost	O&M	Cost	Cost
#	Summary	Energy	Starts	Fuel	Cost	Cost	O&M	Without	With
	Class	GWh			\$1000	\$1000	\$1000	\$1000	Emiss
									\$1000
<hr/>									
	Native Load	3527.							
	Dump Power	0.						0.0	0.0
	PS Load	29.							
	Trans Sales	50.						-893.8	-893.8
Resources:									
	Trans Purchase	52.						1143.4	1143.4
1	COAL	2234.	0.	939981.	25241.7	0.0	994.2	26235.9	27468.7
2	NUCLEAR	860.	0.	53747.	4155.4	0.0	0.0	4155.4	4155.4
3	COM TURB	0.	0.	0.	0.0	0.0	0.0	0.0	0.0
4	PUMP STR	23.	19.	0.	0.0	11.3	1.9	13.1	13.1
5	HYDRO	252.	0.	0.	0.0	0.0	17.6	17.6	17.6
6	\$IMPORT	168.	110.	0.	0.0	0.0	2824.7	2824.7	2824.7
7	PEAKING	0.	0.	0.	0.0	0.0	0.0	0.0	0.0
	Totals	3589.	129.		29397.1	11.3	3838.4	34390.2	35622.9
	E.N.S.	0.						0.0	0.0
	Spin Resv Viol	0.						0.0	
	Oper Resv Viol	0.						0.0	
	Bkup Resv Viol	0.						0.0	
	Wheeling Charge							0.0	0.0
	Total System Cost							33496.3	34729.1

Figure 2: Sample Single Area Print Report

The weekly print report lists the transaction area sales in gigawatthours for the total report period. The revenue that these sales produce is shown as a negative number to reflect the fact that these are not costs. The revenue reflects the cost of the market generation alternative that was offset by this sale (based on their demand curve as defined in the incremental / decremental cost curve). This price is reduced to account for margin required by the market, wheeling costs, and the allowance for losses. Thus, the revenue shown is the anticipated revenue that will be realized by the central area for the sale.

Transaction area purchases are also listed in gigawatthours. The cost of purchases includes the price paid to the market (their production cost as defined by the incremental / decremental curve plus the margin required by the market). The cost also includes wheeling charges and the allowance for losses. The cost of producing the power that is sold is captured in the production cost data.

Sales and purchase data contained in the print report reflect the total transactions determined by summing transactions with all transaction areas. Data regarding transactions with each individual area can only be obtained from the OFC output files (see below).

Since emissions are not associated with the purchase (it is assumed that any costs associated with emissions has been included in the incremental / decremental cost curve), the sales and purchase values shown in the last two columns are identical.

The total system cost sums the production cost, purchases, and wheeling charges, and credits the revenue received from sales.

The transaction link reports provide other information regarding purchases and sales. The “Transarea Exchange Summary” report notes the percentage of time during the period in which sales and purchases were made as well as the percentage during which exchanges were not occurring. The “Link Totals Summary” captures the wheeling charges incurred as a result of the trades. Since losses are treated as a purely economic penalty in this model, however, they are not reported in the “Link Activity Summary” report.

Hourly transaction results can also be obtained from the **FUN 01** file if this is being produced. In addition to the details for individual operating units, this report includes data pertaining to market transactions as illustrated in Figure 3.

Totals	18641	18641	18741	18841	18841	19743	22259	23106	22470	21827	21445		19745	18941	18841	18441	482217	9.87
Sales	-2173	-2181	-2123	-1969	-1158	-20	-20	-20	-20	-20	-20		-20	-124	-1417	-2173	-13638	-18.01
Revenue	18	18	18	18	18	18	18	18	18	18	18		18	18	18	18	0	-18.01
Ref. Cost	20	20	20	20	20	20	20	20	20	20	20		20	20	20	20	0	20
Purchase	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Cost	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0
Load	16568	16560	16718	16972	17783	19823	22339	23186	22550	21907	21525		19825	18917	17524	16368	470975	9.59

Figure 3: FUN 01 Output Example (partial)

The following definitions apply to the data given in FUN 01:

Total	Total Generation (MWh)
Sales	Total Off-System Sales (MWh)
Revenue	Price Received for Sales (\$/MWh)
Ref. Cost	Transaction Area Cost (at lambda, \$/MWh)
Purchases	Total Off-System Purchases (MWh)
Cost	Price Paid for Off-System Purchases (\$/MWh)
Load	Net System Load (MW) (Total – Sales + Purchases)

10.4.2 OFC Reports

Spot market output is captured in PowrSym4’s output data files (**FUN 33, FUN 34, FUN 35, FUN 36, and FUN 37**). Table 5 describes the output AIDS associated with the spot market.

Table 5: Spot Market Related Output AIDS

AID	Type	Definition	Measurement Units	
			Hourly File	Other Files
SYS TRANS PURCH	System	Purchases from all Transaction Areas Combined	Thousands of Dollars	Thousands of Dollars for weekly, millions of dollars for monthly or annual
SYS TRANS SALES	System	Sales to all Transaction Areas Combined	Thousands of Dollars	Thousands of Dollars for weekly, millions of dollars for monthly or annual
SYS PURCH ENGY	System	Energy Purchased from all Transaction Areas Combined	Megawatthours	Gigwatthours
SYS SALES ENGY	System	Energy Sold to all Transaction Areas Combined	Megawatthours	Gigwatthours
PURCH ENGY FROM	Area	Energy purchased from the Transaction area specified by N3	Megawatt Hours	Gigwatthours
SALES ENGY TO	Area	Energy sold to the Transaction area specified by N3	Megawatt Hours	Gigwatthours
PURCH FROM	Area	Cost of energy purchased from the Transaction area specified by N3	Thousands of Dollars	Thousands of Dollars
SALES TO	Area	Revenue for Energy sold to the Transaction area specified by N3	Thousands of Dollars	Thousands of Dollars

Each of the area AIDs are output for each transaction area being simulated. The N3 field in the output data file identifies the exchange area number.

10.5 Executing A Spot Market Analysis Case with SPOT97

OSA provides a separate database program, *SPOT97*, to facilitate running spot market analysis cases. The three basic functions of *SPOT97*, as illustrated in figure 4, are adjusting the market price curves, executing the appropriate PowrSym4 runs, and compiling the results into easy-to-understand reports. Each of these functions is described in the following sections.

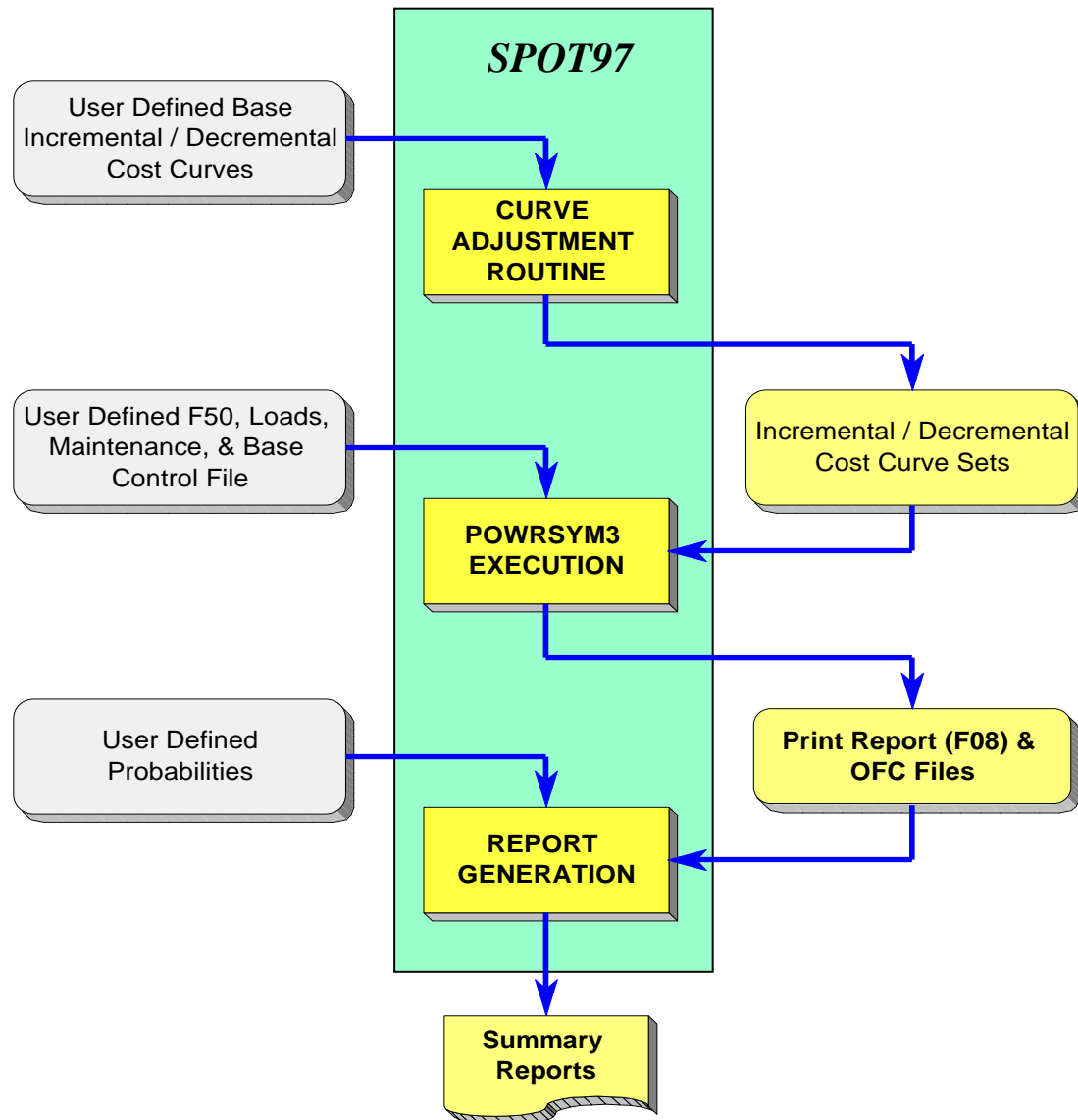


Figure 4: SPOT97 Program

10.5.1 Preparing to Use SPOT97

SPOT97 functions by performing three sequential functions. The program automatically carries forward information from previous steps to later operations. Thus, efficient program operation imposes some requirements are placed on the user in setting up the files for *SPOT97*.

The user should create a single directory containing the following files:

Base incremental / decremental cost curves for each transaction area
PowrSym4 Fun 50
PowrSym4 Control File
PowrSym4 Loads File
PowrSym4 Maintenance File

All files created by **SPOT97** will be placed in this directory as well.

Step 1: Data Adjustment

OSA provides a separate database program, **SPOT97**, to facilitate manipulation of the incremental / decremental cost files. This program adjusts the data contained in one Incremental / Decremental Cost Data file to produce another altered Incremental / Decremental Cost Data file. The user can adjust the beginning Incremental / Decremental Cost Data file values in the following ways:

Each incremental / decremental cost value can be increased or decreased by a constant amount
The incremental / decremental cost curve can be shifted by a specified number of megawatts (either to the right or left)
The incremental / decremental cost vales can be shifted by a specified percentage (either increased or decreased)
The incremental / decremental cost curve can be shifted by a percentage of the Load value
The incremental / decremental costs can be forced to have at least a minimum value
The incremental / decremental costs can be forced to have no more than a maximum value

Upon starting **SPOT97**, the screen illustrated in Figure 5 will open in Microsoft Access 97.

From this point, the transaction area incremental / decremental cost curve can be adjusted by clicking on the “**Adjust SpotMarket Curve**” button. Once this button is selected, a screen will open for the user to specify the starting curve and the adjustments to be applied. Up to four different transactions areas may be specified and up to five adjustment cases. This is illustrated for 3 transaction areas and 4 cases in figure 6.

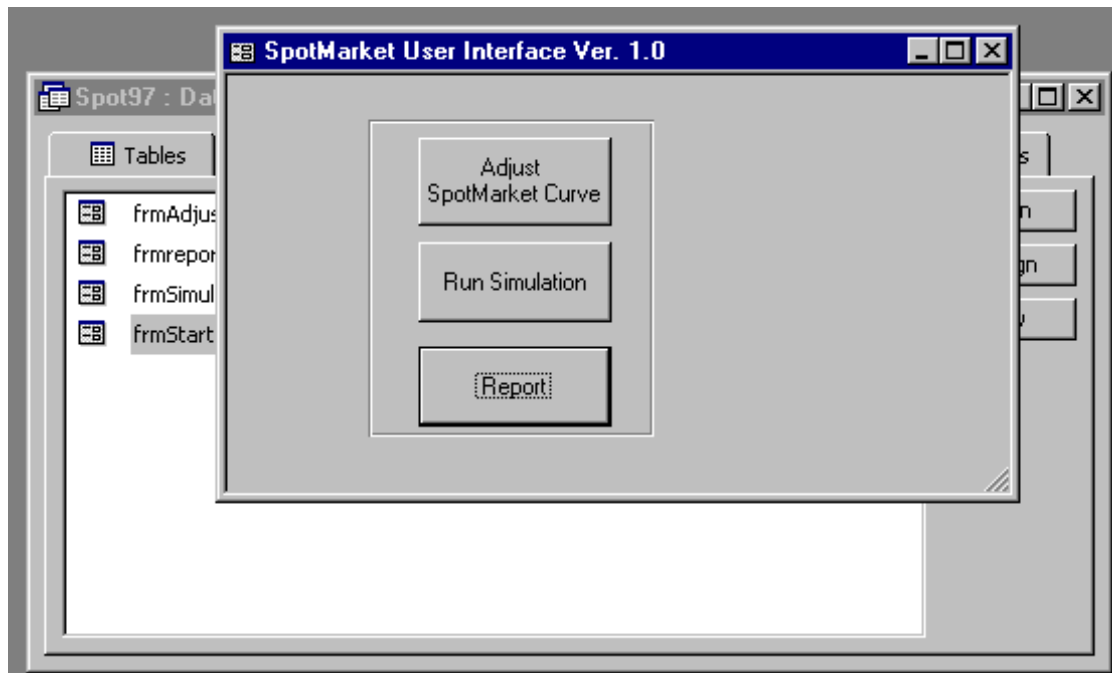


Figure 5: SPOT97 Start Screen

SPOT97 automatically adjusts the input screen to reflect the number of transaction areas (Transareas) and the number of cases specified by the user. Each transaction area may use a different incremental / decremental cost curve as a starting point for making the adjustments. Either these files can be entered with the complete path, or the “File” button can be used to pull down a “windows explorer”-type browse window.

Cases define the number of adjusted curves that are to be produced. Each case consists of a set of adjusted curves for each of the transaction areas. The same adjustment factors are applied to each transaction area for each case.

If the “% Value” box is not checked:

- Horizontal shift is specified in megawatts. The value will be rounded to the closest integer number of steps. A positive horizontal shift causes the source curve to shift to the left (prices increase) by this number of steps. A negative horizontal shift causes the source curve to shift to the right (prices decrease) by this number of steps.

- Vertical shift is specified in dollars/megawatt-hour. A positive value will cause each price in the source curve to be increased by the specified amount. A negative value will cause each price in the source curve to be decreased by the specified amount.

If the “% Value” box is checked:

- Horizontal shift is specified in percentage of transaction area load (column 5 in the source curve). The megawatt shift will be determined by applying this percentage to the transaction area load and rounding the result to the closest integer number of steps. Since the transaction area load may be different for each hour, the amount of shift applied may also be different for each hour. A positive horizontal shift causes the source curve to shift to the left (prices increase) by this number of steps. A negative horizontal shift causes the source curve to shift to the right (prices decrease) by this number of steps.
- Vertical shift is specified in percentage of the source curve price. Since this is treated as a percentage of the original price, the amount of adjustment may be different for each point in the incremental / decremental cost curve. A positive value will cause each price in the source curve to be increased by the specified percentage. A negative value will cause each price in the source curve to be decreased by the specified percentage.

Horiz. Shift	Vert. Shift	<input type="checkbox"/> % Value	
100	10		Case 1 Upper Limit
0	5		Case 2 990
0	0		Case 3 Lower Limit
-100	-5		Case 4 0

Figure 6: SPOT97 Adjustment Input Screen

The user should also specify the minimum and maximum prices that are to be output in the adjusted curve. All incremental / decremental prices are verified to be greater than the minimum value and less than the maximum value. Any values that violate these criteria are changed to either the lower limit or upper limit value, as appropriate. The largest upper limit that can be

accommodated by the incremental / decremental cost curve is \$999/MWh. If the user specifies a value that exceeds \$999/MWh, the **SPOT97** will automatically limit the output to \$999. The default value for the minimum price is \$0/MWh.

The adjusted files are created when the **Adjust** button is clicked. These files are created in the directory for the last transaction area source file. The adjusted files are named using the following convention:

CASExy where x = transaction area number and y = case number

An information box will open to let the user know when the data file adjustments are complete. At that point, use the “Exit” button to return to the main screen.

Step 2: Executing Spot Market Analysis Cases

PowrSym4 may be executed from within the **SPOT97** program. Once the desired changes have been made and the “adjust” button clicked, the user will be returned to the screen illustrated in Figure 5. At this point, the user may begin execution by clicking the “**Run Simulation**” button. This will open the screen shown in Figure 7.

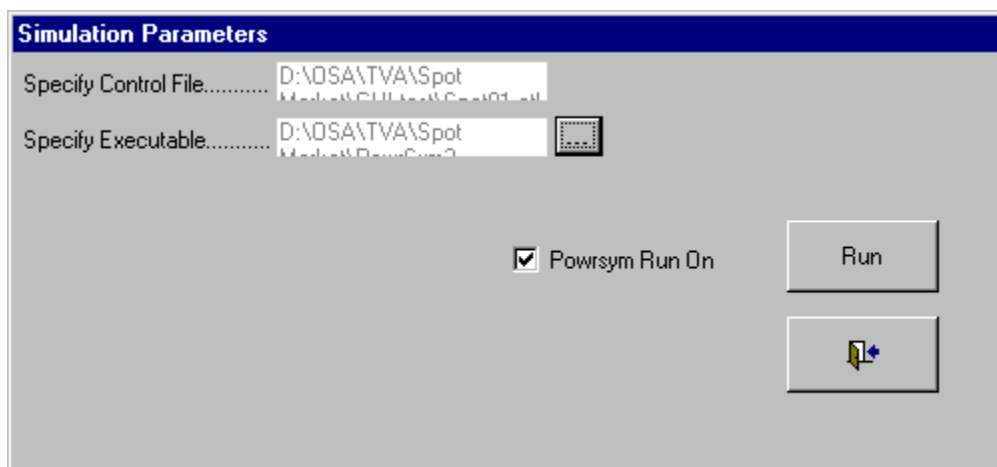


Figure 7: Simulation Parameter Screen

To begin execution, the user need only identify the base Control file and the PowrSym4 Executable file. **SPOT97** will create new control files for each case (each case will include all of the transaction areas defined in the F50 data set). **SPOT97** automatically creates the output files listed in Table 6 for each case. These files are saved in the directory that contains the base Control file:

Table 6: Files Created by SPOT97

Case#.f08	Weekly Print File
Case#.f33	Hourly OFC Output File
Case#.f34	Weekly OFC Output File
Case#.f35	Monthly OFC Output File
Case#.f36	Calendar Year OFC Output File
Case#.f37	Fiscal Year OFC Output File
Case#.f51	Data Input Log File
Case#.f52	Data Input Error File
<i>where # represents the case number.</i>	

While all files will be created for each case run, only files that are activated by the F50 data will contain information; OFC files not activated by the F50 data will be of zero length. Other output files specified in the control file (e.g. the F02 marginal cost file) will only be produced for the last case run and will retain the name specified in the base control file.

The user can also use this screen to point the report generator to a directory that already contains the desired output files by un-checking the **PowrSym Run On** box.

Step 3: Producing the Summary Reports

The *Spot97* program calculates the expected value for system generation cost, power purchases from each transaction area, and power sales to each transaction area. The program determines the expected values based on user supplied information about the probabilities of different transaction area price curves.

To use the probability analysis mode, it is only necessary to assign probabilities to each of the available cases that are shown when the report button is selected. A deterministic case occurs when a probability of 1 is assigned to a single case. A probabilistic analysis occurs when a set of different potential outcomes is considered. In this case, the results produced in the output table reflect the “expected value” for market transactions and the resulting cost.

The user begins producing the summary report by clicking the **Report** button on the main menu screen. This opens the screen shown in figure 8.

The dialog box will show the number of cases defined by the user when the curve adjustment operation was performed. The probabilistic result can be obtained by assigning probabilities to each case output. *Spot97* verifies that the sum of the probabilities equals 1.

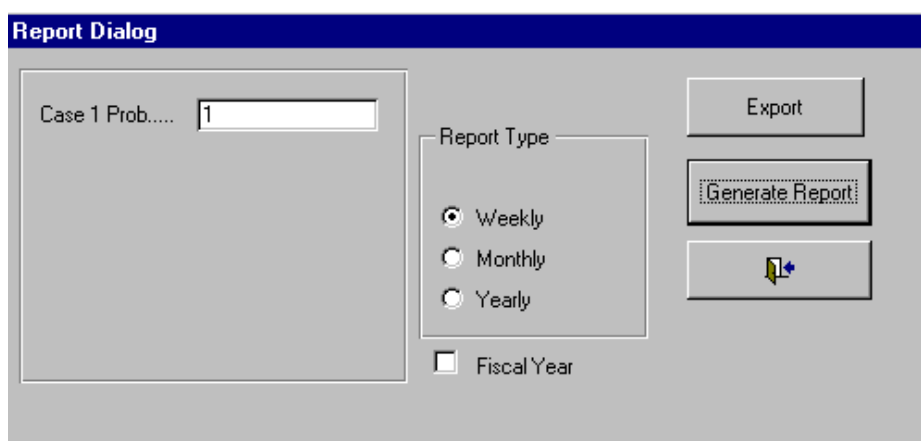


Figure 8: Report Dialog Box

The user can also specify the type of report to be generated. In running the simulation, all of the different OFC files necessary to produce these reports were created. The files will only contain data, however, if the FUN 50 data set calls for their generation as well. Spot97 verifies that the files required to produce the selected report are not of zero length. If they are, (i.e. if they were not generated by PowrSym4) an error message is returned.

Once the probabilities are assigned, the summary report is produced by clicking on the **Generate Report** button. This will initiate the importing of the appropriate data and the creation of a report similar to that shown in figures 9 and 10.

	97-01	97-02	97-03	97-04	97-05	97-06	97-07	97-08	97-09	97-10	97-11	97-12	97-13
System Generation													
Amount (GWh)		4,008	3,898										
Cost (\$MWh)		71,220	122,787										
Composite Spot Market Transactions													
Purchases													
Amount (GWh)		3	0										
Cost (\$MWh)		62	0										
Sales													
Amount (GWh)		485	891										
Revenue (\$MWh)		32,226	83,400										
Net													
Amount (GWh)		-482	-891										
Cost (\$MWh)		-32,194	-83,400										
Net System Production													
Cost (\$MWh)		6,769	16,986										

Figure 9: SPOT97 Output Report Sample – Composite Results

	97-01	97-02	97-03	97-04	97-05	97-06	97-07	97-08	97-09	97-10	97-11	97-12	97-13
Transaction Area # 2													
Purchases													
Amount(GWh)		1	0										
Cost (\$/MWh)		20	0										
Sales													
Amount(GWh)		119	140										
Revenue(\$/M)		7,974	11,843										
Net													
Amount(GWh)		-118	-140										
Cost (\$/MWh)		-7,954	-11,843										
Transaction Area # 3													
Purchases													
Amount(GWh)		1	0										
Cost (\$/MWh)		28	0										
Sales													
Amount(GWh)		117	189										
Revenue(\$/M)		7,982	14,882										
Net													
Amount(GWh)		-116	-189										
Cost (\$/MWh)		-7,994	-14,882										
Transaction Area # 4													
Purchases													
Amount(GWh)		1	0										
Cost (\$/MWh)		27	0										
Sales													
Amount(GWh)		120	146										
Revenue(\$/M)		7,991	12,887										
8/2/98													

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Figure 10: SPOT97 Output Report Sample - Single Area Reports

The output screen also provides the option of exporting the analysis results as an EXCEL worksheet to facilitate additional data evaluation.

11.0 Reliability

Using PowrSym4 to Calculate
System Generating Margin Reliability Implications

11.1 Introduction To RELI

As excess regional generating capacity is consumed by growing demand, managing system operations and marketing activities to achieve desired levels of reliability becomes increasingly important. Utilities routinely perform analyses that provide information to system planners and marketers that inherently consider reliability. As discussed later in this report, however, in many of these analyses reliability is an implicit consideration represented by reserve margins rather than an explicit measure.

Reliability can be measured in many different ways; the measure chosen needs to be carefully selected to correlate with the anticipated decision. By its very nature reliability is a probabilistic function and does not lend itself well to a single deterministic measure. These factors significantly complicate using reliability as a basis for predicting the quantity of surplus (or deficit) generating capacity that may exist at any point in the future.

The growing importance of power purchases and sales, however, requires that power marketers also be provided with near-term information on the effect of market transactions on system reliability. Some level of risk is inherent in these marketing transactions – off-system sales reduce system reliability while purchases increase reliability. Improvements in unit forced outage rates make reliability effects more dramatic.

Substantial progress has been made in recent years at improving the operation of existing generating units. While these improvements reduce the overall system production cost, they also increase sensitivity to reliability excursions. With high unit availability, relatively small changes in load can produce dramatic changes in loss of load probability. Thus, the better generating units operate, the more important is monitoring system reliability.

PowrSym4 calculates generation reliability probabilistically, and provides the unique ability to relate the probability of reliability events to potential market transactions. PowrSym4 determines the generating capability margin (surplus or deficit) associated with a specified probability of incurring a service interruption. This capability gives the power marketing organization a powerful tool for evaluating the risk effects inherent in making power trades.

11.2 Generation Surplus / Deficit Model

Hourly surplus projections provide useful information for making trading decisions. Individual trades may encompass a broad spectrum of terms and range from one-hour to several weeks in length. Hourly surplus projections provide power marketers with a measure of how much power they should buy or can sell based on reliability considerations by supplying the following information:

- ◆ Hourly surplus amounts to provide an indication of how the surplus varies with time across a given day,
- ◆ A relation between the amount of surplus and the type of interruption that might occur if more than that amount of surplus power were sold, and
- ◆ A measure of the probability of incurring an interruption as a function of the level of surplus held.

Figure 1 illustrates the basic model for calculating the generating surplus. The probability of interrupting any particular class of service depends on three major uncertain factors:

- ◆ The demand for power
- ◆ The supply of power
- ◆ Alternatives actions that can be taken to forestall interruption

While most of the inputs to this model exhibit some level of uncertainty, the principal contributors to uncertainty are those elements shown with the double borders.

The following discusses the major elements of this model:

Determining Probable Demand

The demand for any specific hour comprises firm demand from native load and firm off-system sales, interruptible demand from ESP and LIP customers, and non-firm off-system sales. Of these, native load demand contributes most of the uncertainty. Since this is a short-term (10-day) analysis, the largest contributors to native load uncertainty are the weather forecasts and errors in the load forecasting model. For purposes of calculating generating surplus, it is reasonable to characterize the uncertainty in the native load demand as a normal distribution about the “expected” demand for that hour. It is also reasonable to believe that the standard deviation of the error in the native demand forecast will be larger for longer range forecasts. Estimates for the standard deviation of the forecast error can be derived by comparing previous forecasts to actual hourly demand. As a further refinement of this model, it may be appropriate to use different standard deviations depending on the season.

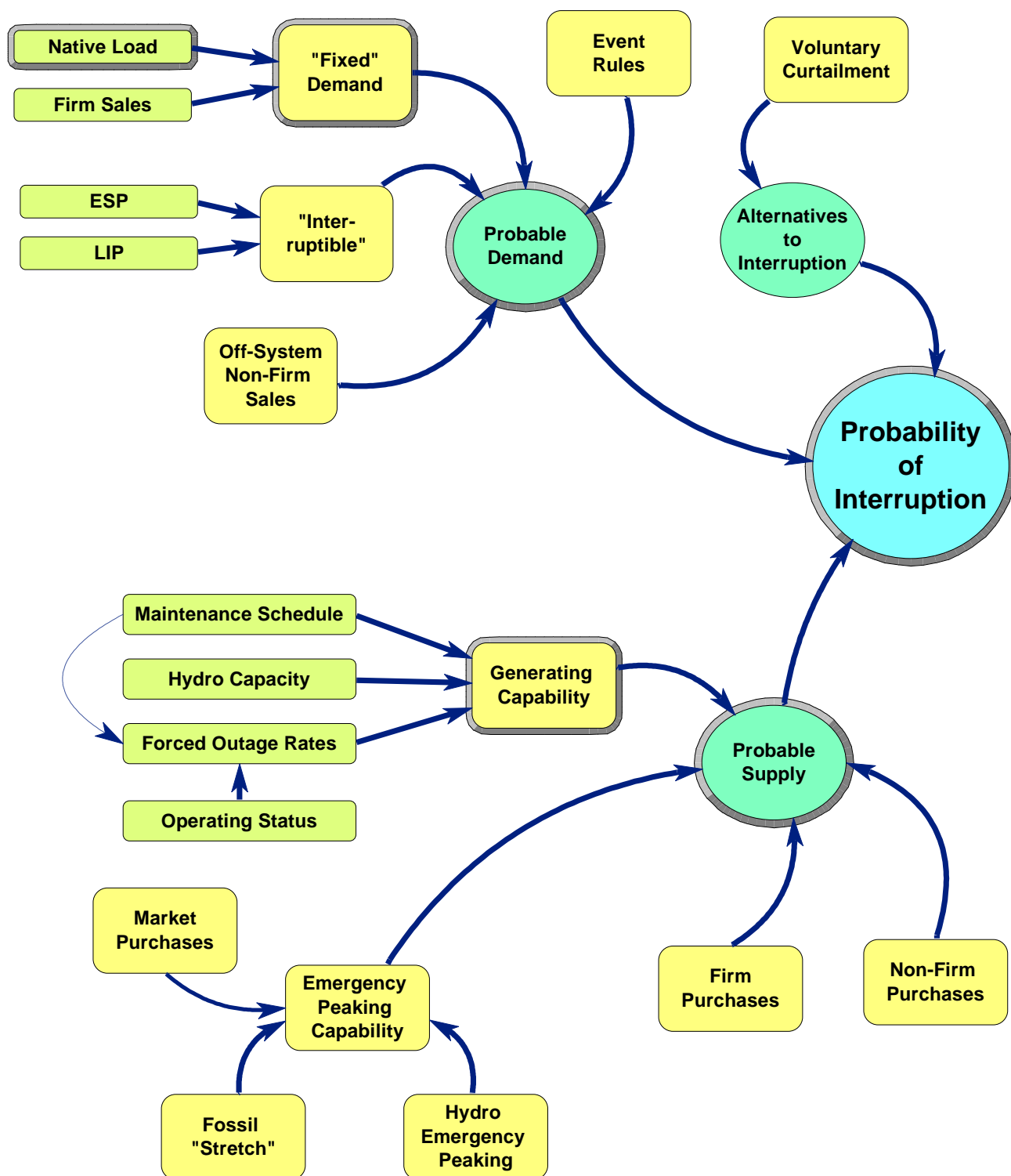


Figure 11: Model for Calculating Reliability

The other contributors to probable demand are assumed to be known exactly. This is certainly true of off-system sales (since these reflect only “booked” sales, not potential sales). The quantity of ESP and LIP being used in any particular hour may not be known exactly. However, for purposes of this calculation, these can be assumed to be known exactly, with any uncertainty included in the uncertainty that pertains to native load. It is further assumed that all

ESP and LIP will be interrupted before the fixed demand is interrupted. If so, then it is not necessary to consider the uncertainty with the quantity ESP and LIP will actually be curtailed upon demand.

A final input to the probable demand box is the rules for evaluating events. These rules constitute a list of the demand segments that are being served before a particular class of service is interrupted. The demand numbers do not include reserves (these are considered as part of the probable supply).

Load demand used in the calculation of reliability does not include any reserves (spinning, operating, or back-up). It is assumed that the reserves will be depleted before service is interrupted. If the user wishes to include an additional reserve requirement, this can be accomplished by subtracting the reserve amount from one of the emergency supply sources for each applicable interruption case.

Alternatives to Interruption

It is assumed that voluntary and in-house load curtailment will be used to reduce load before using involuntary interruptions. The quantity of load that can be shed through these techniques is treated as a single deterministic value.

Determining Probable Supply

System generation provides the primary source of supply. Most of the data needed to characterize available generation is captured in the PowrSym4 data files. The maximum generation capability assumed by Reli is defined using the following hierarchy:

Maximum Capacity for a unit = STA POWER CAP, if given
 STA POWER MAX, if STA POWER CAP is not given
 POWER LEVEL 5, if STA POWER MAX is not given

The maintenance schedule provides specific information on current unit availability and anticipated future availability. In addition, information is required from System Operations regarding current unit commitment status.

Average forced outage rates are used as a basis for estimating the probability that any particular unit will be available during an upcoming hour. The option is provided, however, to reduce forced outage rates so that currently committed units have a higher than average probability of being available in the next hour. The assumed probability decays to average over the ensuing 48 hours. Units that are available, but not currently dispatched are assumed to have a probability of being made available if required equal to the average forced outage rate.

Units that are not currently available are assumed to become available on the date indicated in the maintenance schedule. However, it is recognized that the probability of a unit being returned to service as scheduled is not 100%. Therefore, the average forced outage rate for a unit is increased for the first two days after its scheduled return to account for the probability that it may not be returned to service as

scheduled. The magnitude of the increase depends on the length of time before the unit is scheduled to return to service.

Hydroelectric capacity is taken as a fixed number equal to the generation capacity planned for that hour. Note that this introduces a potential conservatism in that the maximum hydroelectric generation that can be produced in a particular hour will exceed this value. However, if the maximum generation were used in all hours it would imply a greater hydroelectric energy than is appropriate.

Pumped hydroelectric or other energy storage technologies have limited generating capability. They cannot generate for all of the hours during a week because of recharging requirements. This limitation is considered by determining the maximum number of hours for which generation can occur during a week. In calculating this number, it is assumed that the energy in storage at the end of the week is the same as at the beginning of the week. The energy storage unit is assumed available during the hours with the highest peak demand.

For some events, such as preventing the interruption of “fixed” demand, it may be appropriate to push the generating system a bit harder than normal. An “emergency” peaking capability is used to represent this action and comprises additional generation that can be extracted from the fossil system and the hydroelectric system. The amount of “emergency” peaking that is assumed may be different for each of the different reliability events. In addition to the internal emergency generating capability, it may also be possible to purchase some amount of power from the grid.

Similar to the “emergency” peaking capability, the reserve requirements that are to be maintained may be different depending on the event.

Finally, the probable supply includes scheduled purchases. These may be firm or non-firm as defined by the purchase contracts. In the first version of this model, it will be assumed that the firm contracts have a zero probability of interruption. Non-firm contracts can be characterized by some average probability of interruption that is less than that of individual generating stations.

11.3 Preparing a Probabilistic Reliability Analysis Case

Setting-up & Running Reli

PowrSym4 is used to analyze loss-of-load probability as a function of changes in the total system load. Separate analyses are performed for each hour of the analysis period, with all of the results captured in output file FUN 19.

The PowrSym4 Reli analysis is performed for a three-week period that begins on the Monday of or preceding the first day for which the results are desired. PowrSym4 uses an artificial calendar, so some adjustment may be required to determine the appropriate PowrSym4 weeks to associate with the dates of interest.

Typical Control File

A typical control file for running PowrSym4 in this mode is shown in Figure 2.

Loads & Maintenance Files

The loads used for PowrSym4 analysis are taken from the load file specified in the PowrSym4 control file (TVALoad.f04 in the figure 2 example). These are hourly loads and must cover the entire year for which the Reli analysis is being performed. The load file used for other PowrSym4 applications can be used for this purpose, but the data should be updated to reflect the most recent near-term load forecast available. The Reli analysis assumes that the load forecast is current as of the first day of the simulation. If this is not the case, the values for the standard deviation of the load should be adjusted. The only data used in the analysis, however, is for the three weeks being simulated, so it is acceptable to specify zero loads for all other hours. The loads for the simulated weeks, however, should include all scheduled firm sales, scheduled non-firm sales, all interruptible loads, and the native system load.

Similarly, the maintenance plans are taken from the maintenance file specified in the PowrSym4 control file (TVAMain.f03 in the figure 2 example). This can be the same maintenance file used in other PowrSym4 applications, but should be updated to reflect any changes in planned maintenance that are anticipated during the 3-week simulation window.

```

TVA Reli Test Case:  0% Load Std Dev; No Load Adder
DUMMY                Commit Report                      F01
DUMMY                Marginal cost output                F02
TVAmain.f03          Maintenance schedule input         F03
TVAlload.f04         Loads input for central area       F04
DUMMY                File name input                    F05
DUMMY                Constraint violation output          F06
DUMMY                Heat demand input                   F07
reli0000.f08         Weekly print                       F08
DUMMY                Weekly station & marg'l cost output F09
DUMMY                Hourly debug output                 F10
DUMMY                Energy limited fuel output          F11
DUMMY                Hourly average cost output          F12
DUMMY                Hourly output ( SELECT HR OUT )     F13
DUMMY                Hourly output                      F14
DUMMY                Old SEP card input (not used )      F15
reli0000.f16         LOLP report and header              F16
DUMMY                Pumped hydro output                 F17
DUMMY                Random number starting seed input  F18
reli0000.f19         Reli output                         F19
DUMMY                Initial BF Gas input                F20
DUMMY                Incremental / Decremental cost curves F21
DUMMY                Spot price pattern input table      F22
DUMMY                RBE Maintenance                    F23
DUMMY                Wind power generation input         F24
DUMMY                Debug output                       F25
DUMMY                User-defined unformatted output     F26
DUMMY                User-defined unformatted output     F27
DUMMY                User-defined unformatted output     F28
DUMMY                User-defined unformatted output     F29
DUMMY                KWHREP subroutine output            F30
DUMMY                SEP format input data for ifc       F31
DUMMY                TVA format input data for ifc       F32
DUMMY                Week by hour OFC output             F33
reli000.f34         Year by week OFC output             F34
DUMMY                Year by month OFC output            F35
DUMMY                Study by calendar year OFC output   F36
DUMMY                Study by fiscal year OFC output     F37
DUMMY                Monthly print                       F38
DUMMY                Calendar year print                 F39
DUMMY                Fiscal year print                   F40
DUMMY                GEN FILE FOR (FINESS)               F41
DUMMY                Commit data input                   F42
DUMMY                PSYM output (hr,ld,spinres,NU)      F43
DUMMY                F44
DUMMY                F45
DUMMY                F46
DUMMY                F47
DUMMY                F48
DUMMY                F49
reli0000.f50         FINAL PSM3 INPUT FILE              F50
x.log                XYZ log file                       F51
x.err                XYZ error file                     F52
DUMMY                F53
DUMMY                F54
DUMMY                Debug / dump output                 F97
DUMMY                pump stg costs pump/gen             F98
DUMMY                Debug / dump output                 F99
DUMMY                NOT USED                            F100
DUMMY                TAREA 2 Loads input                  F101
DUMMY                TAREA 3 Loads input                  F102
END

```

Figure 12: Example Reli Control File

FUN 50 File Changes & Additions

For the most part, the Reli analysis uses a normal FUN 50 data set. The following cards must be added, however:

Table 7: PSM FUN 50 Records

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1997	40	0	0	0	0	RELI PRINT FLAG	SYSTEM	3	Rel	Turns on option to output RELI results
1997	40	0	0	0	0	HR LOLP TYPE	SYSTEM	2	Rel	Activates convolution reliability method
1997	40	0	0	0	0	LOLP CNTL	SYSTEM	1	Rel	Sets PowrSym to run reliability, only
1997	40	0	0	0	0	RELI STEP	SYSTEM	100	Rel	Sets size of probability analysis step
1998	23	81	104	0	0	STD DEV OF LOAD	SYSTEM	0.04	Rel	Day 1 Load Forecast Error
1998	23	105	128	0	0	STD DEV OF LOAD	SYSTEM	0.05	Rel	Day 2 Load Forecast Error
1998	23	129	152	0	0	STD DEV OF LOAD	SYSTEM	0.057	Rel	Day 3 Load Forecast Error
1998	23	153	168	0	0	STD DEV OF LOAD	SYSTEM	0.064	Rel	Day 4 Load Forecast Error
1998	23	81	168	0	0	EXECUTE	SYSTEM	0	Rel	Begin execution in Wk 23, Hr 73
1998	23	1	8	0	0	STD DEV OF LOAD	SYSTEM	0.064	Rel	Day 4 Load Forecast Error
1998	24	9	32	0	0	STD DEV OF LOAD	SYSTEM	0.069	Rel	Day 5 Load Forecast Error
1998	24	33	56	0	0	STD DEV OF LOAD	SYSTEM	0.075	Rel	Day 6 Load Forecast Error
1998	24	57	80	0	0	STD DEV OF LOAD	SYSTEM	0.082	Rel	Day 7 Load Forecast Error
1998	24	81	104	0	0	STD DEV OF LOAD	SYSTEM	0.093	Rel	Day 8 Load Forecast Error
1998	24	105	168	0	0	STD DEV OF LOAD	SYSTEM	0.1	Rel	Day 9 & Later Load Forecast Error
1998	24	1	152	0	0	EXECUTE	SYSTEM	0	Rel	Executes Wk 24 through Hr 152

The above example illustrates an analysis for 10 days beginning on 8:00 AM on Thursday (i.e. the 4th day) of week 23. The weeks and hours assigned to the STD DEV OF LOAD data will need to be adjusted to reflect the analysis period. If STD DEV OF LOAD values are not input, Reli assumes that the load forecast is perfect.

The default assumption in Reli is that all available units have a forced outage rate equal to their long-term forced outage rate. Reli provides the option, however, of reducing the assumed near-term forced outage rate for units that are currently operating based on the following equation:

$$EFOR_t = EFOR_{long-term} \times [1 - e^{-At} (1 + Kt^2)]$$

Utilizing this option, requires that the following data be included in FUN 50:

Table 8: FUN 50 Data for Gradient Forced Outage Option

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1998	23	8	0	0	0	OUTAGE TYPE	SYSTEM	2	Rel	Sets start time for calculating gradient forced outage rate
1997	40	0	0	1	0	EFOR A CONSTANT	STA #1	0.15	Rel	Station specific forced outage rate equation coefficient
1997	40	0	0	1	0	EFOR K CONSTANT	STA #1	0	Rel	Station specific forced outage rate equation coefficient
1998	23	0	0	1	0	STA BEGIN UP	STA #1	1	Rel	X1 > 0 if unit is currently operating X1 = 0 if unit is currently not operating

The above records need to be included for each unit for which the gradient forced outage probability model is to be used. The 1YR, 1WK, and N1 fields of the OUTAGE TYPE record set the time for which the unit status is assumed to be known. This time should correspond to the starting time for the study. The values for the constants listed in Table 2 provide a reasonable gradient and can be used in the absence of more rigorously determined numbers. A value for STA BEGIN UP greater than or equal to 1 should be used for each unit that is currently operating. A value of 0 is used for units not currently operating. Units not currently operating can be either available, but idle, or unavailable due to maintenance. Reli determines whether the unit is reliable based on data contained in the maintenance file.

Reli can also use a gradient method to represent the probability of a unit being returned to service as scheduled in the maintenance plan based on the following equation:

$$EFOR_{x+t} = EFOR_{long-term} \times (1 + M_1 e^{-M_2 t})$$

The scheduled date for the return to service, x, is obtained from the maintenance file. By default, Reli assumes that this date is known exactly. The option is provided, however, to characterize the return to service date as an uncertain variable by assigning a higher forced outage to a unit on the date it is scheduled to return to service. This rate decays to the long-term average forced outage rate with time. To use this option, the following data must be included in Fun50:

Table 9: FUN 50 Data for Return-to-Service Forced Outage Option

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1997	40	0	0	0	0	EFOR M1	STA #1	5	Rel	Coefficient for increasing EFOR for delay in return-to-service
1997	40	0	0	0	0	EFOR M2	STA #1	0.15	Rel	Exponential Constant for increasing EFOR for delay in return-to-service

The values for the constants listed in Table 3 provide a reasonable gradient and can be used in the absence of more rigorously determined numbers.

Reli Output

The Reli analysis produces the FUN 19 table of the hourly interruption probability as a function of changes in system load. A sample output table is illustrated in Figure 3 and graphically portrayed in Figure 4 (note: the FUN 19 file does not include column headings). These data are input to the probability analysis program along with other data that describes the interruption events and other system conditions. The probability analysis program is described in the next section.

Year	Week	Hour	Load Increment	Base Load	Probability of Interruption at Load Increment:												
					Jan-95	96	97	98	99	Base Load	101	102	103	104	105	106-199	
1998	20	1	100	12329	•••	0	0	0	0	0	0	0	0	0	0	0	•••
1998	20	2	100	11942	•••	0	0	0	0	0	0	0	0	0	0	0	•••
1998	20	3	100	11799	•••	0	0	0	0	0	0	0	0	0	0	0	•••
1998	20	4	100	11741	•••	0	0	0	0	0	0	0	0	0	0	0	•••
1998	20	5	100	11742	•••	0	0	0	0	0	0	0	0	0	0	0	•••
1998	20	6	100	14005	•••	0	0	0	0	0	0	0	0	0	0	0	•••
1998	20	7	100	16986	•••	0	0	0	0	0	0	0	0	0	0	0	•••
1998	20	8	100	18345	•••	0.000001	0.000002	0.000003	0.000004	0.000005	0.000007	0.000009	0.000012	0.000016	0.000022	0.000022	•••
1998	20	9	100	18967	•••	0.00001	0.000013	0.000017	0.000023	0.00003	0.000039	0.000051	0.000066	0.000086	0.00011	0.00011	•••
1998	20	10	100	19548	•••	0.000049	0.000063	0.000082	0.000105	0.000135	0.000171	0.000217	0.000273	0.000342	0.000428	0.000428	•••
1998	20	11	100	20235	•••	0.000265	0.000332	0.000415	0.000518	0.000643	0.000796	0.000981	0.001203	0.001467	0.00178	0.00178	•••
1998	20	12	100	21323	•••	0.002527	0.003028	0.00362	0.004315	0.00513	0.006079	0.007173	0.008426	0.009845	0.011438	0.011438	•••
1998	20	13	100	21232	•••	0.002136	0.002568	0.003076	0.003675	0.004381	0.005208	0.006169	0.007279	0.008545	0.009978	0.009978	•••
1998	20	14	100	22005	•••	0.00819	0.009575	0.011141	0.012897	0.014874	0.0171	0.019608	0.022446	0.025654	0.02924	0.02924	•••
1998	20	15	100	22104	•••	0.009563	0.011125	0.012881	0.014855	0.01708	0.019583	0.022417	0.025625	0.029204	0.033185	0.033185	•••
1998	20	16	100	21577	•••	0.00398	0.004738	0.005624	0.006653	0.00783	0.00917	0.010686	0.012386	0.014297	0.016444	0.016444	•••
1998	20	17	100	21796	•••	0.005806	0.006863	0.008072	0.009442	0.01099	0.012727	0.01468	0.016882	0.019364	0.022169	0.022169	•••
1998	20	18	100	21819	•••	0.006039	0.007128	0.008373	0.009789	0.011374	0.013161	0.015169	0.017426	0.019989	0.022871	0.022871	•••
1998	20	19	100	21598	•••	0.004131	0.004915	0.00583	0.006889	0.008101	0.009478	0.011029	0.012769	0.014727	0.016937	0.016937	•••
1998	20	20	100	21011	•••	0.0014	0.001701	0.002056	0.002473	0.002965	0.003544	0.004226	0.005026	0.005958	0.007037	0.007037	•••
1998	20	21	100	21331	•••	0.002564	0.003071	0.00367	0.004375	0.005201	0.00616	0.007269	0.008533	0.009963	0.01158	0.01158	•••
1998	20	22	100	19956	•••	0.000137	0.000174	0.000221	0.000278	0.000348	0.000435	0.000542	0.000673	0.000832	0.001025	0.001025	•••
1998	20	23	100	18281	•••	0.000001	0.000002	0.000002	0.000003	0.000004	0.000006	0.000008	0.00001	0.000014	0.000018	0.000018	•••
1998	20	24	100	15555	•••	0	0	0	0	0	0	0	0	0	0	0	•••
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•

Figure 13: Sample Reli Output (FUN 19)

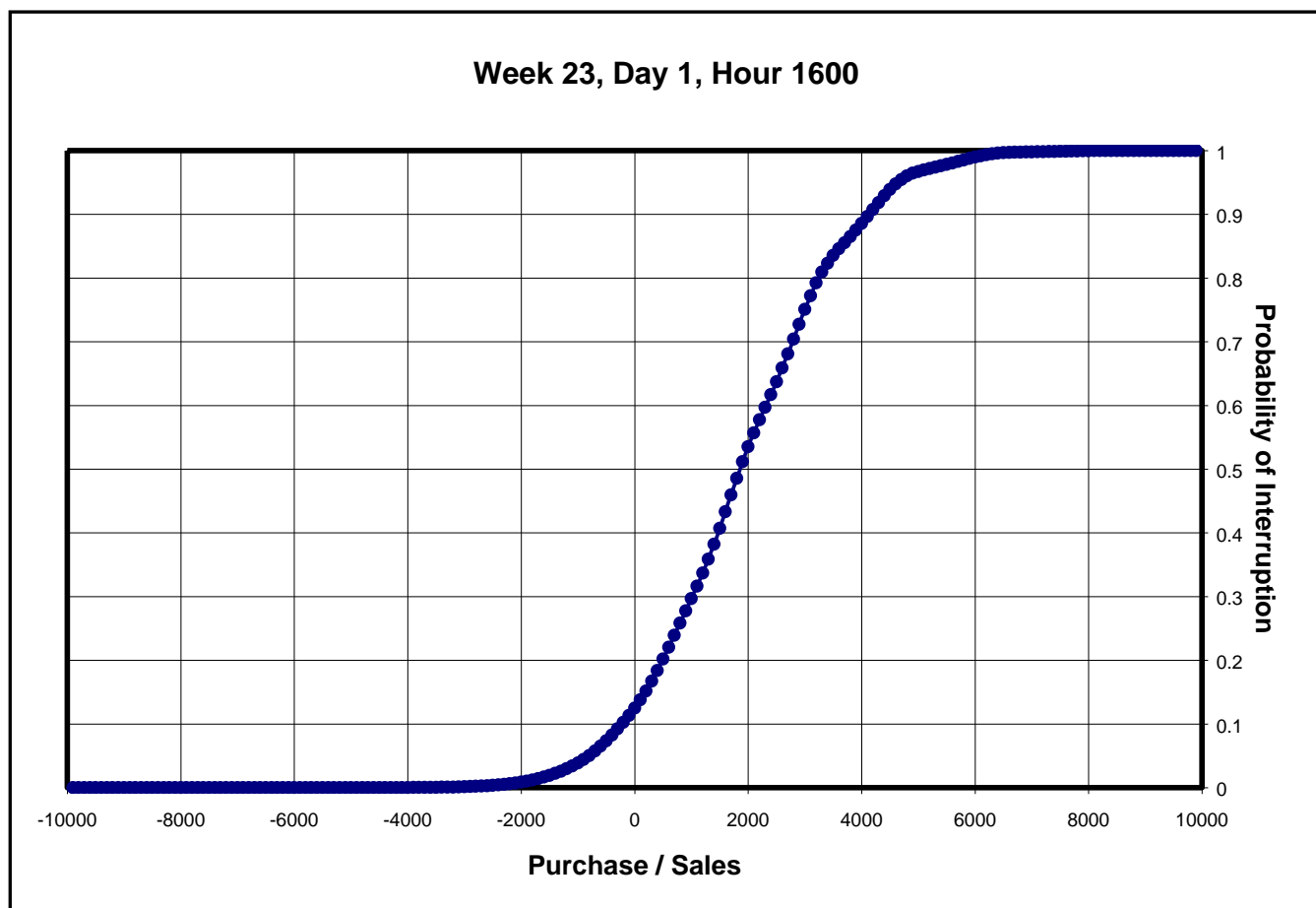


Figure 14: Graphical Illustration of FUN 19 for a single hour

Running the Reliability Analysis Program

The reliability analysis program performs a number of manipulations on the probability data produced by reli to calculate the amount of surplus power available. Three different levels of interruption events are defined:

1. Failure to satisfy the total load requirement
2. The need to interrupt at least some level of ESP or LIP service
3. The need to interrupt at least some level of native load or firm power sales

Each event is examined for up to three different user-specified probabilities. For each probability level, the program determines the amount of surplus generating capability available (or amount of power required) above that required to produce the specified interruption probability. Therefore, if the probabilities are specified at the acceptable level of risk, the results will show the amount of power that can be sold, or must be purchased, to maintain the desired risk.

Interruption probabilities are specified on an hourly basis. Thus, an interruption probability of 1% corresponds to a 1% probability that an interruption would occur in any single hour. Since each hour is evaluated independently, a constant hourly interruption probability of 1% corresponds to a >20% probability that an interruption would occur sometime during the 24 hour period.

Surplus generation amounts are calculated for each hour of a 10-day (240 hour) period specified by the user. The analysis period can begin at any desired hour, but the starting time must correspond to the starting time used in reli for producing the FUN 19 output.

Starting the Reliability Analysis Program

The reliability analysis is written as a Microsoft Access 97 program. An executable version of the program can be used if Access 97 is not installed on the host computer.

Preparation of Hourly Data

The PowrSym4 reli analysis determined the probability of failure to satisfy any portion the total demand as a function of additional sales or purchases. As described above, the total demand used for this analysis includes native load, firm sales, interruptible loads (ESP and LIP), and non-firm sales. The user needs to specify the level of loads that can be interrupted for each event being considered, as well as other mitigating actions that are assumed to be taken. The probabilistic reliability program allows the user to specify the amount of off-system, non-firm sales hourly. Similarly, the user may identify the level of ESP/LIP that is assumed to be available for interruption on an hourly basis.

Hourly data are input using an EXCEL spreadsheet like the one illustrated in Figure 5.

zstartdate	Hour	nonfirm	esplip	Start Date	5/23/98
05/23/98	8	100.00	100.00	Start Hour	8
05/23/98	9	100.00	100.00		
05/23/98	10	100.00	100.00		
05/23/98	11	100.00	100.00		
05/23/98	12	100.00	100.00		
05/23/98	13	100.00	100.00		
05/23/98	14	100.00	100.00		
05/23/98	15	100.00	100.00		
05/23/98	16	100.00	100.00		
05/23/98	17	100.00	100.00		
05/23/98	18	100.00	100.00		
05/23/98	19	100.00	100.00		
05/23/98	20	100.00	100.00		
05/23/98	21	100.00	100.00		
05/23/98	22	100.00	100.00		
05/23/98	23	100.00	100.00		
05/24/98	24	100.00	100.00		
05/24/98	1	100.00	100.00		
05/24/98	2	100.00	100.00		

Figure 15: Reli Hourly Input Spreadsheet

Using this spreadsheet requires that the user enter the beginning date and hour for the study. The 240 day and hour index values shown in the two left columns of the spreadsheet will be automatically filled based on the start date and hour provided by the user. The date is based on a real calendar date and must correspond to the starting time for the PowrSym4 Reli analysis run.

Non-Firm Sales

The “nonfirm” column contains the hourly quantities of non-firm off-system sales (MW) that were included in the total system load used in the PowrSym4 Reli analysis. This, combined with load reductions from in-house and voluntary curtailment, represents the load requirement difference between the first interruption level and the second interruption level.

Economy Surplus Power & Limited Interruptible Power

The “esplip” column contains the hourly quantities of interruptible and economy surplus power (MW) that were included in the total system load used in the PowrSym4 Reli analysis. This represents the load requirement difference between the second interruption level and the third interruption level.

Input Data

All of the data required for calculating probabilistic reliability are input using the MAIN report form which is illustrated in Figure 6. The following describes each of the required inputs:

Begin Date

Begin Date is the beginning date for the analysis; usually the current date. This date is expressed as a real calendar date. The “calendar” button can be used as an aid to determine

the proper date to enter. This date must correspond to the beginning date for the PowrSym4 Reli analysis.

Begin Hour

Begin Hour is the first hour for which the study is to be performed. Hour 1 corresponds to the hour beginning at midnight (i.e. 12:01 AM) on the specified date. This hour must correspond to the beginning hour for the PowrSym4 Reli analysis and is assumed to be the time for which the current unit operating conditions are known.

Voluntary Reduction

Voluntary Reduction is the amount of load reduction (MW) that is expected to occur as a result of in-house load reduction measures and voluntary response by the public to a request for load reduction. The analysis treats Voluntary Reduction as a single value.

Consequently, the amount of load reduction that would occur at peak demand should be used for this quantity.

Event Analysis Probabilities

Each interruption event can be evaluated at three different probabilities. Probabilities are entered as fractional numbers (not percentages). It is necessary to specify a value for each of the nine probability levels although they do not need to be different. The probabilities should be selected based on the level of risk that the company is willing to accept for that event. As such, these numbers may will be different for different events and may also change with time. Using management's desired level of risk for the middle probability will allow the output reports to reinforce the desire to observe this risk level.

Emergency Market Purchase

Market is the amount of power (MW) that is assumed obtainable from the grid. This includes power available for purchase. The amount of power assumed to be available should be limited to that which can reasonably be expected to be deliverable (i.e. subject to any transmission system limitations). Since each event may correspond to different regional power demand conditions, the user may specify different market amounts for each of the interruption events. Each interruption event is treated independently, and each input **Market** value represents the entire market purchase opportunity expected to exist for that event.

Emergency Fossil Generation

Fossil is the amount of power (MW) that is assumed obtainable from pushing operation of the fossil generating units beyond their normal rated maximum capacity. A different level of power may be available for each event because of operating practices (i.e. operations may not be willing to push the units for some events while they are willing to push the units for others). Each interruption event is treated independently, and each input **Fossil** value represents the entire emergency fossil unit operation expected to exist for that event.

Emergency Hydro Generation

Hydro is the amount of power (MW) that is assumed obtainable from pushing operation of the hydro generating units beyond their scheduled operation. A different level of power may be available for each event because of operating practices (i.e. operations may not be willing to deviate from planned generation for some events while they are willing to expand generation for others). Each interruption event is treated independently, and each input **Hydro** value represents the entire emergency hydro unit operation expected to exist for that event.

The screenshot displays the 'Probabilistic Reliability Input Screen' with the following fields and values:

- Begin Date** (1): 06/04/1998
- Calendar**: (Dropdown menu)
- Start Hr** (2): 8
- Voluntary Reduction** (3): 150
- ESP/LIP**: (Dropdown menu)
- Off-System Sales**
 - Interruption Probability**: 0.002, 0.005, 0.01
 - Market**: 2000
 - Fossil**: 0
 - Hydro**: 0
- Firm System Demand**
 - Interruption Probability**: 0.0001, 0.0002, 0.0003 (4)
 - Market** (5): 0
 - Fossil** (6): 320
 - Hydro** (7): 150
- Report** (8): (Button)

- 1 Starting date for the analysis
- 2 Starting time for the analysis; Hour 1 begins at 12:01 AM
- 3 Amount of load reduction from in-house and voluntary load reduction programs
- 4 Probabilities for which surplus is to be determined for each event
- 5 Amount of power that can be purchased from market assuming that event occurs
- 6 Amount of emergency fossil generation above normal unit capacities that can be used
- 7 Amount of emergency peaking power that can be obtained from hydro system
- 8 Button begins execution (described more fully below)

Figure 16: Probabilistic Reliability Input Screen

Report Generation

Before beginning execution for the probabilistic analysis the following should have been completed:

1. PowrSym4 Reli analysis performed and the FUN 19 file saved
2. Hourly Data updated in the Excel spreadsheet and saved
3. Analysis and system data entered in the probabilistic program input form

Upon completing these steps, execution is initiated by selecting the “Report” button. This button will open a Windows Browser form and ask the user to select the FUN 19 file to be used for this analysis. Once the FUN 19 File is selected (either by double-clicking or selecting and then selecting “open”), a second Windows Browser form will open. The second window asks the user to select the Excel spreadsheet that contain the hourly data to be used in this analysis. Once the spreadsheet is selected, execution will begin and produce the 10 daily reports identified in the next section.

11.4 Interpreting Reliability Output Results

The probabilistic reliability analysis program produces either 10 or 11 calendar days of results. Each day’s results are captured on a separate report page similar to that illustrated in Figure 7. Most reports will include a full 24 hours, but depending on the start hour for the study, the first and last pages may contain less than 24 hours of results.

Each day’s report includes both tabular and graphical presentations. The table includes nine columns. Each column corresponds to one of the interruption events and analysis probabilities specified by the user. The numbers in the column show the amount of surplus generating capacity available above that required for the indicated hourly loss-of-load probability. Negative numbers show the amount of additional capacity that is needed to achieve the indicated interruption probability.

The total load demand associated with the “**Off-System Sales**” event is the largest. Probabilities for this case correspond to the probability of failing to serve all levels of demand (i.e. the point at which any level of load curtailment first occurs). A lower demand level corresponds to the “**ESP/LIP**” event. This second event assumes that the voluntary curtailment and non-firm off-system sales have already been interrupted. The “**Firm System Demand**” event corresponds to the lowest level of demand since it assumes that the ESP and LIP loads have been interrupted. Since different probabilities and emergency power supply sources are associated with each event, however, the events do not necessarily maintain this hierarchy.

The graph shows the hourly surplus/deficit generating capacity for the middle probability of each event. Regardless of which event proves to be controlling, the lowest plotted point will show the minimum surplus (or maximum deficit) available when all risk probabilities are satisfied. The graph quickly indicates projected surpluses in terms of magnitude and duration.

In interpreting these results, however, it is important to consider the projection period being reported. Load forecasting error typically increases with the length of the projection (see the appendix to this report for an estimate of load forecast error as a function of forecast period). As a particular date approaches, the error will narrow. This may or may not reduce the margin required to achieve the specified loss-of-load probability since the load forecast will also change

Surplus Generating Capacity Report for Friday, Jun 5, 1998 <u>Sale (Purchase) that Produces Indicated Probability of Interruption</u>									
Hr	<u>Firm System Demand</u>			<u>ESP & IP</u>			<u>Off-System Sales</u>		
	<u>0.010%</u>	<u>0.020%</u>	<u>0.030%</u>	<u>0.100%</u>	<u>0.200%</u>	<u>0.500%</u>	<u>0.200%</u>	<u>0.500%</u>	<u>1.000%</u>
1	11,220	11,520	11,620	10,520	10,520	10,520	11,900	11,900	11,900
2	11,620	11,820	12,020	10,520	10,520	10,520	11,900	11,900	11,900
3	11,520	11,820	12,020	10,520	10,520	10,520	11,900	11,900	11,900
4	11,520	11,820	12,020	10,520	10,520	10,520	11,900	11,900	11,900
5	10,220	10,520	10,720	9,520	9,920	10,420	11,300	11,800	11,900
6	7,520	7,820	8,020	6,820	7,220	7,620	8,600	9,000	9,400
7	7,320	7,620	7,720	6,620	6,920	7,420	7,500	8,000	8,400
8	6,020	6,320	6,520	5,420	5,720	6,220	6,300	6,800	7,200
9	4,820	5,020	5,220	4,120	4,420	4,920	5,000	5,500	5,900
10	3,420	3,620	3,820	2,720	3,020	3,520	3,600	4,100	4,500
11	2,120	2,420	2,620	1,420	1,820	2,320	2,400	2,900	3,300
12	1,120	1,420	1,620	420	820	1,320	1,400	1,900	2,300
13	420	720	920	-280	120	620	700	1,200	1,600
14	-180	120	220	-880	-580	-80	0	500	900
15	-780	-480	-380	-1,480	-1,180	-680	-600	-100	300
16	-880	-580	-380	-1,580	-1,180	-680	-600	-100	300
17	-880	-580	-380	-1,580	-1,180	-680	-600	-100	300
18	-480	-180	20	-1,080	-780	-280	-200	300	700
19	20	320	520	-580	-280	220	300	800	1,200
20	-380	-80	20	-1,080	-780	-280	600	1,100	1,500
21	820	1,120	1,320	120	420	920	1,800	2,300	2,700
22	3,420	3,720	3,820	2,720	3,020	3,520	4,400	4,900	5,300
23	6,420	6,720	6,920	5,720	6,120	6,620	7,500	8,000	8,400
24	7,420	7,720	7,920	6,720	7,120	7,620	8,500	9,000	9,400

as the date approaches.

Surplus / Deficit Interruption Probability

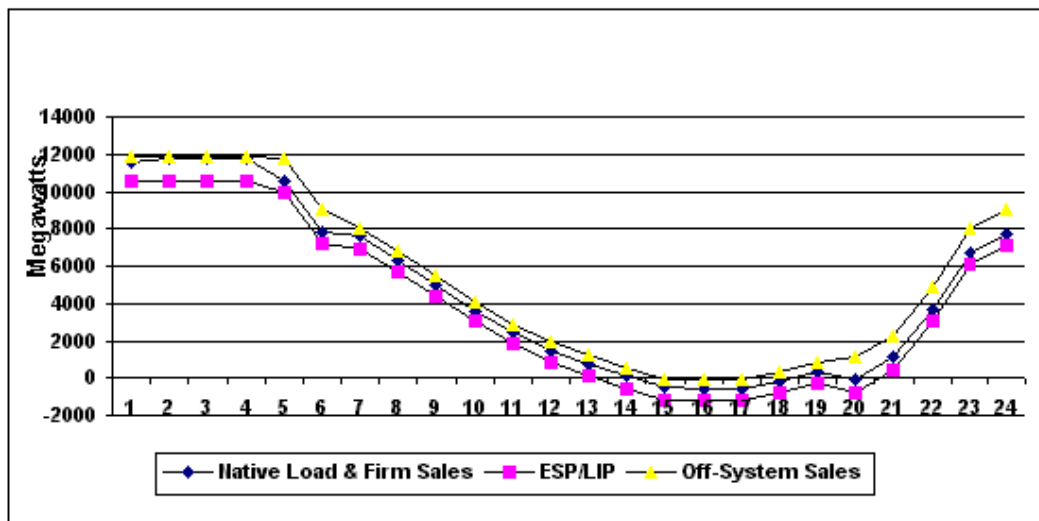


Figure 17: Sample Output Report

12.0 Using PowrSym4 to Calculate Marginal Cost

PowrSym4 provides an excellent tool for calculating the marginal cost of supplying power, often a critical input to making operational decisions. **Marginal Cost** typically refers to the cost of providing the next increment of power for a modeled system. If the step size used to calculate marginal cost is small relative to the total system being modeled, however, the cost of providing the last increment of power is closely approximates the cost of the next increment. PowrSym uses this relationship to greatly simplify the marginal cost calculation.

While the marginal cost has a simple definition, it must be applied carefully to assure that the marginal cost being calculated matches the decision for which it is to be used. PowrSym4 provides several different formulations to allow the user to calculate the appropriate marginal cost values.

For purposes of the following discussion, it is assumed that the user has a base case model constructed and verified. This document describes:

- ◆ the types of marginal cost calculations performed by PowrSym4,
- ◆ the steps for converting the base case model into a marginal cost model, and
- ◆ the interpretation of the PowrSym4 marginal cost output.

A wide range of production costing problems can be analyzed through the application of these tools. PowrSym4 makes performing these calculations easy while still providing the degree of accuracy that is critical to good decision making.

12.1 Marginal Cost Calculation Methods

PowrSym4 provides four distinct methods for calculating marginal cost. Three of these methods are implemented from within PowrSym4. The fourth, and most flexible, method is based on comparing output from different, but related, PowrSym4 runs. Each of these alternatives is described in the following sections.

Fixed Unit Commitment Model

PowrSym4 can calculate of the marginal cost for power using a fixed unit commitment assumption. In this case, the unit commitment schedule is determined using the base case analysis. A second analysis is performed internally through which the load demand for all simulated hours is reduced by the marginal load increment. The difference between the two yields the hourly marginal cost of providing the last increment of power. Since unit commitment is not changed in this model, there is no change in unit start costs. PowrSym4 will, however re-optimize unit dispatch based on the lowered load pattern (which exists for all hours of the simulated week). Fuel costs and variable costs will change reflecting the response of the system operation to the different demand.

This method can be used in either of two ways. In the first case, the base case is run as is to

produce the starting point for calculating the marginal cost. All loads are then reduced by a constant marginal cost step and the analysis is repeated. The commitment is not changed, so the result reflects the change in cost associated with re-dispatching the system to produce less power in each hour of the analysis period. In essence, this analysis yields the marginal cost of producing the last increment of power being generated in the base case.

Alternatively, the loads used in the initial base case can be adjusted upward by a fixed amount equal to the marginal cost step and PowrSym4 run to determine the commitment and optimum dispatch for the higher loads. The internal marginal cost calculation is then performed as described above, except in this case, applying the marginal cost step size returns the hourly loads to the initial base case values. This analysis essentially determines the marginal cost of producing the next increment of power above the base case.

The results for these two approaches will not necessarily be the same since the commitment schedule can differ between the two.

The lowest marginal cost that will be reported is the value of “dump” power (if it is specified in the PowrSym Data set). The highest marginal cost that will be reported is the value of “energy not served” cost. Units with production costs below the “dump” power cost or above the “energy not served” cost are not included in the marginal cost output curve.

Unconstrained Commitment Model

Freezing the unit commitment schedule is appropriate for some forms of analyses, particularly cases where the analysis is intended to reflect uncertainties that may exist during the simulated week. In other cases, however, the question being answered pertains to the cost that could be saved if the last increment of power were not incurred. By the logic described above, this value will also approximate the cost of serving the next increment of load (although not perfectly). As described above, PowrSym4 uses the base case analysis as a starting point. Loads are then internally adjusted downward by the marginal load increment and a second case internally run. With this model, however, PowrSym4 determines a new commitment and dispatch schedule to maximize the savings that can be obtained from the lower load demand. Consequently, unit start costs, fuel costs, and variable costs will change to reflect the new optimized operation for the lower demand.

As for the fixed commitment case, this method can be used in either of two ways. In the first case, the base case is run as is to produce the starting point for calculating the marginal cost. All loads are then reduced by a constant marginal cost step and the analysis is repeated. The commitment may change, so the result reflects the change in cost associated with both re-committing and re-dispatching the system to produce less power in each hour of the analysis period. In essence, this analysis yields the marginal cost of producing the last increment of power being generated in the base case.

Alternatively, the loads used in the base case can be adjusted upward by a fixed amount equal to the marginal cost step by using a positive value for the marginal cost step. The internal marginal cost calculation is performed as described above, except in this case applying the marginal cost step determines the marginal cost of producing the next increment of power above the base case.

The results for these two approaches will not necessarily be the same since the commitment schedule can differ between the two.

The lowest marginal cost that will be reported is the value of “dump” power (if it is specified in the PowrSym Data set). The highest marginal cost that will be reported is the value of “energy not served” cost. Units with production costs below the “dump” power cost or above the “energy not served” cost are not included in the marginal cost output curve.

Incremental / Decremental Cost Curve

Both of the above methods provide a single point calculation of marginal cost based on supplying the last increment of power using an increment size defined by the user. In evaluating some situations, however, it is useful to determine how the marginal cost changes as the increment size is increased or decreased. PowrSym4 can calculate an hourly picture of how the marginal cost changes if varying loads are added (incremental) or subtracted (decremental) from the base load. PowrSym4 produces 250 calculated marginal production cost numbers around the base case analysis load. The marginal production costs are determined for each of 124 blocks below the system lambda and for 125 blocks above system lambda. The block size is defined by the user.

This option uses a methodology that essentially combines the two above methods. When PowrSym4 calculates the cost of a decremental block, it does so by reducing the power level of the marginal operating unit. A unit’s power level will be reduced until it reaches its minimum operating power level. A unit will not be decommitted. If all units are reduced to minimum power and there are still steps remaining to be evaluated, each remaining step is assigned a value of dump power. If dump power cost has not been specified, the default value of zero is used. Also, the lowest value power that will be shown will be the dump power cost (even if some units are operating at less than dump power cost and could be backed down further).

In determining the incremental cost, PowrSym will first increase the power levels for committed units to their maximums. New units will then be committed in their economic commitment order as needed. The maximum power level that will be shown in the incremental cost is that of “energy not served”. Generating units that have production costs in excess of energy not served will not be called upon in this analysis. The additional start costs associated with the new commitments are not included in the calculation of the marginal cost.

Direct Comparison of Cases

Each of the above calculation methods entails making some assumptions regarding the type of load change for which the marginal cost is being calculated. Both of the first two methods assume that the change occurs in all hours of the week. The third method essentially assumes that the change occurs only in the specific hour and does not consider the potential effect of changes in other hours on optimal dispatch or commitment. In many cases, these assumed behaviors will provide a sufficiently accurate representation of the problem being considered. In other cases, however, the question may entail a specific change (for example, whether to accept an offer to deliver a block of power for a specified period at a specified price).

PowrSym4 can be used to answer these more detailed questions as well by comparing the results of separate analysis cases. In using this methodology, the base case analysis is saved (along with the appropriate maintenance schedule). The analysis is then repeated after adjusting the load pattern for the conditions being considered. The results of the two analyses can then be compared to determine how much cost increased or decreased as a result of the change. In performing this analysis, the commitment schedule can either be frozen or allowed to change. Since dispatch (and possibly commitment) differ between the two analyses, the cost change will not necessarily be in the same direction for all hours of the week. For example, some hours may experience increased cost even if the aggregate cost for the week is reduced.

12.2 Preparing a Marginal Cost Analysis Case

The following discusses the changes that need to be made to the base case PowrSym4 data to produce the marginal cost analysis.

Fixed Unit Commitment Model

As noted above, two alternative approaches can be used with this methodology:

1. Evaluate the effect of decreasing the load from that specified in the base case, or
2. Increase the load and subsequently return it to the base case value.

Alternative 1: Marginal Cost Based on Decreased Load

Add the following two records to the PowrSym4 Data Set (File 50):

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1996	1	0	0	0	0	MCOST FLAG	SYSTEM	1	B	Internal Marginal Cost Simulation Flag
1996	1	0	0	0	0	MCOST STEP	SYSTEM	-100	B	Megawatt Step for Internal Marginal Cost

Setting **MCOST FLAG** X1 to 1 activates PowrSym4's internal marginal cost calculation. The **MCOST STEP** X1 value is set to the marginal cost step size. This value must be a negative value. In general, this should be held to a small value (approximately 1% of the total system installed capacity). As with other PowrSym4 input data, the class field can be used to specify a user defined class, and the comment field can be used to capture other desired notes.

The PowrSym Control File also needs to be modified to identify a name for File 02 (the marginal cost output file).

Once these changes are made, PowrSym4 can be operated in its normal mode and the marginal cost output will be captured in File 02 (in addition to all other reports that are otherwise specified by the user).

Alternative 2: Marginal Cost Based on Increased Load

Add the following two records to the PowrSym4 Data Set (File 50):

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1996	1	0	0	0	0	LOAD ADDER	SYSTEM	100	B	Adds x1 to each hour of loads
1996	1	0	0	0	0	MCOST FLAG	SYSTEM	1	B	Internal Marginal Cost Simulation Flag
1996	1	0	0	0	0	MCOST STEP	SYSTEM	-100	B	Megawatt Step for Internal Marginal Cost

LOAD ADDER is used to add the fixed load specified by X1 to each hour. Setting **MCOST FLAG** X1 to 1 activates PowrSym4's internal marginal cost calculation. The **MCOST STEP** X1 value is set to the marginal cost step size. This value must be a negative value. In general, this should be held to a small value (approximately 1% of the total system installed capacity). As with other PowrSym4 input data, the class field can be used to specify a user defined class, and the comment field can be used to capture other desired notes. The X1 values for **LOAD ADDER** and **MCOST STEP** need to be the same.

The PowrSym Control File also needs to be modified to identify a name for File 02 (the marginal cost output file).

Once these changes are made, PowrSym4 can be operated in its normal mode and the marginal cost output will be captured in File 02 (in addition to all other reports that are otherwise specified by the user).

Unconstrained Commitment Model

As noted above, two alternative approaches can be used with this methodology:

1. Evaluate the effect of decreasing the load from that specified in the base case, or
2. Increase the load and subsequently return it to the base case value.

Alternative 1: Marginal Cost Based on Decreased Load

Add the following two records to the PowrSym4 Data Set (File 50):

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1996	1	0	0	0	0	MCOST FLAG	SYSTEM	6	B	Internal Marginal Cost Simulation Flag
1996	1	0	0	0	0	MCOST STEP	SYSTEM	-100	B	Megawatt Step for Internal Marginal Cost

Setting **MCOST FLAG** X1 to 1 activates PowrSym4's internal marginal cost calculation. The **MCOST STEP** X1 value is set to the marginal cost step size. This value must be a negative value to consider the cost of the last increment of power being provided. In general, this should be held to a small value (approximately 1% of the total system installed capacity). As with other PowrSym4 input data, the class field can be used to specify a user defined class, and the comment field can be used to capture other desired notes.

The PowrSym Control File also needs to be modified to identify a name for File 02 (the marginal cost output file).

Once these changes are made, PowrSym4 can be operated in its normal mode and the marginal cost output will be captured in File 02 (in addition to all other reports that are otherwise specified by the user).

Alternative 2: Marginal Cost Based on Increased Load

Add the following two records to the PowrSym4 Data Set (File 50):

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1996	1	0	0	0	0	MCOST FLAG	SYSTEM	6	B	Internal Marginal Cost Simulation Flag
1996	1	0	0	0	0	MCOST STEP	SYSTEM	100	B	Megawatt Step for Internal Marginal Cost

Setting **MCOST FLAG** X1 to 6 activates PowrSym4's internal marginal cost calculation in the unconstrained mode. The **MCOST STEP** X1 value is set to the marginal cost step size. This value must be a positive value to consider the cost of increments above the base case. In general, this should be held to a small value (approximately 1% of the total system installed capacity). As with other PowrSym4 input data, the class field can be used to specify a user defined class, and the comment field can be used to capture other desired notes.

The PowrSym Control File also needs to be modified to identify a name for File 02 (the marginal cost output file).

Once these changes are made, PowrSym4 can be operated in its normal mode and the marginal cost output will be captured in File 02 (in addition to all other reports that are otherwise specified by the user).

Incremental / Decremental Cost Curve

Add the following two records to the PowrSym4 Data Set (File 50):

IYR	IWK	N1	N2	N3	N4	AID	A1	X1	CLASS	COMMENT
1996	1	0	0	0	0	MCOST FLAG	SYSTEM	3	B	Internal Marginal Cost Simulation Flag
1996	1	0	0	0	0	PHYD DISP STEP	SYSTEM	50	B	Megawatt Step for Incr/Decr Cost

Setting **MCOST FLAG** X1 to 3 activates PowrSym4's internal incremental / decremental marginal cost calculation. The **PHYD DISP STEP** X1 value is set to the marginal cost step size. (For systems that also include pumped hydro units, this value is used for dispatching these units as well). In general, this should be a reasonably small value since the range of output will cover 250 times the step size. As with other PowrSym4 input data, the class field can be used to specify a user defined class, and the comment field can be used to capture other desired notes.

The PowrSym Control File also needs to be modified to identify a name for File 21 (the incremental / decremental marginal cost output file). The user should be aware that since this file produces 250 values for each hour, it can become quite large.

Once these changes are made, PowrSym4 can be operated in its normal mode and the incremental / decremental marginal cost output will be captured in File 21 (in addition to all other reports that are otherwise specified by the user).

Direct Comparison of Cases

Running variations of the base case provides the most flexible means for calculating cost differences (i.e. marginal costs). The full range of PowrSym4's modeling capability can be used to define differences between individual cases. The PowrSym4 Tool Kit contains a report writer feature that allows the direct comparison of Annual, Monthly, or Weekly output file results to facilitate marginal cost determinations. Due to the considerable number of potential applications that are possible, the details for using this option is not discussed in this instruction.

To use the Analyzer as discussed later, the two cases must have exactly the same generating units.

12.3 Interpreting Marginal Cost Results

File 02: The Marginal Cost Output File

PowrSym4 marginal cost output is captured in output FILE 02. The marginal cost output file is a data file, rather than a print file, and consequently does not include any column headings. The format for the data presentation in file 02 is as follows:

Year	Week	Day	Hour	Marginal Cost	Hourly Load	Load Adjusted for Energy Storage	Steam Unit Marginal Cost	Value of Water
1996	1	1	1	13.58	605	625	13.58	11.56
1996	1	1	2	13.58	569	629	13.58	11.56
1996	1	1	3	13.58	577	627	13.58	11.56
1996	1	1	4	13.58	584	608	13.58	11.76
1996	1	1	5	13.58	611	611	13.58	11.76
1996	1	1	6	14.15	686	686	14.15	11.76
1996	1	1	7	26.68	874	1139	26.68	11.76
1996	1	1	8	23.8	974	1238	23.8	11.76
1996	1	1	9	23	888	1152	23	11.76
1996	1	1	10	23	869	1134	23	11.76
1996	1	1	11	23	822	1087	23	11.76
1996	1	1	12	21.5	795	1060	21.5	11.76
1996	1	1	13	21.05	788	1053	21.05	11.76
1996	1	1	14	18.21	735	999	18.21	11.76
1996	1	1	15	18.11	719	982	18.11	11.76
1996	1	1	16	17.86	726	990	17.86	11.76
1996	1	1	17	21.64	797	1062	21.64	11.76
1996	1	1	18	23	914	1178	23	11.76

The first four columns key the marginal cost results to a specific hour using the same basic format as used for input data in File 50 and using the normal PowrSym4 calendar. The remaining data can be interpreted as follows:

Column 1	Year
Column 2	Week
Column 3	Day
Column 4	Hour
Column 5	The marginal cost for the system during that hour
Column 6	The native load upon which the marginal cost is based
Column 7	The native load plus any energy being used to add energy to energy storage units minus any energy being produced from energy storage units
Column 8	The marginal cost considering only “steam” units (includes conventional steam units, combustion turbines, and nuclear units)
Column 9	The value of water as assigned by the internal calculational algorithm

Using the PowrSym4 Helper to Interpret Marginal Cost Results

While File 02 can be used to determine marginal cost directly, the PowrSym4 Helper includes tools to make interpreting marginal cost results easier.

Tabular Presentation of Marginal Cost Results

Once the PowrSym4 Helper is loaded, the following outlines the steps to be followed to produce tabular output of the marginal cost results:

- | | |
|---------------|--|
| Step 1 | Select LOAD ANALYZER |
| Step 2 | Select GO TO FILE IMPORT |
| Step 3 | Verify that the FY beginning week is set Correctly |
| Step 4 | Select MARGINAL COST |
| Step 5 | Select the desired File 02 output file from the appropriate file directory |
| Step 6 | No action required: HELPER will load the file |
| Step 7 | When the time panel populates all three boxes: Select RETURN |
| Step 8 | Select DATA ANALYSIS |

Step 9 Select **REPORT** (from the Marginal Cost Boxes)

Step 10 Select the desired Marginal Cost Report Format:

TOP HOURS: User can define number of hours in first vector (see fig 1)

BOTTOM HOURS: User can define number of hours in first vector (see fig 2)

PEAK/OFF-PEAK: (see fig 3)

Step 11 Enter Desired Report Title

Step 12 Select **REPORT -** Helper will generate the table which can be viewed, printed, or saved to a file

Step 13 Select **PREVIOUS** to return to the Main Report Menu window

The marginal cost numbers reported in the tabular output is the average marginal cost for the appropriate period. For example, if the first block of the **TOP HOUR** report is set at the default of 18 hours, the value reported in this column is the arithmetic average of the 18 highest hourly marginal costs for that year. Similarly, the number reported in the “6000” column is the arithmetic average marginal cost for the 6000 highest hourly costs for that year.

Figure 1: Top Hours Marginal Cost Report

Annual Average of Top Hours Operating Costs \$/MWh												
<u>Year</u>	<u>Top Hours</u>											<u>All</u>
	<u>18</u>	<u>100</u>	<u>500</u>	<u>1000</u>	<u>1500</u>	<u>2000</u>	<u>3000</u>	<u>4000</u>	<u>5000</u>	<u>6000</u>	<u>7000</u>	
1996	32.5	31.8	28.8	27.9	27.6	26.9	25.6	24.9	23.9	22.7	21.6	20.0
1997	34.1	33.9	31.1	29.6	29.1	28.8	27.6	26.7	25.7	24.5	23.2	21.4
1998	37.0	36.8	35.7	33.8	32.4	31.6	30.7	29.3	28.4	27.2	25.7	23.6
1999	35.4	35.3	34.4	33.2	32.4	31.9	31.1	29.8	29.0	27.7	26.3	24.2
2000	111.6	64.7	42.0	37.6	35.4	34.2	32.7	31.3	29.7	28.2	26.7	24.7
2001	119.4	91.4	50.2	44.9	43.0	41.6	39.3	37.6	35.1	32.9	30.9	28.1
2002	127.5	102.5	54.8	48.6	46.5	45.1	42.3	40.3	37.6	35.1	32.9	29.9
2003	136.3	135.8	66.5	55.8	51.9	49.4	45.3	42.8	39.6	36.8	34.4	31.2
2004	145.8	145.8	72.9	60.6	56.4	53.7	49.4	46.4	42.9	39.8	37.1	33.6
2005	155.8	155.8	89.7	69.4	62.4	58.9	54.5	50.5	46.6	43.1	40.0	35.9
01-Apr-98												

Figure 2: Bottom Hours Marginal Cost Report

Annual Average of Bottom Hours Operating Costs \$/MWh												
<u>Year</u>	<u>Bottom Hours</u>											<u>All</u>
	<u>18</u>	<u>100</u>	<u>500</u>	<u>1000</u>	<u>1500</u>	<u>2000</u>	<u>3000</u>	<u>4000</u>	<u>5000</u>	<u>6000</u>	<u>7000</u>	
1996	13.1	13.3	13.5	13.6	13.7	13.8	14.2	15.1	16.3	17.4	18.2	20.0
1997	13.4	13.7	13.9	14.0	14.1	14.3	14.8	16.0	17.3	18.4	19.5	21.4
1998	14.2	14.3	14.4	14.5	14.8	15.0	16.1	17.6	19.1	20.2	21.5	23.6
1999	14.8	15.0	15.1	15.2	15.5	15.7	16.7	18.2	19.7	20.9	22.2	24.2
2000	15.4	15.8	16.0	16.2	16.4	16.6	17.2	18.2	19.5	20.8	22.2	24.7
2001	15.6	16.1	16.5	16.7	16.9	17.1	17.9	19.0	20.7	22.8	24.6	28.1
2002	16.5	16.9	17.2	17.4	17.6	17.9	18.7	19.8	21.7	23.9	25.9	29.9
2003	17.1	17.6	18.1	18.2	18.4	18.6	19.3	20.4	22.1	24.4	26.4	31.2
2004	17.8	18.4	18.8	19.0	19.2	19.4	20.3	21.4	23.6	25.8	28.3	33.6
2005	18.0	18.7	18.9	19.1	19.3	19.5	20.6	21.9	24.3	26.9	29.8	35.9
01-Apr-98												

Figure 3: Peak/Off-Peak Hours Marginal Cost Report

Annual Average Energy Cost					
	Winter		Summer		
<u>Year</u>	<u>Onpeak</u>	<u>Offpeak</u>	<u>Onpeak</u>	<u>Offpeak</u>	<u>Annual</u>
1996	23.3	18.2	23.6	17.2	20.0
1997	25.2	19.6	25.0	18.1	21.4
1998	27.6	21.6	28.1	19.7	23.6
1999	27.5	22.1	29.0	20.7	24.2
2000	28.7	23.6	27.5	20.7	24.7
2001	32.3	26.3	33.7	23.2	28.1
2002	33.7	27.9	36.5	24.8	29.9
2003	36.1	29.6	36.8	25.5	31.2
2004	39.0	31.8	40.1	27.1	33.6
2005	42.8	34.4	41.7	28.2	35.9
Based on the onpeak/offpeak periods as below:					
Time Period	Onpeak	Offpeak			
Summer (17-23; 23 Weeks)	10 AM - 10 PM (M-F)	10 PM - 10 AM (M-F); Sat & Sun			
Winter (40-16; 29 Weeks)	6 AM - 12 Noon (M-F) 4 PM - 10 PM	10 PM - 6 AM and 12 Noon - 4 PM (M-F); Sat & Sun			
01-Apr-98					
1					

Graphical Presentation of Marginal Cost Results

The PowrSym4 Helper also includes tools for producing graphical illustrations of the marginal cost results.

Once the PowrSym4 Helper is loaded, the following outlines the steps to be followed to produce graphical output of the marginal cost results:

-
- Step 1** Select **LOAD ANALYZER**
 - Step 2** Select **GO TO FILE IMPORT**
 - Step 3** Verify that the FY beginning week is set Correctly

- Step 4** Select **MARGINAL COST**
- Step 5** Select the desired File 02 output file from the appropriate file directory
- Step 6** No action required: **HELPER** will load the file
- Step 7** When the time panel populates all three boxes: Select **RETURN**
- Step 8** Select **DATA ANALYSIS**
- Step 9** Select **GRAPHICS** (from the Marginal Cost Boxes)
- Step 10** A menu will appear for selecting the time period to be included in the graph (the smallest permitted time period is 24 hours)
- Select a date for **STARTING DAY** from Drop-down box
Select a date for **ENDING DAY** from Drop-down box
- Step 11** Enter Desired Graph Header
- Step 12** Select **SHOW GRAPH** - Helper will generate the graph which can be viewed, printed, or saved to a file (figures 4, 5, & 6 show typical output for one day, one week, and one month graphs)
- Step 13** Select **RETURN** to return to the Main Graph Menu window
-

Figure 4: One-Day Marginal Cost Graph

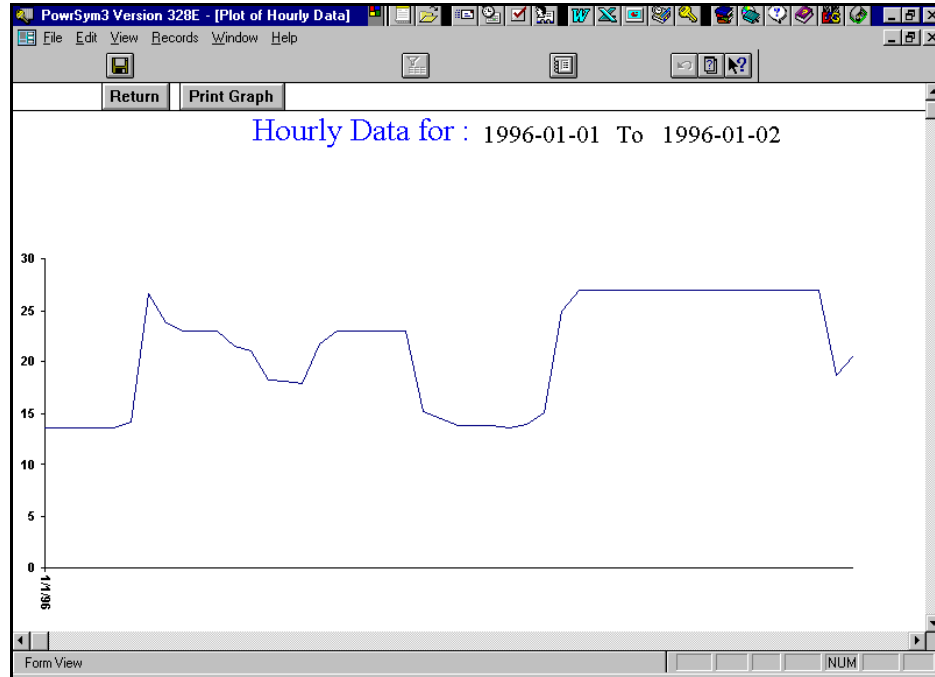


Figure 5: One-Week Marginal Cost Graph

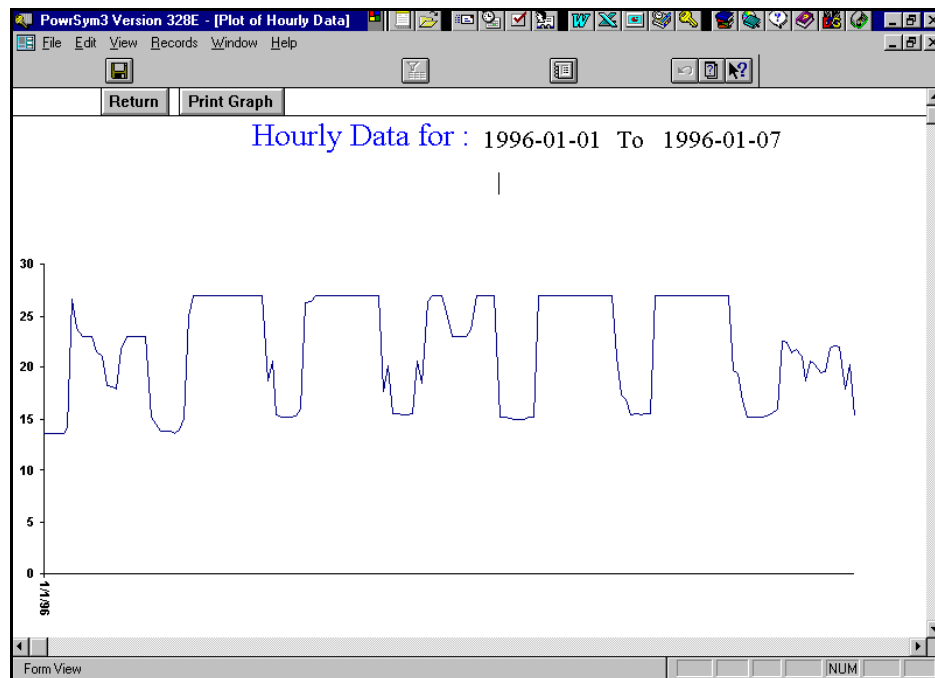
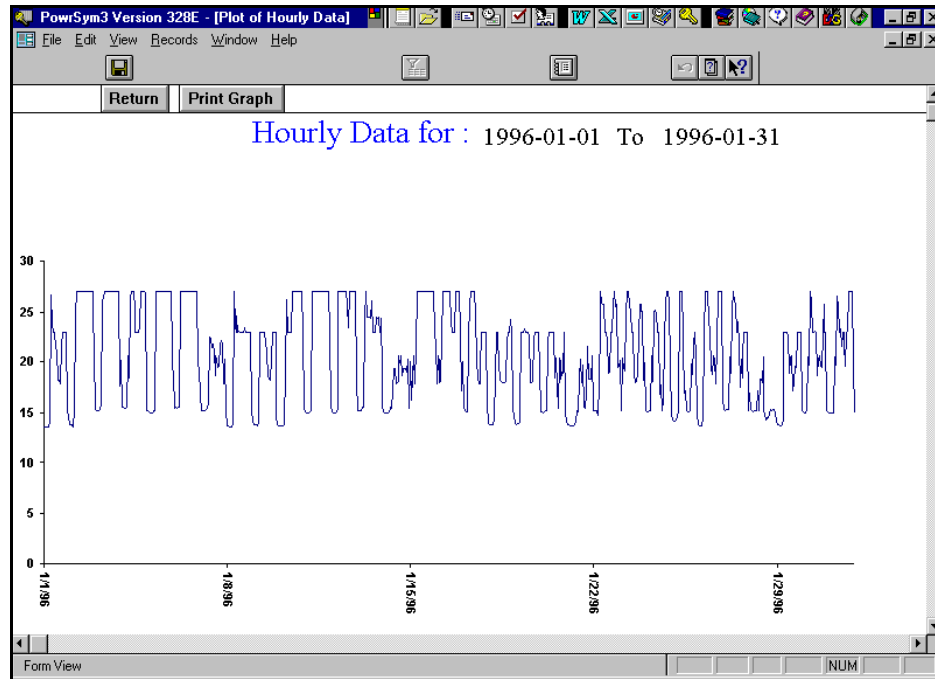


Figure 6: One-Month Marginal Cost Graph



Evaluating Marginal Cost Using Incremental / Decremental Cost

No tools are currently available to facilitate the viewing of the incremental / decremental cost curve, although this curve can be used in conjunction with a spreadsheet to perform a variety of analyses.

Evaluating Marginal Cost Using the Direct Comparison Method

The direct comparison method requires that two PowrSym4 analyses cases have been completed. The input data for the two cases should only differ for those conditions for which the marginal cost is to be evaluated.

Once the two PowrSym4 cases have been run, the PowrSym4 Helper can be used to facilitate comparing the results of the two analyses. The following outlines the steps for using Helper in this mode:

-
- | | |
|----------------|--|
| Step 1 | Select REPORT WRITER |
| Step 2 | Select UPDATE STATION RELATIONS |
| Step 3 | Select the Base Case Access-type Output File (e.g. File 36) |
| Step 4 | Select ANNUAL, MONTHLY, OR WEEKLY consistent with file selected |
| Step 5 | Select IMPORT POWRSYM4 DATA |
| Step 6 | Select IMPORT FILE |
| Step 7 | Select the same Base Case Access-type Output File used for Step 3 |
| Step 8 | Select the Starting Date from List (“9600” = 1996); Select SELECT |
| Step 9 | Select IMPORT SCENARIO DATA on Data Screen |
| Step 10 | Select the Second Case Access-type Output File (same form as base) |
| Step 11 | Select SELECT REPORTS |
| Step 12 | Input Report Title (if desired) |
| Step 13 | Select report to print from drop-down list |
| Step 14 | Select station grouping by drop-down list (by unit or by station) |
| Step 15 | Select Study to Report from drop-down list (base, scenario, or delta) |
| Step 16 | Select number of decimal to be used in reporting results |
| Step 17 | Select PRINT, PREVIEW REPORT, REPORT TO FILE to produce output |
-

13.0 POWER PURCHASE CONTRACT SIMULATION

Introduction

This manual describes how PowrSym4 users may simulate power purchase contracts with specifications and provisions such as energy limits, commit hours, and capacity factors on a dispatchable A * B (Where A is the number of days in a contract week, and B is the number of hours in a contract day, e.g., 5X16). One of the new options, real calendar, can be used to simulate these unique purchases with specified beginning and ending dates. Purchases with durations exceeding a week can be simulated as well.

13.1 New and Existing AIDs Used for Contract Simulation

13.1.1 New AIDs

The following new and existing AIDs are used for contract definition and simulation.

New AIDs that have been introduced are:

CONTRACT DEFINE

- N1** Contract start day of week. 1=Monday...7=Sunday)(default=1)
- N2** Contract end day of week. (1=Monday...7=Sunday)(default=7)
- N3** Contract number (1 to 20)
- N4** Not used
- X1** Purchase contract power dispatch increment (MW)

Each contract must be assigned a unique number, N3, by the user. The maximum number of contracts that can be evaluated simultaneously is 20. (Can be increased upon request to OSA.).

Note: when CONTRACT FLAG=2, the user should make sure that the capacity of a contract (defined by power level 5 of its corresponding station) is a multiple of the contract dispatch step (increment). This X1 also must be a multiple of PHYD DISP STEP. If PHYD DISP STEP <10 in the fun50, it will be reset to =10. If it is not defined in the fun50, it will be set to =20.

Example: 5X16

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	1	5	13	0	CONTRACT DEFINE	CONTRACT	50

CONTRACT STA

- N1** Not used
N2 Not used
N3 Contract Number (1 to 20)
N4 A unique ELF number used by this station (1 to MAXELF)
X1 A unique station number (1 to ITOP) (default=0, i.e. this contract is de-activated)

Note: If CONTRACT FLAG=2 and EXEC MODE=0, N4 is ineffective.

Each contract must be assigned a unique station number, X1, by the user. Most of the inputs for this station (with some exceptions discussed later) in the fun50 will be internally set. The user assigned name for this station will be used in output reports. ITOP (set in usr file) is the maximum number of stations permitted for the PowrSym4 compilation being used for the study. MAXELF (set in the usrcom file) is the maximum number of ELF (Energy Limited fuels) permitted for the PowrSym4 compilation being used for the study.

Example: Contract 12 assigned to Station 100, which uses ELF 9,

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	12	9	CONTRACT STA	CONTRACT	100

Note: N2=26 (May be another week number depending on loads setup)

CONTRACT BEGIN

- N1** Day of week (Monday=1...Sunday=7), (default=1)
N2 Week (1 to 52) (default=1)
N3 Contract number (1 to 20)
N4 Not used
X1 Year (4-digit integer), (default=3000)

Example: Contract 12 begins on Monday in the 40th week of year 1999

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	1	40	12	0	CONTRACT BEGIN	CONTRACT	1999

CONTRACT END

- N1** Day of week (Monday=1...Sunday=7), (default=7)
N2 Week (1 to 52) (default=52)
N3 Contract number (1 to 100)
N4 Not used
X1 Year (4-digit integer)

Example: Contract 12 ends on Friday in the 39th week of year 2000

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	5	39	12	0	CONTRACT BEGIN	CONTRACT	2000

Note: currently the length of a contract should not exceed one year (calendar or Fiscal year). Multiple year contracts can be split into multiple contracts for simulation.

CONTRACT HOURS

- N1** Start hour (1 to 24, 0 defaults to 1)
N2 End hour (1 to 24, 0 defaults to 24)
N3 Contract number
N4 Not used
X1 Not used

This record defines the normal hours used by a contract during any day the contract is in effect.

Example: Each valid day from 0700 to 2200 hour for contract 12.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	7	22	12	0	CONTRACT HOURS	CONTRACT	

CONTRACT LIMIT

- N1** 0=MWh, 1=Capacity factor, 2=Hours at full load, 3=Days at full load
N2 0=year, 1=day, 2=week (default=0)
N3 Contract number (1 to 20)
N4 0=Minimum, 1=Maximum, 2=Minimum continuous
X1 The numerical limit on the parameters for N1 (default=0)

The user has the ability to set contract limits based on energy (MWh), capacity factor, or hours scheduled at full load depending on contract specifications for this purchase

contract.

If N1 is 0 or 1, then N4 can only take 0 or 1.

If N1 is 2, then N4 can only take 0 or 2, but not 1.

If N1 is 3, then N2 can only take 0 or 2, but not 1, and N4 can only be 0

If N1=0, then x1 represents the number of MWh

If N1=1, then x1 represents the %, example CF=25% should be input as 0.25

If N1=2, then x1 represents the number of hours

If N1=3, then x1 represents the number of days

Note 1: Only one of the following three limits can be applied to the same contract

(N1=2, N4=0), (N1=2, N4=2) and (N1=3, N4=0)

That is, any two of them cannot be enforced on a single contract at the same time.

Note 2: The contract's Capacity Factor (CF) is defined as:

CF (%)=(purchased MWh in a period)/(total available MWh for purchase in this period). This is different from the current Powrsym4 reported CF for other stations. For example, a contract 5x16 counts 80 hours in the numerator, whereas regular stations count 168 hours in the numerator.

More than one CONTRACT LIMIT record may be required to define the limits of a Contract. However, the multiple records must yield a feasible solution; otherwise PowrSym4 will generate an error message and stop execution.

Example: Contract 12 with minimum energy limit of 6400 MWh/week

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	2	12	0	CONTRACT LIMIT	CONTRACT	6400

Example: Contract 12 with weekly capacity factor maximum of 0.20

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	1	2	12	1	CONTRACT LIMIT	CONTRACT	0.2

Example: Contract 12 with minimum commit of 8 full load hours each day.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	2	1	12	2	CONTRACT LIMIT	CONTRACT	32

CONTRACT MARGIN

N1 Currently not used

N2 Currently not used

N3 Contract number.

N4 Currently not used

X1 The \$/MWh margin added to the purchase price in the dispatching consideration of contract pseudo unit. Thus, a positive margin makes the purchase more conservative (favors using internal resources) while a negative one makes the purchase more aggressive (favors purchases over using internal resources). However, this margin has no effect on final production cost calculation.

Example: Contract 2, has a margin =3.2 \$/MWh

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	8	0	2	2	CONTRACT MARGIN	CONTRACT	3.2

N1 Not used

N2 Not used

N3 Not used

N4 Not used

X1 0=the contracts will not be evaluated

1=All purchase contracts will be evaluated by ELF & Concurrent (old approach, maintenance module marginal cost-based, pump hydro dispatch first), must take EXEC MODE = 1

2=All purchase contracts will be evaluated by new approach, (incremental/decremental curve base, purchase contract dispatch before pump hydro pass), works for both sequential and concurrent. In sequential case, **don't need ELF set-up**. Must take EXEC MODE =0 or =1.

Note: This record should be used once at the beginning of FUN 50.

Example: Contracts not to be evaluated

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	0	0	CONTRACT FLAG	SYSTEM	0

CONTRACT STRIKE

N1 Not used

N2 Not used

N3 Contract number

N4 0=Day, 1=Week, 2=Year (default=0)

X1 Dollars per strike (default=0)

If there is no strike price, no record is required since the X1 default=0. If N4=1, the weekly strike price is added to system costs one time per week if a strike is made. If N4=0, the daily strike price is added to system costs for each strike day. Strike prices are listed as start costs under the corresponding station in output reports. Currently N4=2 has no effect.

Example: Contract 12 with daily strike price of \$500.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	12	0	CONTRACT STRIKE	CONTRACT	500

CONTRACT PRICE

- N1** Begin peak hour in a weekday (Mon-Sat), (in effect when n4=1)
N2 End peak hour in a weekday (Mon-Sat), (in effect only when n4=1).
N3 Contract number.
N4 0=All hours 1=Peak hours, 2=Offpeak hours (default=0)
X1 Energy price in \$/MWh.

This is the energy price delivered to the recipient's border including all markups and wheeling charges. It is the price the buyer will use for dispatch.

Note: If peak hour price is different with off-peak hour', then peak hours (hours in 24 hours day) must be defined for this contract by N1 & N2. All 24 hours in Sunday are considered to be off-peak. For a given contract, if peak hours are defined, then all the remaining hours in the week are off-peak. For the same contract, if all hour's price is given, then peak and off-peak hours' price should not be used.

Example: Contract 12 with an energy price of \$25.50/MWh, for all hours

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	12	0	CONTRACT PRICE	CONTRACT	25.50

Example: Contract 11 (6x24) with peak energy price of \$30/MWh and \$15/MWh off-peak. Peak hours of Contract 11 are hours 7:00-21:00 from Monday to Saturday.

Two records are required for the price of this contract.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	7	21	11	1	CONTRACT PRICE	CONTRACT	30

Second Record for offpeak period costs

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	11	2	CONTRACT PRICE	CONTRACT	15

Example: Contract 11, must purchase at least 4 days in a week, each purchase day must have minimum 10 continuous hours at full load.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	10	4	11	1	CONTRACT PRICE	CONTRACT	0

CONTRACT WEEKLY

- N1** minimum continuous full load hours in a day when there is purchase
- N2** minimum purchase days in a contract week.
- N3** Contract number.
- N4** 0=not effective, 1=effective
- X1** currently not used.

Note: This input cannot be used in a contract that contains a partial week, and this input cannot be used simultaneously for the same contract with CONTRACT LIMIT N1=2 or N1=3.

CONTRACT DAYXHR

- N1** Currently not used
- N2** Currently not used
- N3** Contract number.
- N4** Currently not used
- X1** =1, effective (on), ≠1, not effective

This switch, if on, will estimate whether a full time full load purchase will be economical (reduce production cost) or not. If economical, then make the purchase in PowrSym4 simulation; otherwise do not make the purchase. For example, if the contract is for 5 weekdays, each day with a 16 continuous hour purchase window, then it will evaluate ahead of the simulation, the 5x16 contract. But if the contract is for 6 days and 20 continuous hours, then the 6x20 contract will be evaluated. The contract will be scheduled the A x B or not at all.

Note 1: This AID applies to all weeks of the contract.

Note 2: This input will be effective only when CONTRACT FLAG=1. It will override (make ineffective) all inputs from CONTRACT LIMIT of the same contract. It will also make CONTRACT WEEKLY, CONTRACT WKPAT0, CONTRACT WKPAT1, and CONTRACT WKPAT2 for the same contract ineffective.

CONTRACT FIXDAY

- N1** starting day in a week for a fixed purchase
N2 end day in a week for a fixed purchase
N3 Contract number.
N4 =1, effective. ≠1, not effective
X1 MWh purchase in each hour

This input is used to make a fixed purchase at a given MWh level in certain days during valid contract hours. The purchase can occur only during valid contract days.

Example 1: Contract 9 must purchase at 100 MWh on Wednesday, Thursday, and Friday

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	3	5	9	1	CONTRACT FIXDAY	CONTRACT	100

Example 2: Contract 8 must purchase at 80 MWh on Monday, Thursday, and Friday in all contract effective weeks. Two inputs are required.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	1	1	8	1	CONTRACT FIXDAY	CONTRACT	80

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	4	5	8	1	CONTRACT FIXDAY	CONTRACT	80

Note 1: This AID works for partial contract weeks. For example, if a contract begins at week 1 on Wednesday, but CONTRACT FL DAY asks for a certain MWh purchase on Monday and Wednesday in all weeks, then in week 1, only Wednesday will be at this MWh purchase. Also note that this MWH purchase request is in effect only for contract valid days specified by CONTRACT DEFINE, CONTRACT BEGIN, and CONTRACT END.

Note 2: When this AID applies to a contract, all the CONTRACT LIMIT, WKPAT0, WKPAT1, and WKPAT2 inputs of the same contract will be overridden (void).

Note 3: This Aid can be used to fix a purchase contract after determining how to best apply it such as when N contracts (requiring WKPAT1 or WKPAT2 purchases) are considered during the same week (Note that the order of contracts, decided by contract number, matters in such cases!). If all are simulated simultaneously, some interaction may occur and preclude finding the optimal solution. In such a situation, first simulate contract #1, which should be the lowest cost contract, then fix it. Then simulate contract #2, which should be the second cheapest contract, and fix it. Continue for N-1 contracts, then simulate contract N, which should be the most expensive contract.

CONTRACT WKPAT0

- N1** Starting day in a week for this purchase pattern
(1=Monday, 2=Tuesday, ..., 7=Sunday)
- N2** Ending day in a week for this purchase pattern
(1=Monday, 2=Tuesday, ..., 7=Sunday)
- N3** Contract number.
- N4** =1, pattern effective for all weeks when this contract is valid;
≠1, pattern ineffective
- X1** The exact number of full load hours forced to purchase in a given day this pattern is effective. These full load hours will be in a continuous block, and PowrSym4 will search for the best block within the day's purchase window (the contract valid hours).

Note 1: This input will be effective only when CONTRACT FLAG=1, and this will override (make ineffective) all inputs from CONTRACT LIMIT of the same contract. It will also make CONTRACT WEEKLY, CONTRACT WKPAT1, and CONTRACT WKPAT2 of the same contract ineffective.

Note 2: This AID applies to all the weeks of a contract, but it may not yield optimum results for a partial week.

Note 3: Multiple inputs are permitted for this AID to specify non-neighboring weekdays, and the purchase hours for different days can be different. See Example 2 in the following for details.

Example 1: Contract 3, must purchase on Wednesdays, Thursdays, and Fridays. For each day the purchase occurs, there must be 10 continuous hours purchased at full load.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	3	5	3	1	CONTRACT WKPAT0	CONTR3	10

Example 2: Contract 2 must purchase on Tuesday with a 6 full load hour block, and Thursdays with a 12 full load hour block. Two inputs are required to implement this.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	2	2	2	1	CONTRACT WKPAT0	CONTR2	6

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	4	4	2	1	CONTRACT WKPAT0	CONTR2	12

CONTRACT WKPAT1

- N1** Minimum continuous full load hours in a day when there is purchase
N2 Minimum purchase days in a contract week.
N3 Contract number.
N4 =0, not effective; =1, effective, without maximum daily hrs constraint.
=2, effective, with maximum daily hrs restriction given by X1.
X1 The maximum full load hours allowed to purchase each day which must be in a continuous block during any day when purchase occurs.

Note 1: This input will be effective only when CONTRACT FLAG=1, and this will override (make ineffective) all inputs from CONTRACT LIMIT of the same contract. It will also make CONTRACT WEEKLY and CONTRACT WKPAT2 of the same contract ineffective.

Note 2: This AID specifies the purchase minimum and maximum in continuous full load hours (block).

Note 3: This AID is similar to CONTRACT WKPAT2. Usually WKPAT2 will find the better solution; however, WKPAT1 occasionally finds the better solution.

Note 4: This AID applies to all the weeks of a contract, but it may not give optimal results for a partial week.

Example 1: Contract 2 must purchase at least 4 days in a week, and each purchase day must have a minimum of 10 continuous hours at full load.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	10	4	2	1	CONTRACT WKPAT1	CONTRACT	0

Example 2: Contract 2 must purchase at least 0 days in a week, and each purchase day must have a minimum of 8 continuous hours, but no more than 10 hours, at full load.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	8	0	2	2	CONTRACT WKPAT1	CONTRACT	10

CONTRACT WKPAT2

- N1** Minimum continuous full load hours in a day when there is purchase
N2 Minimum purchase days in a contract week.
N3 Contract number.
N4 =0, not effective; =1, effective, without maximum daily hours constraint;
=2, effective, with maximum daily hrs restriction given by X1.

X1 The maximum full load hours allowed to purchase each day, and they must be in a continuous block during any day when purchase occurs.

Note 1: This input will be effective only when CONTRACT FLAG=1, and this will override (make them ineffective) all inputs from CONTRACT LIMIT of the same contract. It will also make CONTRACT WEEKLY ineffective. Note that this is effective only when there are no CONTRACT WKPAT0 and CONTRACT WKPAT1 on the same contract since they will override this one.

Note 2: This AID is identical to CONTRACT WKPAT1 except for the implementation method. The method behind this AID is to include the consideration of dispatching certain “expensive” hours to get large block of hours thus lowering the (expected) production cost. This AID may be more aggressive (than WKPAT1) on purchasing when the contract price is near the system marginal cost.

Note 3: This AID applies to all the weeks of a contract, but it may not yield optimal results for a partial week.

Example1: Contract 1 must purchase at least 0 days in a week, and each purchase day must have a minimum of 8 continuous hours, but no more than 12 hours, at full load.

IYR	IWK		N1	N2	N3	N4	AID	A1
1999	1		8	0	1	2	CONTRACT WKPAT2	CONTRACT

CALENDAR

N1 Not used

N2 Not used

N3 0=internal calendar; 1=Real Calendar

N4 Not used

X1 Date of first Monday in year (either CY or FY), e.g., 1004=Oct 4th.

Example: Use real calendar

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	1	0	CALENDAR	SYSTEM	104

This record is used to choose between the internal PowrSym4 calendar and the real calendar. For contract simulation the real calendar should be used in short term operational studies. For long range planning studies most, users will prefer to use the internal calendar.

13.1.2 Existing AIDS with added scope.

STA NAME

Each purchase contract station should be assigned a STA NAME that will be used for PowrSym4 reporting.

POWER LEVELS

Minimum and maximum dispatch levels for a contract will be assigned using POWER LEVELS. (Example: first level=0, fifth level=max hourly purchase)

INSTALLED UNITS

This record X1 value will be set internally to 1 for all contract stations.

STA ELF INDEX

N1: Not used

N2: not used

N3: Station number

N4: station specific fuel index (=1, first choice, =2, second choice), etc.

X1: elf fuel number, must be a unique number for a contract station, and cannot be used by any other station.

Example: station 97 is used to represent contract 2, it uses elf fuel 2 as its first (and only) choice of elf fuel.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	97	1	STA ELF INDEX	Contr 2	2

ELF NAME

Should be a unique name for each contract.

The following will be set internally for each elf used by a contract station:

ELF COST, ELF DAILY ICST, ELF DAILY FINV, ELF DAILY IINV, ELF DAILY IMAX, ELF DAILY IMIN, ELF HEAT VALUE, ELF HOURLY FINV, ELF HOURLY ICST, ELF HOURLY IINV, ELF HOURLY IMAX, ELF HOURLY IMIN, ELF HOURLY SMIN, STA ELF INDEXC, HEAT RATE LVLS, etc.

Note: Even if they are input, they will be internally overwritten

PLANT NAME

It is suggested that Contract Stations be assigned a Plant Name of “Contracts”.

STA PLANT NUM

N3 = Contract Station number

X1 = Plant number for Plant Name “Contracts”

13.2 Longer Term Contracts

For contract periods longer than one week, PowrSym4 allocates the available energy of a longer-term purchase option over the contract period (based on the hourly system production cost). For example, a 5X16 for the month of August with a specified capacity factor limit will have the energy spread over the contract period (the month of August), and PowrSym4 will commit and schedule the energy during the periods allocated to minimize system production costs. But for contracts longer than one year (fiscal or calendar) year, the user can split it into multiple contracts (each within one year) and simulate. But in one simulation, only one type of year is allowed (fiscal or calendar).

13.3 Output

Contracts output will be listed following other stations if the large station numbers (near itop) are assigned to the contract stations. Total purchase contract energy (MWh) will be listed under plant name “contract” in the summary report.

13.4 Real Calendar

The user has the option of using the real calendar or of using PowrSym4's internal calendar for backward compatibility. The real calendar option requires an alternate loads file format and output reporting. The loads file format and output reporting remain unchanged for the internal PowrSym4 calendar, and the system data input file structure has not been changed.

The real calendar loads format is: bYYYYbWWAbMMbDD 24f8.0.

YYYY is the year. WW is the week of the year. "A" is the day of the week. This is for compatibility with the standard PowrSym4 input. This year and week match the year and week of the system input data. The day of the week is converted to hour of the week for the 24 loads in the record. MM is the month of the year. DD is the day of the month. To span years week 53 is modeled. The 53rd week has data from two calendar years. PowrSym4 uses the calendar dates in the loads file to report simulated data. The internal PowrSym4 calendar is used for dating loads data read using file format 0 and 1. For most long range planning studies the standard internal calendar is more practical, but for short-range studies the real calendar is usually preferable.

When a Monte Carlo study is performed, all output statistical arrays are accumulated by day even though the optimizing time horizon for PowrSym4 remains one week. The simulated statistics are averaged by day. Each day of data is tagged with the calendar date from the loads file.

The output reports will be backward compatible. For multiple iteration simulations, the data by iteration are output with the iteration number and, the average is output as zero iteration. The weekly data are the statistics for the seven days in the week. The monthly statistics are tabulated from the daily arrays that are tagged for that month. If the loads simulated for January have 31 days of loads, the statistics are for those 31 days. The calendar and fiscal year reports are also for the correct time periods.

The real calendar option in PowrSym4 permits the generation plan for the budget year to be based on the real calendar. The monthly data have the correct number of trading days, and the statistics are based on the projected loads by month. The differences between simulated and actual results should be less using the real calendar option as compared to those using the internal calendar.

13.4.1 Outputs under real Calendar

The out files, referred to as OFC files in the PowrSym4 manual, will remain unchanged except that a **DAY OUT FILE**, file 22, has been added.

Example: To obtain the DAY OUT FILE, X1=1.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	0	0	DAY OUT FILE	SYSTEM	1

Output files for printing will be obtained using a new AID, **PRINT OUTPUT**. The X1 value will determine the print file output.

X1=1 Hourly print to file 14
 X1=10 Daily print to file 15
 X1=100 Weekly print to file 8
 X1=1000 Monthly print to file 38
 X1=10000 Calendar year print to file 39
 X1=100000 Fiscal year print to file 40

Combinations may be used to get multiple print files:

Example: Hourly and weekly print

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	0	0	PRINT OUTPUT	SYSTEM	101

Example: All six period print files, hourly through FY.

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	0	0	PRINT OUTPUT	SYSTEM	111111

The AID, **PERIOD PRINT**, will remain in use for backward compatibility; however, if both are in the file 50, the model will use the last record read, either **PRINT OUTPUT** or **PERIOD PRINT**. If the user desires to use **PRINT OUTPUT**, the **PERIOD PRINT** record may be omitted and vice versa.

The revised output logic permits obtaining only the desired print files. In previous versions of PowrSym4 if a weekly print was desired, the monthly and annual print were output as well. Under the new procedures weekly print only can be obtained. Any one and any combination of print files can be obtained.

13.4.2 Loads File Format

Since the real calendar option requires a different loads format, the existing AID, LOAD FORMAT, has a new third option.

X1=0 Daily load input format (European format)

X1=1 Weekly load input format (US format with internal PowrSym4 calendar)

X1=2 Real calendar loads format

IYR	IWK	N1	N2	N3	N4	AID	A1	X1
1999	1	0	0	0	0	LOAD FORMAT	SYSTEM	2

13.5 Control File

Format and use of the control file remains unchanged. Note the new files listed under Output above for daily output and see the sample control file on the next page.

GENERIC SYSTEM SAMPLE CONTROL FILE

SAMPLE.F01	COMMIT REPORT	FUN01
SAMPLE.F02	MARGINAL COSTS	FUN02
SAMPLE.F03	MAINTENANCE FILE	FUN03
SAMPLE.F04	LOADS FILE FOR TAREA 1	FUN04
DUMMY		FUN05
DUMMY		FUN06
DUMMY		FUN07
SAMPLE.F08	WEEKLY PRINT FILE	FUN08
DUMMY		FUN09
DUMMY		FUN10
DUMMY		FUN11
DUMMY		FUN12
SAMPLE.F13	HOURLY STATION OUTPUT (NUM STA HR OUT)	FUN13
SAMPLE.F14	HOURLY PRINT FILE	FUN14
SAMPLE.F15	DAILY PRINT FILE	FUN15
SAMPLE.F16	LOLP REPORT	FUN16
DUMMY		FUN17
DUMMY		FUN18
SAMPLE.F19	HOURLY OUTPUT FOR RELI	FUN19
DUMMY		FUN20
SAMPLE.F21	INCREMENTAL/DECREMENTAL COST OUTPUT	FUN21
SAMPLE.F22	DAY OUT FILE	FUN22
DUMMY		FUN23
DUMMY		FUN24
DUMMY		FUN25
DUMMY		FUN26
DUMMY		FUN27
DUMMY		FUN28
DUMMY		FUN29
DUMMY		FUN30
DUMMY		FUN31
DUMMY		FUN32
SAMPLE.F33	HR OUT FILE	FUN33
SAMPLE.F34	WEEK OUT FILE	FUN34
SAMPLE.F35	MONTH OUT FILE	FUN35
SAMPLE.F36	CY OUT FILE	FUN36
SAMPLE.F37	FY OUT FILE	FUN37
SAMPLE.F38	MONTH PRINT FILE	FUN38
SAMPLE.F39	CY PRINT FILE	FUN39
SAMPLE.F40	FY PRINT FILE	FUN40
DUMMY		FUN41
SAMPLE.F42	COMMIT DATA INPUT (FROM PREVIOUSLY CREATED F43)	FUN42

SAMPLE.F43	COMMIT DATA OUTPUT (FOR SUBSEQUENT INPUT TO F42)	FUN43
DUMMY		FUN44
DUMMY		FUN45
DUMMY		FUN46
DUMMY		FUN47
DUMMY		FUN48
DUMMY		FUN49
SAMPLE.F50	POWER SYSTEM INPUT FILE TO POWRSYM4	FUN50
SAMPLE.F51	EXECUTION LOG OUTPUT FILE	FUN51
SAMPLE.F52	DATA INPUT AND EXECUTION ERROR FILE	FUN52
SAMPLE.F53	INPUT PUMPED HYDRO DISPATCH SCHEDULE (PHYD DISP STEP N3)	FUN53
SAMPLE.F54	OUTPUT PUMPED HYDRO DISPATCH SCHEDULE	FUN54
DUMMY		FUN97
DUMMY		FUN98
DUMMY		FUN99
DUMMY		FUN100
TAREA2.LDS	LOAD INPUT FILE FOR TAREA2	FUN101
TAREA3.LDS	LOAD INPUT FILE FOR TAREA3	FUN102
?		
SPOT1.IDC	TRANSACTION AREA1 INCREMENTAL/DECREMENTAL COSTS	FUN191
SPOT2.IDC	TRANSACTION AREA2 INCREMENTAL/DECREMENTAL COSTS	FUN192
!		
AREAX.LDS	LOAD OUTPUT FILE FOR TAREAX	
END		

13.6 PowrSym4 Execution

PowrSym4 execution remains unchanged. Version 347 or later is required for purchase contract simulation with PowrSym4 calendar. Version 348 will be required for real calendar usage.

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