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# **APEX User's Guide (Argonne Production, Expansion, and Exchange Model for Electrical Systems)**

Version 3.0

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**MASTER**

**Decision and Information  
Sciences Division  
Argonne National Laboratory**



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ANL/DIS/TM-21

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by J.C. VanKuiken, T.D. Veselka, K.A. Guziel, D.W. Blodgett, S. Hamilton,  
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November 1994

Work sponsored by United States Department of Energy, Office of Coal and Electricity

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## PREFACE

The modeling package described in this report is expected to be modified periodically with database updates and user interface enhancements. As changes are made, documentation inserts or replacements may be issued under new version numbers. The initial release of the APEX documentation corresponds to Version 3.0 of the model, and each page is dated November 1994. Updates or additions will be dated according to their release dates, and a master list of the most current dates for each section of the documentation will be available. For further information, contact the Systems Science Group, Decision and Information Sciences Division, Argonne National Laboratory.



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## ACKNOWLEDGMENTS

The authors would like to express their appreciation to the following individuals, who contributed significantly to this report. Mel Kofkin and Loren Farrar (U.S. Department of Energy) provided valuable guidance, beginning with the inception of the project and continuing through the completion of an operational model. Special thanks go to Dawn Willing (Argonne National Laboratory [ANL]), who coordinated the initial assembly of the draft document, and Betty Waterman (ANL), who provided extensive editorial assistance and support in preparing this comprehensive final report. Lynette McCallum ( ANL) is to be commended for her efforts in preparing the final document.

## NOTATION

ADAP	Automated Data Assembly Package
ANL	Argonne National Laboratory
APEX	Argonne Reduction, Expansion, and Exchange Model for Electrical Systems
APPI	Argonne Power Plant Inventory
ASF	automated supply function
BOM	Bureau of Mines
Btu	British thermal unit(s)
CTC	composite transfer capability
DOE	U.S. Department of Energy
ECAR	East Central Area Reliability Coordination Agreement
EIA	Energy Information Administration
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
FERC	Federal Energy Regulatory Commission
FGD	flue-gas desulfurization
ft	foot (feet)
ft <sup>3</sup>	cubic foot (feet)
gal	gallon(s)
GIS	Geographical Information System
GNP	gross national product
ICARUS	Investigation of Costs and Reliability in Electrical Systems
kWh	kilowatt-hour(s)
lb	pound(s)
LP	linear programming
LTF	long-term firm
MAAC	Mid-Atlantic Area Council
MAIN	Mid-America Interpool Network
MAPP	Mid-Continent Area Power Pool
MW	megawatt(s)
MWh	megawatt-hour(s)
NERC	North American Electric Reliability Council
NPCC	Northeast Power Coordinating Council

NRC	U.S. Nuclear Regulatory Commission
O&M	operation and maintenance
PACE	Production and Capacity Expansion
RCF	regional characteristics file
RQBE	relative query by example
SERC	Southeastern Electric Reliability Council
SMN	Spot Market Network
SPP	Southeast Power Pool
WSCC	Western Systems Coordinating Council



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**ABSTRACT**

This report describes operating procedures and background documentation for the Argonne Production, Expansion, and Exchange Model for Electrical Systems (APEX). This modeling system was developed to provide the U.S. Department of Energy, Division of Fossil Energy, Office of Coal and Electricity with in-house capabilities for addressing policy options that affect electrical utilities. To meet this objective, Argonne National Laboratory developed a menu-driven programming package that enables the user to develop and conduct simulations of production costs, system reliability, spot market network flows, and optimal system capacity expansion. The APEX system consists of three basic simulation components, supported by various databases and data management software. The components include (1) the Interpretation of Costs and Reliability in Utility Systems (ICARUS) model, (2) the Spot Market Network (SMN) model, and (3) the Production and Capacity Expansion (PACE) model. The ICARUS model provides generating-unit-level production-cost and reliability simulations with explicit recognition of planned and unplanned outages. The SMN model addresses optimal network flows with recognition of marginal costs, wheeling charges, and transmission constraints. The PACE model determines long-term (e.g., longer than 10 years) capacity expansion schedules on the basis of candidate expansion technologies and load growth estimates. In addition, the Automated Data Assembly Package (ADAP) and case management features simplify user-input requirements. The ADAP, ICARUS, and SMN modules are described in detail. The PACE module is expected to be addressed in a future publication.





## 1 APEX

### (Argonne Production, Expansion, and Exchange Model for Electrical Systems)

#### 1.1 INTRODUCTION

This report describes operating procedures and background documentation for the Argonne Production, Expansion, and Exchange Model for Electrical Systems (APEX). This modeling system was developed to provide the U.S. Department of Energy, Division of Fossil Energy, Office of Coal and Electricity (DOE/FE-52) with in-house capabilities for addressing policy options that affect electrical utilities. To complete this objective, Argonne National Laboratory (ANL) developed a menu-driven programming package that enables the user to develop and conduct simulations of production costs, system reliability, spot market network flows, and optimal system capacity expansion.

The APEX system consists of three basic simulation components, supported by various databases and data management software. The components include (1) the Investigation of Costs and Reliability in Utility Systems (ICARUS) model, (2) the Spot Market Network (SMN) model, and (3) the Production and Capacity Expansion (PACE) model. The ICARUS model provides generating-unit-level production-cost and reliability simulations with explicit recognition of planned and unplanned outages. The SMN model addresses optimal network flows with recognition of marginal costs, wheeling charges, and transmission constraints. The PACE model is used to determine long-term (e.g., more than 10 years) capacity expansion schedules on the basis of candidate expansion technologies and load growth estimates.

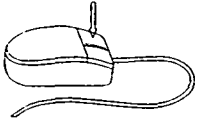
Examples of the databases that support these modeling components include an inventory of U.S. generating facilities, unit performance characteristics, fuel and operating costs, and system load profiles. The Automated Data Assembly Package (ADAP) and case management features simplify user-input requirements for preparing case studies and interpreting results.

The ADAP, ICARUS, and SMN modules are explained in detail in the following sections. The PACE module is expected to be addressed in a future publication.

To further simplify the preparation of power system simulations, APEX was designed to provide a menu-driven environment for user responses to key questions and options. The modeling framework allows reference-case simulations to be prepared and executed with minimal inputs from the user. In addition, APEX menu options allow the user to access and modify pre-formatted simulation input files, to represent alternative system operating conditions. This feature removes the primary data manipulation burdens from the user, allowing more effort to be devoted to case study definitions and sensitivity analysis. Details of the data and simulation components are described in the remainder of this report.

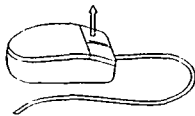
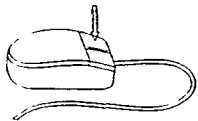
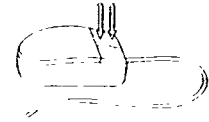
## 1.2 OPERATING INSTRUCTIONS

### 1.2.1 Mouse Conventions



**Click:** Point to the object on the screen with the cursor. Press and release the left mouse button.

**Double-Click:** Point to the object on the screen with the cursor. Rapidly press and release the left mouse button twice.



**Click and Drag:** Point to the object on the screen. Hold the left mouse button down. Move the mouse until the pointer is in the desired location, then release the mouse button.

### 1.2.2 Action Boxes

< ADD >

**Buttons:** If a button is chosen, the specified action is carried out immediately.

[X] Option 1  
[ ] Option 2

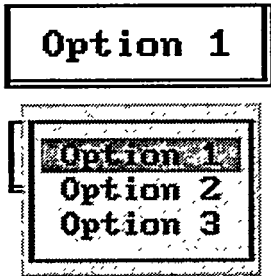
**Check Boxes:** To mark a box, click on the box. An "X" appears in the box ([X]). To unmark the option, select it again, and a blank will appear in the box ([ ]). Any combination of checked and unchecked options is allowed.

(•) Option 1  
( ) Option 2

**Radio Buttons:** Radio buttons provide a set of options, only one of which can be chosen at a time. If an option is selected, the action is carried out immediately. The currently selected option is denoted by a bullet in the parenthesis (•).

Input:

**Field Areas:** Field areas are a portion of the screen that accepts text input.



**Pop-Up Boxes:** Pop-up boxes display a list of items, only one of which can be chosen. To select an item, click on the pop-up box and keep the mouse button pressed to scroll through the list. The highlighted entry cursor will move, indicating the selected choice. Once the item you wish to choose is highlighted, release the mouse button. The selected entry will then appear in the box by itself.

< ADD >

**Dimmed Items:** Items that are dimmed are options that are not active and cannot be selected at this time.

To select any of the above options, use the mouse to move the pointer to the desired location, then press the left mouse button to select the object.

### 1.2.3 Browse Window Options

10:10:32 am

**Delete Entries**  
Use the SPACEBAR to Tag/Untag Entries

Press F2 When Finished

Node	Code	Name	Latitude	Longitude	P_margin	Min_gen
1	ECR	ECAR	39.4	83.5	2.0	15030.00
2	ERC	ERCOT	32.0	100.5	2.0	8779.00
3	MAC	MAAC	39.8	75.0	2.0	5851.00
4	MAN	MAIN	43.0	89.5	2.0	7839.00
22	MEX	MEXICO	27.0	110.0	0.0	800.00
13	MPC	MAPP CANADA	51.0	99.0	2.0	5365.31
5	MPU	MAPP USA	47.0	99.0	2.0	4900.00
14	NPM	NPCC MARITIMES	48.0	68.0	2.0	1222.70
16	NPO	NPCC ONTARIO	47.0	80.5	2.0	5977.87
15	NPQ	NPCC QUEBEC	49.0	73.5	2.0	21324.08
18	NPU	NEPOOL	43.0	70.0	2.0	1297.00
6	NYU	NPCC (NEW YORK)	43.0	76.0	2.0	4927.00
19	SPA	SPP - ARLAMS, SOLA	34.0	91.0	0.0	4952.00
20	SPB	SPP - WEST CENTRAL	35.0	97.0	0.0	3925.00
21	SPC	SPP - NORTH	39.0	94.0	0.0	2681.00

To facilitate the display of long lists of data or reports, APEX will sometimes invoke a browse screen such as the one shown above. You can view different data records by scrolling through the database by using one of several methods. By pressing the Up and Down arrow keys, you can move the highlighted data record in the indicated direction. You can also use the scroll bar that is located on the right side of the window

To view data above the highlighted record, position the mouse on the up arrow symbol (▲) located on the scroll bar, and click on the mouse. Hold the mouse button down until the desired data records are displayed. Move down through the database by clicking on the down arrow symbol (▼). The relative position of the highlighted record in the database is shown by the position indicator (◆). Another method of moving through the database is to click and drag the position indicator. The PageUp and PageDown keys can also be used to maneuver through the database.

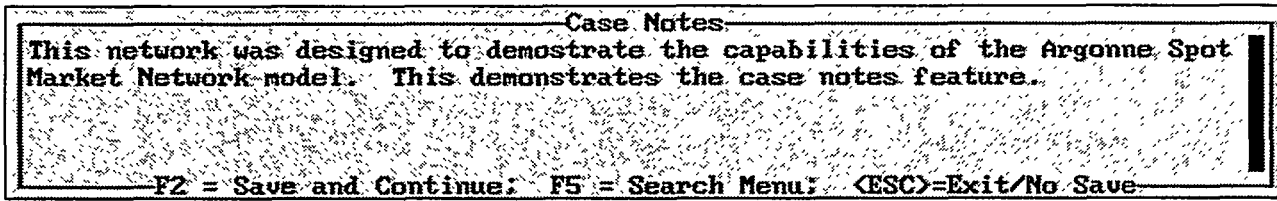
In some cases, the browse window will be split into two or more parts. Move between the left and right (or upper and lower) sections of the window by clicking on the desired window section with the mouse. Use the Tab key to move to the right and the Shift + Tab keys to move to the left.

The number of characters displayed in each data field of a browse window can also be adjusted. To change the width of the field, click on the vertical line between fields with the

mouse, and drag it either to the left or to the right. The following function keys are sometimes operational when split-screen browse windows are activated:

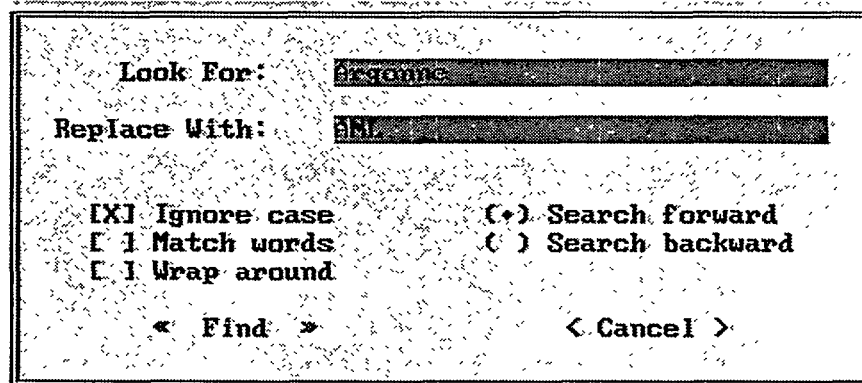
- F4** The F4 key allows you to edit the next record in the database. Use the Tab key to move between data fields and the arrow keys to highlight different records. After the F4 key is pressed, data for the highlighted field appear on another part of the screen, where you can edit the data fields.
- F8** The F8 key allows you to edit the record that is highlighted. Use the Tab key to move between data fields and the arrow keys to highlight different records.
- F9** The F9 key allows you to toggle a browse window between normal size (i.e., initial size when this screen is first activated) and full screen (i.e., zoom).

### 1.2.4 Notes Window Options



To enter user notes in a notes window, use the keyboard to type the information. If the amount of information exceeds the display limits of the window, a small scroll bar will appear that will allow you to scroll back to the beginning of the notes. Pressing the F2 key to permanently save any user note additions and modifications made in this session and exit from the notes window. To exit the notes window and disregard any changes that were made in the session, press the Esc key.

You are also provided with a tool for searching text strings. Press the F5 key to invoke the search menu, as shown below. The search menu allows you to search the notes for a particular word or phrase. Type the text you wish to locate in the Look For box, and type the text that will replace it (if any) in the Replace With box. Click on Ignore Case to disregard the case-sensitive feature. Click on Match Words when you are searching for a set of words and do not want to locate substrings. For example, if you want to search for the word "to" and do not click on Match Words, the search might locate such words as "today," "tomorrow," or "intonation." However, if you check Match Words, then only the *word* "to" will be searched for. Click on Wrap Around to search the *entire* file. Next, click on Search Forward to indicate a search from the current cursor position forward through the file, or click on Search Backward to indicate a search from the current cursor position backward through the file. Once all items have been entered and options are checked, click on <Find> to start the search, or click on <Cancel> to exit the search menu.



## 1.2.5 Keyboard Conventions

### 1.2.5.1 Combination Keystrokes

Example: **Shift + Tab**

A combination keystroke is denoted by two keys expressed with a plus sign between them. For example, "Shift + Tab" instructs you to hold down the Shift key, then press the Tab key, then release both keys.

### 1.2.5.2 Hot Keys

Example: **< Backup >**

A hot key is a letter on a button that, when pressed, positions the cursor and selects the option with which it is associated. Hot keys are shown as a different color letter on active buttons. The above example shows a button with a hot key defined. With the above button, you may either click the mouse on this button or press the B key on the keyboard. Either action will carry out the button function.

### 1.2.5.3 Default Actions










Example: **« OK »**

The default action button can be identified by the double brackets. If this button is active, pressing Ctrl + Enter will disregard the current cursor item and immediately carry out the action for that button.



### 1.2.6 Function Keys

The following function keys are used in various sections of the model:

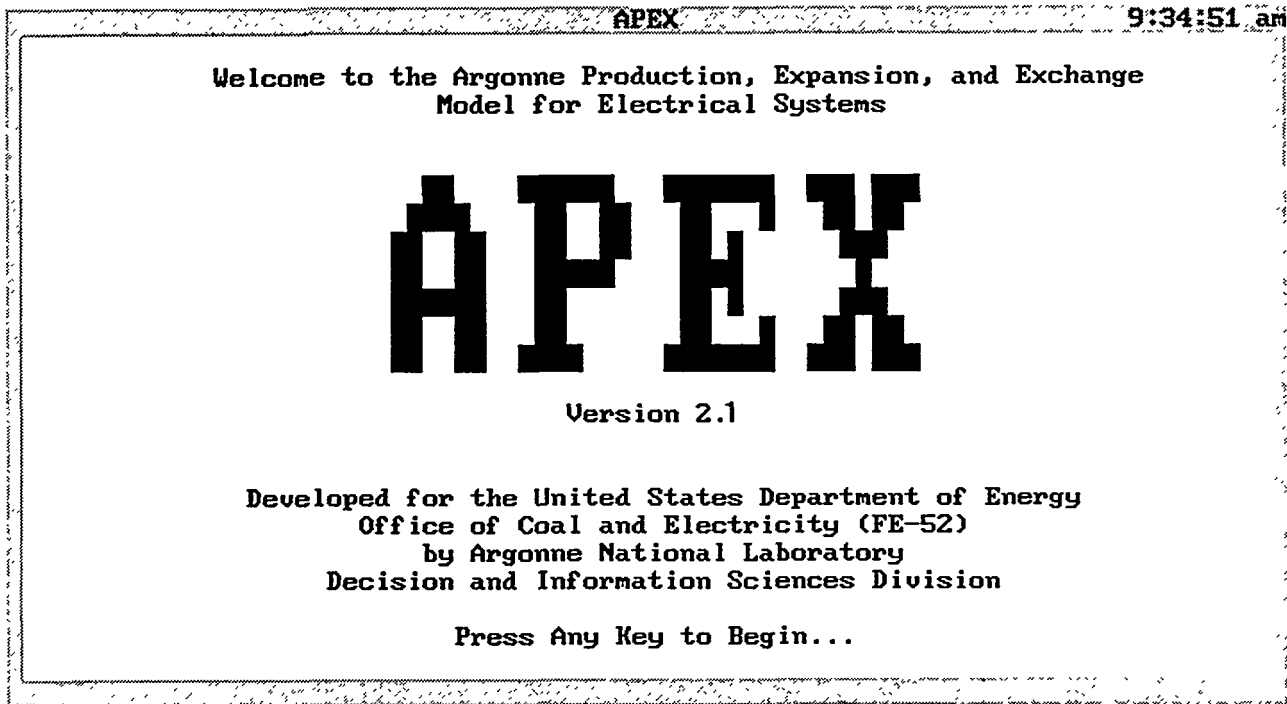
-  Help
-  Continue (or) Exit Query
-  Cancel
-  Edit Next Record
-  Search
-  Edit Current Record
-  Zoom (or) Unzoom
-  Exit Current Screen
-  Main Menu

Help	Continue — or — Exit Query		Edit Next Record		Search	<b>APEX</b>	Edit Current Record		Zoom — or — Unzoom		Exit Current Screen	Main Menu
F1	F2		F4		F5		F8		F9		F11	F12

APEX Template

### 1.3 APEX Screens

The three APEX screens that follow are the introductory screens to the APEX model. Following the screen image, the Purpose section describes the objective of that screen. If there are key options associated with a screen, they appear in a section called Options.



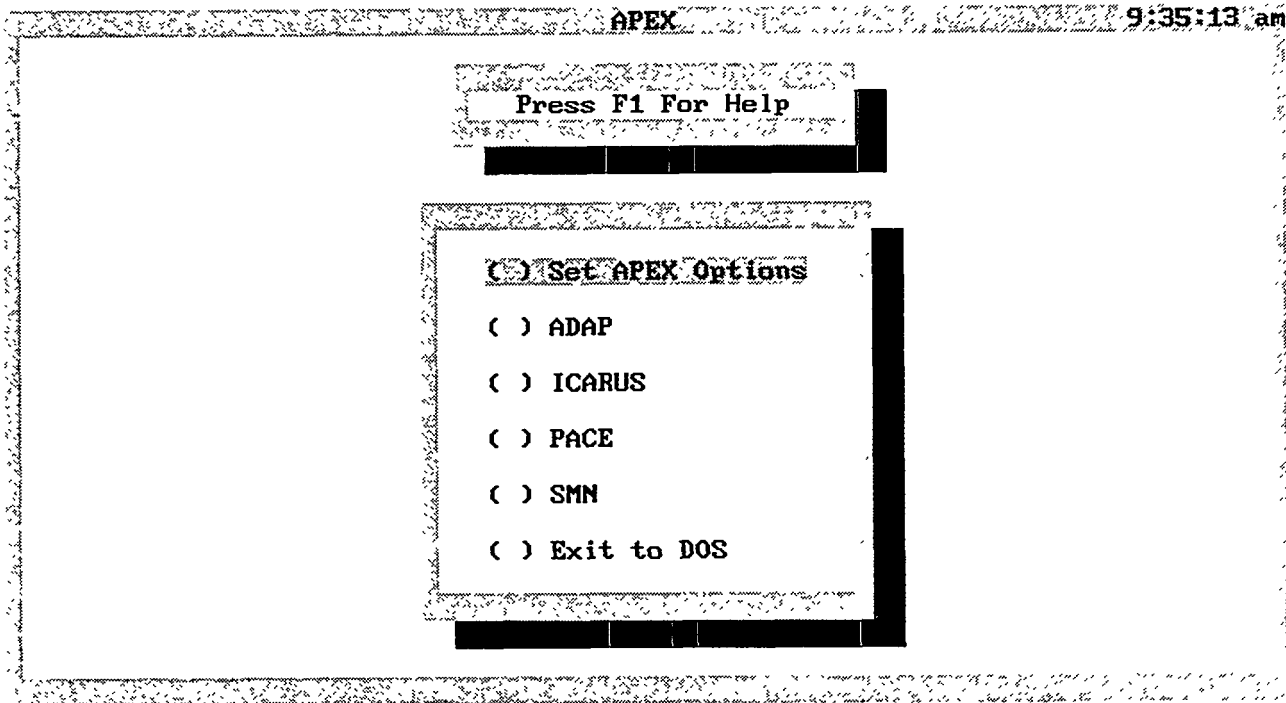
#### APEX-01

##### **Purpose**

The APEX-01 screen is the opening screen of the APEX model. It serves as a title screen for the rest of the program.

##### **Options**

Press any key to begin.



## APEX-02

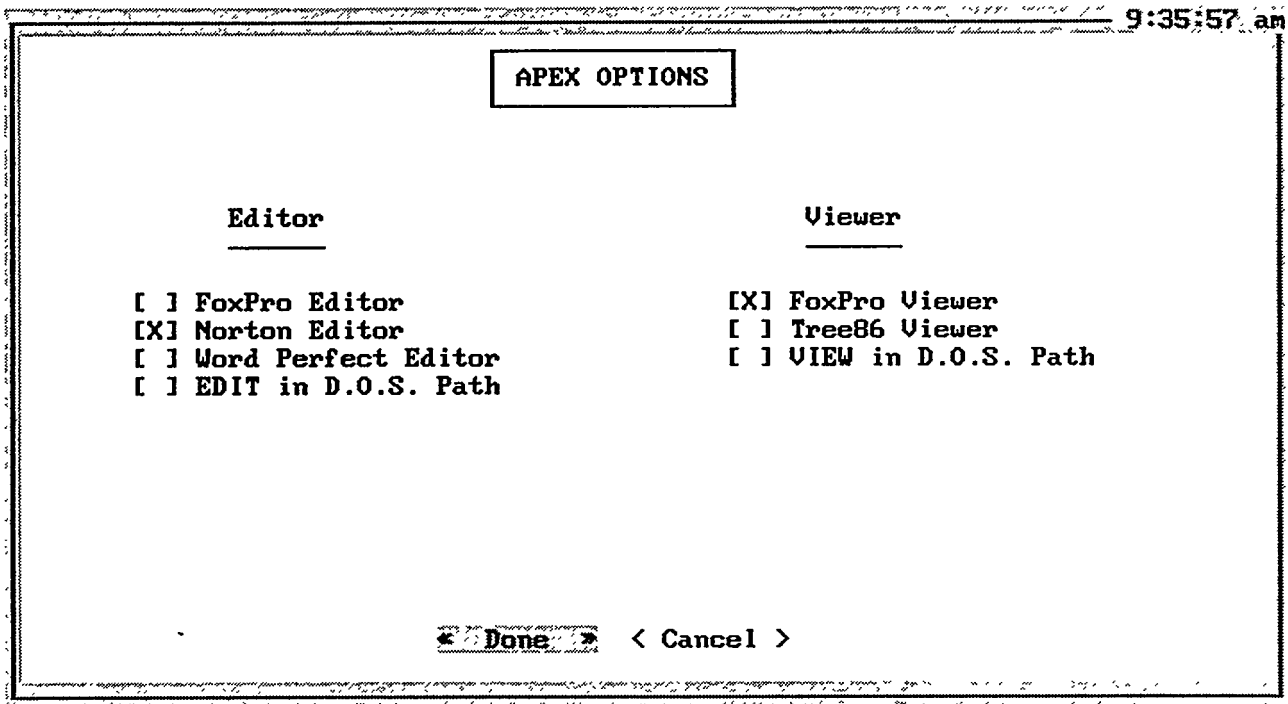
### Purpose

The APEX-02 screen is the main menu of the APEX system. It allows you to advance into the various modules of APEX.

### Options

- To view or change APEX default settings for the editor or viewer, select the first option.
- To enter the ADAP module, select the second option.
- To enter the ICARUS module, select the third option.
- To enter the PACE module, select the fourth option.
- To enter the SMN module, select the fifth option.
- To exit the APEX model and return to DOS, select the sixth option.

**F1** Press this key for help.



**APEX-03**

**Purpose**

The APEX-03 screen allows you to change the default settings for the editor and the viewing utility that will be used in the modules of APEX.

**Options**

- Click on the box ([ ]) in front of the editor or viewer you wish to use.

**Buttons**

**<Done>** Select this button to save the selections you made and exit the screen. You will return to APEX-02. In addition to the three named editors listed, you can access any other text editor by naming it EDIT.COM or EDIT.EXE and placing it in a directory included in the DOS path. Similarly, you can access any viewing program by naming it VIEW.COM or VIEW.EXE and placing it in a directory included in the DOS path.

**<Cancel>** Select this button to exit the screen without saving your selections. You will return to screen APEX-02.



## 2 ADAP

### (Automatic Data Assembly Package)

The first module in the APEX system is ADAP. It allows you to create data files for input into the APEX module, ICARUS. You can define these data files on the basis of the power system selection criteria you specify. Namely, you can select the scope of the data files: utility, power pool, or North American Electric Reliability Council (NERC) region. In addition, ADAP lets you perform FoxPro queries on the Argonne Power Plant Inventory (APPI) database. You can view a list of defined systems or delete a system within the ADAP module. Finally, ADAP allows you to summarize the historical cost and quality of fuels and heat rates for fossil-fueled generating units.

#### 2.1 BACKGROUND

Figure 2.1 illustrates the interface between ADAP and ICARUS. The ADAP module contains data preparation features and an extensive database of electric utility systems. The ICARUS module performs the production cost and reliability simulations for generating systems.

#### 2.2 DATA SOURCES

This section identifies the primary sources of data used to determine installed capacity and assign performance characteristics, costs, loads, and firm power transfers. Unit-level installed capacity is determined from the APPI, while the other parameters are stored in files called regional characteristics files (RCFs), with default values assigned by power pool, generating technology, and unit size. Parameter values can be altered for each case study, but the defaults form the usual starting point for ICARUS simulations. The following sections identify basic data sources for the default parameter values.

##### 2.2.1 Argonne Power Plant Inventory

The APPI is a database of unit-level information for generating units in the continental United States. The database is updated annually on the basis of information in the regional NERC reports and other sources. The most recent update represents the status of the units as of December 31, 1992. This "standard" version of the database is known as APPI92.

An "expanded" version of the inventory, named APPI92U, was developed to aid in database searches involving jointly owned units. For the purpose of preparing simulation inputs, APPI92 contains only one entry per power pool for jointly owned units, and the

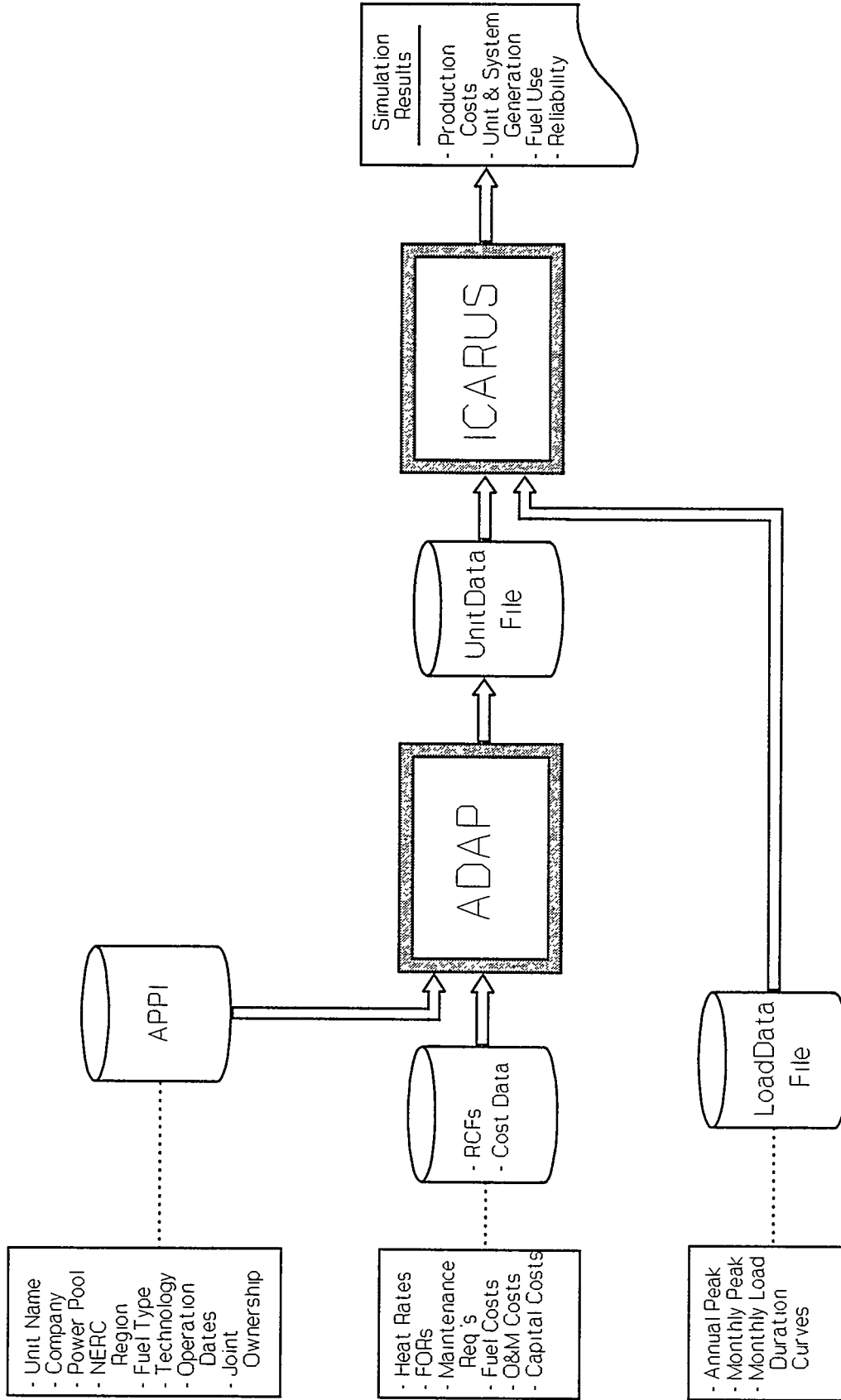


FIGURE 2.1 Major Components of the ADAP and ICARUS Modules

company name (CO\_NAME) field contains the name of the utility holding the largest share of capacity for that unit.<sup>1</sup> In contrast, the expanded database (APPI92U) contains multiple entries for all jointly owned units. Separate entries are included for each of the companies with partial ownership. Thus, APPI92U should be used for searching the database when the objective is to determine all units a particular company owns fully or jointly. The ADAP module uses APPI92 to assemble the appropriate shares of capacity for simulations of utilities, power pools, or NERC regions.

The database is currently stored in a FoxPro database format. A list of the field names is found in Table 2.1, and further details are given in Tables 2.2-2.7.

Unit data for the APPI were verified primarily on the basis of the 1992 reports on bulk power supply from each NERC region (NERC 1992a-i). Federal Energy Regulatory Commission (FERC) Form 423 was used to confirm fuel use designations (DOE 1992a).

Additional efforts were made to resolve fuel designations for "dual-fueled" steam units. These units are designed with the capability to use two fuels, usually natural gas and residual oil. In some regions, the dual-fueled capacity represented a significant fraction of the total capability, and unit-specific fuel use data were consulted to assign the appropriate fuel type.

Commercial start-up dates and restart dates for nuclear reactors were estimated from U.S. Nuclear Regulatory Commission (NRC) sources (NRC 1991; VanKuiken et al. 1992). The dates for nuclear units used in this study represent the status as of January 1992. Unit capacities for reactors were based on the maximum net dependable capacities reported in *Information Digest* (NRC 1991).

### 2.2.2 Generating Unit Characteristics

Unit operating parameters used in the production cost model include forced outage rates, heat rates, and planned maintenance requirements. These parameters were assigned as a function of unit type (e.g., steam turbine, diesel, gas turbine), unit size, fuel type, emission control type, and regional location. Thus, although the operating characteristics are somewhat generic because they are based on regional or power pool averages, they are sensitive to the key factors that affect unit performance.

Forced outage rates were derived from the NERC (1991b) annual report on equipment availability. "Equivalent forced outage rates" were used in the calculations to

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<sup>1</sup> The only cases involving multiple entries for a given unit in APPI92 are a few instances in which units are jointly owned by utilities in different NERC regions. By duplicating the unit entries in each of the appropriate NERC regions, you are assured that ADAP will include the appropriate unit shares in simulation inputs prepared at the NERC region level.



TABLE 2.1 Data Fields in APPI

Field Name	Type	Description
NAME (*)	Character	Unit name. Asterisk (*) indicates jointly owned unit.
UNIT	Character	Unit identifier for a utility generating unit, "NUG" for a nonutility generating unit.
DEPCAP	Numeric	Dependable capacity of a generating unit (MW).
POOLPR (APPI92)	Numeric	Joint ownership fraction of a generating unit for the listed power pool. If POOLPR = 1.0 and JOINT is not blank, the unit is jointly owned by more than one company in the same pool. If POOLPR < 1.0, the unit is jointly owned by companies in more than one pool.
UTIL_SHARE (APPI92U)	Numeric	Portion of dependable capacity (MW) owned by company indicated in CO_NAME. For jointly owned units, UTIL_SHARE is less than DEPCAP.
TOT_OWNERS	Numeric	Total owners for this unit.
POOLOWNERS	Numeric	Owners in the listed pool for this unit.
UTILPR (APPI92U)	Numeric	Joint ownership fraction of a unit for the listed company. UTILPR < 1.0 indicates jointly owned by more than one company.
PFUEL	Character	Type of primary fuel, as defined in Table 2.3.
NUMPFUEL	Numeric	Fuel type number corresponding to primary or alternate fuel, as defined in Table 2.3.
TYPE	Character	Type of unit, as defined in Table 2.2.
NUMPTYPE	Numeric	Unit type number corresponding to type of unit, as defined in Table 2.2.
CO_NAME	Character	Company name.
POOL	Numeric	Pool number.
STATUS	Character	Status code for a utility generating unit or a nonutility generating unit, as defined in Tables 2.4 and 2.5.
ST_CODE	Character	Two-character postal abbreviation for the state name.

TABLE 2.1 (Cont.)

Field Name	Type	Description
YEARUP	Numeric	Year in which the unit is to begin commercial operation.
WEEKUP	Numeric	Week in which the unit is to begin commercial operation.
YEARDOWN	Numeric	Year in which the unit is to be retired.
WEEKDOWN	Numeric	Week in which the unit is to be retired.
COMPANY	Numeric	Five-digit identifier for a company.
AFUEL	Character	Type of alternate fuel, as defined in Table 2.3.
FGD_TYPE	Character	Type of sulfur control, as defined in Table 2.6.
FIPSCODE	Numeric	Five-digit identifier for the location of a unit. The first two digits identify the state, and the last three digits identify the county.
JOINT	Character	Four-character joint ownership code for a jointly owned unit.
NERCCODE	Character	Four-character identifier for a NERC region.
PLANT	Numeric	Four-digit plant identifier based on the ORIS code.
POOL_SHARE (APPI92)	Numeric	Capacity of this unit owned by the listed pool.
POOL_NAME	Character	14-character identifier for pool.
FUELCST	Numeric	Unit fuel cost ( $\$/10^6$ Btu). Currently, only nuclear generating units have data.
HEATRT	Numeric	Unit heat rate ( $10^3$ Btu/kWh). Currently, only nuclear generating units have data.
LUPDATE	Date	Last date a unit record was updated.
C_FUEL	Character	Type of primary fuel after the conversion process, as defined in Table 2.3.
C_MW	Numeric	Generating capacity (MW) after the conversion process.

TABLE 2.1 (Cont.)

Field Name	Type	Description
C_NUMPFUEL	Numeric	Fuel type number corresponding to C_FUEL, as defined in Table 2.3.
C_TYPE	Character	Type of unit after the conversion process, as defined in Table 2.2.
C_NUMTYPE	Numeric	Unit type number corresponding to C_TYPE after the conversion process, as defined in Table 2.2.
C_YR_DOWN	Character	Year in which the unit is taken off line to begin the conversion process.
C_MO_DOWN	Character	Month in which the unit is taken off line to begin the conversion process.
C_YR_UP	Character	Year in which the unit is to begin commercial operation after the conversion process.
C_MO_UP	Character	Month in which the unit is to begin commercial operation after the conversion process.

account for partial outages, or deratings, as well as full unscheduled outages. These outage rates vary by unit type, unit size, and fuel type. For coal units with flue-gas desulfurization (FGD) systems, outage rates were adjusted to reflect the additional impact that emission controls have on unit failures.

Heat rates for nonnuclear units were developed from plant-specific DOE (1989) data. Average values were calculated for different unit-size categories, fuel types, emission control equipment, generator types, and power pools. The use of these averages is more reliable than using plant-specific data directly because of data anomalies and reporting errors that occasionally appear in generator performance data. The information was screened for such anomalies prior to the simulations.

Heat rates for existing nuclear units were assigned on the basis of plant-specific data from *Historical Plant Cost and Power Production Expenses: 1990* (DOE 1992b). The use of historical information to assign unit-specific rates accounts, in part, for variations that occur as a result of reactor design differences. While heat rates for a given unit can change from year to year as a result of different operating conditions, these variations are expected to be less significant than those arising from differences in reactor designs. In a few cases in which data were missing (e.g., for units under construction), the heat rates were based on power pool averages. Because data are typically reported for plants, not units, identical heat rates are generally assigned to multiple units at a given site.

**TABLE 2.2 Unit Type Codes**

NUMPTYPE	TYPE	Description
1	ST	Steam turbine (boiler)
2	GE	Steam turbine (geothermal)
3	IC	Internal combustion (piston)
4	GT	Combustion turbine (gas turbine)
5	HY	Hydraulic turbine (conventional)
6	PS	Hydraulic turbine (pumped storage)
7	NB	Steam turbine — boiling water nuclear reactor
8 <sup>a</sup>	NG	Steam turbine — graphite nuclear reactor
9	NP	Steam turbine — pressurized water nuclear reactor
10	NH	Steam turbine — high-temperature gas-cooled nuclear reactor
11	CC	Combined-cycle plant
12	FC	Fuel cell
13	JE	Jet engine
14 <sup>a</sup>	VR, OT or ZZ, NA, or UN	Various, other, unknown at this time
15	CT	Combined-cycle combustion turbine portion
16	CA	Combined-cycle steam turbine with supplemental firing
17	CW	Combined-cycle steam turbine — waste heat boiler
18	CS	Combined-cycle — single shaft
19	SS, SO	Steam turbine — solar, solar
20	WT, WM	Wind turbine, wind power
21	CG	Cogeneration
22	CE	Compressed air energy storage

TABLE 2.2 (Cont.)

NUMPTYPE	TYPE	Description
23	HL	Hydraulic turbine (pipeline)
24 <sup>a</sup>	OC	Ocean thermal turbine
25	PV	Photovoltaic
26	CH	Steam turbine, common-header
27	IG	Integrated coal gasification combined cycle
28	PB	Pressurized fluidized-bed combustion
29	AB	Atmospheric fluidized-bed combustion
30	PF	Nonutility thermal generation
31	PH	Nonutility hydro generation

<sup>a</sup> None of the records in the 1992 APPI database contain this NUMPTYPE/TYPE code.

A separate heat rate module is included in ADAP that is supported by data from the 1992 Energy Information Administration (EIA) Form 767 (DOE 1989). However, these data are not automatically integrated into ICARUS input files because there is no one-to-one correspondence between EIA and NERC technology codes. Results from the heat rate module can be used manually to update values used by ADAP for ICARUS inputs.

Scheduled maintenance requirements were based on NERC (1991b) data. These statistics vary according to unit type, unit size, and fuel type.

### 2.2.3 Cost Assumptions

All costs presented in APEX are given in 1994 dollars unless otherwise indicated. The primary components include variable costs for fuel, variable operation and maintenance (O&M), and fixed O&M. Capital costs can be tabulated in ICARUS, but their treatment is usually left to longer term analysis as addressed in PACE. Consequently, ADAP databases do not currently contain capital costs. Zero real escalation rates are typically assumed for the cost components unless they are overridden by user inputs.

**TABLE 2.3 Fuel Type Codes**

NUMPFUEL	PFUEL/AFUEL	Description
1 <sup>a</sup>	WH	Waste heat
2	COL	Coal (general)
3	BIT	Bituminous coal
4	SUB	Subbituminous coal
5	ANT	Anthracite coal
6	LIG	Lignite coal
7	PC	Petroleum coke
8	LNG	Liquefied natural gas
9 <sup>a</sup>	MTH	Methanol
10	GAS	Gas (general)
11	NG	Natural gas
12	RG	Refinery gas
13	BFG	Blast-furnace gas
14	COG	Coke-oven gas
15 <sup>a</sup>	VAR, OT, NA, UNK	Various, other, not available, unknown at this time
16	GST	Geothermal steam
17	MF	Multifuel (two or more fuels burned simultaneously, not as a mixture)
18	REF	Refuse (solid waste), bagasse, or other nonwood waste
19	OIL	Oil (general)
20	FO2	No. 2 fuel oil
21	FO4	No. 4 fuel oil
22	FO5	No. 5 fuel oil
23	FO6	No. 6 fuel oil
24 <sup>a</sup>	CRU	Crude oil
25 <sup>a</sup>	TOP	Top crude oil

TABLE 2.3 (Cont.)

NUMPFUEL	PFUEL/AFUEL	Description
26	JF	Jet fuel
27	KER	Kerosene
28	LPG	Liquefied propane gas
29 <sup>a</sup>	RRO	Re-refined motor oil
30	SNG	Synthetic natural gas
31	UR	Uranium
32	PL	Plutonium
33	WAT	Water
34	SUN	Solar
35	WND	Wind
36	WD, WOD	Wood or wood waste
37	MET	Methane (landfill gas)
38	NON	None
39	BIO	Biomass
40 <sup>a</sup>	COM	Coal-oil mixture
41 <sup>a</sup>	CWM	Coal-water mixture
42	FO1	No. 1 fuel oil
43	PET	Petroleum (general)
44 <sup>a</sup>	STM	Steam
45	WC	Waste coal (culm)
46 <sup>a</sup>	PRO	Propane
47 <sup>a</sup>	TH	Thorium
48 <sup>a</sup>	ZZ, ZZF	Fuel brought to the plant site that is converted before the combustion process, such as for a coal gasification system, is to be identified as type ZZF.
49 <sup>a</sup>	B/C	Biomass and/or coal

TABLE 2.3 (Cont.)

NUMPFUEL	PFUEL/AFUEL	Description
50 <sup>a</sup>	G/C	Gas and/or coal
51 <sup>a</sup>	O/C	Oil and/or coal
52 <sup>a</sup>	T/O	Tires and/or oil
53 <sup>a</sup>	W/G	Wood and/or gas
54 <sup>a</sup>	W/O	Wood and/or oil
55 <sup>a</sup>	PEA	Peat

<sup>a</sup> None of the records in the 1992 APPI database contain this NUMPFUEL/PFUEL/AFUEL code.

Fossil fuel prices are derived separately for each power pool, on the basis of FERC Form 423 data for 1992 (DOE 1992a). The form differentiates major fuel categories, such as coal, oil, and gas, and makes further distinctions related to fuel quality within the major categories (e.g., bituminous coal, lignite, subbituminous coal, and anthracite or different grades of distillate and residual oils).

Power pool differentiations are made for the various categories and qualities of fuels because of significant differences that exist in production, processing, and transportation costs for each pool. These pool averages were adopted rather than unit-specific estimates, because annual pool averages exhibit a general stability, whereas unit-specific costs often show significant fluctuations due to factors such as contract expirations and spot market conditions.

Nuclear fuel costs were treated on a plant-specific basis, according to 1990 data reported in *Historical Plant Cost and Annual Production Expenses for Selected Electric Plants* (DOE 1992b). Data for planned facilities were estimated from power pool averages.

In addition to the default values for fossil-fueled units, ADAP also contains a fuel cost module that can be used to prepare cost averages for other regional aggregates (such as by NERC region or utility). The results from this module can be passed directly to RCFs for preparation of ICARUS inputs.

Variable O&M costs, except those for nuclear units, were determined from the Electric Power Research Institute (EPRI) Regional Systems Database (EPRI 1989). These costs reflect sensitivities to fuel types, unit sizes, and emission control equipment. Gross national product (GNP) price inflators (U.S. Department of Commerce 1982-1992) were used to adjust the costs to 1994 dollars because little or no real escalation has been shown in recent fossil-fueled O&M costs.



**TABLE 2.4 Status Codes for Utility Units**

Codes	Status	Comment
FC	Existing generator planned for conversion to another fuel or energy source.	Enter changes in fields C_MO/YR_DOWN, C_MO/YR_UP, C_MW, C_FUEL, and C_TYPE. Up/down dates are assumed to be the same.
P	Planned for installation but not utility authorized and not under construction.	
RA	Previously deactivated generator planned for reactivation (future reactivation).	Enter changes in fields C_MO/YR_DOWN, C_MO/YR_UP, and C_MW. If a unit in the database is currently in "M" status, change the status to "RA," and C_MO/YR_DOWN default is assumed to be 1/1950.
RS	Generating units returned to service from deactivated shutdown (already reactivated).	Enter changes in fields C_MO/YR_DOWN, C_MO/YR_UP, and C_MW.
RP	Proposed for repowering (future repowering).	Enter changes in fields C_MO/YR_DOWN, C_MO/YR_UP, and C_MW. Assumed three months of unavailability for the repowering process.
RE	Generating unit permanently removed from any service.	Formerly "R."
S	In service.	Capacity changes are identified data in fields C_MO/YR_UP, C_MO/YR_DOWN, C_TYPE, and C_MW.
L	Regulatory approval pending but not under construction.	
T	Regulatory approval received but not under construction.	
U	Under construction, less than about 50% completed.	
V	Under construction, more than about 50% completed.	
A	Generating unit capability increased (rerated or relicensed).	Enter changes in fields C_MO/YR_DOWN and C_MO/YR_UP with the same scheduled date and C_MW with new capacity. The status remains "S."
D	Generating unit capability decreased (rerated or relicensed).	Enter changes in fields C_MO/YR_DOWN and C_MO/YR_UP with the same scheduled date and C_MW with new capacity. The status remains "S."

**TABLE 2.4 (Cont.)**

Codes	Status	Comment
E	Generating unit capability rerating.	Enter changes in fields C_MO/YR_DOWN and C_MO/YR_UP with the same scheduled date and C_MW with new capacity. The status remains "S."
M	Generating unit put in deactivated status (long term maintenance).	For current maintenance (currently deactivating), enter changes in fields C_MO/YR_DOWN with 1/1950 and C_MO/YR_UP with 1/9999, and enter status as "M." For future maintenance, enter changes in fields C_MO/YR_DOWN with a scheduled date and C_MO/YR_UP with 1/9999. The status remains "S." Note that the previous records with "M" status do not contain the data for C_MO/YR_DOWN/UP and C_MW. The same rules will apply for the standby units.
OT	None of the above.	Code has been changed to either "S" or "P."

**TABLE 2.5 Additional Status Codes for Nonutility Units<sup>a</sup>**

Codes	Status
C	Signed power contract with utility, financing not obtained, not under construction.
F	Fully licensed (including building permit), all third-party contracts (including fuel supply construction, and wheeling) obtained, financing obtained, not under construction.

<sup>a</sup> The codes used for utility-owned units are also valid for nonutility units.

**TABLE 2.6 FGD Control Descriptors**

FGD Control	Description
ALK	Alkaline fly ash
ASB <sup>a</sup>	Aqueous sodium base scrubbers
CB <sup>a</sup>	Combination
DA <sup>a</sup>	Double alkali
FUL <sup>a</sup>	Low-sulfur fuel
HS <sup>a</sup>	High stack
LIM	Lime
LMA	Lime/alkaline fly ash
LSA	Limestone/alkaline fly ash
LST	Limestone
MOS	Magnesium oxide scrubbers
OTH	Other than above
PS <sup>a</sup>	Particulate scrubber
SC	Sodium carbonate
SCR <sup>a</sup>	Unknown type of scrubber
SLW	Soda liquor waste
SS	Sodium sulfate

<sup>a</sup> None of the records in the 1992 APPI database contain this code.

**TABLE 2.7 Pool Name Abbreviations<sup>a</sup>**

Pool	Pool Name
1	AEP et al.
2	CAPCO et al.
3	APS
4	MECS et al.
5	TEXAS
6	TEXAS
7	PJM
8	COM ED
9	IL-MO
10	IL-MO
11	WUMS
12	MAPP
14	NEPOOL
15	NYAPP
16	FL
17	SOUTHERN
18	TVA
19	VACAR
20	AR-LA-MS
21	OK et al.
22	MO-KS
25	NWPP
26	AZ-NM
27	CA-NV
28	ROCKY MT
31	OH (CINC.)
32	KY et al.
33	IN

<sup>a</sup> These abbreviations have been adopted for the POOL\_NAME field in APPI. A more complete description and map are provided in Sec. 2.3.

The data used in assigning nuclear O&M costs were based on FERC Form 1 filings of the utilities. The reports *Historical Plant Cost and Annual Production Expenses for Selected Electric Plants: 1988 and 1989* (DOE 1990, 1991) summarize O&M costs from 1982 through 1989, and preliminary results for 1990 were obtained from *Historical Plant Cost and Annual Production Expenses for Selected Electric Plants* (DOE 1992b).

#### **2.2.4 Energy Demand**

The production cost analysis requires electricity demand for each power pool in terms of monthly peak loads, load duration curves, and load growth rates. These load characteristics were constructed primarily from data published in regional NERC reports (NERC 1992a-i). Relative monthly peak loads (fractions of annual peak) were based on 1994 estimates, and monthly load factors were derived from projected 1993 data. Cumulative load duration curves were constructed to fit the monthly load parameters, based largely on EPRI load curve shapes. The resulting load representations provided close matches to the load parameters reported for each power pool.

#### **2.2.5 Energy Transfers between Power Pools**

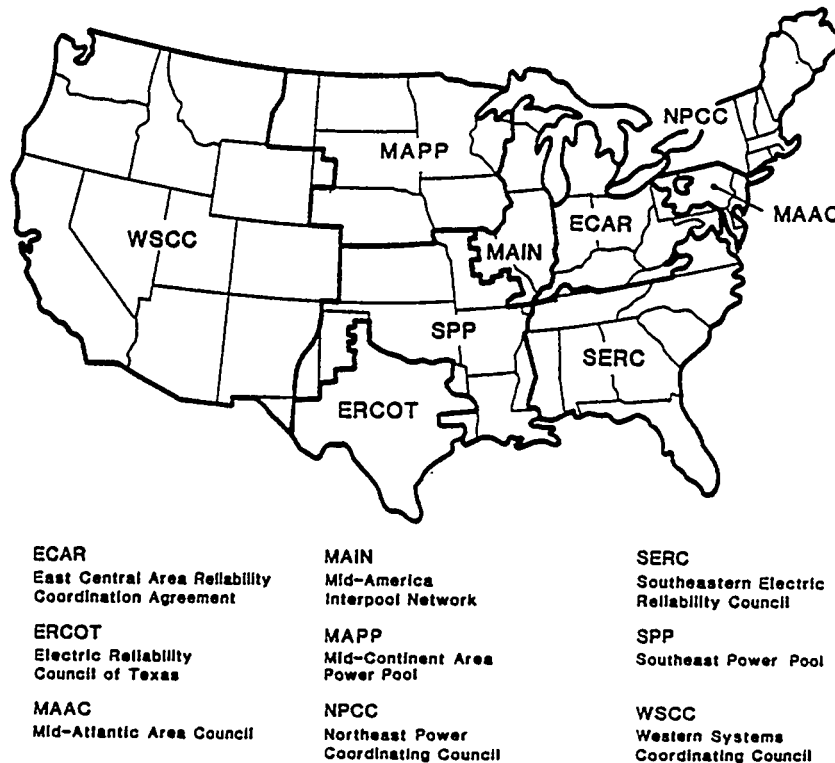
Firm interpool transfers are characterized on the basis of *Electric Power Supply and Demand for 1991-2000* (NERC 1991a). The net imports (total imports minus exports) approximately represent firm contracts for energy exchanges.

### **2.3 POWER POOL DESCRIPTIONS**

This section identifies the nine NERC regions and the power pools located within them. Figure 2.2 illustrates the approximate geographical boundaries of the nine NERC regions. Members and associate members of these regions include virtually all of the generating capability in the United States.

Power pool boundaries are displayed in Figure 2.3, and their compositions are described in Table 2.8. The utilities were grouped into power pool areas, which constitute subregions of NERC regions, according to reports from FERC, DOE, and NERC. The primary objective in designating power pools was to group the utilities that have highly coordinated unit dispatch or energy exchanges.

To satisfy this objective, the pool designations were based on broader definitions than the formal power pool agreements, which include "tight" and "loose" pools as defined by the FERC. Tight pools are centrally dispatched and include penalties for failing to meet reserve requirements. Loose pools are coordinated but have no central dispatch or penalties for failing to meet reserve requirements. The power pools defined in Table 2.8 go one step further in grouping utilities that may lack formal coordination agreements but are likely to achieve significant operating economies through energy exchanges.



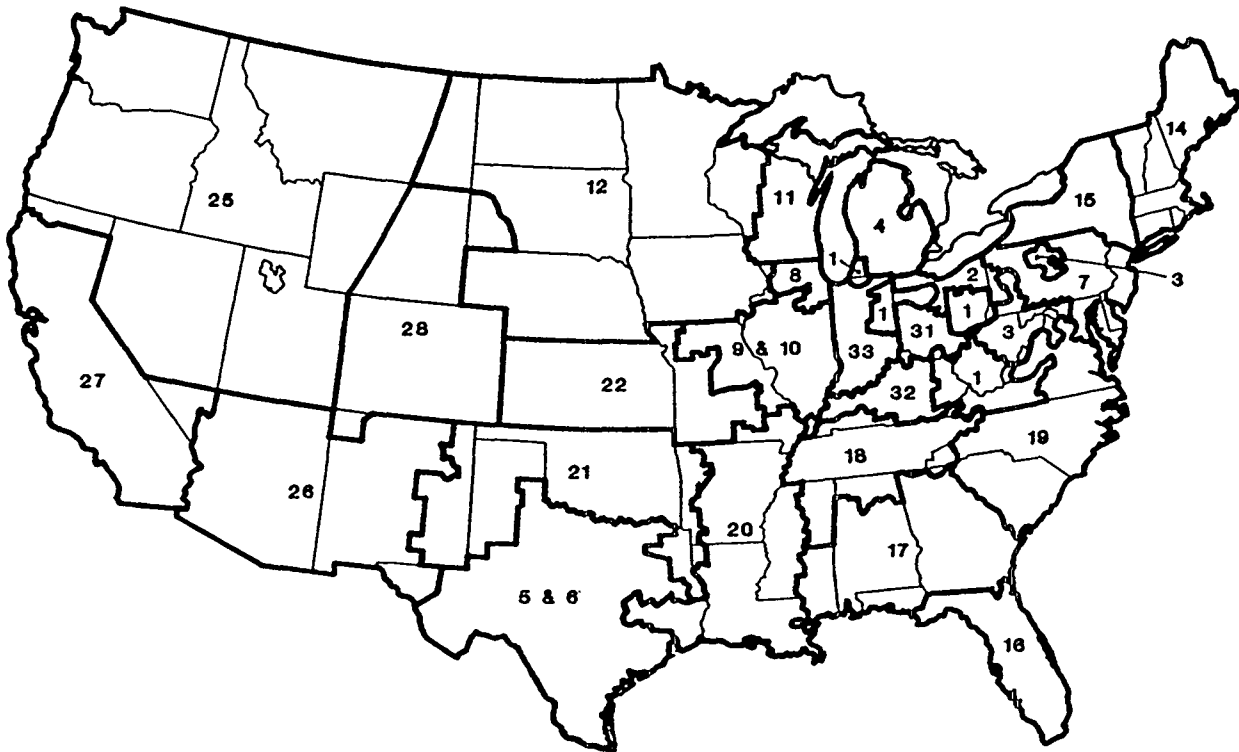
**FIGURE 2.2 NERC Regions in the United States**

## 2.4 OVERVIEW OF DATA ASSEMBLY

The UNITDATA option in ADAP creates an input file for the ICARUS program. The input file is created in the format of a UNITDATA file, as described in the ICARUS User's Guide (Appendix 3C).

After selecting the UNITDATA option, you are asked whether units of less than a user-specified size should be combined (to reduce ICARUS execution time) and whether the reference RCF containing performance characteristics, costs, loads, and firm power transfers should be used. For cases that do not require a detailed examination of small units, combining units of less than 50-100 MW is recommended.

After specifying these parameters, you are asked to specify the area (e.g., utility or pool) for which the UNITDATA file will be created. Depending on the area, you will be led through a series of screens that will identify a unique region. Units that are located in the specified region are then selected from the APPI and stored in a temporary file.



**FIGURE 2.3 Power Pools in the United States**

If the selected region is a power pool or utility, the corresponding RCF is used as input to the ASSIGN program, unless an alternative RCF is defined. If the selected region is a NERC region, you are presented with a list of power pools that reside in the selected NERC region. You then select a pool from the list to use as input for the ASSIGN program.

The ASSIGN program reads in the list of units selected from the APPI and assigns each unit a fuel cost, heat rate, forced outage rate, maintenance requirement, fixed O&M cost, and variable O&M cost on the basis of information in the RCF. The ASSIGN program also performs blocking operations (to split selected units into two portions for spinning reserves and other loading restrictions) and assigns each unit a fuel type code. The unit operating and cost data are assigned on the basis of the unit size and type. For jointly owned units, the operating and cost data are assigned on the basis of the total unit size; however, the unit size is adjusted to represent the owner's share before the unit information is written to the UNITDATA file.

Depending on your selection, ASSIGN will combine units of less than the designated size with other units of the same fuel and unit type that have an on-line year within 5 years of that of the first unit. This action reduces the number of units without significantly

**TABLE 2.8 Power Pool Compositions**

Power Pool	NERC Region	Power Pool Composition
1	ECAR	American Electric Power System, Buckeye Power Incorporated, Ohio Valley Electric Corporation, Richland Power and Light
2	ECAR	Central Area Coordination Group, Byron Municipal Light and Water, Cleveland Division of Light and Power
3	ECAR	Allegheny Power System
4	ECAR	Michigan Electric Coordinated Systems, Michigan Municipal Cooperative Pool, Detroit Public Lighting Department, Edison Sault Electric Company, Lansing Board of Water and Light, Michigan Public Power Agency
5-6 <sup>a</sup>	ERCOT	Texas Interconnected Systems, associate members
7	MAAC	Pennsylvania-New Jersey-Maryland Interconnection, associate members
8	MAIN	Commonwealth Edison Company
9-10 <sup>b</sup>	MAIN	Illinois-Missouri Group (South-Central Illinois subregion and East Missouri subregion of MAIN)
11	MAIN	Wisconsin-Upper Michigan subregion of MAIN
12	MAPP	Mid-Continent Area Power Pool
13 <sup>c</sup>	MAPP	Nonmember utilities in the MAPP region
14	NPCC	New England Power Pool
15	NPCC	New York Power Pool
16	SERC	Florida subregion of SERC
17	SERC	Southern subregion of SERC
18	SERC	Tennessee Valley Authority
19	SERC	Virginia-Carolinas subregion of SERC
20	SPP	Group A (West Arkansas-Louisiana-Mississippi area of SPP)
21	SPP	Group B (Oklahoma area of SPP)
22	SPP	Group C (West Missouri-Kansas area of SPP)
23, 24 <sup>c</sup>	--	No longer used. Originally covered two additional groups in SPP until that region was characterized by three groups.
25	WSCC	Northwest Power area of WSCC



TABLE 2.8 (Cont.)

Power Pool	NERC Region	Power Pool Composition
26	WSCC	Arizona-New Mexico area of WSCC
27	WSCC	California-Nevada area of WSCC
28	WSCC	Rocky Mountain area of WSCC
29 <sup>c</sup>	--	Alaska Systems Coordinating Council (affiliate NERC member)
30 <sup>c</sup>	--	Hawaii
31	ECAR	Cincinnati Gas and Electric Company, Dayton Power and Light Company, Hamilton Department of Public Utilities Electric Division
32	ECAR	Kentucky Utilities Group, Big Rivers Electric Corporation, Eastern Kentucky Power Cooperative Incorporated, Henderson Municipal Power and Light, Louisville Gas and Electric Company, Owensboro Municipal Utilities
33	ECAR	Hoosier Energy Rural Electric Cooperative Incorporated, Indianapolis Power and Light Company, Northern Public Service Company, Public Service Company of Indiana Incorporated, Southern Indiana Gas and Electric Company, Wabash Valley Power Association

<sup>a</sup> Although there are two components of the ERCOT region (basically the Texas Utilities Group and the Central and Southwest Group), they are typically treated as a single power pool because the Texas Interconnected System provides a high level of coordination in planning and operation.

<sup>b</sup> The two components of the Illinois-Missouri Group are treated as a single pool because of their high level of coordination in planning and operation.

<sup>c</sup> These power pools are not currently included in APPI.

affecting the simulation results. Because ICARUS can treat 600 unique units at most, it is recommended that the combined unit option be used whenever a UNITDATA file is created for a power pool or NERC region.

When a UNITDATA file for a utility is created within ADAP, it is always given a unique identifier. However, UNITDATA files for a particular NERC region or power pool will replace existing files if a UNITDATA file was previously created for the selected NERC region or power pool. Thus, if the UNITDATA file is to be modified for several region-level or pool-level case studies, a case study in the ICARUS module must be created for a given set of assumptions, prior to the next set of changes to the UNITDATA file in ADAP. In other words, you must sequence back and forth between ADAP and ICARUS to set up the alternative cases if there are to be changes in the basic setup assumptions.

## **2.5 FUEL COST AND QUALITY BACKGROUND MATERIAL**

### **2.5.1 Objectives**

The fuel cost section enables you to examine the cost and quality statistics associated with specific fuel types used in various power plants covered by FERC Form 423. (Appendix 2A discusses the data sources and transformation.) It also allows you to pass the cost parameters to RCFs for subsequent use by the ASSIGN program to assemble input files for the ICARUS and PACE modules. (Appendix 2B gives a sample exercise.) Fuel cost and quality statistics include data on fuel quantity, sulfur content, ash content, heat (Btu) content, and delivered cost.

The fuel cost section allows you to look at the characteristics of fuels at five levels: NERC, pool, state, company, and plant. Within each level, specific fuel types and their corresponding costs are further classified into the five aggregate groupings used in the ASSIGN program: bituminous-lignite, subbituminous-anthracite, residual oil, peak oil, and gas. The standard groupings are used to make fuel cost parameters compatible with other modules in APEX.

Because the fuel cost section is based largely on information gathered from FERC Form 423, it reports statistics only for fossil fuels.

### **2.5.2 Approach**

The first menu in the fuel cost and quality section allows you to select option 1, view fuel cost and quality summary at different group levels, or option 2, pass fuel cost values to the RCFs. Neither option is a prerequisite to the other. That is, you can proceed directly to option 2 without going through option 1.

After selecting option 1, you are presented with five group levels from which to choose, namely, NERC, state, pool, company, and plant. After selecting the group level, you can view fuel quantity purchased, ash content, sulfur content, heat (Btu) content, and cost of each of the fuel types covered in that group level. You also have the option to print the data after viewing.

In option 2, data are reported at the pool level corresponding to the reference RCFs. Before the cost parameters are incorporated into the RCFs, the data are presented in a view window to enable you to judge whether or not the data are acceptable. If the data are acceptable, proceed with the data transfer. Otherwise, the values can be changed, or you can exit and return to previous menus.

The analysis procedure in option 2 determines whether there is sufficient information at the pool level; if not, it searches at the NERC and national levels to assemble the required data.

### 2.5.3 Functions and Sample Outputs

The specific functions of this section are as follows:

- Displays (with option to print) the cost and quality characteristics by fuel type;
- Displays (with option to print) the average costs by fuel type and category, and
- Allows for the transfer of values (pool level) of the average cost associated with the five aggregate fuel groupings to the RCFs.

A sample output of this section is shown in Figure 2.4.

### 2.5.4 Data Sources and Transformations

The data used in the fuel cost section came from two sources: FERC Form 423 and the APPI database. FERC Form 423 provided data on fuel quality, ash content, sulfur content, heat (Btu) content, and fuel cost on a monthly basis for each plant. The APPI database provided information such as pool number, company name, plant name, and NERC code. The FERC Form 423 and APPI data were connected on a common field, PLTCODE.

Fuel Characteristics, for Pool 14 (Scroll Down for Unit Descriptions)						
Year: 1992						
Fuel Type	Fuel Quantity	Sulfur (%)	Ash (%)	Btu Content	Delivered Fuel Price (cents/million Btu)	
Bituminous Coal	6,212,931	1.18	7.66	13,120	172.09	
Fuel Oil No. 2	164,312	0.19	0.00	139,355	443.24	
Fuel Oil No. 6	35,697,048	1.38	0.05	151,667	232.29	
Natural Gas	41,287,360	0.00	0.00	1,031	257.89	
Fuels Within Category		Average Delivered Price (cents/million Btu)				
Bituminous or Lignite		172.09				
Subbituminous or Anthracite		0.0				
Fuel Oils No. 4, 5, 6		232.29				
Fuel Oil No.2 or Kerosene		443.24				
Natural Gas		257.89				
DOS C:\... \NEW_FC\OUTPUT\JAC_POL2.TXT			File 1 Pg 1 Ln 1		Pos 1	

FIGURE 2.4 Sample Output from Fuel Cost and Quality Analysis

The full step-by-step transformation of the FERC Form 423 file to its current form is presented in Appendix 2A.

## **2.6 HEAT RATE BACKGROUND MATERIAL**

### **2.6.1 Objectives**

The heat rate section allows you to examine net heat rates of various boiler and plant types covered in EIA Form 767. (Appendix 2C discusses the data sources and transformations.) In addition to the heat rates, the section also displays information on fuel, age of units, number of units, unit capacities, capacity factors, and annual load hours. (Appendix 2D gives a sample exercise.)

Average net heat rates and other associated information can be analyzed in six levels: (1) NERC, (2) pool, (3) state, (4) company, (5) plant, and (6) boiler. Within each level, heat rates are further examined according to fuel type and plant size.

### **2.6.2 Approach**

The heat rate section opens with a menu that permits you to choose the level at which boilers and plants are to be grouped and analyzed. Heat rate calculations are based mainly on information contained in EIA Form 767 and cover only steam electric power units. Average net heat rates are determined by first grouping units according to the selected level and then taking the ratio of the total energy (Btu) consumed and the total energy (kWh) generated. Average heat rates are analyzed according to the types of primary fuel for which the units were designed and then further classified with respect to unit sizes. Note that the current version of the ADAP module groups heat rates on the basis of primary fuel type labels independently of the type of fuel actually consumed.

### **2.6.3 Functions and Sample Outputs**

The specific functions of the heat rate section are as follows:

- Calculates and displays (with option to print) heat rates of various plant types in six levels with further subgroupings as follows:
  - plant type
  - fuel type
  - unit size
- Displays other information, such as age, number of units, capacity factors, and load hours, along with the heat rates.

Figure 2.5 shows a sample output of the module.

## 2.6.4 Data Sources and Transformations

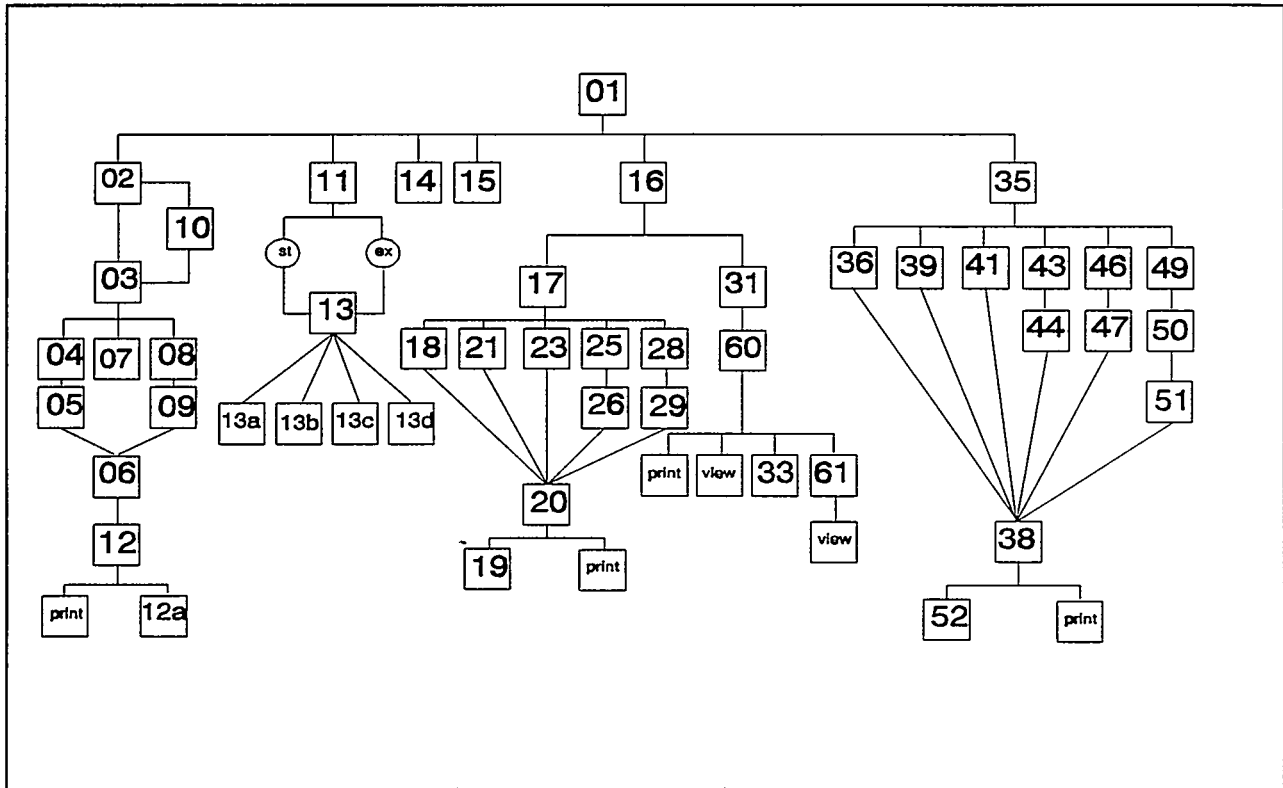
The information provided by the heat rate section is based on EIA Form 767 and the APPI. Data on quality of fuel consumed, fuel heating value, unit energy output, annual load hours, and some nameplate capacities were selected from the EIA Form 767 files. The APPI provided information on start-up years, pool numbers, NERC codes, plant name, company name, and some nameplate capacities.

Details on how the various EIA Form 767 and APPI files were linked and merged are given in Appendix 2C.

APEX							10:54:55 am
SUMMARY OF RESULTS							
AVERAGE HEAT RATES FOR POOL 8							
(Scroll Down for More)							
STEAM TURBINE - ANT							
Size Cat	Heat Rate (Btu/kWh)	Age (yrs)	No. of Units	Ave Cap (MW)	Ave C.F. (%)	Hours Load (hrs)	
200	0	0.0	0	0	0.0	0	
400	0	0.0	0	0	0.0	0	
600	0	0.0	0	0	0.0	0	
800	0	0.0	0	0	0.0	0	
<1000	0	0.0	0	0	0.0	0	
>1000	0	0.0	0	0	0.0	0	
Average	0	0.0	0	0	0.0	0	
-							
-							
STEAM TURBINE - BIT							
Size Cat	Heat Rate (Btu/kWh)	Age (yrs)	No. of Units	Ave Cap (MW)	Ave C.F. (%)	Hours Load (hrs)	

FIGURE 2.5 Sample Output for Heat Rate Analysis

2.7 ADAP SCREEN STRUCTURE

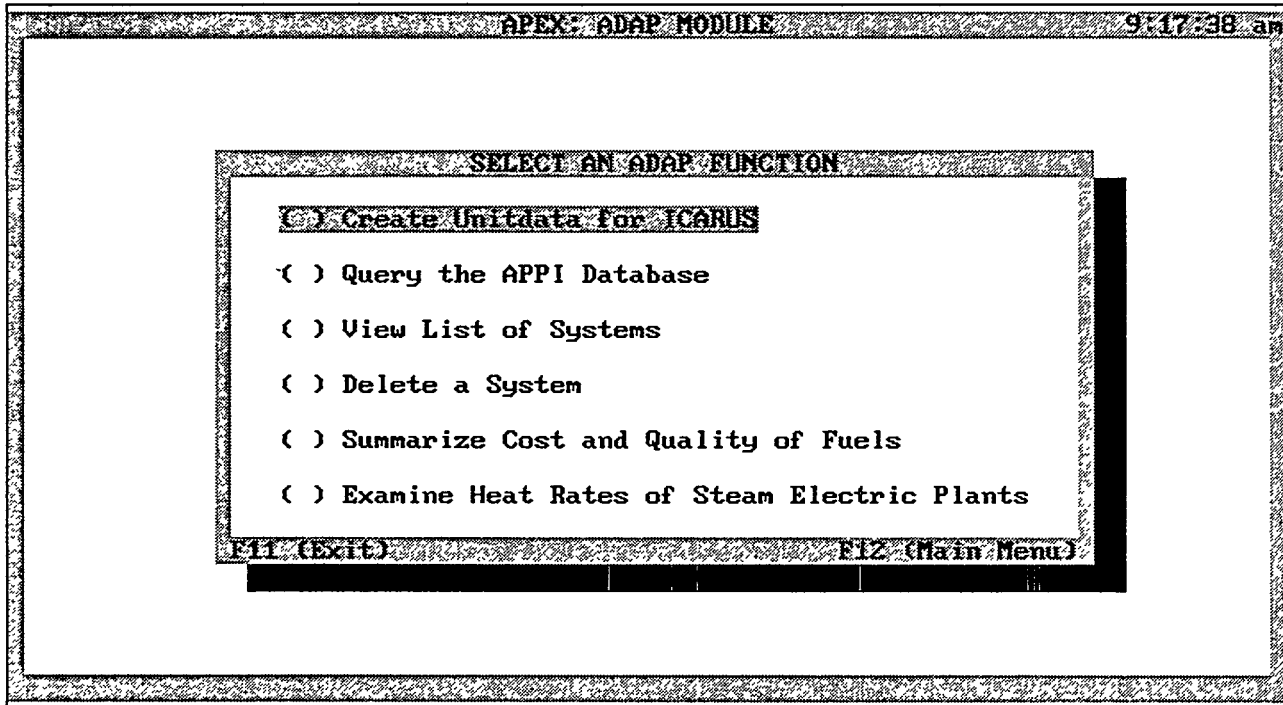


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## 2.8 ADAP SCREENS

This section provides you with a picture of each screen in ADAP. Following the screen image, the Purpose section describes the objective of that screen. When key options are associated with a screen, they appear in a section called Options. A third section, titled Data Fields, describes each data space on the screen into which you can enter data. The data screens are displayed with example data that can be considered typical for ADAP.



ADAP-01

### Purpose

The ADAP-01 screen (main menu) allows you to select an activity associated with the reference data in the APEX system. You can create a UNITDATA file for use in ICARUS, query the APPI database, view a list of previously created systems, delete a system, review the historic fuel cost and quality data, or examine heat rates. To prepare the required files for ICARUS simulations, you must select the first menu item (Create UNITDATA for ICARUS) before executing ICARUS.

**Options**

Select an option by highlighting the desired activity and pressing the Enter key.

- To create a UNITDATA file for ICARUS, select the first option.
- To examine the APPI database (without creating input data files), select the second option.
- To view a list of previously created systems, select the third option.
- To delete a previously created system, select the fourth option.
- To review historic fuel cost and quality data, select the fifth option.
- To examine heat rates, select the sixth option.

**F11** Press this key to return to screen APEX-02.

**F12** Press this key to return to screen APEX-02.



APEX: ADAP MODULE		8:52:00 am
DEFINE ASSIGN PARAMETERS		
The first year of the study is 1994.		
Combine small units? (Y/N):	<input type="checkbox"/>	Unit size in MW to combine: 0.0
Use default regional characteristic file? (Y/N):	<input type="checkbox"/>	
Press F2 When Done		

ADAP-02

### Purpose

The ADAP-02 screen allows you to define basic parameters needed to create the UNITDATA file for ICARUS. All costs are in mid-year 1994 dollars (estimated).

### Options

- F2** Press this key after the desired data have been entered. You will advance to screen ADAP-03.

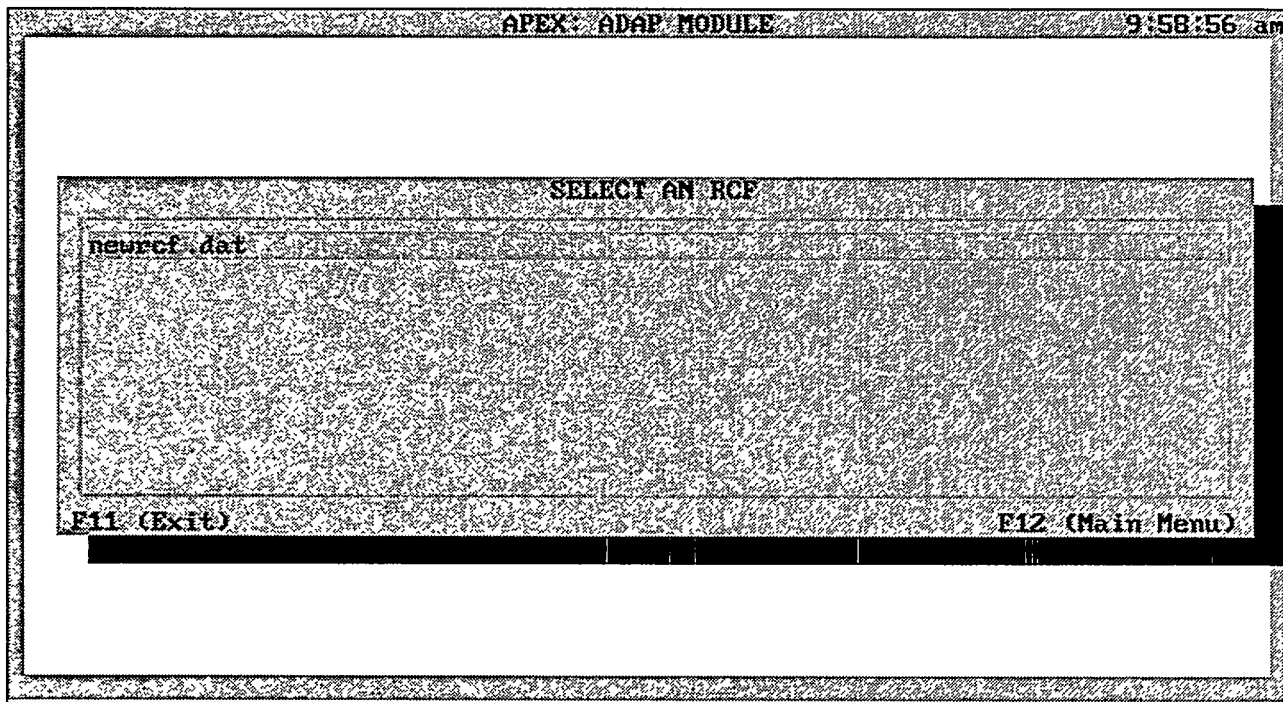
Note: The first year of study is the year in which the ICARUS simulation is to begin. The length of the simulation period is defined in the LOADDATA file in the ICARUS module. The default is 1 year, but the data is assembled to support a 6-year run.

### Data Fields

Switch to combine small units: Enter Y for yes, to combine small units (less than 50 MW). Units are combined only if they have a similar unit type and fuel type, and their start-up dates are within 5 years of each other. If you specify N for no, units will not be combined. The N option should be used only for utility-level simulations (not for power pools or NERC regions); otherwise, the system may exceed the 600-unit limit in ICARUS.

Unit size in MW to combine: If you answered Y for yes to the combine small units question, you can enter a value here that instructs the program to combine all units that are less than the specified value.

Use default regional characteristic file: Enter Y for yes, to accept the default RCF. Enter N for no, to view a list of modified RCFs that were previously created in the fuel cost section (option 5 on screen ADAP-01).



ADAP-10

### Purpose

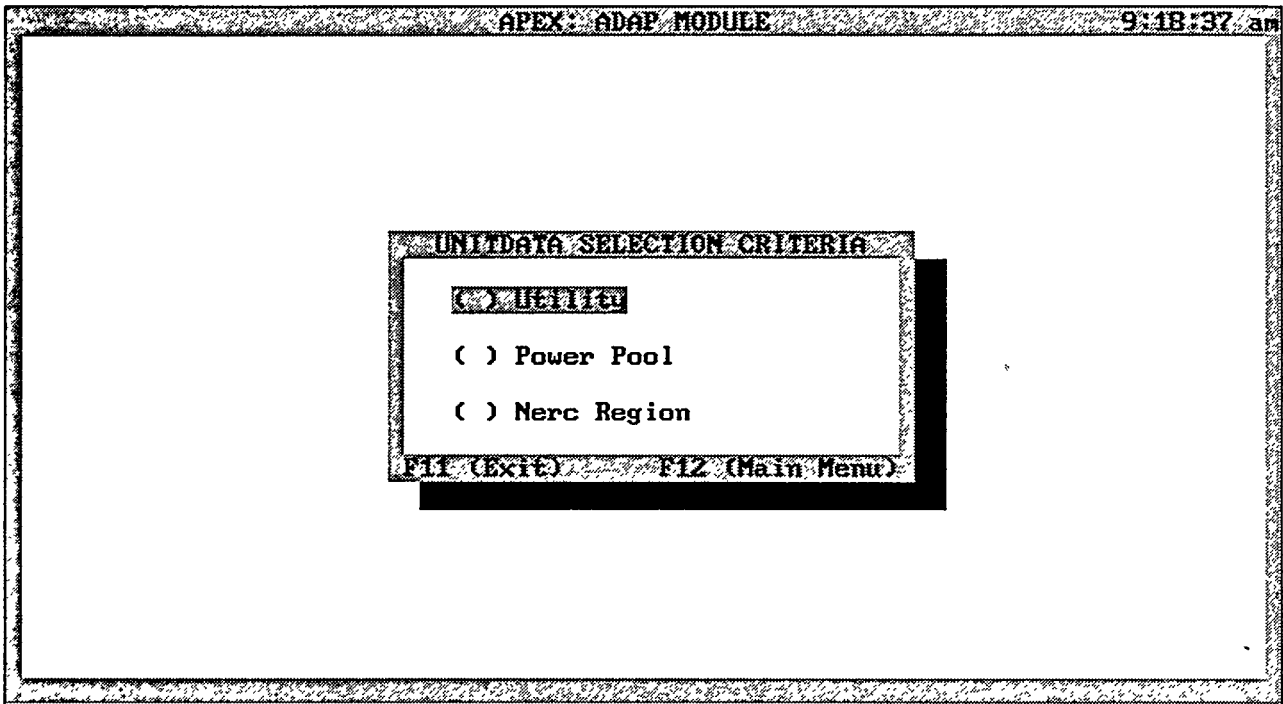
The ADAP-10 screen allows you to select an RCF that was previously created in the fuel cost section (option 5 on screen ADAP-01).

### Options

- Highlight the name of the modified RCF you want to use and press the Enter key.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



ADAP-03

### Purpose

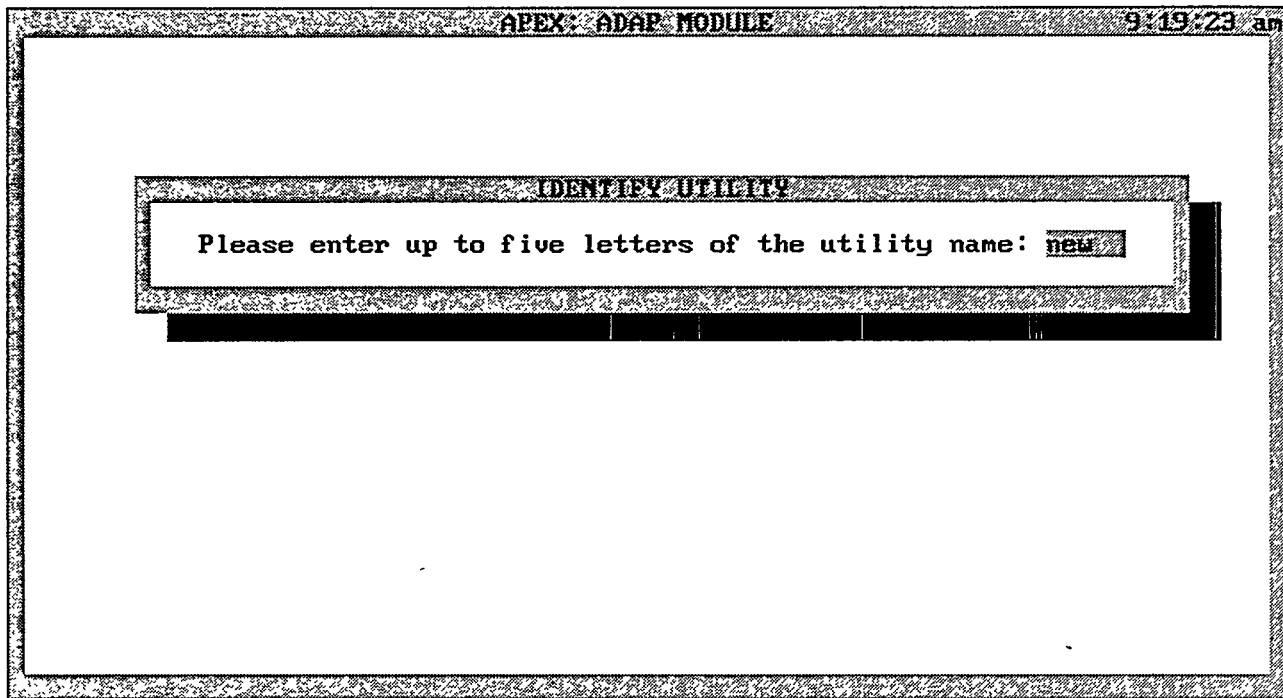
The ADAP-03 screen allows you to choose the selection criteria for creating the UNITDATA file. The UNITDATA file can be created on the basis of a specified utility, power pool, or NERC region.

### Options

- To create a UNITDATA file for a utility, select the first option.
- To create a UNITDATA file for a power pool, select the second option.
- To create a UNITDATA file for a NERC region, select the third option. When the menu of NERC regions is displayed, an indicator shows which regions contain more than 600 units. Because ICARUS can simulate 600 units at most, you must use the unit grouping feature to reduce the final list of composite units to 600 or fewer.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



The screenshot shows a terminal window titled "APEX: ADAP MODULE" with a timestamp of "9:19:23 am". Inside the window, a sub-window titled "IDENTIFY UTILITY" contains the text: "Please enter up to five letters of the utility name: new". The word "new" is entered in a small rectangular input field.

#### ADAP-04

#### Purpose

The ADAP-04 screen allows you to specify up to five letters of a utility name. APEX will search the APPI database for matching utilities. You can then advance to screen ADAP-05 to view a list of utilities.

#### Data Fields

Enter five letters of the utility name: Enter up to five consecutive letters of a utility name, which will be used to search the database. The letters do not have to be the first five letters but rather any consecutive string up to five letters. For example, if you are interested in New England Power Company, you could enter up to five consecutive letters from the utility name (e.g., new). In the APPI database, this utility is listed under N ENG ELEC:New England Power Company, but because the "new" string was entered, this utility would appear in the view window. The string entered is not case-sensitive. After you have entered the string you want, you will be shown a list of all utility names matching those criteria.

```
APEX: ADAP MODULE 9:19:56 am

SELECT A UTILITY

EAST UTIL:NEWPORT ELECTRIC CORP
EMTERGY:NEW ORLEANS PUBLIC SERVICE
LEPA: NEW ROADS LIGHT & WATER PLANT
N ENG ELEC:NEW ENGLAND POWER CO
NE UTIL:PUB SER CO OF NEW HAMPSHIRE
NEW SMYRNA BEACH, CITY OF
NEW ULM PUB UTILS COMM
NEW YORK STATE ELEC & GAS CORP
PUBLIC SERVICE CO OF NEW MEXICO

F11 (Exit) F12 (Main Menu)
```

ADAP-05

### Purpose

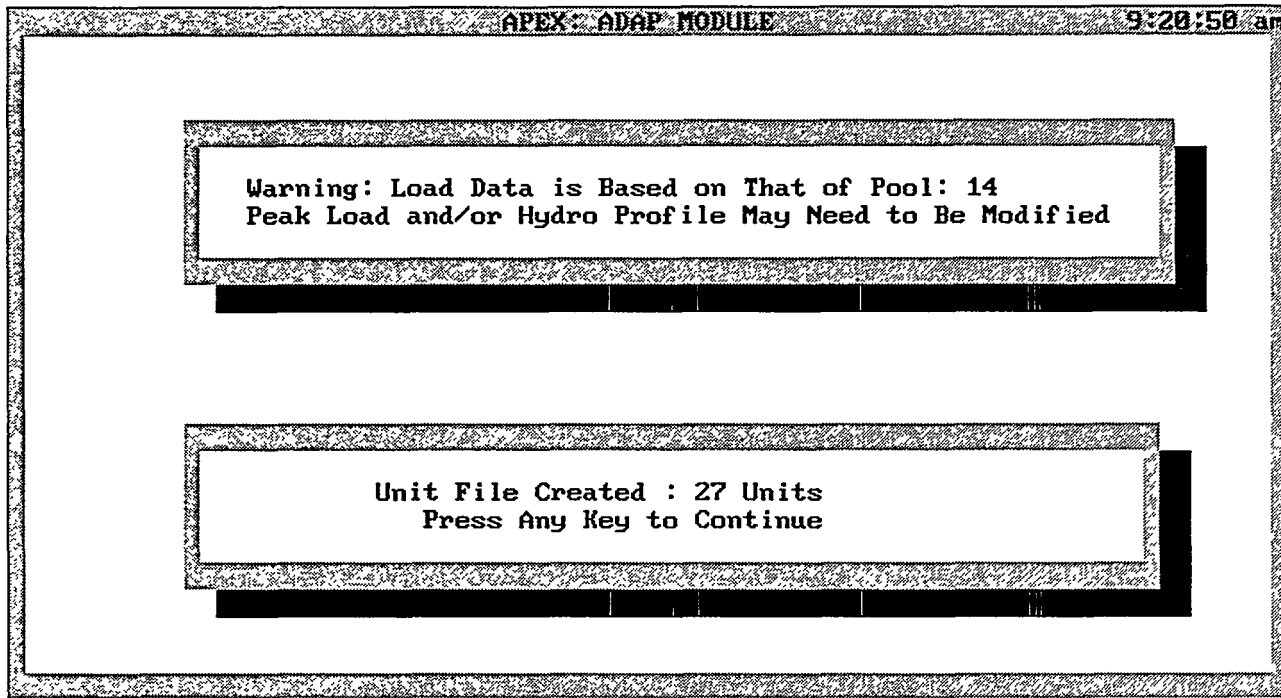
The ADAP-05 screen allows you to select the utility for which an ICARUS UNITDATA file will be created.

### Options

- Select a utility by highlighting the desired entry and pressing the Enter key. After you select a utility, the system will select units that correspond to the selected utility and execute the ASSIGN program to assemble the UNITDATA file for ICARUS.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



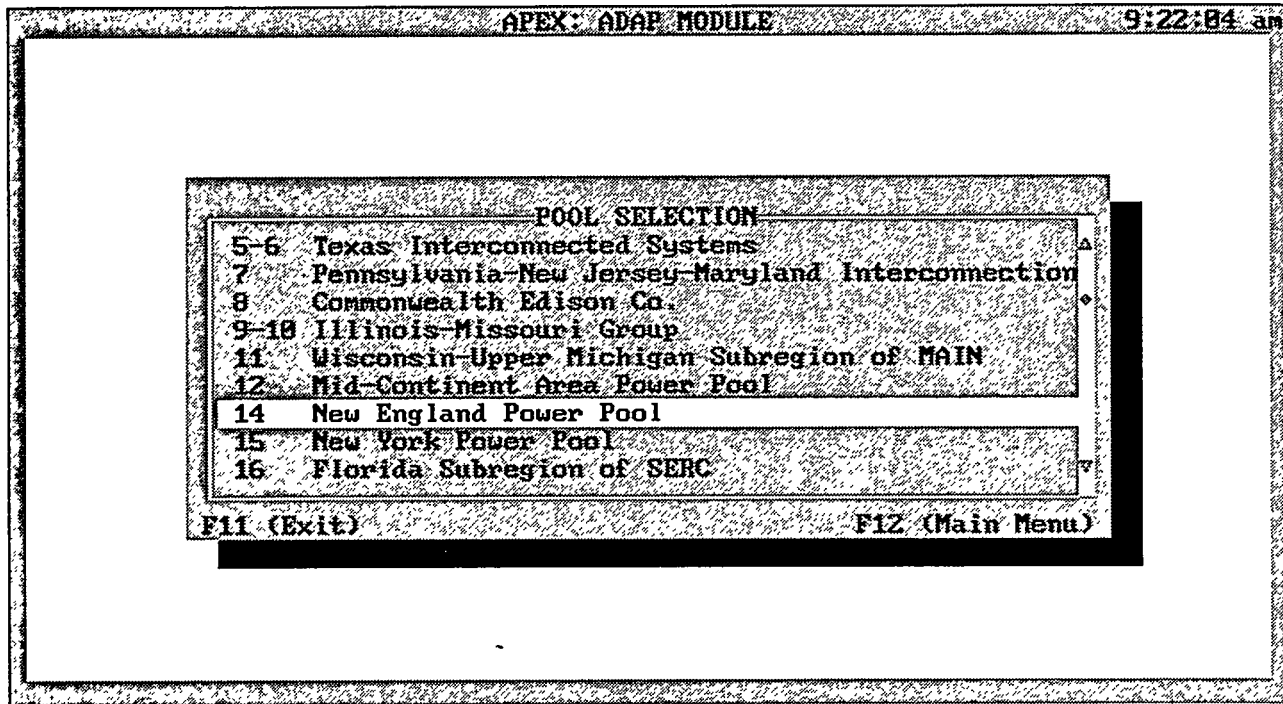
ADAP-06

### **Purpose**

The ADAP-06 screen displays a warning message when a UNITDATA file is created for a utility or NERC region. The creation of the UNITDATA and LOADDATA files is based on a reference power pool file. The data selected from the LOADDATA file contain information (e.g., peak load data, hydro data, firm purchase, and sale data) for the power pool that contains the selected utility or NERC region. It is the responsibility of the user to update the load data before executing ICARUS. The program will accept the power pool data; however, there may be unusual results, for example, the load may be greater than the available capacity.

### **Options**

- Press any key to continue.



ADAP-07

### Purpose

The ADAP-07 screen allows you to select a power pool for which an ICARUS UNITDATA file will be created. Power pools 5 and 6 are always simulated together, as are pools 9 and 10.

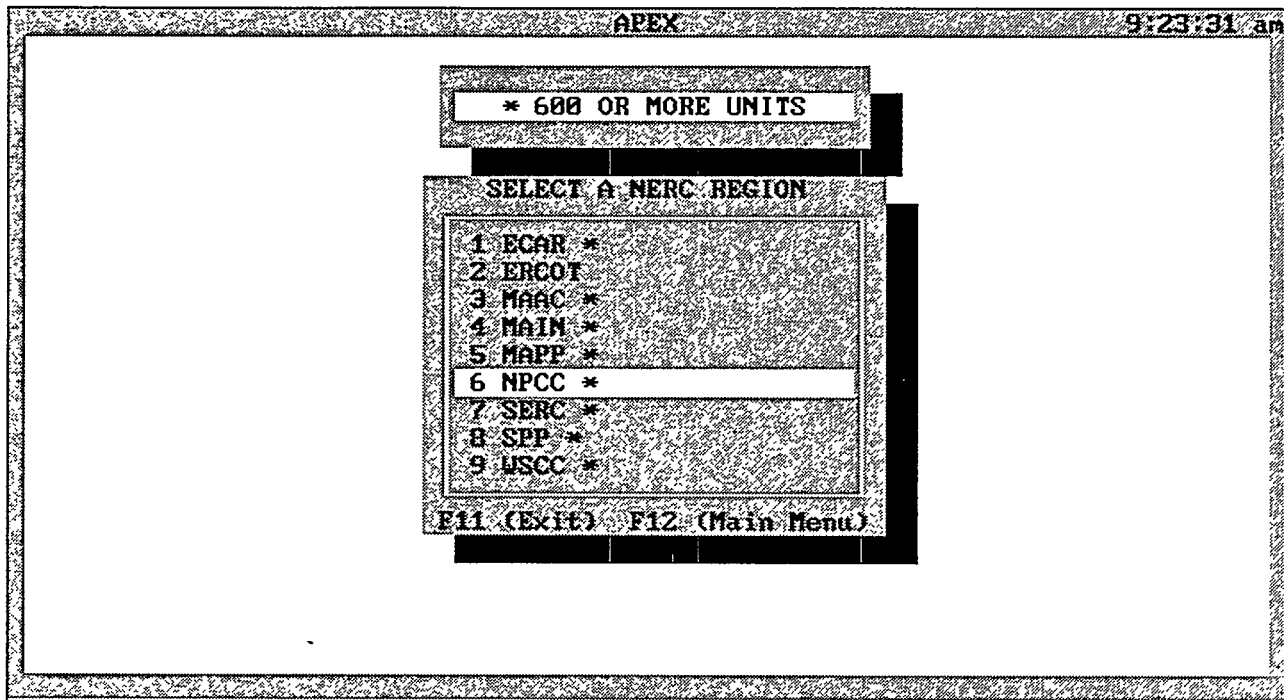
### Options

- Select an option by highlighting the desired power pool and pressing the Enter key. Use the Down arrow or PageDown key to view additional power pools.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.





ADAP-08

### Purpose

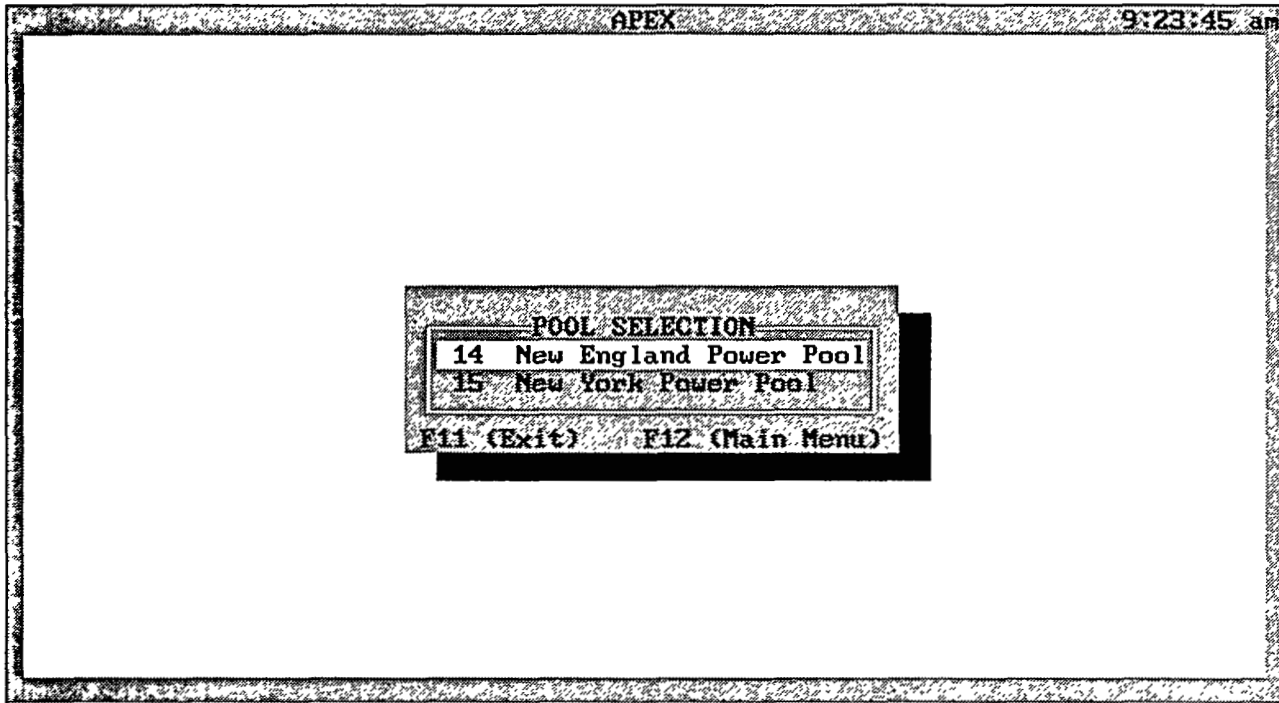
The ADAP-08 screen allows you to select a NERC region for which an ICARUS UNITDATA file will be created.

### Options

- Select a NERC region by highlighting the desired region and pressing the Enter key.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



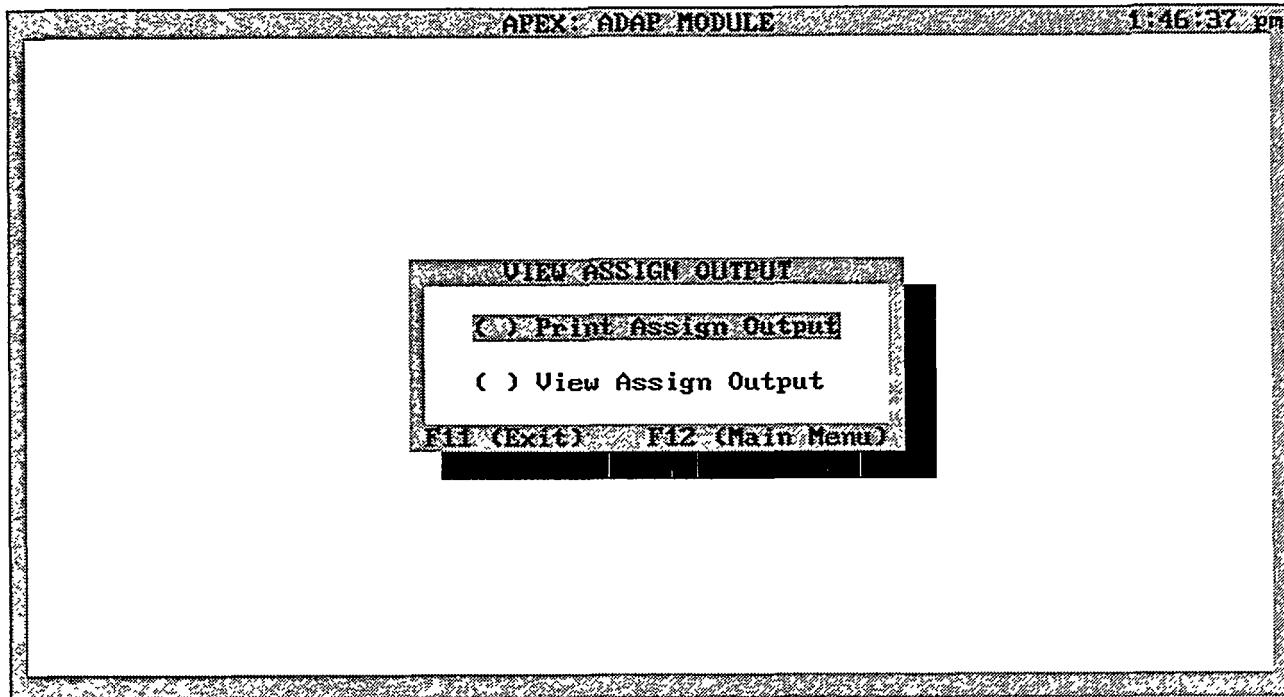
ADAP-09

### Purpose

The ADAP-09 screen allows you to specify which reference power pool data will be used for the previously selected NERC region. The system will display only those power pools that are subregions of the selected NERC region.

### Options

- Select a reference power pool by highlighting the desired pool and pressing the Enter key.
- F11** Press this key to return to screen ADAP-01.
- F12** Press this key to return to screen ADAP-01.



ADAP-12

### Purpose

The ADAP-12 screen allows you to print or view the output from the ASSIGN program (the UNITDATA file).

### Options

- To print the ASSIGN output, select the first option.
- To view the ASSIGN output, select the second option. You will advance to screen ADAP-12a.

APEX										1:46:51 pm
1970	2069	25	52							
2	0.00		2.01	55.00	8	0	99.36	.194000	3	DRES
	711.2	11.20	0.100	61.8	11.20	0.000				
1971	2070	45	52							
2	0.00		2.01	55.00	8	0	99.36	.194000	3	DRES
	712.1	11.20	0.100	61.9	11.20	0.000				
1972	2071	31	52							
2	0.00		2.01	58.00	8	0	99.36	.194000	3	QUAD
	530.6	10.90	0.100	46.1	10.90	0.000				
1972	2071	40	52							
2	0.00		2.01	58.00	8	0	99.36	.194000	3	QUAD
	530.6	10.90	0.100	46.1	10.90	0.000				
1973	2072	51	52							
2	0.00		2.01	55.00	11	0	99.36	.084000	3	ZION
	956.8	10.90	0.100	83.2	10.90	0.000				
1974	2073	38	52							
2	0.00		2.01	55.00	11	0	99.36	.084000	3	ZION
	956.8	10.90	0.100	83.2	10.90	0.000				
1988	2087	28	52							
2	0.00		2.01	55.00	11	0	99.36	.084000	3	BRAI
	1030.4	10.40	0.100	89.6	10.40	0.000				
1988	2087	41	52							
2	0.00		2.01	55.00	11	0	99.36	.084000	3	BRAI

ADAP-12a

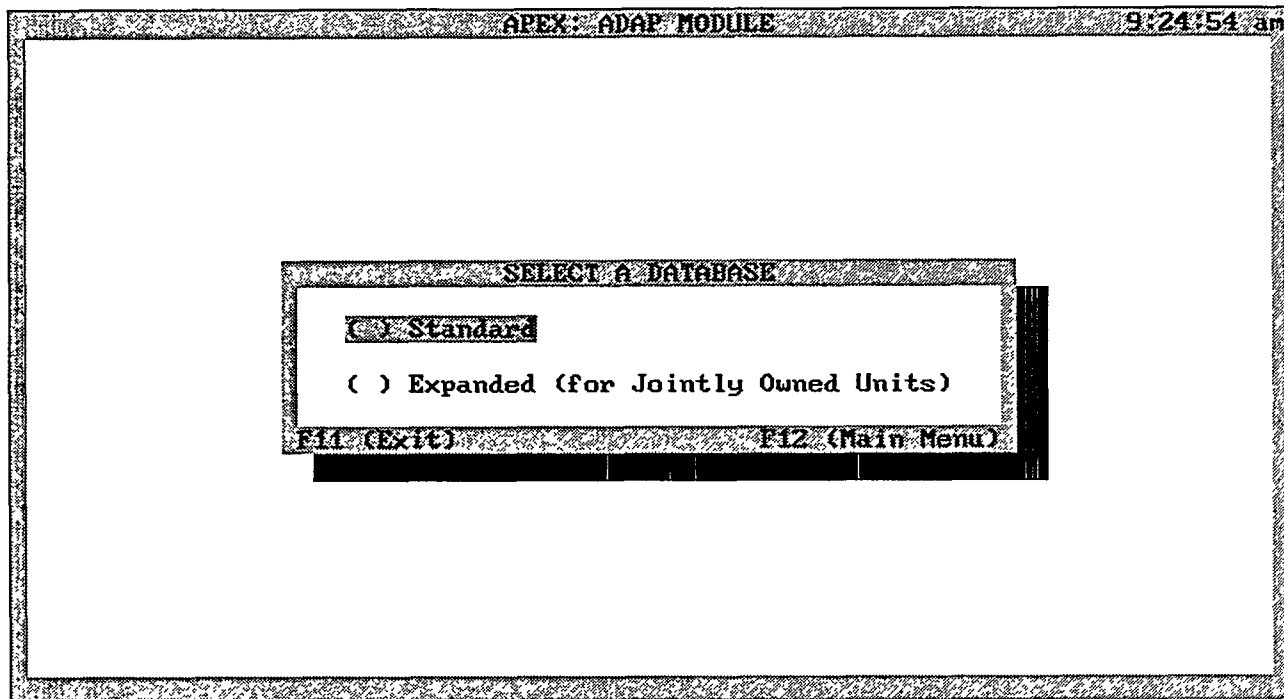
**Purpose**

The ADAP-12a screen is a representation of output from the ASSIGN program, namely, the UNITDATA file.

**Options**

- You can scroll up and down or left and right through the file.

**Esc** Press this key to exit the viewer. You will return to screen ADAP-12.



ADAP-11

### Purpose

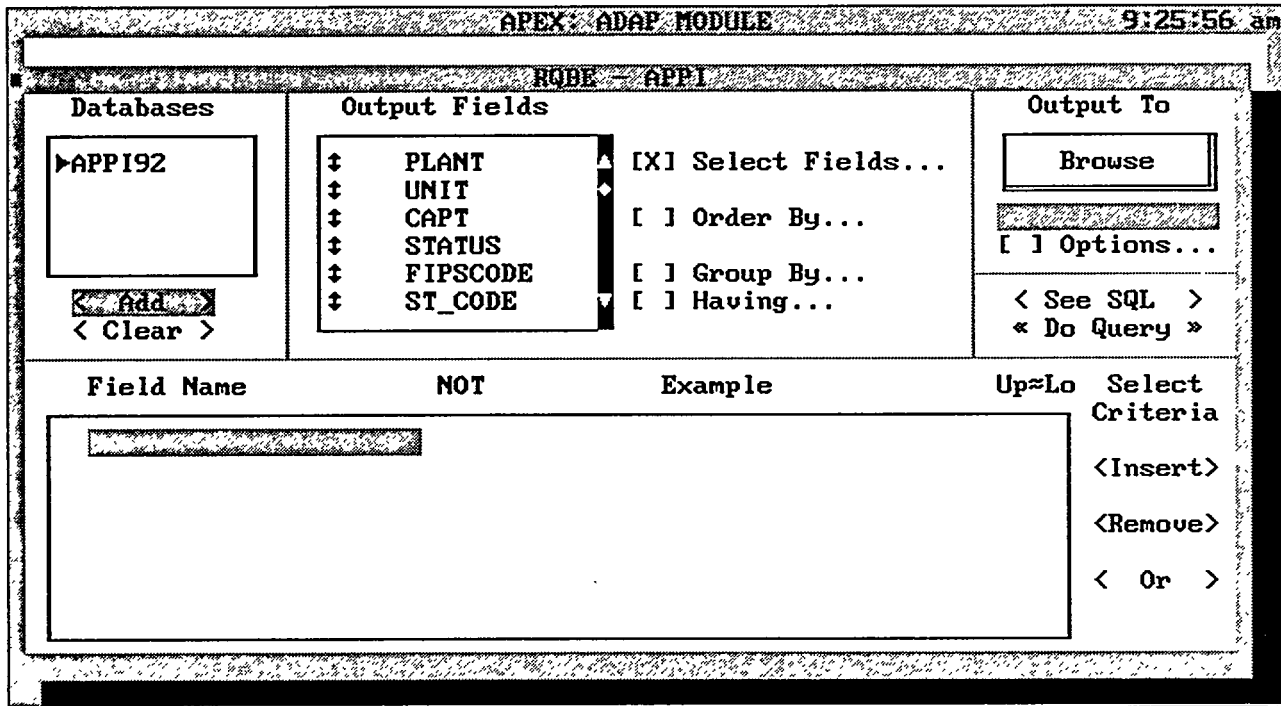
The ADAP-11 screen allows you to select either the standard or the expanded APPI database to query. The standard APPI database contains a unit-level entry for each power pool that owns a unit. The expanded APPI database contains a unit-level entry for each utility owner of a jointly owned unit (see discussion in Section 2.2.1).

### Options

- To choose the standard database, select the first option.
- To choose the expanded database, select the second option.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



ADAP-13

**Purpose**

The ADAP-13 screen is the standard FoxPro relation query by example (RQBE) screen, which can be used to access the APPI database.

**Options**

A brief summary of the RQBE screen functionality procedures is given below. For a more thorough discussion on how to perform queries in FoxPro, consult the FoxPro user's manual.

The FoxPro RQBE window is automatically displayed when you request to query the APPI database. The name of the database being queried is displayed in the upper left hand corner, under the Databases box. APPI92 is the standard database, and APPI92U is the extended database. The Add and Clear buttons under the Databases box are used to clear the current database or to select another database to query.

The Output Fields box contains a list of the field names in the selected database. To select specific data fields, click on the Select Fields option. You will advance to screen ADAP-13a.

Database Fields		Selected Output	
APP192.FUELCST	N	< Move >	APP192.PLANT
APP192.YEARUP	N	< All >	APP192.UNIT
APP192.WEEKUP	N	< Remove >	APP192.STATUS
APP192.YEARDOWN	N	< Remove All >	APP192.FIPSCODE
APP192.WEEKDOWN	N		APP192.ST_CODE
APP192.PFUEL	C		APP192.NUMPFUEL
APP192.TYPE	C		APP192.NUMTYPE
APP192.CO NAME	C		APP192.POOL

Functions/Expressions	Options
<input type="button" value="Functions"/> <input type="text"/>	<input type="checkbox"/> No Duplicates <input type="checkbox"/> Cross Tabulate <input type="button" value="OK"/> <input type="button" value="Cancel"/>

ADAP-13a

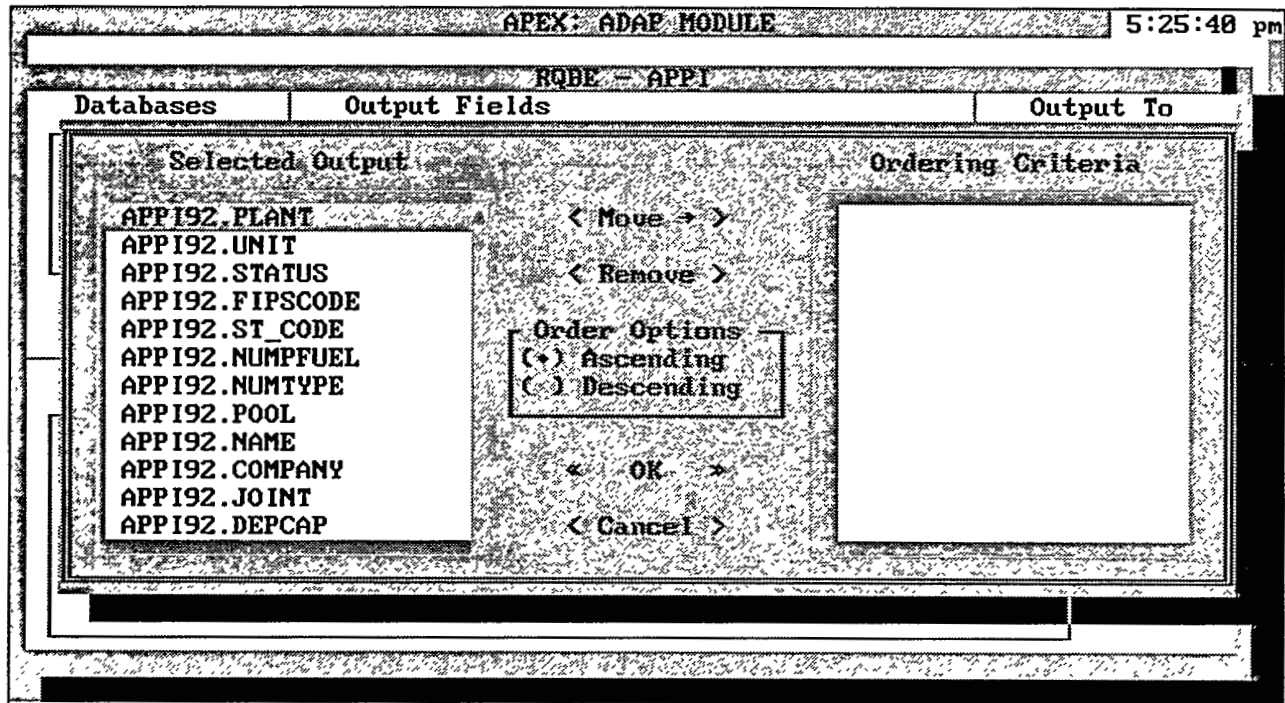
By default, all fields are initially selected. After you click on the Select Fields option, the RQBE Select Fields screen will display the fields in the current database. You can remove all fields by clicking on the Remove All button. To remove one field at a time, highlight a field under the Selected Output box, and click the Remove button or double-click on the highlighted field name. To select all fields, press the All button. To select one field at a time, highlight the field under the Database Fields list, and press the Move button or double-click on the highlighted field name.

The Functions/Expressions box allows you to perform simple summary statistics on the selected data fields. For example, you can request FoxPro to determine the minimum or maximum value within a field or to sum the values within a field. Press the Functions box to see a complete list of functions. After you select a function, FoxPro will display a list of variables that can be used with that function. Select a variable and press the Move button. More than one function can be selected in a query.

If you do not want to include duplicate records (for example, company names) click on the No Duplicates box. An X will appear in the box to indicate that the option has been selected.

The Cross Tabulate option can be used when three items are selected. The order of the items represents the X axis, Y axis, and cell value (e.g., coal capacity by year and state). After you select the desired options, press the OK button to continue or the Cancel button to remove the options selected.

The Order By option is used to determine the order of the query results. Before you select the Order By box, you must select the fields in the query. After you select the Order By option, FoxPro displays the RQBE Order By window (screen ADAP-13b).



ADAP-13b

The field names under the Selected Output box are those you previously selected. To select a field to order the query results, highlight the field name under the Selected Output box, select Ascending or Descending under the Order Options box, and press the Move button. You can select several fields to order the output results. The results will be sorted on the basis of the order of the selected fields in the Ordering Criteria box. To change the order specified, click on the small box to the left of the field name and drag it to its new location. After you specify the order option, be sure to press the OK button to activate the desired options. Otherwise, press the Cancel button.

The fields selected in the Order By option will be identified in the beginning RQBE screen by an up or down arrow before the field name.

The Group By option allows you to obtain calculated information on subgroups. To group records, choose the Group By option. The RQBE Group By window (screen ADAP-13c) will be displayed.



APEX: ADAP MODULE 5:25:52 pm

RQBE = APP1

Databases      Output Fields      Output To

Database Fields      Group By Fields

APP192.PLANT      < Move >

APP192.UNIT      < Remove >

APP192.STATUS

APP192.FIPSCODE

APP192.ST\_CODE

APP192.NUMPFUEL

APP192.NUMTYPE

APP192.POOL      \* OK \*

APP192.NAME

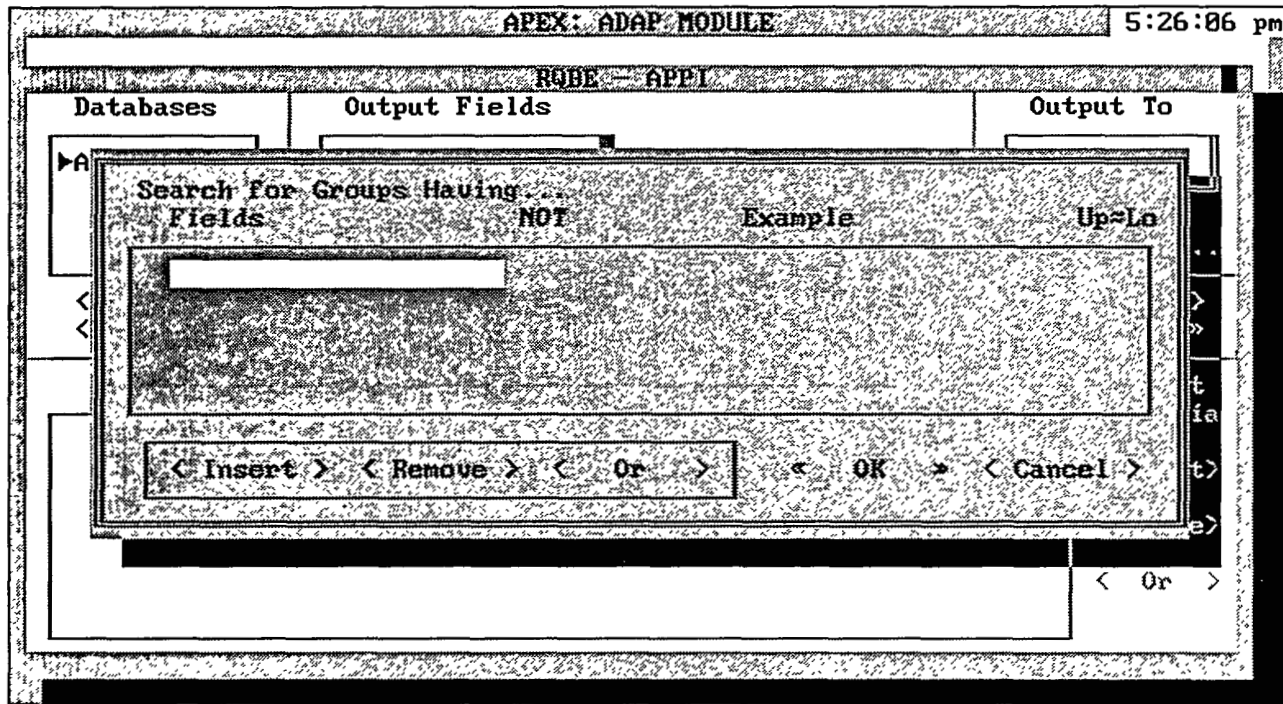
APP192.COMPANY      < Cancel >

< Or >

ADAP-13c

Highlight a field from the Database Fields box, and press the Move button. More than one field can be used to group the query results. For example, you may want to summarize new capacity addition by year on-line and state. After you select the fields by which to group, press the OK button to activate the desired options. Otherwise, press the Cancel button.

The Having option allows you to specify certain conditions in the query (e.g., coal units on-line after 1975). After you select the Having option, the RQBE Having window (screen ADAP-13d) will appear.



ADAP-13d

Under the Field Name, choose a field name that will be used as part of the selection criteria. After you select a field, choose the type of comparison from the comparison pop-up box. The options are as follows:

***Like***: field name must match (e.g., STATE Like O would match OH, OK, and OR);

***Exactly Like***: field must match exactly, character for character (e.g., STATE Exactly Like O would find no matching records);

***More Than***: specifies that the field must be greater than the example value (e.g., DEPCAP More Than 100);

***Less Than***: specifies that the field must be less than the example value (e.g., EPCAP Less Than 800);

***Between***: specifies that the field must be greater than or equal to the lower value and less than or equal to the higher value (e.g., DEPCAP Between 200,600); and

***In***: specifies that the field must match one of several comma-delineated examples in the example box (e.g., STATE in IN,IL would select records that have a STATE identifier of IL or IN).

When entering the comparison in the criteria example box, do not enclose character strings in quotation marks unless the string is the same as the name of a field in the table

query. If you want the comparison to be the inverse of the stated condition, check the Not box. To ignore the capitalization of character data, check the Up/Lo box to find matches without regard to case matching.

If you specify multiple conditions, all conditions must be met for the query to match (e.g., TYPE Like ST (and) DEPCAP More Than 300). If you want to create OR conditions, choose the OR button or select OR from the RQBE Menu.

After you define the conditions, press the OK button to accept the conditions; otherwise, press the Cancel button. The selected criteria will appear in the Selection Criteria section of the RQBE window.

APEX: ADAP MODULE 9:27:28 am

LIST OF SYSTEMS			
System Name	Pool Number	Units Before Assign	Units Aft
6 NPCC *	14	454	
N ENG ELEC:NEW	14	162	
F11 (Exit)		F12 (Main Menu)	

**ADAP-14**

**Purpose**

The ADAP-14 screen displays the systems for which ICARUS input files have been created. The initial System and System Name are created by APEX. The Pool Number corresponds to the power pool used to create the UNITDATA file. The Before Assign column identifies the number of units in APPI for the selected system before filtering or combining of any units. The After Assign column displays the number of units in the selected system after small units have been combined (if specified by the user on screen ADAP-02).

**Options**

- Use the Tab and arrow keys to review the list of previously created systems.
- F11** Press this key to return to screen ADAP-01.
- F12** Press this key to return to screen ADAP-01.

APEX: ADAP MODULE				9:27:53 am
Delete Systems Defined in ADAP				
System	System Name	Pool Number	Units Before Assi	
Ng	6 NPCC	14	45	
U1	N ENG ELEC:NEW	14	16	

Use Space Bar to Mark, Arrow Keys to Navigate, and F2

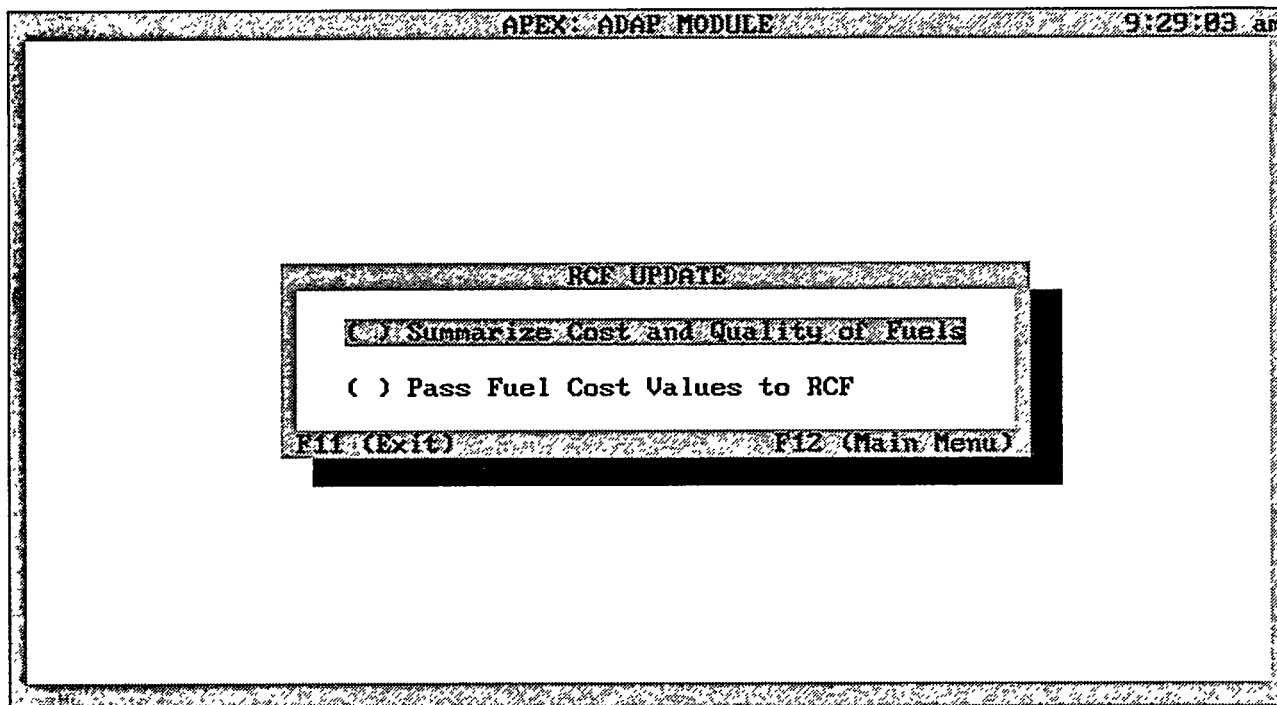
## ADAP-15

**Purpose**

The ADAP-15 screen allows you to view a list of defined systems and select (or tag) the systems for deletion.

**Options**

- Highlight each system to be deleted, and press the space bar to tag or mark it for deletion.
- F2** Press this key to close the window after marking the systems to be deleted.



## ADAP-16

### Purpose

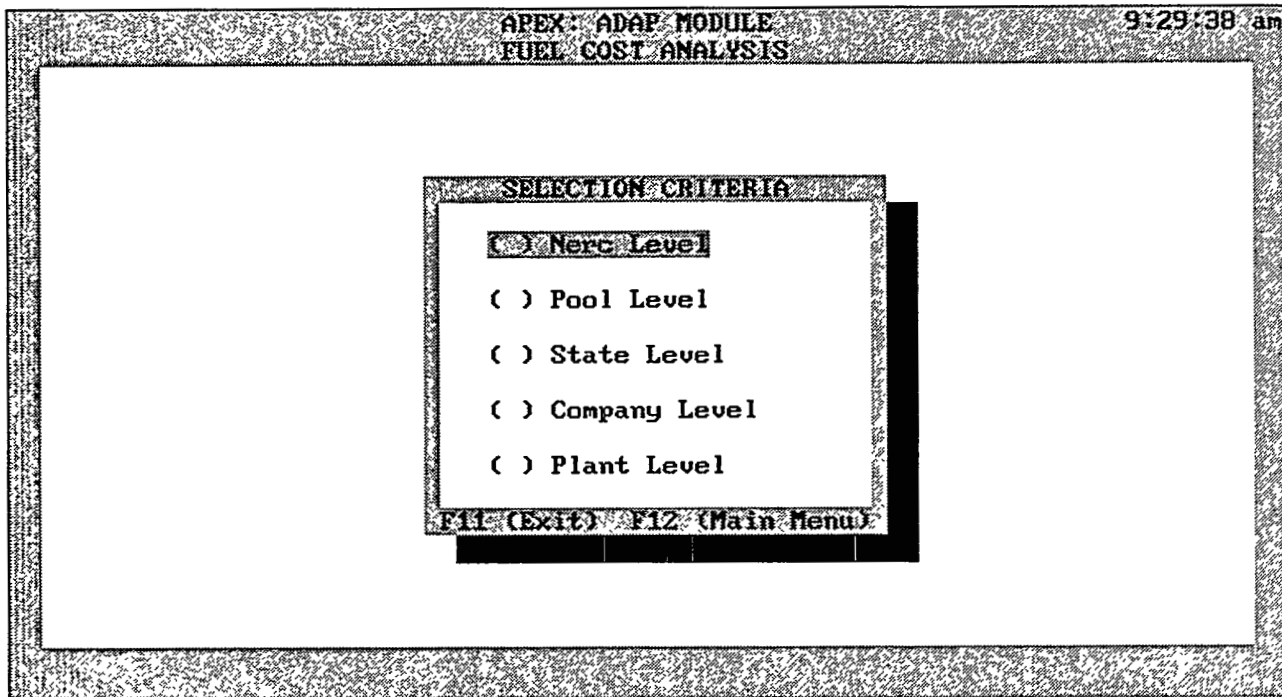
The ADAP-16 screen is the opening screen for the fuel cost and quality section. You can view this screen by selecting the Summarize Cost and Quality of Fuel option from the ADAP-01 screen. On this screen, you can choose to generate a summary of fuel characteristics at various levels or proceed to transfer pool-level cost values to the RCFs.

### Options

- To generate fuel cost and quality characteristics, select the first option.
- To pass pool-level fuel costs to a RCF, select the second option. Results will be displayed on screen before final transfer to a RCF.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



ADAP-17

### Purpose

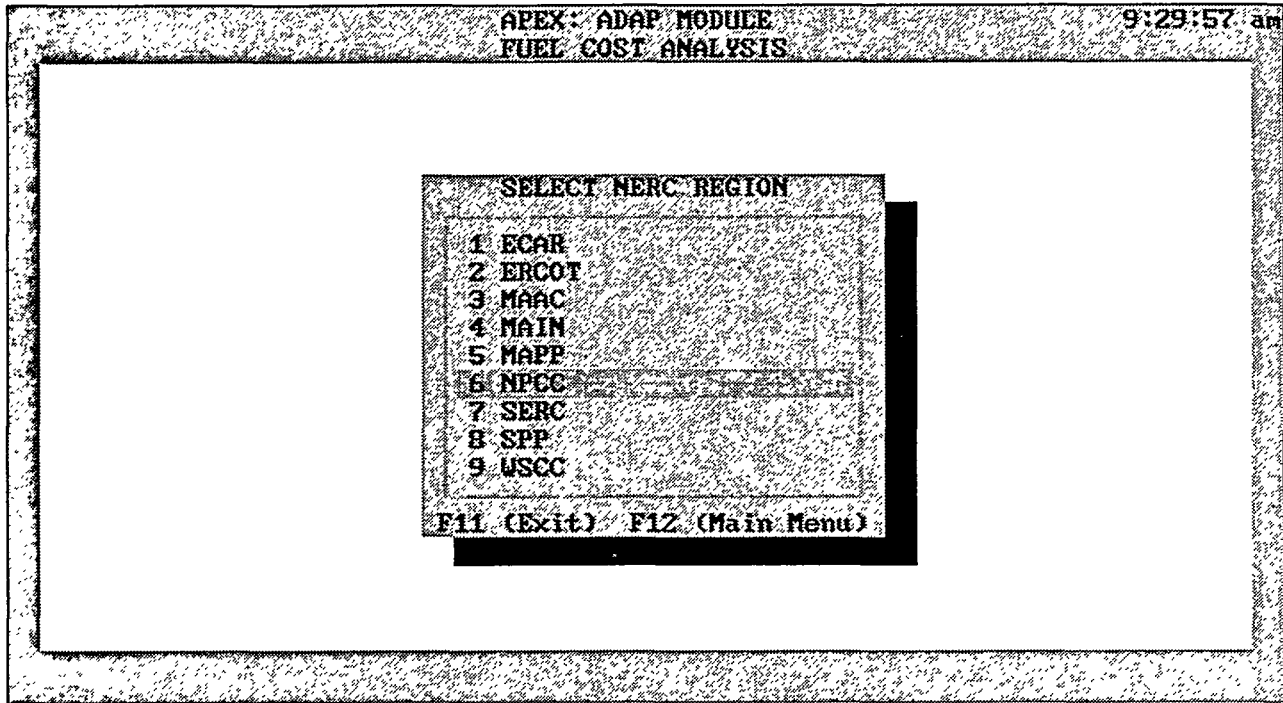
The ADAP-17 screen displays the levels at which the fuel cost and quality parameters can be grouped and processed. The levels are arranged in ascending order with respect to coverage and unit population.

### Options

- To categorize fuels at the NERC level, choose the first option.
- To categorize fuels at the pool level, choose the second option.
- To categorize fuels at the state level, choose the third option.
- To categorize fuels at the company level, choose the fourth option.
- To categorize fuels at the plant level, choose the fifth option.

**F11** Press this key to return to screen ADAP-16.

**F12** Press this key to return to screen ADAP-01.



## ADAP-18

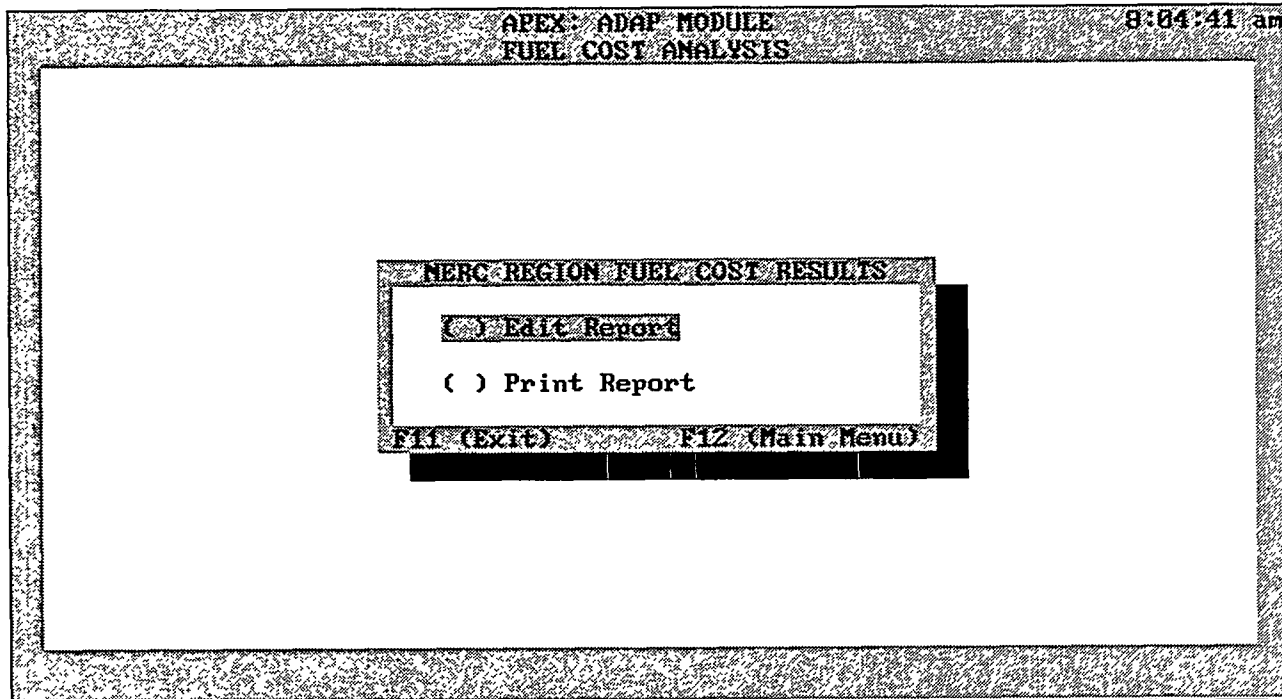
### Purpose

The ADAP-18 screen displays a list of the NERC regions in the United States. Choosing one of the regions will categorize fuels for that region.

### Options

- To choose a NERC region, use the Up and Down arrow keys to highlight your choice, and press the Enter key.
- F1** Press this key for a description of each NERC code.
- F11** Press this key to return to screen ADAP-17.
- F12** Press this key to return to screen ADAP-01.





ADAP-20

### Purpose

The ADAP-20 screen allows you to edit or print the results of the fuel cost and quality analysis.

### Options

- To edit the output, choose the first option.
- To print the output, choose the second option.

**F11** Press this key to return to screen ADAP-16.

**F12** Press this key to return to screen ADAP-01.

Fuel Characteristics, for NERC Code NPCC (Scroll Down for Unit Descriptions)						
Year: 1992						
Fuel Type	Fuel Quantity	Sulfur (%)	Ash (%)	Btu Content	Delivered Fuel Price (cents/million Btu)	
Anthracite Coal	6,900	0.55	25.06	9,555	124.83	
Bituminous Coal	16,599,476	1.48	7.88	13,032	157.62	
Fuel Oil No. 2	224,502	0.22	0.00	139,074	457.28	
Fuel Oil No. 6	64,406,399	1.14	0.06	151,467	245.04	
Natural Gas	236,763,041	0.00	0.00	1,029	244.14	
Refuse (Solid Waste)	4,020	0.72	37.83	8,299	11.14	
Wood	2,800	0.05	1.91	5,240	143.98	
Fuels Within Category		Average Delivered Price (cents/million Btu)				
Bituminous or Lignite		157.62				
Subbituminous or Anthracite		124.83				
Fuel Oils No. 4, 5, 6		245.04				
DOS C:\...\NEW_FC\OUTPUT\JAC_NER2.TXT			File 1	Pg 1	Ln 1	Pos 1

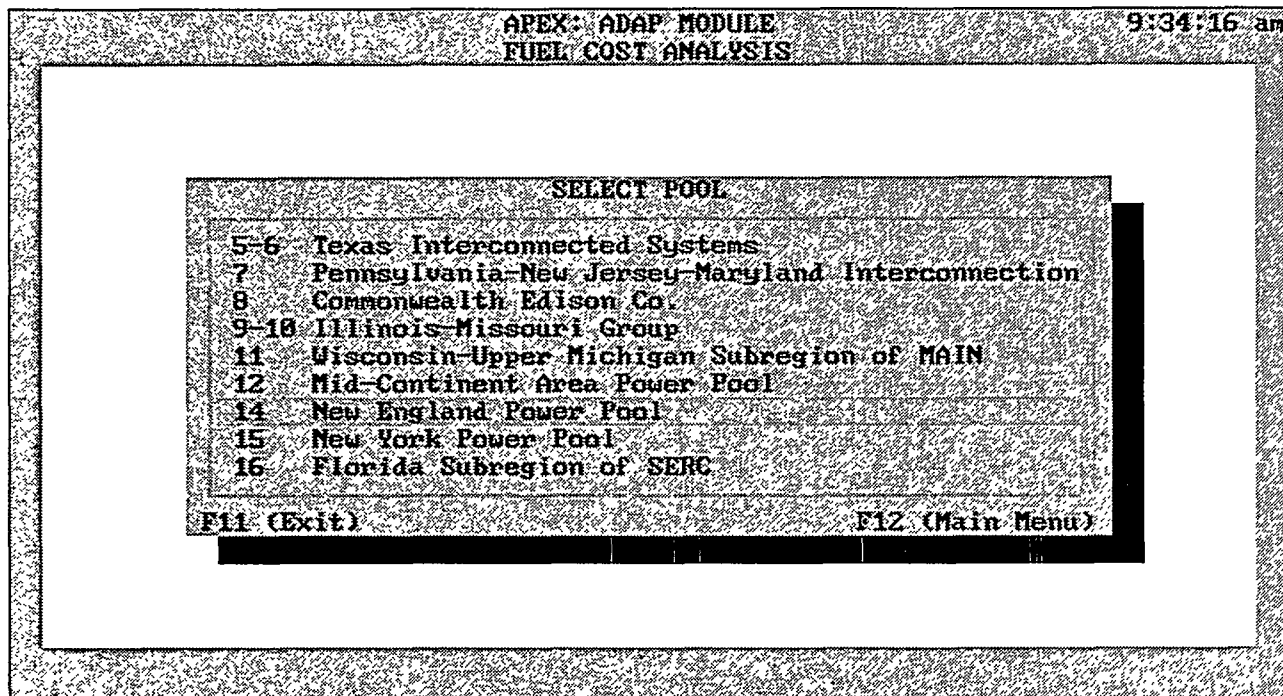
ADAP-19

### Purpose

The ADAP-19 screen represents a preview of typical results obtained from the fuel cost and quality analysis.

### Options

- Q** Press this key to quit the editor after viewing the results. You will advance to screen ADAP-20.



## ADAP-21

### Purpose

The ADAP-21 screen allows you to select a target pool for fuel cost and quality analysis. Pools are designated by numbers 1-33. Pool numbers are sequential but pools 13, 23, 24, 29, and 30 are not used.

### Options

- Use the arrow keys to move vertically along the list of pool numbers. To select a pool, highlight the desired number and press the Enter key.
- F1** Press this key for more information about utility membership in each pool.
- F11** Press this key to return to screen ADAP-17.
- F12** Press this key to return to screen ADAP-01.

APEX: ADAP MODULE  
FUEL COST ANALYSIS

9:36:24 am

SELECT STATE

NEVADA  
NEW HAMPSHIRE  
NEW JERSEY  
NEW MEXICO  
NEW YORK  
NORTH CAROLINA  
NORTH DAKOTA  
OHIO  
OKLAHOMA

F11 (Exit) F12 (Main Menu)

**ADAP-23****Purpose**

The ADAP-23 screen allows you to select the state for which fuel cost and quality characteristics are analyzed.

**Options**

- Use the arrow keys to move through the state list. Highlight the target state and press the Enter key to select that state.

**F11** Press this key to return to screen ADAP-17.

**F12** Press this key to return to screen ADAP-01.

The screenshot shows a terminal window with a title bar at the top containing the text "APEX ADAP MODULE" and "FUEL COST ANALYSIS" on two lines. The time "9:39:46 am" is displayed in the top right corner. The main area of the screen contains a prompt "IDENTIFY COMPANY" followed by a line of text: "Please enter up to five letters of the company name: engla". The text "engla" is underlined, indicating it is the current input.

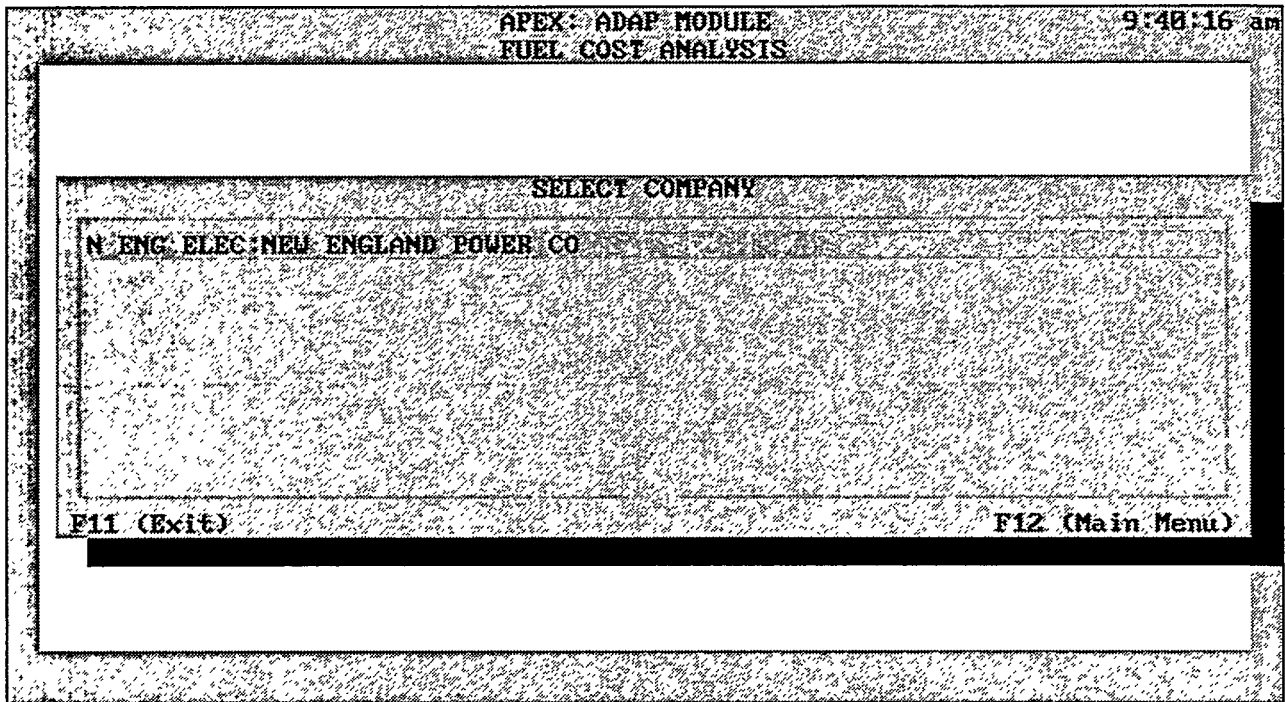
ADAP-25

### **Purpose**

The ADAP-25 screen allows you to specify up to five characters of the company name for which the fuel cost and quality analysis will be performed. All company names that contain the specified character string will be displayed on screen ADAP-26.

### **Data Fields**

Company Name: Enter up to five characters (either uppercase or lowercase) of the target company name. The program automatically transforms lowercase entries to uppercase during the search. If the search fails, the program prompts you for another entry.



ADAP-26

### Purpose

The ADAP-26 screen displays all company names that match the characters supplied in screen ADAP-25.

### Options

- Use the arrow keys to move through the company list. Highlight the desired company name and press the Enter key to select that company.

**F11** Press this key to return to screen ADAP-17.

**F12** Press this key to return to screen ADAP-01.

The screenshot shows a terminal window with a header bar containing the text "APEX: ADAP MODULE" and "FUEL COST ANALYSIS" on the left, and "9:42:50 am" on the right. Below the header is a large rectangular area with a thick border. Inside this area, there is a smaller rectangular box with a thick border. At the top of this inner box is the text "IDENTIFY PLANT". Below this text is a line of text that reads "Please enter up to five letters of the plant name: new", where "new" is entered in a small input field.

ADAP-28

### **Purpose**

The ADAP-28 screen allows you to specify up to five characters of the plant name for which the fuel cost and quality analysis will be performed. All plant names that contain the specified character string will be displayed on screen ADAP-29.

### **Data Fields**

*Plant Name:* Enter up to five characters (either uppercase or lowercase) of the target plant. The program automatically transforms lowercase entries to uppercase during the search.

The screenshot shows a terminal window with a title bar at the top containing 'APEX: ADAP MODULE' and 'FUEL COST ANALYSIS' on the left, and '9:43:35 am' on the right. The main content area is titled 'SELECT PLANT' and contains a list of plant names: GADSDEN NEW, NEW BOSTON, NEW CASTLE, NEW HAVEN HARBOR (highlighted), NEW MADRID, NEWINGTON, NEWMAN, NEWMAN, C E, and NEWTON. At the bottom left, it says 'F11 (Exit)' and at the bottom right, it says 'F12 (Main Menu)'.

ADAP-29

### Purpose

The ADAP-29 screen displays a list of plant names that match the criteria supplied in screen ADAP-28.

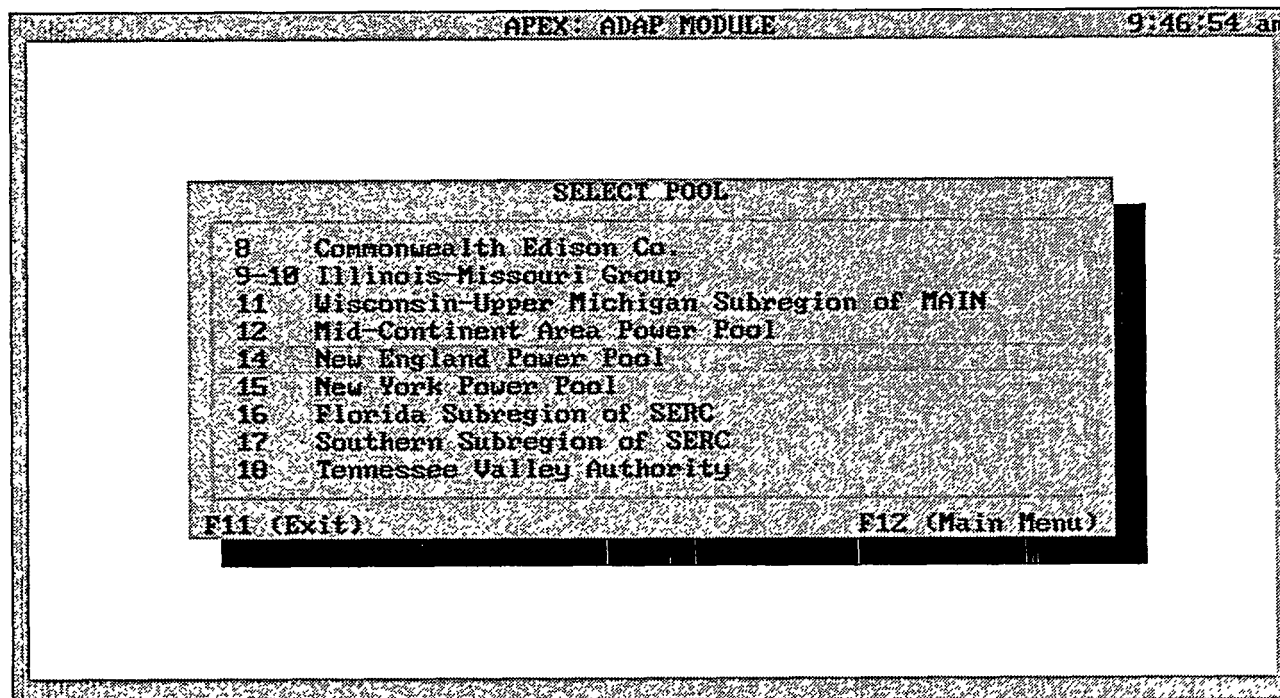
### Options

- Use the arrow keys to move through the plant list. Highlight the desired plant name and press the Enter key to select that plant.

**F11** Press this key to return to screen ADAP-17.

**F12** Press this key to return to screen ADAP-01.





## ADAP-31

### Purpose

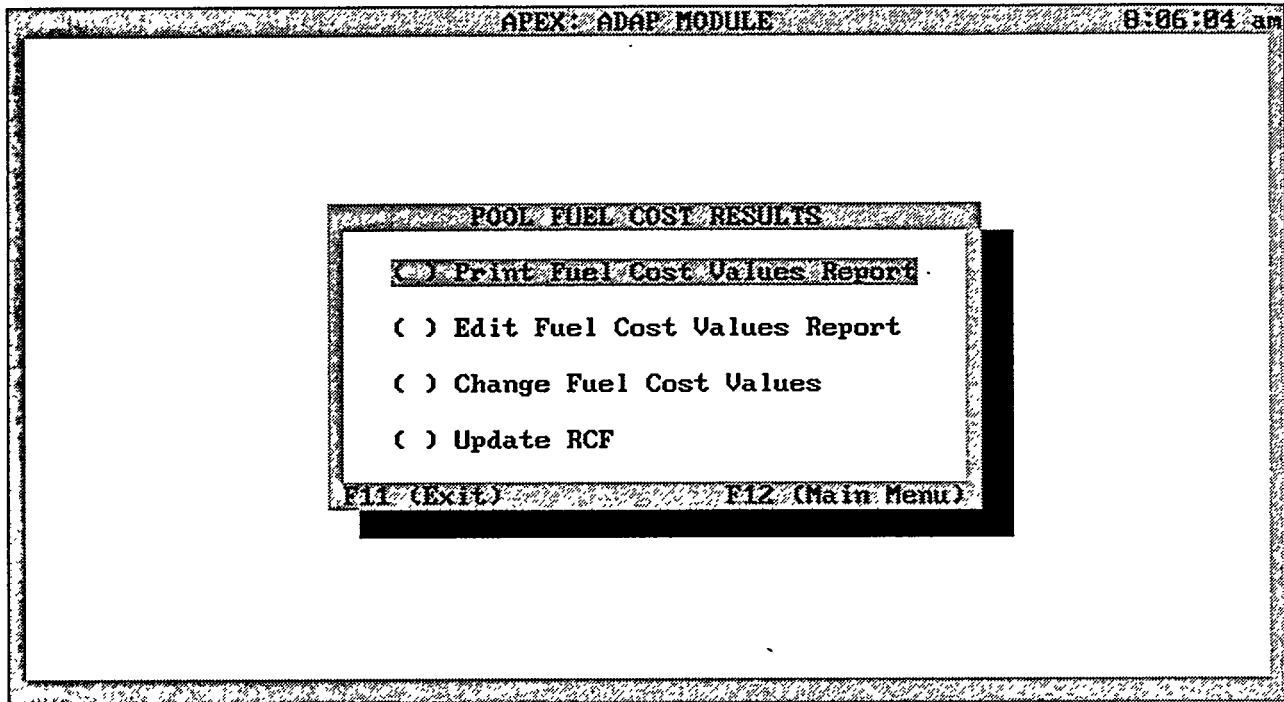
The ADAP-31 screen allows you to select a pool for fuel cost and quality analysis. Pool numbers range from 1 to 33. Pool numbers are sequential, but pools 13, 23, 24, 29, and 30 are not used.

### Options

- Use the arrow keys to move through the list of pool numbers. Highlight the desired target pool number and press the Enter key to select that pool.

**F11** Press this key to return to screen ADAP-16.

**F12** Press this key to return to screen ADAP-01.



## ADAP-60

### Purpose

The ADAP-60 screen allows you to print or edit the fuel cost values report, change fuel cost values, or update the RCFs.

### Options

- To print the results, select the first option.
- To view or change fuel cost values, select the second option.
- To change fuel cost values, select the third option.
- To update the RCF, choose the fourth option.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.

EDIT FUEL PRICES	
Category	Price
Bituminous, Lignite	172.89
Subbituminous, Anthracite	124.83
Fuel Oils No. 4,5,6	232.29
Fuel Oils No. 2, Kerosene	443.24
Natural Gas	257.89
F11 (Exit)	F12 (Main Menu)

## ADAP-33

**Purpose**

The ADAP-33 screen allows you to change the fuel cost values to be transferred to the RCFs. This capability is especially helpful when the values of the calculated fuel cost do not seem reasonable.

**Options**

- Use the arrow keys to move vertically along the price column. Type in new values for items you want to change. New entries will overwrite previous values. Press the Esc key when editing is completed.

**F11** Press this key to return to screen ADAP-60.

**F12** Press this key to return to screen ADAP-01.

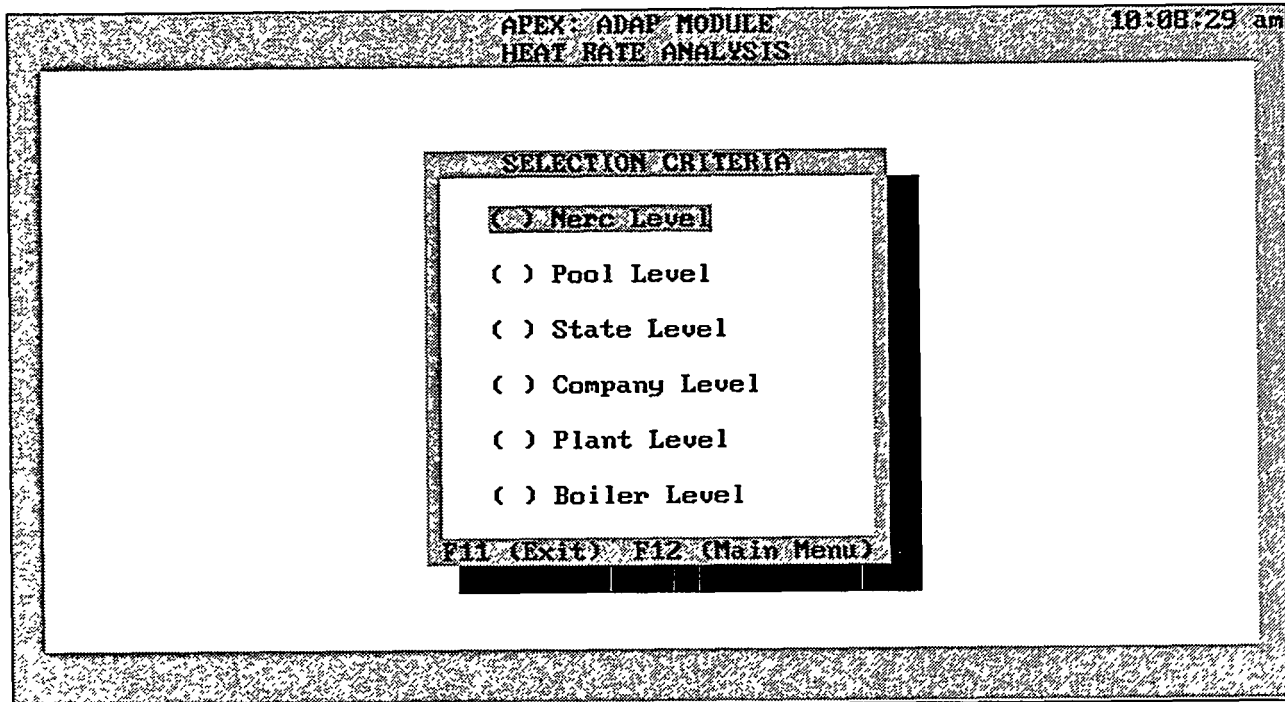
*Caution:* Before pressing the Esc key, be sure to move the cursor out of the cell in which changes have just been made, to make certain that the new values are recognized by the program.

The screenshot shows a terminal window titled "APEX: ADAP MODULE" with a timestamp of "9:32:29 am". The main window is titled "NON-DEFAULT RCF FILE NAME DEFINITION". The prompt reads: "Please provide Name of Output RCF File (no extension)". Below the prompt is a text input field containing "newrcf". At the bottom of the window, a note states: "Please Use Only Letters and Digits".

ADAP-61

### Purpose

The ADAP-61 screen allows you to assign a name to the RCF that you modified in ADAP-33. Enter up to eight DOS filename characters (no extension) for the new RCF name. In screen ADAP-02, if you answer N for no to the Default Regional Characteristics File option, you will see the names of the modified RCFs in a view window.



ADAP-35

### Purpose

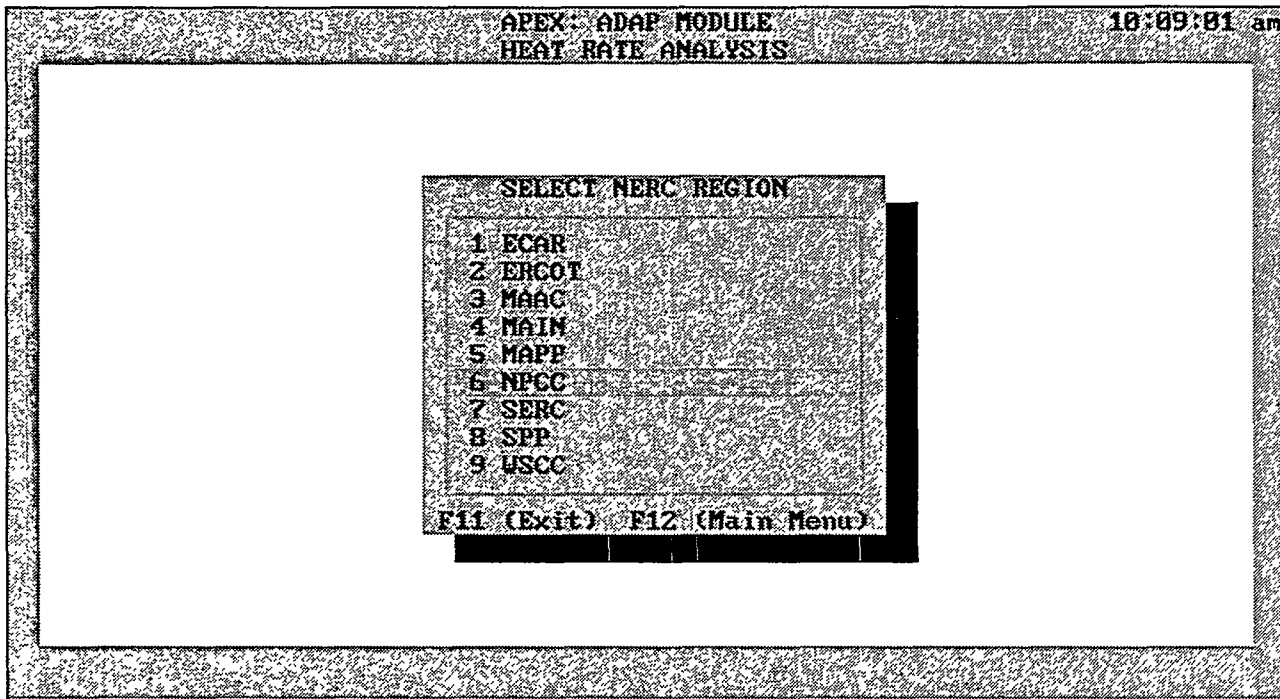
The ADAP-35 screen displays the levels at which the heat rates can be grouped and analyzed. The levels are arranged in ascending order with respect to coverage and unit population.

### Options

- To analyze heat rates at the NERC level, select the first option. Each NERC group consists of one or more pools.
- To analyze heat rates at the pool level, select the second option. Each pool consists of one or more companies or utilities.
- To analyze heat rates at the state level, select the third option. This level includes all plants located within the specified state.
- To analyze heat rates at the company level, select the fourth option. Each company consists of one or more plants.
- To analyze heat rates at the plant level, select the fifth option.
- To analyze heat rates at the boiler level, select the sixth option.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



ADAP-36

### Purpose

The ADAP-36 screen displays a list of the NERC codes adopted by the industry. Highlight a NERC code and press the Enter key to proceed with the analysis.

### Options

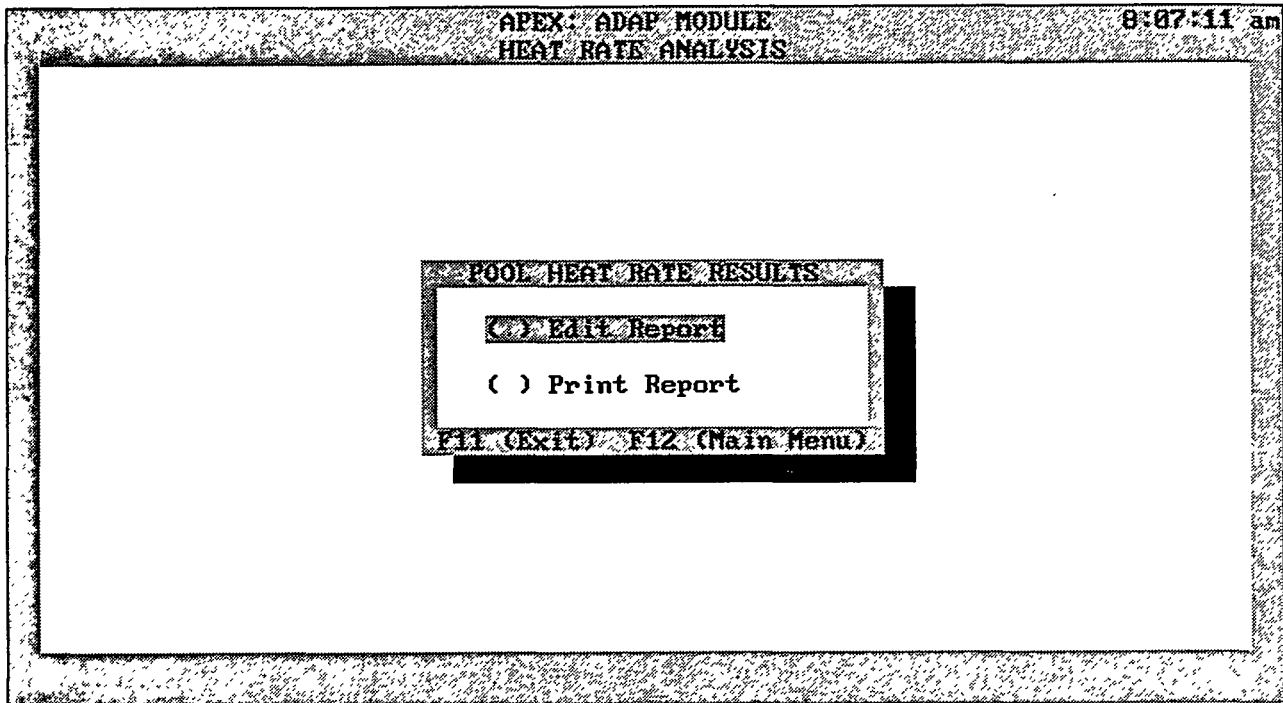
- To choose a NERC code, use the Up and Down arrow keys to highlight your choice and press the Enter key.

**F1** Press this key for a description of each NERC code.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.

Note: The Alaska and Hawaii NERC regions are not supported in the APPI database.



ADAP-38

### Purpose

The ADAP-38 screen allows you to edit or print the results of the analysis.

### Options

- To edit the output, choose the first option.
- To print the output, choose the second option.

**F11** Press this key to return to screen ADAP-01.

**F12** Press this key to return to screen ADAP-01.



APEX							2:34:23 pm
<1000	0	0.0	0	0	0.0	0	
>1000	0	0.0	0	0	0.0	0	
Average	0	0.0	0	0	0.0	0	
-							
STEAM TURBINE - NG							
Size Cat	Heat Rate (Btu/kWh)	Age (yrs)	No. of Units	Ave Cap (MW)	Ave C.F. (%)	Hours Load (hrs)	
200		0	0.0	0	0	0.0	
400		0	0.0	0	0	0.0	
600		0	0.0	0	0	0.0	
800		0	0.0	0	0	0.0	
<1000		0	0.0	0	0	0.0	
>1000		0	0.0	0	0	0.0	
Average		0	0.0	0	0	0.0	
-							
STEAM TURBINE - SUB							
Size Cat	Heat Rate (Btu/kWh)	Age (yrs)	No. of Units	Ave Cap (MW)	Ave C.F. (%)	Hours Load (hrs)	

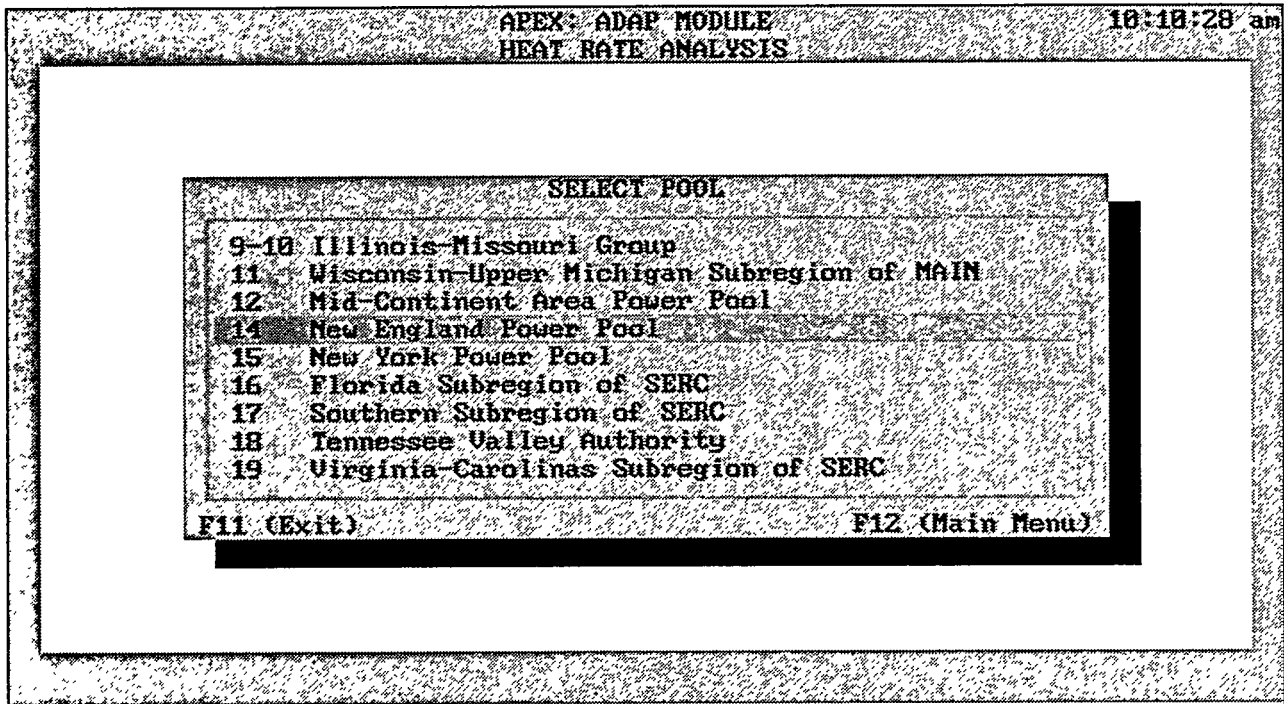
ADAP-52

**Purpose**

The ADAP-52 screen represents a preview of typical results obtained from the heat rate analysis.

**Options**

**Esc** Press this key to quit the viewer. You will return to screen ADAP-38.



## ADAP-39

### Purpose

The ADAP-39 screen allows you to select a target pool for which heat rates are to be analyzed. Pools are designated by numbers 1-33. Pool numbers are sequential, but pools 13, 23, 24, 29, and 30 are not used.

### Options

- Use the arrow keys to move vertically along the list of pool numbers. To select a pool, highlight the desired number and press the Enter key.
- F1** Press this key for more information about utility membership for each pool.
- F11** Press this key to return to screen ADAP-17.
- F12** Press this key to return to screen ADAP-01.

The screenshot shows a terminal window with a title bar at the top containing 'APEX: ADAP MODULE' and 'HEAT RATE ANALYSIS'. The time '10:11:50 am' is displayed in the top right corner. The main content area is titled 'SELECT STATE' and contains a list of states: NEBRASKA, NEVADA, NEW HAMPSHIRE, NEW JERSEY, NEW MEXICO, NEW YORK, NORTH CAROLINA, NORTH DAKOTA, and OHIO. At the bottom left, 'F11 (Exit)' is shown, and at the bottom right, 'F12 (Main Menu)' is shown. The screen has a dark border and a light background.

ADAP-41

### Purpose

The ADAP-41 screen allows you to select the state for which heat rate analysis will be performed.

### Options

- Use the arrow keys to move through the state list. Highlight the target state and press the Enter key to select that state.

**F11** Press this key to return to screen ADAP-17.

**F12** Press this key to return to screen ADAP-01.

The screenshot shows a terminal window with a title bar at the top containing the text "APEX: ADAP MODULE" and "HEAT RATE ANALYSIS" on the left, and "10:13:15 am" on the right. Below the title bar is a large rectangular area with a stippled border. Inside this area, there is a smaller rectangular box with a stippled border. At the top of this inner box, the text "IDENTIFY COMPANY" is displayed. Below this text, there is a prompt: "Please enter up to five letters of the company name:". To the right of the prompt is a text input field containing the characters "new".

### ADAP-43

#### **Purpose**

The ADAP-43 screen allows you to specify any five characters of the company name on which to base the heat rate analysis. All utilities that contain the specified five-letter string will be displayed.

#### **Data Fields**

Company Name: Enter any five characters (either uppercase or lowercase) of the target utility name. The program automatically transforms lowercase entries to uppercase during the search.

The screenshot shows a terminal window with a title bar at the top. The title bar contains the text 'APEX: ADAP MODULE' on the left and '10:13:43 am' on the right. Below the title bar, the main content area is titled 'SELECT COMPANY'. Underneath this title, there is a list of utility names: 'ENERGY-NEW ORLEANS PUBLIC SERVICE', 'N. ENG. ELEC-NEW ENGLAND POWER CO', 'NEW ULM PUB UTILS COMM', 'NEW YORK STATE ELEC & GAS CORP', and 'PUBLIC SERVICE CO OF NEW MEXICO'. At the bottom of the screen, there are two function key prompts: 'F11 (Exit)' on the left and 'F12 (Main Menu)' on the right. The entire screen is enclosed in a rectangular border.

ADAP-44

### Purpose

The ADAP-44 screen displays all the utility names that match the characters specified in screen ADAP-43.

### Options

- Use the arrow keys to move vertically up and down the utility list. Highlight the utility name and press the Enter key to select that utility.
- F11** Press this key to return to screen ADAP-17.
- F12** Press this key to return to screen ADAP-01.

The screenshot shows a terminal window with a header bar containing the text 'APEX: ADAP MODULE' and 'HEAT RATE ANALYSIS' on the left, and '10:15:21 am' on the right. The main area of the screen is titled 'IDENTIFY PLANT' and contains a prompt: 'Please enter up to five letters of the plant name:'. The input field shows the characters 'hac'.

## ADAP-46

### Purpose

The ADAP-46 screen allows you to specify any five characters of the plant name on which to base the heat rate analysis. All plants that contain the five-character string will be displayed.

### Data Fields

***Plant Name:*** Enter any five characters (either uppercase or lowercase) in the name of the target plant. The program automatically transforms lowercase entries to uppercase during the search.

APEX: ADAP MODULE  
HEAT RATE ANALYSIS

10:15:46 am

SELECT PLANT

BRIDGEPORT HARBOR  
COUCH, HARVEY  
HARBOR  
HARBOR BEACH  
HARLEE BRANCH  
HARRINGTON  
HARRISON  
NEW HAVEN HARBOR  
NORWALK HARBOR

F11 (Exit) F12 (Main Menu)

ADAP-47

### Purpose

The ADAP-47 screen displays all the plant names that match the criteria supplied in screen ADAP-46.

### Options

- Use the arrow keys to move through the plant list. Highlight the plant name and press the Enter key to select that plant.

**F11** Press this key to return to screen ADAP-17.

**F12** Press this key to return to screen ADAP-01.

APEX: ADAP MODULE  
HEAT RATE ANALYSIS

10:17:00 am

IDENTIFY BOILER

Please enter up to five letters of the boiler name: NEW

ADAP-49

### **Purpose**

The ADAP-49 screen allows you to specify any five characters of the plant to which the target boiler belongs. All plants that contain the five-character string will be displayed.

### **Data Fields**

**Plant Name:** Enter any five characters (either uppercase or lowercase) of the name of the target plant. The program automatically transforms lowercase entries to uppercase during the search.



APEX: ADAP MODULE  
HEAT RATE ANALYSIS

10:17:34 am

SELECT PLANT

GADSDEN NEW  
NEW BOSTON  
NEW CASTLE  
NEW HAVEN HARBOR  
NEW MADRID  
NEW ULM  
NEWINGTON  
NEUMAN  
NEUMAN, C E

F11 (Exit) F12 (Main Menu)

ADAP-50

### Purpose

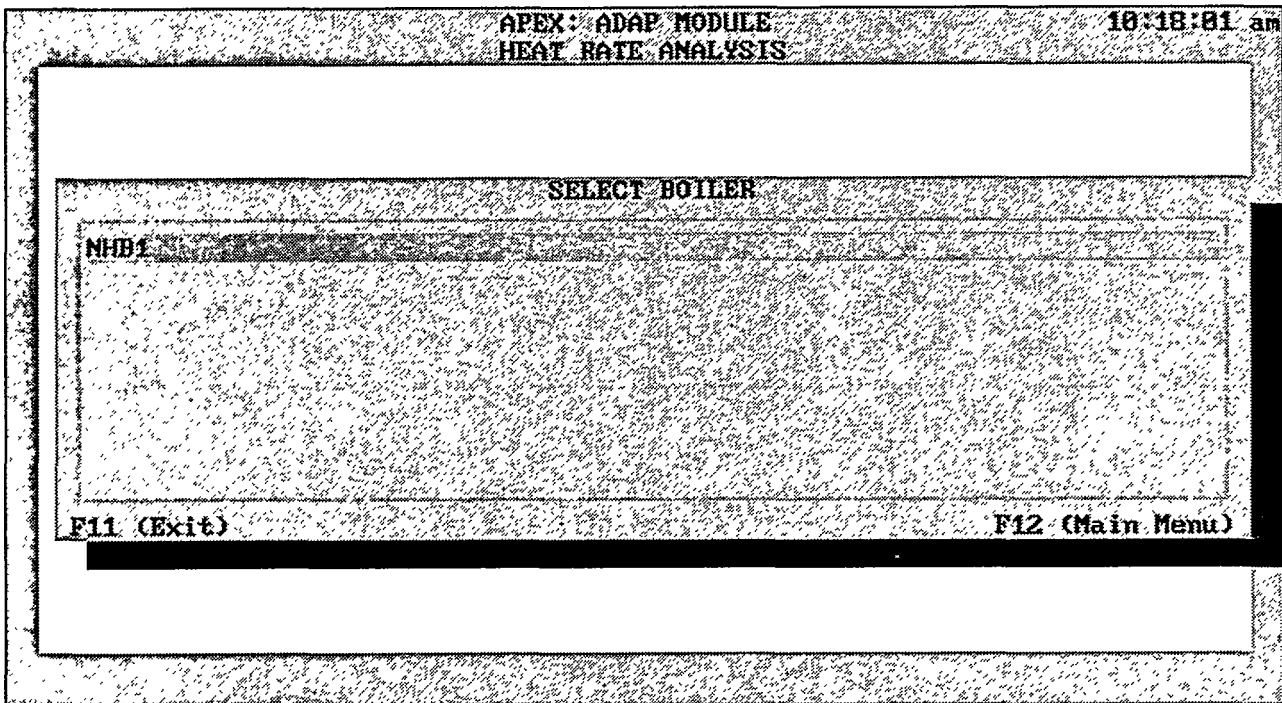
The ADAP-50 screen displays all the plant names that match the criteria supplied in screen ADAP-49.

### Options

- Use the arrow keys to move through the list of plants. Highlight your choice and press the Enter key to start the analysis.

**F11** Press this key to return to screen ADAP-17.

**F12** Press this key to return to screen ADAP-01.



ADAP-51

### Purpose

The ADAP-51 screen allows you to select the target boiler ID to be examined.

### Options

- Use the arrow keys to move through the list of boiler IDs. Highlight the target boiler ID and press the Enter key to begin the heat rate analysis.

**F11** Press this key to return to screen ADAP-17.

**F12** Press this key to return to screen ADAP-01.

## 2.9 REFERENCES

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**APPENDIX 2A**  
**FUEL COST DATA SOURCES AND TRANSFORMATIONS**



## APPENDIX 2A

### FUEL COST DATA SOURCES AND TRANSFORMATIONS

#### 2A.1 THE FERC 423 FILES

The following documentation is included primarily to maintain a written record of procedures and field names used in the fuel cost module. This information is transparent to the APEX user and does not require direct user interaction or familiarity with the definitions.

The raw FERC Form 423 data were obtained in a FoxPro database format. The database has a total of 33,954 records covering monthly fuel statistics for 1991. The structure and field definitions are given in Table 2A.1.

#### 2A.2 TABLE MODIFICATIONS AND REQUIRED ADDITIONAL DATABASE FIELDS

The program that runs this module uses field names and attributes quite different from the raw FERC Form 423 table. To match the raw table with the program, some of the field names and units of measure in the raw database were changed, as shown in Table 2A.2.

Furthermore, in order to categorize fuel characteristics in different levels, the fields listed in Table 2A.3 were added to the raw table.

The modified FERC Form 423 table was mapped against the APPI file to put appropriate labels for the POOL, NERCCODE, CO\_NAME, and PLT\_NAME fields. Mapping was performed by first generating from APPI a set of two-column tables with PLTCODE as the common field. These two-column tables contain distinct records relating PLTCODE to POOL, CO\_NAME, NERCCODE, and PLT\_NAME. A one-to-many relationship was then established between the modified FERC Form 423 table and the two-column tables by using PLTCODE as the common field.

The ST\_NAME and STATE fields were filled by using the auxiliary input file STATE\_2 with NSTATE as the common field. The STATE\_2 file relates the state code numbers, the two-letter abbreviations, and the full names of the states.

#### 2A.3 THE MODIFIED FERC FORM 423 FILE

The final FERC FORM 423 database file used in this module has the structure and field definitions shown in Table 2A.4. The total number of records is 33,954.



TABLE 2A.1 Raw FERC Form 423 Database

Field Name	Description	Type	Width	Units
1 CCODE	Company code	Character	6	
2 PLTCODE	Plant code	Character	5	
3 YEAR	Year of data	Numeric	2	Years
4 MONTH	Month of data	Numeric	2	Months
5 BOM_DIST	Bureau of Mines (BOM) district	Character	2	
6 ORIG_ST	State of origin	Character	2	
7 MINE_TYPE	Mine type	Character	1	
8 REGION	Region (plant)	Numeric	2	
9 FIPS_ST	State number	Numeric	2	
10 GFT	Generic fuel type	Numeric	1	
11 SFT	Specific fuel type	Character	3	
12 CTRCT_TYP	Contract type	Character	1	
13 CTRCT_EXP	Contract expiration	Numeric	1	
14 QTY	Quantity	Numeric	8	Short tons (solid) Barrels (liquid) Thousands of cubic feet (gas)
15 HHV	Heat (Btu) content	Numeric	7	Btu/lb (solid) Btu/gal (liquid) Btu/ft <sup>3</sup> (gas)
16 SULF	Sulfur content	Numeric	5	Percent by weight
17 ASH	Ash content	Numeric	6	Percent by weight
18 COST	Price of fuel	Numeric	7	¢/10 <sup>6</sup> Btu
19 UNIT_TYP	Unit type	Character	1	
20 ORIG_CTY	Origin city	Character	3	
21 SOURCE	Source	Character	5	
22 C_EXP_DATE	Contract expiration date	Character	4	

**TABLE 2A.2 Modified Data Fields**

Previous Field Name	Type	Width	New Field Name	Type	Width
YEAR	Numeric	2	YEAR	Numeric	2
CCODE	Character	6	COCODE	Numeric	6
PLTCODE	Character	5	PLNTCODE	Numeric	6
FIPST	Numeric	2	NSTATE	Numeric	2
REGION	Numeric	2	PLNTREGN	Numeric	2
SFT	Character	3	SPECFUEL	Character	3
HHV	Numeric	7	BTUCNTN	Numeric	7
SULF	Numeric	5	SULCNTN	Numeric	5
ASH	Numeric	6	ASHCNTN	Numeric	6
COST <sup>a</sup>	Numeric	7	COST	Numeric	11
QTY	Numeric	8	QUAN	Numeric	8

<sup>a</sup> Units were also changed to mill/10<sup>6</sup> Btu.

**TABLE 2A.3 Additional Data Fields**

Field	Type	Width	Description
POOL	Numeric	3	Pool number
ST_NAME	Character	20	State name
NERCCODE	Character	5	NERC code
CO_NAME	Character	35	Company name
PLT_NAME	Character	20	Plant name
STATE	Character	2	Two-letter state code

TABLE 2A.4 Final FERC Form 423 Database

Field Name	Type	Width	Decimal	Description
1 COCODE	Numeric	6	0	Company code
2 PLNTCODE	Numeric	6	0	Plant code
3 YEAR	Numeric	4	0	Year of data
4 MONTH	Numeric	2	0	Month of data
5 BOM_DIST	Character	2		BOM district
6 ORIG_ST	Character	2		Origin state
7 MINE_TYPE	Character	1		Mine type
8 PLNTREGN	Numeric	2	0	Region (plant)
9 NSTATE	Numeric	2	0	State code (plant)
10 GFT	Numeric	1	0	Generic fuel type
11 SPECFUEL	Character	3		Fuel specification type
12 CTRCT_TYP	Character	1		Contract type
13 CTRCT_EXP	Character	1		Contract expiration
14 QUAN	Numeric	10		Quantity of fuels
15 BTUCNTN	Numeric	10	2	Heat (Btu) content
16 SULCNTN	Numeric	10	3	Sulfur content
17 ASHCNTN	Numeric	10	2	Ash contents
18 COST	Numeric	11	2	Price
19 UNIT_TYP	Character	1		Unit type
20 ORIG_CTY	Character	3		Origin city
21 SOURCE	Character	5		Source
22 C_EXP_DATE	Character	4		Contract expiration date
23 PAGE	Character	2		Page
24 LINE	Character	2		Line

**TABLE 2A.4 (Cont.)**

Field Name	Type	Width	Decimal	Description
25 STATE	Character	2		Two-letter state code
26 POOL	Numeric	3		Pool number
27 NERCCODE	Numeric	5		NERC code
28 ST_NAME	Character	20		State full name
29 CO_NAME	Character	35		Company name
30 PLT_NAME	Character	20		Plant name



**APPENDIX 2B**  
**SAMPLE EXERCISE FOR FUEL COST MODULE**



## APPENDIX 2B

### SAMPLE EXERCISE FOR FUEL COST MODULE

#### 2B.1 SAMPLE PROBLEM

The following is a record of procedural notes that include updates to the RCFs. The default RCFs contained in APEX have already been updated with 1992 data. No further updates are required except to alter base-case assumptions.

Suppose you want to simulate production costs for pool 8 by using ICARUS and would like the fuel cost data to be based on 1992 deliveries to pool 8 with alterations for the assumed price of natural gas. To accomplish this task, you will use the fuel cost and quality section of ADAP to examine fuel costs of various fuel types in pool 8 and then transfer these data to the ICARUS input file.

#### 2B.2 EXAMINING FUEL COST DATA

To examine the cost and quality of fuels in pool 8, perform the following steps:

1. From the APEX main menu (screen APEX-02), choose the ADAP option. You will advance to screen ADAP-01. Select the Summarize Cost and Quality of Fuels option. You will advance to screen ADAP-16.
2. From screen ADAP-16, choose the Fuel Cost Summary at Different Levels option. You will advance to screen ADAP-17. Because it is your objective to examine fuel costs in pool 8, choose the Pool-Level option. You will advance to screen ADAP-21.
3. Use the arrow keys to highlight the number 8 in the Select Pool window, and press the Enter key.
4. The program flashes the following message:

"Please Wait...Program Running"

The program is consolidating all records that belong to Pool 8 and processing the fuel cost data. This process takes a few seconds.

5. When the calculations are complete, the results will be displayed on in the same format as in screen ADAP-19. After viewing the results, exit the viewer. You will advance to screen ADAP-20. This screen offers you the option of printing a hard copy of the results. Choose the first option to print a hard copy of the results, or choose the second option if you elect not to print the results.



### 2B.3 TRANSFERRING VALUES TO RCFs

Steps 1-5 have allowed you to examine the cost and quality of fuels in pool 8. The next steps (6-10) will enable you to transfer these values to the RCF for subsequent use by ICARUS. Press the F11 key to return to screen ADAP-16, then perform the following steps:

6. From the ADAP-16 screen, choose the Pass Fuel Cost Values to RCF Files option. You will advance to screen ADAP-21. Highlight pool number 8 and press the Enter key.
7. After selecting pool 8, the program will evaluate fuel cost at the pool level, for that pool. Results will be displayed through the editor, as shown in screen ADAP-32. Note that the results contain only fuel cost data and that the fuels are grouped in five standard fuel categories. The standard fuel groupings were adopted in order to make the data compatible with the requirements of the ICARUS module.
8. After viewing the results, exit the viewer. You will advance to screen ADAP-60. This screen offers you three options:
  - a. Print the fuel cost data;
  - b. Change the values of fuel cost data; or
  - c. Proceed directly to RCF update.

You can also cancel the job at this point by pressing the F11 or F12 key.

9. If, after examining the results in step 7, you find that some of the calculated fuel cost data should be modified, choose the second option, Change Fuel Cost Values. You will advance to screen ADAP-33. This screen allows you to enter new values for those you wish to change. After completing an entry in a cell, always move the cursor out of the cell to make sure the changes you made are recognized by the program. When you are finished editing, press the F2 key to return to screen ADAP-33. You can verify your changes by choosing the second option again and viewing the new fuel cost data.
10. If you are satisfied with the revised values, you are ready to transfer the fuel cost data to the RCF. To do this, choose the third option, Proceed to RCF Update. The program will transfer the fuel cost data to a new RCF after prompting you for a file name. Press the F12 key to return to screen ADAP-01.

**APPENDIX 2C**  
**HEAT RATE DATA SOURCES AND TRANSFORMATIONS**



## APPENDIX 2C

### HEAT RATE DATA SOURCES AND TRANSFORMATIONS

#### 2C.1 THE EIA FORM 767 DATABASE FILE

The following information is included as programmer reference material.

The raw EIA Form 767 data were obtained in a FoxPro database format that has the component files listed in Table 2C.1.

#### 2C.2 THE EIA FORM 767 FUELCQ.DBF DATABASE FILE

Of the three database files presented in Table 2C.1, FUEL\_CQ is the largest; it contains the core information needed by the module. The FUEL\_CQ.DBF file has 31,681 records and has the structure and field definitions listed in Table 2C.2. The description and units for each field are given in Table 2C.3.

**TABLE 2C.1 EIA Form 767 Database**

File	Information Content
1 GEN.DBF	Monthly unit generation output
2 GEN2BLR.DBF	Boiler ID to Generator ID correspondence
3 PLTS.DBF	Address of each plant
4 STK_FLUE.DBF	Stack characteristics
5 FUEL_CQ.DBF	Fuel consumption and heat (Btu) content
6 COLLECTR.DBF	Collector ID and characteristics
7 BLRDSGN.DBF	Boiler ID and design characteristics
8 BLREMSTD.DBF	Boiler emission standards
9 BLR2STK.DBF	Boiler ID to stack ID correspondence
10 BLR2COLL.DBF	Boiler ID to collector ID correspondence
11 FGD.DBF	Scrubber characteristics

TABLE 2C.2 FUELCQ.DBF Database File

Field Number	Field Name	Type	Width	Decimal
1	PLTCODE	Character	5	
2	BLRID	Character	9	
3	BLRSTATUS	Character	2	
4	LOAD_HRS	Numeric	4	
5	MONTH	Numeric	2	
6	COAL_CONS	Numeric	7	1
7	OIL_CONS	Numeric	7	1
8	GAS_CONS	Numeric	7	1
9	OTHER_CODE	Character	2	
10	OTHER_CONS	Numeric	6	1
11	COAL_HHV	Numeric	7	1
12	COAL_SULF	Numeric	5	2
13	COAL_ASH	Numeric	5	2
14	OIL_HHV	Numeric	8	1
15	OIL_SULF	Numeric	5	2
16	GAS_HHV	Numeric	6	1
17	OTHER_HHV	Numeric	8	1
18	AVG_NIT_CN	Numeric	4	1

**TABLE 2C.3 Description of FUELCQ.DBF Fields**

Field Number	Fiel Name	Description	Units
1	PLTCODE	Plant code	
2	BLRID	Boiler ID	
3	BLRSTATUS	Boiler status	
4	LOAD_HRS	Annual hours under load	
5	MONTH	Month	
6	COAL_CONS	Coal consumption	10 <sup>3</sup> short tons
7	OIL_CONS	Oil consumption	10 <sup>3</sup> barrels
8	GAS_CONS	Gas consumption	10 <sup>6</sup> ft <sup>3</sup>
9	OTHER_CODE	Code for consumption of other fuels	
10	OTHER_CONS	Quantity of other fuels consumed	
11	COAL_HHV	Coal heating value	Btu/lb
12	COAL_SULF	Coal sulfur content	Percent by weight
13	COAL_ASH	Coal ash content	Percent by weight
14	OIL_HHV	Oil heating value	Btu/gal
15	OIL_SULF	Oil sulfur content	Percent
16	GAS_HHV	Gas heating value	Btu/ft <sup>3</sup>
17	OTHER_HHV	Heat value of other fuel consumed	
18	AVG_NIT_CN	Average nitrogen content	

### 2C.3 ADDING TOTAL ENERGY CONSUMPTION TO FUELCQ.DBF

In order to have the total energy consumption for each fuel type ready for the module, the following fields were added to the structure:

- COAL\_BTU, equivalent coal energy consumed ( $10^6$  Btu),
- OIL\_BTU, equivalent oil energy consumed ( $10^6$  Btu),
- GAS\_BTU, equivalent gas energy consumed ( $10^6$  Btu), and
- TOT\_BTU, total energy consumed ( $10^6$  Btu)

These fields were then filled by using the following formulas:

$$\begin{aligned} \text{COAL\_BTU} &= \text{COAL\_HHV} * \text{COAL\_CONS} * 2 \\ \text{OIL\_BTU} &= \text{OIL\_HHV} * \text{OIL\_CONS} * 42/1000 \\ \text{GA BTU} &= \text{GAS\_HHV} * \text{GAS\_CONS} \end{aligned}$$

### 2C.4 LINKING GEN2BLR.DBF WITH FUELCQ.DBF TO INSTALL GENERATOR ID

The 767 FUEL\_CQ.DBF database has a field for boiler IDs (BLRID) but no field for generator ID. The presence of a generator ID field in FUEL\_CQ.DBF is necessary to link FUEL\_CQ.DBF with GEN.DBF and obtain the corresponding generation at the unit level. For this purpose, a new field, GENID, was added to FUEL\_CQ.DBF. The GENID field was filled by mapping FUEL\_CQ.DBF with GEN2BLR.DBF through a common index consisting of PLTCODE and BLRID.

### 2C.5 LINKING GEN.DBF WITH FUELCQ.DBF TO INSTALL UNIT GENERATION

To provide information on generation output related with each boiler, GEN.DBF was interrelated with the modified FUEL\_CQ.DBF through an index, PLTCODE and GENID. This interrelation is possible because GENID in GEN.DBF is identical to GENID in FUEL\_CQ.DBF (both are EIA Form 767 files). Monthly and yearly generations were installed in FUEL\_CQ.DBF under the field name TOT\_GEN (generations are given in kilowatt-hours).

### 2C.6 LINKING THE APPI FILE WITH FUELCQ.DBF FOR PLANT LOCATION

To provide information on NERC code, pool, state, plant type, primary fuels, full company name, full plant name, and other location codes, FUEL\_CQ.DBF was linked with the TEST91.DBF (APPI) file. Specifically, the fields listed in Table 2C.4 were added to FUEL\_CQ.DBF for mapping with TEST\_91.DBF.

**TABLE 2C.4 Fields Added to  
FUELCQ.DBF**

Field Name	Description
NERCCODE	NERC code
POOL	Pool number
CNAME	Full company name
CCODE	Company code
PLTNAME	Full plant name
PLATECAP	Plant nameplate capacity
TYPE	Plant type (ST, CT, HY, etc.)
YEAR_UP	Start-up year
PFUEL	Primary fuel (BIT, FO2, etc.)

Mapping was done by first generating from TEST\_91.DBF a set of two-column tables relating PLTCODE with NERCCODE, POOL, CNAME, and PLTNAME. A one-to-many relationship was established between these sets of two-column tables with FUEL\_CQ.DBF and a common field, PLTCODE.

Mapping between TEST\_91.DBF and FUEL\_CQ.DBF for the PLATECAP, TYPE, YEAR-UP, and PFUEL fields, however, had to be done at the unit level. Some difficulty was encountered because GENID in TEST\_91.DBF is only partly identical to GENID in FUEL\_CQ.DBF. To address this problem, a three-step GENID matching procedure was developed to match as many GENIDs in both databases as possible. A common index comprising PLTCODE and GENID was used during the mapping process.

## 2C.7 INSERTING SIZE CATEGORIZATION FIELDS

In order to sort the various plants into sizes of 200, 400, 600, 800, 1000, and >1000 MW, an additional field named SIZ\_CAT was inserted in FUEL\_CQ.DBF.

## 2C.8 THE FINAL OR REQUIRED FUELCQ.DBF

The transformation steps discussed above led to the desired FUEL\_CQ.DBF structure. The final structure of FUEL\_CQ.DBF is shown in Table 2C.5.



**TABLE 2C.5 Final Structure of the  
FUELCQ.DBF Database File**

Field	Field Name	Type	Width
1	PLTCODE	Character	5
2	BLRID	Character	9
3	BLRSTATUS	Character	2
4	LOAD_HRS	Numeric	4
5	MONTH	Numeric	2
6	COAL_CONS	Numeric	7
7	OIL_CONS	Numeric	7
8	GAS_CONS	Numeric	7
9	OTHER_CODE	Character	2
10	OTHER_CONS	Numeric	6
11	COAL_HHV	Numeric	7
12	COAL_SULF	Numeric	5
13	COAL_ASH	Numeric	5
14	OIL_HHV	Numeric	8
15	OIL_SULF	Numeric	5
16	GAS_HHV	Numeric	6
17	OTHER_HHV	Numeric	8
18	AVG_NIT_CN	Numeric	4
19	COAL_BTU	Numeric	15
20	OIL_BTU	Numeric	13
21	GAS_BTU	Numeric	13
22	TOT_GEN	Numeric	10
23	GENID	Character	9
24	PLATECAP	Numeric	7
25	PFUEL	Character	3
26	NERCCODE	Character	5

TABLE 2C.5 (Cont.)

Field	Field Name	Type	Width
27	CCODE	Numeric	10
28	CNAME	Character	35
29	PLTNAME	Character	20
30	POOL	Numeric	3
31	STATE	Character	2
32	ST_NAME	Character	15
33	TYPE	Character	2
34	SIZE_CAT	Character	7
35	TOT_BTU	Numeric	15
36	YEAR_UP	Numeric	5



**APPENDIX 2D**  
**SAMPLE EXERCISE FOR HEAT RATE MODULE**



## APPENDIX 2D

### SAMPLE EXERCISE FOR HEAT RATE MODULE

#### 2D.1 SAMPLE PROBLEM

Suppose that you want to examine heat rates for pool 8 on the basis of actual 1991 performance of plants in pool 8.

#### 2D.2 SOLUTION STEPS:

To examine the empirical heat rate data, perform the following procedures:

1. Open the APEX main menu (screen APEX-02) and select the ADAP option. From screen ADAP-01, choose the Examine Heat Rate option. You will advance to screen ADAP-34.
2. Choose the Heat Rate Summary at Different Levels option. You will advance to screen ADAP-35. Because your objective is to examine the heat rates in pool 8, choose the Pool-Level option.
3. Selection of the Pool-Level option causes the program to create the pool reference file and advances you to screen ADAP-39. Before selecting pool 8, you might want to recall what utilities make up pool 8. You can press the F1 key at this point to see the pool help screen. To return to the pool list (screen ADAP-39), press the Esc key. Use the arrow keys to move down the list until the number 8 is highlighted, and press the Enter key.
4. The program flashes the following message:  
  
"Please wait...Program running"  
  
along with other information about the categorization process. This procedure takes a few seconds to complete.
5. When the calculations are complete, the results are displayed on screen ADAP-40. Note that the results display heat rates of all size and type categories independently of whether there are any entries (i.e., zeroes indicate no units present in the given category). Note also that for each fuel category, the average line indicates averages of the displayed columns except for the number of units.

SUMMARY OF RESULTS AVERAGE HEAT RATES FOR POOL 8							
STEAM TURBINE - ANT							
Size Cat	Heat Rate (Btu/kwh)	Age (yrs)	No. of Units	Ave Cap (Mw)	Ave C.F. (%)	Hours Load (hrs)	
200	0	0.0	0	0	0.0	0	
400	0	0.0	0	0	0.0	0	
600	0	0.0	0	0	0.0	0	
800	0	0.0	0	0	0.0	0	
<1000	0	0.0	0	0	0.0	0	
>1000	0	0.0	0	0	0.0	0	
Average	0	0.0	0	0	0.0	0	
-							
STEAM TURBINE - BIT							
Size Cat	Heat Rate (Btu/kwh)	Age (yrs)	No. of Units	Ave Cap (Mw)	Ave C.F. (%)	Hours Load (hrs)	
Line=1	Col=1	C:\APEX\ADAP.SRC\NEW HR\OUTPUT\MJK				Insert	WW=off

ADAP-40

- When you exit the editor, you will advance to screen ADAP-38. This screen offers you the option of printing a hard copy of the results. Choose an option. After either choice, you will return to screen ADAP-35. Press the F11 key to return to screen ADAP-34.

### 3 ICARUS

#### (Investigation of Costs and Reliability in Utility Systems)

The ICARUS module is a simulation tool for assessing the reliability, fuel use, and economic performance of electric utility generating systems. Input information includes capacity, forced outage rate, number of weeks of scheduled maintenance, and economic data for individual units, along with expected utility load characteristics. The model calculates (1) a system maintenance schedule, (2) the loss-of-load probability, (3) unserved demand for electrical energy, (4) required capacity reserve to meet a specified reliability criterion, (5) the effects of emergency interties, (6) expected energy generation and cost from each unit and block, (7) total generating systems costs, and (8) fuel use. Firm purchases and sales of electricity are also treated in the analysis. ICARUS uses a modified probabilistic simulation technique that maintains a high level of accuracy while significantly reducing computation requirements.

The following section describes the sequence of APEX screens used to control ICARUS case-study management options, program execution, and summary of results. Section 3.3 and Appendixes A and B describe recent updates to the program and support materials that are not covered in the original ICARUS user's guide (copied here for convenience in Appendix 3C). The manual describes the input requirements, program logic, and outputs in detail. You are urged to read these related sections for a more thorough coverage of topics not addressed in the APEX screen descriptions that follow.

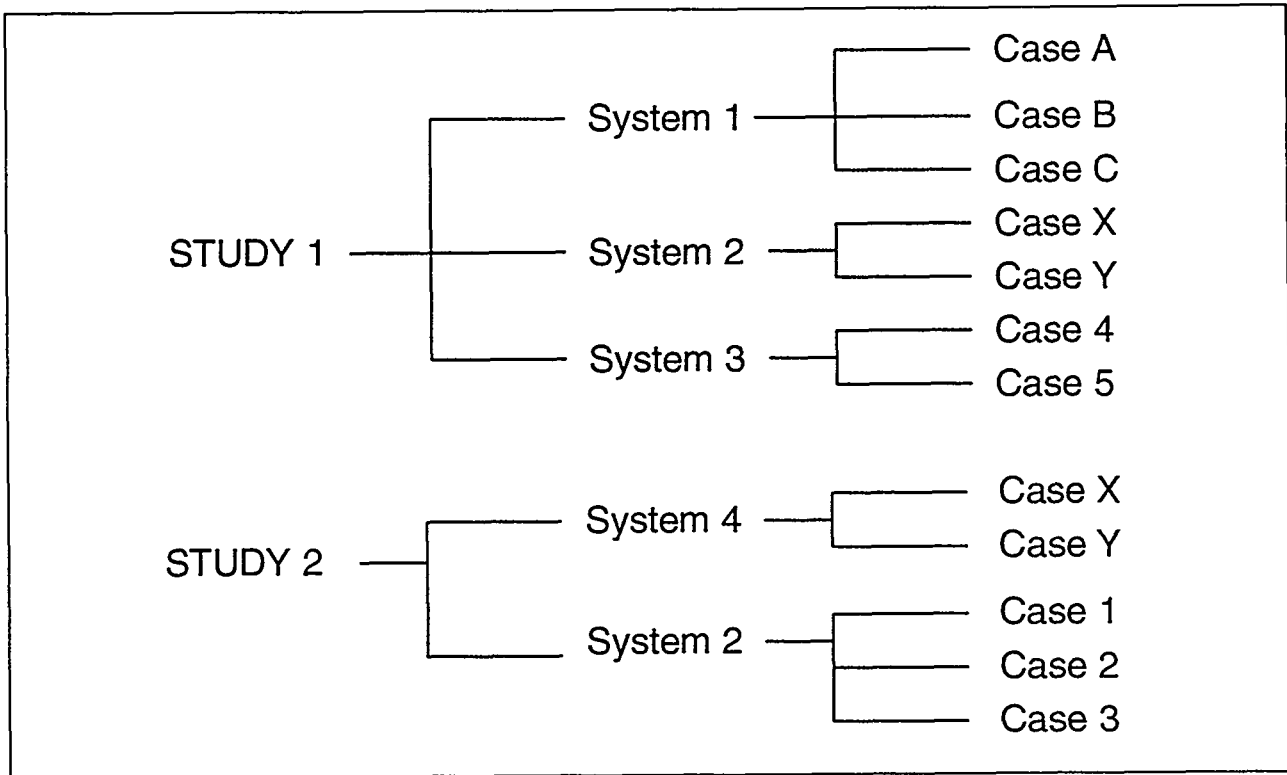
#### 3.1 ICARUS CASE MANAGEMENT AND SCREEN STRUCTURE

Sections 3.1 and 3.2 describe ICARUS case management conventions, which are designed with a three-level hierarchical structure, as illustrated in Figure 3.1. The purpose of this structure is to organize case studies in the following ways:

- by general concept (e.g., study = oil embargo, coal strike, flood effects, etc.),
- by generating system (e.g., system = power pool 1, utility x, etc.), and
- by general case assumptions (e.g., case = 20% oil use reduction, 25% oil use reduction, 50% oil use reduction, etc.).

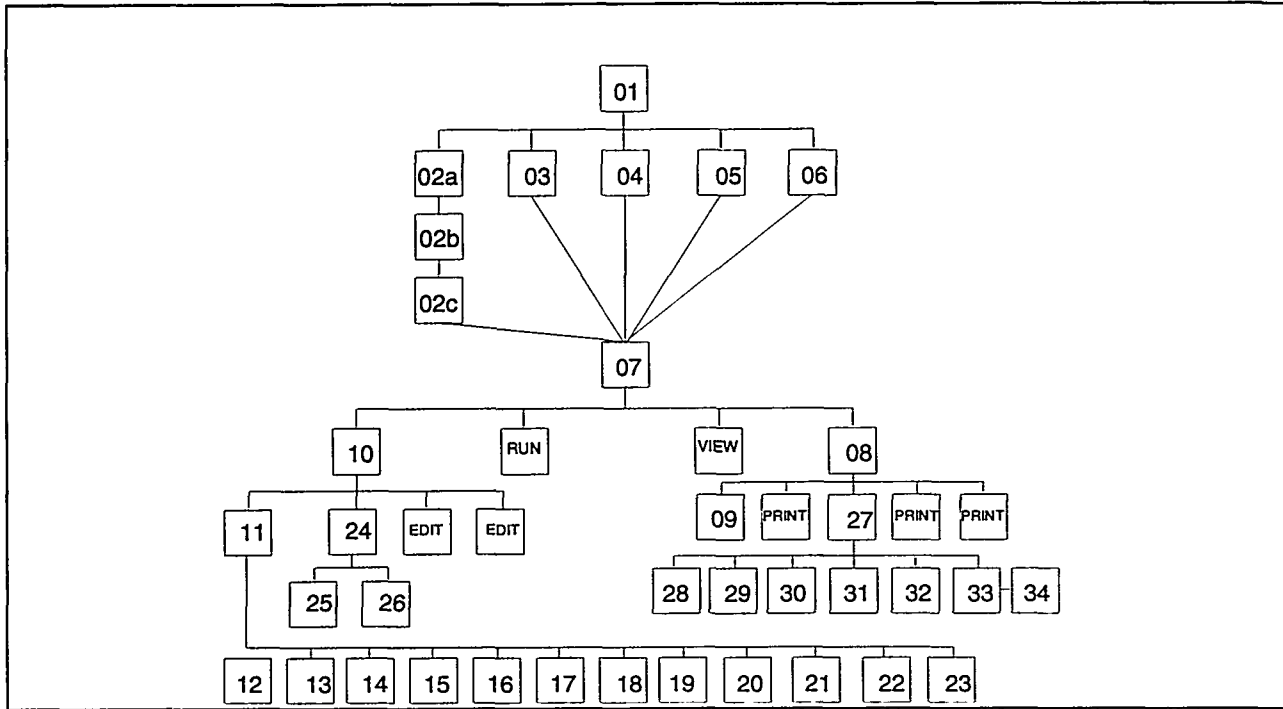
The details of this hierarchical structure and the user-defined choices are described in the following section.





**FIGURE 3.1 Three-Level Hierarchical Structure**

The overall screen sequence for managing and running ICARUS cases is illustrated below.



**ICARUS Screen Index**

ICARUS-01	ICARUS Data Management	page 5	ICARUS-17	Change Costs for a Unit	page 40
ICARUS-2a	Study Creation	page 10	ICARUS-18	Change Block Loading Order	page 43
ICARUS-2b	Select a System	page 11	ICARUS-19	Change Maintenance Information	page 46
ICARUS-2c	Add a Case	page 12	ICARUS-20	Change Block Information	page 49
ICARUS-03	Copy Case	page 13	ICARUS-21	Change Print Indicator	page 52
ICARUS-04	Delete a Case	page 15	ICARUS-22	Stop Execution in Midyear	page 55
ICARUS-05	Back Up Case to Disk	page 16	ICARUS-23	Capacity Factor Limits	page 56
ICARUS-06	Restore a Case	page 18	ICARUS-24	Edit ICARUS Unit Inventory	page 59
ICARUS-07	Select an Option (Functions)	page 20	ICARUS-25	Unit Inventory Standard Edit	page 62
ICARUS-08	Select a Print Option	page 21	ICARUS-26	Unit Inventory Outages/Derating	page 65
ICARUS-09	Output Print Range	page 22	ICARUS-27	Customized Report Generator	page 67
ICARUS-10	Select an Option (Edits)	page 23	ICARUS-28	Customized Report-Standard	page 69
ICARUS-11	Update Card Selection	page 24	ICARUS-29	Customized Report-User Defined	page 71
ICARUS-12	Change Annual Peak Demand	page 25	ICARUS-30	Customized Report-Units	page 73
ICARUS-13	Change Forced Outage Rate	page 29	ICARUS-31	Customized Report-Years	page 75
ICARUS-14	Change Fuel Cost	page 32	ICARUS-32	Customized Report-Select Fields	page 76
ICARUS-15	Retire a Unit	page 35	ICARUS-33	Customized Report-Select Order	page 77
ICARUS-16	Reschedule System Maintenance	page 38	ICARUS-34	Customized Report-Select Order	page 79

### **3.2 ICARUS SCREENS**

This section provides you with a picture of each significant screen in the ICARUS module of APEX. Following the screen image, there is a section called Purpose that describes the objective of that screen. When key options are associated with a screen, they appear in a section called Options. A third section, titled Data Fields, describes each data space on the screen into which you can enter data. The final section, called Buttons, describes the button options available on that screen. The data screens appear with example data that can be considered typical for ICARUS.

ICARUS Data Management		3:14:10 pm
Study:	<input type="text" value="Add New Study"/>	< Add >
		< Copy From >
System:	<input type="text"/>	< Delete >
		< Backup >
Case:	<input type="text"/>	< Restore >
(*) Enter/View Case Notes		< ICARUS Menu >
		< APEX Menu >

ICARUS-01

**Purpose**

Screen ICARUS-01 allows you to retrieve electronically stored ICARUS configurations and scenarios and to create the necessary data structures to build new configurations. Data contained in ICARUS are aggregated and organized at three different levels. As illustrated in Figure 3.1, the "study" level is at the top of the data management hierarchy and contains one or more systems. For example, a study of greenhouse gas emissions may be conducted for several different utility systems. The "system" level is the second level of data management. The third level allows you to define one or more cases (i.e., scenarios), for example, high, medium, and low growth rate scenarios.

Screen ICARUS-01 allows you to create a new study, system, or case. You can enter notes that contain textual details describing this ICARUS configuration. You can also select a predefined case for editing and processing. Data associated with entire studies or systems as well as individual cases can be deleted. Also, data for one case can be copied to another, or a case can be backed up and restored in a subsequent session.

You must select a study, system, and case before you can proceed to other ICARUS menus.

## Options

- Screen ICARUS-01 is divided into two parts. The left side consists of pop-up windows that display the studies, systems, and cases you have previously defined. The right side of the screen contains buttons that control screen functions. The buttons are either active (blue in color) or inactive (light gray). If a button is light gray, it is inactive and cannot be invoked until further selections are made. Buttons become active or inactive as selections are made.
- To enter or view notes associated with the newly defined or selected system, click on the Enter/View Case Notes option. This button is activated only when a study, system, and case have been selected. You enter text into the window by using the keyboard. The F2 key will permanently save any user note additions and modifications made in this session and remove the user notes window. User notes are permanently associated and stored with each case and can be retrieved by using the case selection process. Notes are also saved when a case is backed up and restored when the selected case is retrieved. However, when one case is copied to another case, user notes are not copied. A separate set of user notes is associated with the backup routine. These notes are used to document backup procedures and the physical location of files.
- To exit the user notes window and disregard any changes that were made in the session, press the Esc key.
- Press the F5 key to invoke the search menu (see Section 1.2).

## Buttons

### <Add>

The <Add> button is active only if the Add New...." prompt is displayed in one of the pop-up boxes. Once a study, system, and case have been selected, the <Add> button is deactivated and all other buttons on the right side of the screen are activated. After a case has been defined in the data management hierarchy, you should click on the button adjacent to the Enter/View Case Notes option and enter text that describes the case in the pop-up window. To exit this window, press the F2 key to save your notes. These notes can be viewed whenever the case has been selected by using the pop-up menus.

Once a case has been created in the data management hierarchy, all databases that describe a network (i.e., node and link data sets) will be created but will contain no information. Data can be input into these fields or copied from an existing case. To add

a study, system, or case to the data management hierarchy, you must select that option in the pop-up menu.

To add a study, go to the shaded rectangle area adjacent to the "Study:" prompt in the upper window and select Add New Study from the pop-up list. Then, click on the <Add> button on the right side of the screen. A pop-up box will appear in the middle of the screen and prompt you for a new study name, a new system name, and a new case name. Press the F2 key to exit the screen and return to the data management menu.

To add a new system to the data management hierarchy, select the study to which you want to add the system. Go to the shaded rectangle area next to the "System:" prompt and select Add New System from ADAP from the pop-up list. Click on the <Add> button on the right side of the screen. A pop-up box will appear in the middle of the screen and display the study to which you are adding a system. The screen also prompts you for the new system name and new case names.

To add a new case to an existing study and system, select a system and study by using the study and system pop-up prompts. Select Add New Case from the "Case:" prompt pop-up. Click on the <Add> button on the right side of the screen. A pop-up will appear in the middle of the screen and display the study and system to which you are adding and prompts you for the new case name. Once the new case has been added to the data management system, the date on which the case was created is filed and will appear on the screen every time that database is retrieved. The data management system also keeps track of the last time the case was accessed.

Note that you must select a study before selecting a system, and you must select a study and system before you can select a case. If you select a new study after a study, system, and case have been selected, the system and case pop-up boxes become blank. You must then make new selections before proceeding.

To avoid ambiguity, the data management system will not allow you to create duplicate study, system, or case names. All names must be unique at a given hierarchy level. When you attempt to create duplicate entries, a warning appears on the screen. No two studies can have the same name; however, identical system names are permitted as long as the names are not contained in the same study. Likewise, identical case names are permitted

as long as the names are not contained in the same study and system.

**<Copy From>**

The <Copy From> button allows you to copy data from an existing case to another case. First, you must identify a destination case (i.e., the case to which the data will be copied) by selecting the study, system, and case by using the pop-up menus on the left side of the screen. If the destination case has not yet been created through the data management system, you must add it to the data management hierarchy by using the <Add> button.

Once you have selected a destination case, click on the <Copy From> button. The copy menu will be displayed on the screen (screen ICARUS-03).

**<Delete>**

The <Delete> button removes the data management names and all associated data files at three different hierarchical levels (i.e., study, systems, and cases). Deletion of a study, system, or case is *Permanent* (i.e., files cannot be retrieved or reconstructed). To delete a study, select the desired study from the study pop-up menu and click on the <Delete> button on the right side of the screen. The delete screen will be displayed (screen ICARUS-04). Answering "Y" on the delete screen will destroy all data for the study and all systems and cases under the selected study. Answering "N" will keep all data intact and active in the data management system. After you have answered the question on this screen, the delete screen is removed and you return to the data management menu.

To delete a system, select System under a specific study, select the system for deletion by using the study and system pop-up menus, and click on the <Delete> button on the right side of the screen.

To delete a specific case, select the study, system, and case from the pop-up menus and click on the <Delete> button. Answering "Y" on the following delete screen will destroy only that one case and leave the system, study, and all other cases associated with that system intact. However, if there is only one case under a study and system, both the study and system labels will be removed from the data management system.

- <Backup>** The backup feature allows you to save a case to a hard drive or other removable or portable storage media (e.g., 3.5-in. floppy disk, tape drive, network disk, or Bernoulli disk). To activate the <Backup> button, select a study, system, and case by using the pop-up menus. Next, click on the <Backup> button to display the backup screen (screen ICARUS-05).
- <Restore>** The <Restore> button allows you to retrieve a case that was previously backed up. This option ignores the study, system, and case currently selected on screen ICARUS-01. The list of backed up studies, systems, and cases can be selected through the data management menu. To restore a case, simply click on the <Restore> button (it is always activated) on the lower portion of the data management menu. This action will invoke the restore screen (screen ICARUS-06).
- <ICARUS Menu>** To advance to the ICARUS Main Menu (screen ICARUS-07), click on the <ICARUS Menu> button. This button is activated only when a study, system, and case have been selected.
- <APEX>** To return to the APEX main menu (screen APEX-01), click on the <APEX> button. This button is always activated.



ICARUS Data Management		8:43:28 am	
Study:	<input type="text" value="Add New Study"/>	< Add >	
		< Copy >	
System:	<input type="text"/>	< Delete >	
		< Backup >	
<input type="text"/>			
Study Creation			
Enter New Study Name: New England Test Study			
			Menu >
Press Enter to Continue, F3 to Cancel			enu >

## ICARUS-2a

**Purpose**

Screen ICARUS-2a allows you to define a new study name.

**Options**

**Enter** After entering the study name, press this key to exit the pop-up and proceed to screen ICARUS-2b. The study name cannot be blank.

**F3** Press this key to cancel and return to screen ICARUS-01.

**Data Fields**

Enter new study name: Type in the name of the study you wish to create.

The screenshot shows a terminal window titled "ICARUS Data Management" with a timestamp of "2:42:45 pm". The main area contains a "Study:" label followed by a text box containing "Add New Study". To the right of this box are navigation arrows and the word "Add". Below this is a large rectangular area titled "SELECT A SYSTEM FROM ADAP" containing a list of system identifiers and names: "U1 ALABAMA POWER COMPANY", "U2 AEP/AMERICAN ELECTRIC POWER CO, INC", "P11 Wisconsin-Upper", and "P14 New England Power Pool". At the bottom of the screen, there are two function key prompts: "F11 (Exit)" on the left and "F12 (Main Menu)" on the right.

ICARUS-2b

### Purpose

Screen ICARUS-2b allows you to select a system that was previously defined in ADAP and add it to the newly created study.

### Options

- Enter** Select the system you want to add to this study from the pop-up list of systems (created previously in ADAP) and press the Enter key to proceed to screen ICARUS-2c.
- F11** Press this key to cancel and return to screen ICARUS-01.
- F12** Press this key to cancel and return to screen ICARUS-01.

The screenshot shows the 'ICARUS Data Management' interface. At the top right, the time is 3:42:45 pm. The main window has a title bar 'ICARUS Data Management'. Below the title bar, there are two input fields: 'Study:' with a button labeled 'Add New Study' and 'System:' with an empty input box. To the right of these fields is a menu with options: '< Add >', '< Copy From >', '< Delete >', '< Backup >', and '< ore >'. A 'Study Creation' pop-up window is overlaid on the main screen. It contains the following text: 'Enter New Study Name: New England Test Study', 'Enter New System Name: P14 New England Power Pool', 'Enter New Case Name: NE Pool Base Case', and 'Press Enter to Continue, F3 to Cancel'. To the right of the pop-up window, there are menu options: 'Menu >' and 'enu >'.

ICARUS-2c

**Purpose**

Screen ICARUS-2c allows you to define a case name to add to a newly created study and system.

**Options**

**Enter** After entering the case name, press this key to exit the pop-up and return to screen ICARUS-01. The case name cannot be blank.

**F3** Press this key to cancel and return to ICARUS-01.

**Data Fields**

Enter new case name: Enter the case name to be added.

ICARUS-03

### Purpose

Screen ICARUS-03 allows you to copy electronically stored data for one existing ICARUS case to another existing case. Any information that is contained in the destination data set (i.e., the case to which the data are copied) will be *permanently* deleted once this procedure is initiated. The data contained in the origin case (i.e., the case from which the data are copied) are not altered by this procedure.

### Options

- Screen ICARUS-03 is divided into two parts. The left side of the screen contains pop-up windows in which you select the study, system, and case from which the data will be copied (i.e., origin case). The right side of the window displays the study, system, and case to which data will be copied (destination case). This case was previously selected in screen ICARUS-01. Click and drag on the pop-up boxes to make the desired selections.

### Buttons

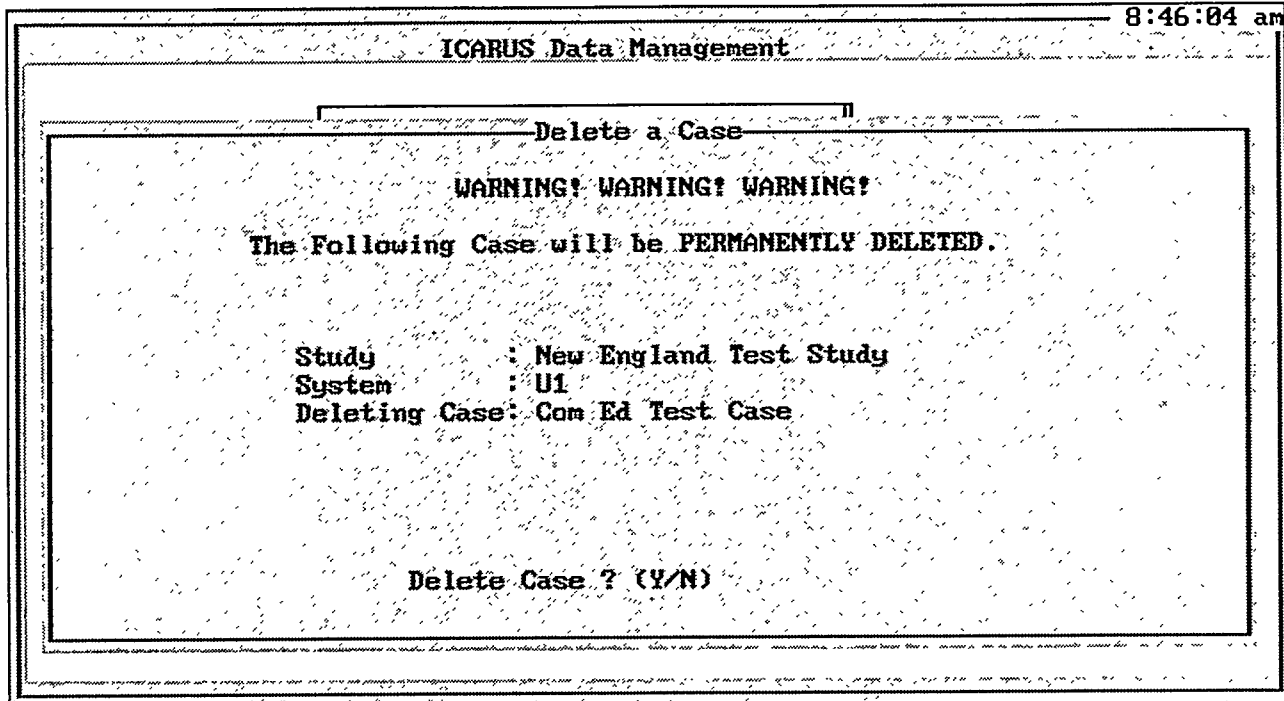
<OK>

After you have selected the origin case, click on the <OK> button to copy the case data. The <OK> button is active only when the destination case has been selected. Any information that was previously contained in the destination case will be destroyed

and replaced with a copy of the information contained in the origin case. Only cases can be copied; entire studies or systems *cannot* be copied. To help ensure that data are not mistakenly deleted, a verification message alerting you that data will be deleted is displayed after the <OK> button is clicked. The copy procedure will not allow the destination and origin case to be identical. If you attempt to copy a set of data onto itself, a warning message will be displayed on the screen.

**<Exit>**

To cancel the copy procedure and return to the previous menu, click on the <Exit> button. The <Exit> button is always active.



ICARUS-04

### Purpose

Screen ICARUS-04 informs you that all data associated with one or more cases will be deleted after user verification (i.e., approval). File and directory structures and database management entries associated with the cases will also be removed. Cases and associated data will be *permanently* deleted once the deletion procedure is initiated. However, data can be recovered if they are first backed up by using the backup procedures.

### Options

- Screen ICARUS-04 lists all cases and associated data files that will be permanently deleted (i.e., files cannot be retrieved or reconstructed). Answering "Y" to the delete query will remove all data. Answering "N" will keep all data intact and active in the data management system. After the question on this screen has been answered, the delete screen (ICARUS-04) is removed and you return to the data management menu.

ICARUS Data Management 8:47:25 am

Backup Case to Disk

Case Being Backed Up:

Study: New England Test Study

System: U1

Case: Com Ed Test Case

Backup to Drive: A

(.) Enter Backup Notes

<Backup> <Cancel>

ICARUS-05

### Purpose

Screen ICARUS-05 lists the case you selected for backup in the database management screen (ICARUS-01). All data and information associated with the selected case are copied onto an electronic storage media accessed by the device you specify. Note that the case is copied; that is, the case is not deleted or altered.

### Options

- To back up the case displayed on the left side of the screen, first select the drive on which the data will be backed up, by clicking on the pop-up menu labeled "Backup to Drive:." Only those drives that are connected to your computer are displayed in the pop-up menu. If you select drive A, B, or D, a message will appear reminding you to insert a disk into the specified drive. If you do not insert a disk into the backup drive and the backup command is invoked, a DOS error message is displayed at the bottom of the screen.
- To enter user notes regarding backing up the case, click on the Enter Backup Notes option. You enter text into the window by using the keyboard. User notes associated with the backup routine are usually used to document backup procedures and the physical location of files. The F2 key will permanently save any user note additions and modifications made in this session and remove the user notes window. To exit the user notes window and disregard any changes that were made in the session, press the Esc key.

- Press the F5 key to invoke the search menu (see Section 1.2).

Note: If the drive you specified in "Backup to Drive:" is a Bernoulli disk drive, be sure to Reboot before trying to write to a new cartridge.

## Buttons

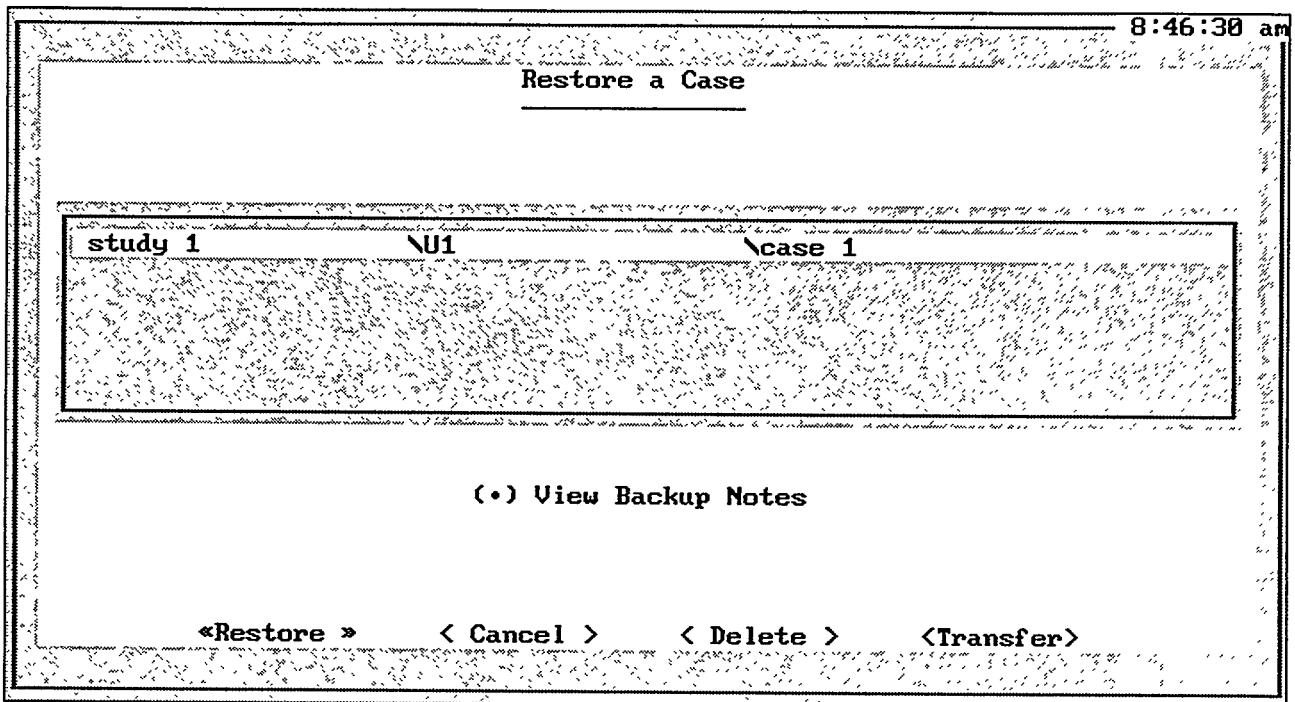
### <Backup>

To back up the case, click on the <Backup> button. If you selected a drive in which only read access is permitted, a warning message appears on the screen and you return to the data management menu. You are also warned if there is insufficient storage space on the selected drive or if there is a problem with writing to the disk (i.e., disk segment error).

### <Cancel>

If you decide not to back up the case, click on the <Cancel> button. When either the <Backup> or <Cancel> button is clicked, the backup window disappears and you return to the data management screen.





ICARUS-06

### Purpose

Screen ICARUS-06 lists all the cases that have been backed up with the backup procedure and are currently available to be restored (note that backed up cases can be deleted from this list). The screen allows you to restore or delete backup cases, view backup notes, and transfer a case from one machine to another.

### Options

- To restore a case that was backed up on the current machine, select the system, study, and case combination from the middle window by highlighting the entry and pressing the Enter key. The backup drive and date will appear at the top of the screen. To restore this case, click on the <Restore> button. To restore a case that was backed up on a different machine (on a removable storage medium), click on the <Transfer> button.

### Buttons

**<Restore>**      To restore the highlighted case, click on the <Restore> button.

- <Cancel>** If you decide not to restore the case, click on the <Cancel> button. When you click on either the <Restore> or <Cancel> button, the restore window disappears and you return to the data management screen.
- <Delete>** To delete the highlighted case from the list, click on the <Delete> button. Once a backed up case has been deleted, it cannot be recovered. This procedure only deletes the entry from the internal list of backed up cases and will not prompt you to insert a disk from which to delete case study files.
- <Transfer>** To retrieve a case that has been backed up by a different machine on a removable storage medium, click on the <Transfer> button.

```
APEX 3:11:46 pm
Current Study: ERASABLE: Test Study 1    Current System: U1 ALABAMA POWE
Current Case: Base Case

          SELECT AN OPTION
          ( ) Edit ICARUS Input Files
          ( ) Run ICARUS
          ( ) View Results of Run
          ( ) Print Menu
          F11 (Exit)    F12 (Main Menu)
```

## ICARUS-07

### Purpose

Screen ICARUS-07 allows you to modify the ICARUS input files or proceed with an ICARUS run.

### Options

- To edit ICARUS input data, select the first option. You will advance to screen ICARUS-10.
- To run ICARUS, select the second option.
- To view the results of a run, select the third option.
- To print the results, select the fourth option. You will advance to screen ICARUS-08.

**F11** Press this key to return to screen ICARUS-01.

**F12** Press this key to return to screen ICARUS-01.

```
APEX 10:44:11 am
Current Study: Pool 11 Study      Current System: P11
Current Case:  Base Case

                SELECT A PRINT OPTION

      ( ) Print A Range of Output Lines
      ( ) Print Entire Output
      ( ) Print Custom ICARUS Reports
      ( ) Print Input Load File
      ( ) Print Input Unit File

F11 (Exit)      F12 (Main Menu)
```

ICARUS-08

### Purpose

Screen ICARUS-08 allows you to define printing options.

### Options

- To print a range of output lines, select the first option. You will advance to screen ICARUS-09.
- To print the entire output, select the second option.
- To print custom ICARUS reports, select the third option.
- To print the input load file, select the fourth option.
- To print the input unit file, select the fifth option.

**F11** Press this key to return to screen ICARUS-07.

**F12** Press this key to return to screen ICARUS-01.

APEX 10:44:26 am  
Current Study: Pool 11 Study Current System: P11  
Current Case: Base Case

ICARUS OUTPUT PRINT RANGE

First Line to Print: 1  
Last Line to Print: 1

Press F2 When Done

## ICARUS-09

### Purpose

Screen ICARUS-09 allows you to specify the range of output lines you wish to print.

### Options

- F2** Press this key to print the lines specified in the pop-up window. The default values that first appear in the data fields are the first and last lines of the ICARUS output file.

### Data Fields

First Line to Print: Enter the line number of the first line you wish to print.

Last Line to Print: Enter the line number of the last line you wish to print.

```

APEX 2:09:25 pm
Study: TEST 1
Case:  BASE CASE
System: U1 ALABAMA POWER COMPANY

SELECT AN OPTION

( ) Edit ICARUS Update Cards
( ) Edit ICARUS Unit Inventory
( ) Directly Edit ICARUS Loaddata File
( ) Directly Edit ICARUS Unitdata File
F11 (Exit) F12 (Main Menu)

```

## ICARUS-10

### Purpose

Screen ICARUS-10 provides several methods for modifying ICARUS data input files. The first two options provide menu-based editing screens for making changes to the inputs, whereas the third and fourth options allow you to modify the loaddata and unitdata files directly by using a text editor.

### Options

- To insert new update cards or to edit existing update cards, select the first option. You will advance to screen ICARUS-11.
- To access menu-based options to modify the unit inventory, select the second option. You will advance to screen ICARUS-24.
- To edit the loaddata file by using a text editor, select the third option.
- To edit the unitdata file by using a text editor, select the fourth option.

**F11** Press this key to return to screen ICARUS-07.

**F12** Press this key to return to screen ICARUS-01.

```

APEX                                     3:36:39 pm
Update Card Selection

[ ] Update 1 - Change Annual Peak Demand
[ ] Update 3 - Change Forced Outage Rate of a Unit
[ ] Update 4 - Change the Fuel Cost of a Unit
[ ] Update 5 - Retire a Unit
[ ] Update 7 - Reschedule Maintenance for the Entire System
[ ] Update 8 - Change Costs for a Single Unit
[ ] Update 10 - Change the Loading Order for a Block of a Unit
[ ] Update 11 - Change Maintenance Information for a Unit
[ ] Update 12 - Change Block Information for a Unit
[ ] Update 14 - Change the Value of the Print Indicator (KP)
[ ] Update 15 - Stop Execution in Mid-Year
[ ] Update 16 - Capacity Factor Limits

<Edit Cards>                            < Quit >

```

ICARUS-11

### Purpose

Screen ICARUS-11 provides a list of options for adding and editing update cards. APEX automatically places these input cards into the correct sequence of records in the loaddata file.

### Options

- Select one or more of the 12 update options identified on this screen by clicking on the desired checkboxes. The update numbers correspond to the numbering system used in ICARUS (as reported in Sec. 3.3.9 and Appendix 3C). A few of the ICARUS update options have been intentionally omitted because they have limited usefulness and can be better implemented with alternative input modifications.

### Buttons

**<Edit Cards>** Click on the <Edit Cards> button to proceed with the editing and data entry steps for each update category selected from this screen.

**<Quit>** Click on the <Quit> button to exit this screen and return to screen ICARUS-10. All changes to the update cards and the loaddata file are retained when you exit this screen.

12:29:38 pm

**Change the Annual Peak Demand**

**Updates Entered:**

Year	Week	Type
1994		3 L
1995		1 M

Highlight Item, F4 Edit Next, and F8 Edit F9 to Zoom/Unzoom

---

**Enter Update Information**

Year:  Week: 

 New Peak Load (MW): 
  
OR  

 Peak Load Multiplier:

ICARUS-12

**Purpose**

Screen ICARUS-12 modifies the annual peak load, either by replacing the old value with a new peak load (expressed in megawatts) or by specifying a multiplier that will be applied to the previous peak load. This screen corresponds to Update 1.

**Options**

- Screen ICARUS-12 is divided into two parts. The upper browse window displays existing updates for the annual peak load and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined peak load update and also enter new data for inserting additional peak load updates.
  - To view the existing list of updates in tabular format, activate the upper window by clicking anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.



- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the peak load is to be adjusted.

Week: Enter the week in which the peak load is to be adjusted.

New Peak Load (MW) or Peak Load Multiplier: Enter either the new peak load in megawatts or a multiplier that will be applied to the previous peak load. The change will be applied once in the specified year and week, after which the peak load will remain unchanged until further updates are specified. The type of change will be indicated in the upper window: "L" for new peak load or "M" for multiplier.

## Buttons

**<Add>**

**<Change>**

To add or change a peak load update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window, and click on the <Change> button to activate the modifications.

**<Delete>**

To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the peak load update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete those entries.

**<Clear>**

To clear the input fields of all data and return to the Add mode, click on the <Clear> button.

**<OK>**

When you have completed all changes and additions to the peak load update cards, press the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

3:47:51 pm

**Delete Entries**  
Use the SPACEBAR to Tag/Untag Entries

Press F2 When Finished

Year	Week	Type
1995		I M

▲  
◆  
▼

Delete Screen

### Purpose

The Delete screen allows you to delete update cards from ICARUS input files. This screen can be accessed from each update option except Update 15, which contains its own cancel feature.

### Options

- To mark (tag) a record for deletion, highlight the entry and press the spacebar. A diamond character (◆) will appear next to the record entry. To unmark entries, highlight the entry and press the spacebar. The diamond character will disappear; the record is no longer tagged for deletion. When all the desired records have been marked, press the F2 key to delete the records.

12:05:35 pm

**Change the Forced Outage Rate**

**Updates Entered:**

Name	Number	Year	Week	Rate
NUG	100	1994		44

Highlight Item, F4 Edit Next, and F8 Edit F9 to Zoom/Unzoom

---

**Enter Update Information**

Year:       Week:       Unit:

Forced Outage Rate (Frac):

< Add >    <Delete >    < Clear >    < OK >

ICARUS-13

**Purpose**

Screen ICARUS-13 modifies the forced outage rate for a generating unit in a specific year and week of a simulation. This screen corresponds to Update 3.

**Options**

- Screen ICARUS-13 is divided into two parts. The upper browse window displays existing updates for forced outage rates and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined forced outage rate update and enter new data for inserting additional forced outage rate updates.
  - To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the forced outage rate is to be adjusted.

Week: Enter the week in which the forced outage rate is to be adjusted.

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

Forced Outage Rate (Frac): Enter the new forced outage rate (expressed as a fraction) for the selected unit.

## Buttons

**<Add>**

**<Change>**

To add or change a forced outage rate update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and to the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.

**<Delete>**

To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the forced outage rate update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.

**<Clear>**

To clear the input fields of all data and return to the Add mode, click on the <Clear> button.

**<OK>**

When you have completed all changes and additions to the forced outage rate update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

12:05:48 pm

**Change the Fuel Cost**

Updates Entered:

Unit	Number	Year	Week	Fuel Cost
PIN PEAK	123	1994		9

Highlight Item, F4 Edit Next, and F8 Edit F9 to Zoom/Unzoom

---

Enter Update Information

Year:  Week:  Unit:

Fuel Cost (Cents/MMBTU):

ICARUS-14

**Purpose**

Screen ICARUS-14 modifies the fuel cost for a generating unit in a specific year and week of a simulation. If the economic loading order option is invoked for the ICARUS simulation, the loading order for this unit will automatically be recalculated. This screen corresponds to Update 4.

**Options**

- Screen ICARUS-14 is divided into two parts. The upper browse window displays existing updates for fuel costs and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined fuel cost update and enter new data for inserting additional fuel cost updates.
  - To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the fuel cost is to be adjusted.

Week: Enter the week in which the fuel cost is to be adjusted.

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

Fuel Cost (Cents/MMBTU): Enter the new fuel cost (expressed in cents per million Btu) for the selected unit.

## Buttons

**<Add>**

**<Change>**

To add or change a fuel cost update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.

**<Delete>**

To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the fuel cost update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.

**<Clear>**

To clear the input fields of all data and return to the Add mode, click on the <Clear> button.



**<OK>**

When you have completed all changes and additions to the fuel cost update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

12:06:00 pm

**Retire A Unit**

**Updates Entered:**

Unit	Number	Retire Year	Retire Week
PIN PEAK	134	1999	1

Highlight Item, F4 Edit Next, and F8 Edit F9 to Zoom/Unzoom

---

**Enter Update Information**

Retire Year:       Retire Week:

Unit:

**ICARUS-15**

**Purpose**

Screen ICARUS-15 is used to retire a unit in a specific year and week of a simulation. This screen corresponds to Update 5.

**Options**

- Screen ICARUS-15 is divided into two parts. The upper browse window displays existing updates for retirements and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined retirement update and enter new data for inserting additional retirement updates.
  - To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the retirement is to occur.

Week: Enter the week in which the retirement is to occur.

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

## Buttons

**<Add>**

**<Change>**

To add or change a retirement update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.

**<Delete>**

To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the retirement update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.

**<Clear>**

To clear the input fields of all data and return to the Add mode, click on the <Clear> button.

**<OK>**

When you have completed all changes and additions to the retirement update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

12:06:11 pm	
<b>Reschedule System Maintenance</b>	
<b>Updates Entered:</b>	
Year	Week
1994	1
Highlight Item, F4 Edit Next, and F8 Edit      F9 to Zoom/Unzoom	
<b>Enter Update Information</b>	
Year: <input type="text" value="0"/>	Week: <input type="text" value="0"/>
< Add >    < Delete >    < Clear >    < OK >	

ICARUS-16

**Purpose**

Screen ICARUS-16 reschedules maintenance for the entire generating system in a specific year and week of a simulation. This screen corresponds to Update 7.

**Options**

- Screen ICARUS-16 is divided into two parts. The upper browse window displays existing updates for maintenance rescheduling and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined maintenance rescheduling update and enter new data for inserting additional maintenance rescheduling updates.
  - To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the maintenance rescheduling is to occur.

Week: Enter the week in which the maintenance rescheduling is to occur.

## Buttons

**<Add>**

**<Change>**

To add or change a maintenance rescheduling update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on <Change> button to activate the modifications.

**<Delete>**

To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the maintenance rescheduling update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.

**<Clear>**

To clear the input fields of all data and return to the Add mode, click on the <Clear> button.

**<OK>**

When you have completed all changes and additions to the maintenance rescheduling update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

12:12:23 pm

**Change Costs for a Unit**

Updates Entered:

Unit	Number	Year	Week	Capital	Fuel	Variabl
PALO VER	423	1994	2	100	100	

Highlight Item, F4 Edit Next, and F8 Edit      F9 to Zoom/Unzoom

---

**Enter Update Information**

Year: 0

Week: 0

Unit: ABILENE1 - 1

	Costs
Capital (\$/kW):	0.000
Fuel (Cents/MMBTU):	0.000
Var. O&M (Mills/kWh):	0.000
Fixed O&M (\$/kW-yr):	0.000

< Add >    < Delete >    < Clear >    < OK >

ICARUS-17

**Purpose**

Screen ICARUS-17 modifies costs for a generating unit in a specific year and week of a simulation. If the economic loading order option is invoked for the ICARUS simulation, the loading order for this unit will automatically be recalculated. This screen corresponds to Update 8.

**Options**

- Screen ICARUS-17 is divided into two parts. The upper browse window displays existing updates for unit costs and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined unit cost update and enter new data for inserting additional unit cost updates.

- To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.

**F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the unit costs are to be adjusted.

Week: Enter the week in which the unit costs are to be adjusted.

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

Capital (\$/kW): Enter the new capital cost (expressed in dollars per kilowatt).

Fuel (Cents/MMBTU): Enter the new fuel cost (expressed in cents per million Btu).

Var. O&M (Mills/kWh): Enter the new variable O&M cost (expressed in mills per kilowatt-hour [same as dollars per megawatt-hour]).

Fixed O&M (\$/kW-yr): Enter the new fixed O&M cost (expressed in dollars per kilowatt-year).

## Buttons

**<Add>**

**<Change>**

To add or change a unit cost update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.



- <Delete>** To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the unit cost update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.
- <Clear>** To clear the input fields of all data and return to the Add mode, click on the <Clear> button.
- <OK>** When you have completed all changes and additions to the unit cost update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

12:06:49 pm

**Change Block Loading Order**

Updates Entered:

Unit	Number	Year	Week	Block	Loa
SAN FERNA	654	1993		1	1

Highlight Item, F4 Edit Next, and F8 Edit F9 to Zoom/Unzoom

---

Enter Update Information

Year:  Week:  Unit: ABILENE1 - 1

Block to Change:  New Loading Order Number:

ICARUS-18

**Purpose**

Screen ICARUS-18 modifies the loading order for a block of a unit in a specific year and week of a simulation. This screen corresponds to Update 10.

**Options**

- Screen ICARUS-18 is divided into two parts. The upper browse window displays existing updates for block loading order changes and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined loading order update and enter new data for inserting additional loading order updates.
  - To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the loading order is to be adjusted.

Week: Enter the week in which the loading order is to be adjusted.

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

Block to Change: Enter 1 or 2 to change the loading order for the first or second block of the selected unit.

New Loading Order Number: Enter the new loading order number for this block.

## Buttons

**<Add>**

**<Change>**

To add or change a loading order update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.

**<Delete>**

To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the loading order update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then perform the deletion of the entries.

**<Clear>** To clear the input fields of all data and return to the Add mode, click on the <Clear> button.

**<OK>** When you have completed all changes and additions to the loading order update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.



- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the maintenance information is to be adjusted.

Week: Enter the week in which the maintenance information is to be adjusted.

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

# of Weeks of Maintenance: Enter the new number of weeks of scheduled maintenance assigned to the selected unit.

Beginning Maintenance Week: Enter the new week that maintenance is to begin for the selected unit, or enter zero if the beginning week is to be scheduled by ICARUS during the next full system maintenance rescheduling.

## Buttons

**<Add>**

**<Change>**

To add or change a maintenance information update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.

**<Delete>**

To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the maintenance information update cards. A message will direct you to tag entries for

deletion by using the spacebar. Pressing the F2 key will then delete the entries.

**<Clear>**

To clear the input fields of all data and return to the Add mode, click on the <Clear> button.

**<OK>**

When you have completed all changes and additions to the maintenance information update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

12:07:08 pm

**Change Block Information for A Unit**

**Updates Entered:**

Unit	Number	Year	Week	Capacity 1	Heat Rate 1	Spinning Reserv

Highlight Item, F4 Edit Next, and FB Edit F9 to Zoom/Unzoom

---

**Enter Update Information**

Year:       Week:

Unit:

	Block 1	Block 2
Capacity (MW):	0	0
Heat Rate (MMBTU/kWh):	0	0
Spinning Reserve (Frac):	0	0
Loading Order:	0	0

ICARUS-20

**Purpose**

Screen ICARUS-20 modifies the block information for a unit in a specific year and week of a simulation. If the economic loading order option is invoked for the ICARUS simulation, the loading order for this unit will automatically be recalculated. This screen corresponds to Update 12.

**Options**

- Screen ICARUS-20 is divided into two parts. The upper browse window displays existing updates for block information changes and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined block information update and enter new data for inserting additional block information updates.
  - To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.



**F8** Press this key to edit the highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.

**F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Year: Enter the year in which the block information is to be adjusted.

Week: Enter the week in which the block information is to be adjusted.

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

Capacity (MW): Enter the new capacity (expressed in megawatts) for each block of the specified unit.

Heat Rate (MMBTU/kWh): Enter the new heat rate (expressed in million Btus per kilowatt-hour) for each block of the selected unit.

Spinning Reserve (Frac): Enter the new spinning reserve contribution (expressed as a fraction of total unit capacity) for each block of the selected unit. Spinning reserves for the second block of two-block units are usually set at zero.

Loading Order: Enter the new loading order for each block of the selected unit.

## Buttons

**<Add>**

**<Change>**

To add or change a block information update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.

- <Delete>** To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the block information update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.
- <Clear>** To clear the input fields of all data and return to the Add mode, click on the <Clear> button.
- <OK>** When you have completed all changes and additions to the block information update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

12:07:13 pm

**Change the Value of the Print Indicator (KP)**

Updates Entered:

Year	Week	KP

Highlight Item, F4 Edit Next, and F8 Edit      F9 to Zoom/Unzoom

---

**Enter Update Information**

Year:       Week:       KP :

ICARUS-21

### Purpose

Screen ICARUS-21 modifies the print indicator (KP) in a specific year and week of a simulation. This screen corresponds to Update 14.

### Options

- Screen ICARUS-21 is divided into two parts. The upper browse window displays existing updates for print indicator changes and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined print indicator update and enter new data for inserting additional print indicator updates.
  - To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

### Data Fields

Year: Enter the year in which the print indicator is to be adjusted.

Week: Enter the week in which the print indicator is to be adjusted.

KP: Enter the new print indicator value (0-9).

### Buttons

**<Add>**

**<Change>**

To add or change a print indicator update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.

**<Delete>**

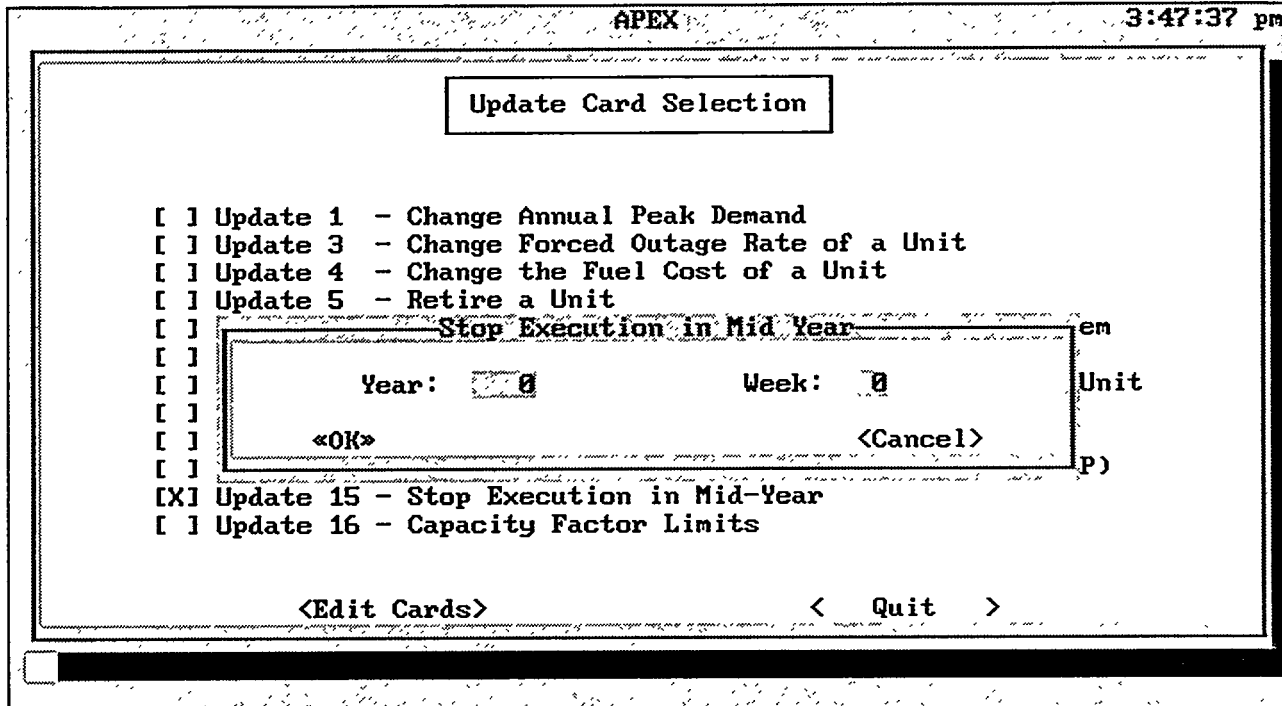
To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the print indicator update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.

**<Clear>**

To clear the input fields of all data and return to the Add mode, click on the <Clear> button.

**<OK>**

When you have completed all changes and additions to the print indicator update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.



**ICARUS-22**

**Purpose**

Screen ICARUS-22 stops ICARUS execution before the end of a simulation year. This option speeds up the model execution time and reduces the amount of output generated for cases that do not require the last year of simulation to be completed. This screen corresponds to Update 15.

**Data Fields**

Year: Enter the year in which the simulation is to be halted.

Week: Enter the week in which the simulation is to be halted.

**Buttons**

**<OK>** Once you have entered the year and week, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

**<Cancel>** Click on the <Cancel> button to ignore any inputs and eliminate this update.

12:07:25 pm

**Capacity Factor Limits**

Updates Entered:

Unit	Number	Start Year	End Year	Number of Iter	Min
1			0	0	

Highlight Item, F4 Edit Next, and F8 Edit      F9 to Zoom/Unzoom

---

**Enter Update Information**

Unit: ABILENE1 - 1      Minimum Capacity Factor: 0.000  
 Maximum Capacity Factor: 0.000  
 Maximum Number of Iterations: 0

Start Year: 0       Print Every Iteration in Report  
 End Year: 0

ICARUS-23

**Purpose**

Screen ICARUS-23 modifies the unit capacity factor limits in a specific year and week of a simulation. This screen corresponds to Update 16.

**Options**

- Screen ICARUS-23 is divided into two parts. The upper browse window displays existing updates for capacity factor limits and is used to select data records for editing. The lower half of the screen allows you to make changes to the data fields for a previously defined capacity factor limit update and enter new data for inserting additional capacity factor limit updates.
- To view the existing list of updates in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.
- The lower window also provides a checkbox for choosing whether the results from all capacity factor iterations are to be included in the ICARUS output. Click on this box to include all iterations in the report. Leave the box blank to include only results from the final iteration.

**F4** While the upper window is activated, press this key to edit the next record in the database. Data for that record will be displayed in the lower half of the

screen for viewing or editing. If the last record is highlighted in the upper window, pressing the F4 key will display the first record for editing in the lower window.

- F8** Press this key to edit the currently highlighted record in the database. Data for that record will be displayed in the lower window for viewing and editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Unit: Click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of generating units and their corresponding numbers in the inventory for this system. Move the cursor to the desired unit and release the mouse button (or press the Enter key again) to select the highlighted unit.

Year: Enter the year in which the capacity factor limits are to be adjusted.

Week: Enter the week in which the capacity factor limits are to be adjusted.

Minimum Capacity Factor: Enter the minimum capacity factor limit for the selected unit.

Maximum Capacity Factor: Enter the maximum capacity factor limit for the selected unit.

Maximum Number of Iterations: Enter the maximum number of ICARUS iterations to be performed.

## Buttons

**<Add>**

**<Change>**

To add or change a capacity factor limit update card, enter information into the lower half of the screen and click on the <Add> button. A new record will be added to the database of update cards and the upper window.

When you have selected a record for editing from the upper screen (by using the F4 or F8 key), the <Add> button is replaced by a <Change> button. Enter changes to the data fields in the lower window and click on the <Change> button to activate the modifications.



- <Delete>** To delete an existing update card, make sure the cursor is in the lower window and then click on the <Delete> button. A separate screen will appear that lists all the capacity factor update cards. A message will direct you to tag entries for deletion by using the spacebar. Pressing the F2 key will then delete the entries.
- <Clear>** To clear the input fields of all data and return to the Add mode, click on the <Clear> button.
- <OK>** When you have completed all changes and additions to the capacity factor update cards, click on the <OK> button to return to screen ICARUS-11 or to proceed with other updates previously selected from screen ICARUS-11.

Edit ICARUS Unit Inventory						12:17:58 pm
Tagged	Plant Name	Capacity (MW)	Fuel Type	On Line Year	On Line Week	R
	JOSEPH1	812.0	URANIUM	1977		52
	JOSEPH2	822.0	URANIUM	1981		32
	BARRY1	143.0	BIT-LIG	1954		8
	ST PK C1	146.0	BIT-LIG	1994		1
	GORGAS10	696.0	BIT-LIG	1972		43
	BARRY2	143.0	BIT-LIG	1954		25
	BIT-LIG	135.0	BIT-LIG	1949		30
	BARRY3	245.0	BIT-LIG	1959		25

Name:  Primary Fuel Type:

< Tag Units >< Clear Tags >< Edit All >< Add Record >

< Standard Edits ><Outages/Deratings>< Cancel >< Exit/Save >

ICARUS-24

**Purpose**

Screen ICARUS-24 edits the unit inventory for the currently selected ICARUS study, system, and case. Several methods are available for performing different types of edits and modifications. The options allow edits to be made to individual generating units or groups of units.

**Options**

- Screen ICARUS-24 is divided into two parts. The upper browse window initially displays the entire list of generating units and can be used to edit data entries for each unit directly, or it can be used to select data records for more structured types of editing. The lower half of the screen provides options for selecting subsets of units for "standard edits" or "outage and derating" assignments.
- To view the existing list of units in tabular format, click anywhere on the upper window. To activate options in the lower window, click on any portion of the lower window.

## Data Fields

Name: Use the pop-up menu to select specific units by name. When a specific name is selected, only units with that name and any previously tagged units will remain in the upper window. To add units to the editing list in the upper window, select the appropriate name from the lower window pop-up menu and tag the units in the upper window. Any units in the upper window that have not been tagged will disappear when additional selection criteria are chosen that do not include the untagged units. The "All" entry appears at the bottom of the name list and should be selected when no units are to be excluded from the editing list according to name.

Primary Fuel Type: Use the pop-up menu to select specific units by primary fuel type. When a specific fuel type is selected, only units with that fuel type and any previously tagged units will remain in the upper window. To add units to the editing list in the upper window, select the appropriate fuel type from the lower window pop-up menu and tag the units in the upper window. Any units in the upper window that have not been tagged will disappear when additional selection criteria are chosen that do not include the untagged units. The "All" entry appears at the bottom of the fuel type list and should be selected when no units are to be excluded from the editing list according to fuel type.

## Buttons

### <Tag Units>

The <Tag Units> button is used to designate units in the upper window to be retained for further screening (e.g., by names or fuel types) or for subsequent edits. To activate the <Tag Units> option, first click on the lower window and then click on the <Tag Units> button. The cursor will return to the upper window, where tags can be designated by pressing the Enter key or clicking the mouse button.

### <Clear Tags>

To clear all tagged units in the upper window, click on the <Clear Tags> button. This option allows you to restart the process of selecting units for editing.

### <Edit All>

To switch to the "standard edits" screen, ICARUS-25, click on the <Edit All> button. You can then sequence forward or backward through all units in the inventory of the current generating system and edit any data item for a given unit.

### <Add Record>

To add a new unit to the inventory, click on the <Add Record> button. An empty line will be added to the upper window, and data can be entered either in the upper window or through the <Standard Edits> feature.

- <Standard Edits>** To switch to screen ICARUS-25, which provides a single screen layout for editing all data fields for generating units that are currently tagged in the inventory, click on the <Standard Edits> button.
- <Outages/Deratings>** To bring up screen ICARUS-26, which contains four options to uniformly modify a set of tagged units, click on the <Outages/Deratings> button. The options allow you to set the forced outage rate, unit size multiplier, start-up date, or shutdown date at a uniform value for all the affected units.
- <Cancel>** To cancel all inventory edits that have not been finalized with the <Exit/Save> button and return to screen ICARUS-10, click on the <Cancel> button.
- <Exit/Save>** To save all edits that have been made and return to screen ICARUS-10, click on the <Exit/Save> button.

Unit Inventory Standard Editing				12:15:15 pm	
Plant Name: POINT B1					
Capacity (MW):		485.0	Primary Fuel Type:		URANIUM
Forced Outage Rate (Frac): 0.08400			Year		
Number of Maintenance Weeks: 11			Week		
Beginning Maintenance Week: 0			On Line: 1970		51
			Retired: 2010		52
Number of Blocks: 2					
			Block 1		Block 2
Capacity (MW):		446.2	38.8		
Heat Rate (MMBTU/kWh):		10.500	10.500		
Spinning Reserve (Frac):		0.100	0.000		
Loading Order:		0	0		
			Costs		
			Capital (\$/kW):		0.00
			Fuel (Cents/MMBTU):		45.00
			Var. O&M (Mills/kWh):		2.01
			Fixed O&M (\$/kW-yr):		99.36
Unit 1 of 5					
<Previous > < Next > < Cancel > <Exit/Save>					

ICARUS-25

**Purpose**

Screen ICARUS-25 provides a single screen layout for editing all data items for generating units. Cost and performance data can be modified, as well as fuel type, unit size, start-up dates, and shutdown dates.

**Data Fields**

Plant Name: This field contains the unit name assigned in the ICARUS unitdata file.

Capacity: This field contains the total capacity for the generating unit. It represents the sum of the capacities for block 1 and block 2, which are contained in data fields near the lower left corner of the screen. You cannot edit the capacity field at the top of the screen directly because it is calculated from the entries for each block of the unit. To change the total unit size, you must modify the entries for block 1 and/or block 2.

Primary Fuel Type: This pop-up menu displays the current fuel type and can be used to select a different fuel type from a list of valid fuel categories. To make a change, click and hold the mouse button on the pop-up menu (or press the Enter key) to display the full list of fuel types. Move the cursor to the desired fuel category and release the mouse button (or press the Enter key again) to select the highlighted option.

Forced Outage Rate (Frac): Enter the new forced outage rate (expressed as a fraction).

Number of Maintenance Weeks: Enter the number of weeks of scheduled maintenance.

Beginning Maintenance Week: Enter the week that maintenance is to begin, or enter zero if the beginning week is to be assigned by ICARUS during the next full system maintenance rescheduling.

On Line Year: Enter the first year of operation for this unit.

On Line Week: Enter the first week of operation for this unit.

Retired Year: Enter the last year of operation for this unit.

Retired Week: Enter the last week of operation for this unit.

Number of Blocks: Enter the number of blocks of capacity for this unit (1 or 2).

Capacity: Enter the capacity (in megawatts) for each block of capacity. If the number of blocks is set at 1, you will not be able to make entries in the fields for block 2.

Heat Rate (MMBTU/kWh): Enter the heat rate (expressed in million Btus per kilowatt-hour) for each block of capacity. If the number of blocks is set at 1, you will not be able to make entries in the fields for Block 2.

Spinning Reserve (Frac): For each block, enter the fraction of total unit capacity that contributes to meeting the spinning reserve goal. For block 1, this variable is usually set to the fraction that block 2 represents for the unit. For block 2, the spinning reserve contribution is usually set to zero.

Loading Order: Enter the loading order for each block of capacity, or enter zero if the economic loading order is calculated by ICARUS.

Capital (\$/kW): Enter the capital cost for this unit (in dollars per kilowatt).

Fuel (Cents/MMBTU): Enter the fuel cost (in cents per million Btu).

Var. O&M (Mills/kWh): Enter the variable O&M cost for this unit (in mills per kilowatt-hour [same as dollars per megawatt-hour]).

Fixed O&M (\$/kW-yr): Enter the fixed O&M cost for this unit (in dollars per kilowatt-year).

Unit *i* of *n*: This field indicates for how many units are currently selected for editing and which unit in the list is currently displayed on the screen. This field cannot be edited.

**Buttons**

- <Next>** To edit the next unit from the group of units currently selected for editing, click on the <Next> button.
- <Previous>** To edit the previous unit from the group of units currently selected for editing, click on the <Previous> button.
- <Cancel>** To cancel all edits made during this sequence with screen ICARUS-25, click on the <Cancel> button. You will return to screen ICARUS-24. Any changes made earlier on screen ICARUS-24 will still be present and can either be saved or cancelled from that screen.
- <Exit/Save>** To *temporarily* save all edits made from this screen (ICARUS-25) and return to screen ICARUS-24, click on the <Exit/Save> button. *Note: To save and finalize edits made from screen ICARUS-25 you must also use the <Exit/Save> button to exit from ICARUS-24 and return to screen ICARUS-10.*

Unit Inventory Outages and Deratings		2:40:35 pm	
Changes will be applied to all 4 tagged units.			
<input checked="" type="checkbox"/>	Forced Outage Rate (Frac):	██████████	
<input type="checkbox"/>	Capacity Multiplier:	0.000	
<input type="checkbox"/>	Startup:	Year: 0	Week: 0
<input type="checkbox"/>	Shutdown:	Year: 0	Week: 0
< Cancel		> < Exit/Save >	

## ICARUS-26

**Purpose**

Screen ICARUS-26 provides a single screen layout for making uniform changes to a group of units previously tagged from screen ICARUS-24. Four types of changes can be made: modifications to the forced outage rate, unit size multiplier, start-up date, and shutdown date. Only one change can be made during a given call to this screen, but this screen can be called as often as necessary for different modifications.

**Data Fields**

Forced Outage Rate (Frac): Enter the new forced outage rate (expressed as a fraction) to be assigned to all the tagged units.

Capacity Multiplier: Enter a multiplication factor to be applied to the capacity of each tagged unit. The factor will be multiplied by the previous block 1 and block 2 capacities for two-block units and by block 1 capacity for one-block units.

Startup Year: Enter a new start-up year to be assigned to all the tagged units.

Startup Week: Enter a new start-up week to be assigned to all the tagged units.

Shutdown Year: Enter a new shutdown year to be assigned to all the tagged units.

Shutdown Week: Enter a new shutdown week to be assigned to all the tagged units.

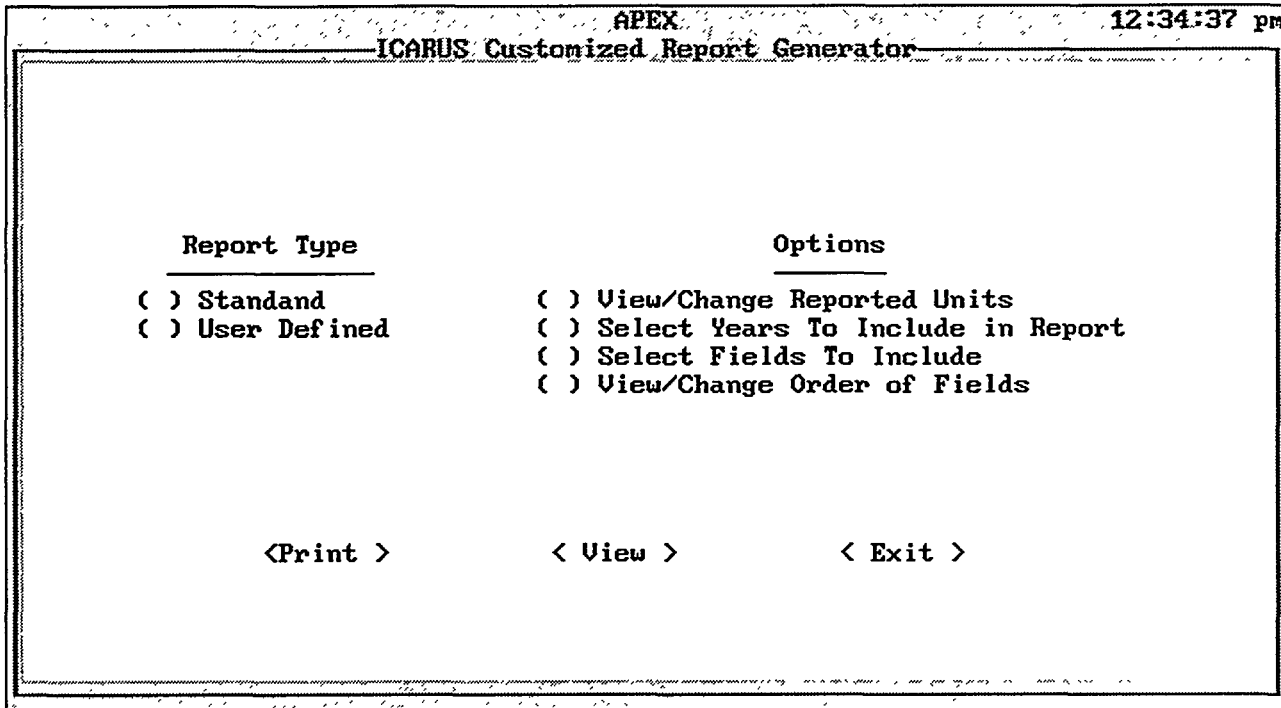


**Buttons****<Cancel>**

To cancel all edits made during this sequence with screen ICARUS-26, click on the <Cancel> button. You will return to screen ICARUS-24. Any changes made earlier on screen ICARUS-24 will still be present and can either be saved or cancelled from that screen.

**<Exit/Save>**

To *temporarily* save all edits from this screen (ICARUS-26) and return to screen ICARUS-24, click on the <Exit/Save> button. *Note: To save and finalize edits made from screen ICARUS-26, you must also use the <Exit/Save> button to exit from ICARUS-24 and return to screen ICARUS-10.*



ICARUS-27

**Purpose**

Screen ICARUS-27 allows you to select the type of report to be viewed or printed, change the reported units of variables, select the variables and order of the variables for user-defined reports, and select the years to be included in the report.

**Options**

- The left side of screen ICARUS-27 provides two choices for preparing ICARUS results: the standard report and the user-defined report. The standard report contains all the basic ICARUS output and is arranged in a fixed report format. The user-defined option allows you to select specific results to be included in the report and the way they are to be ordered. Note that only one choice between the standard report option or the user-defined option can be selected at one time.

If you select the standard report option, a pop-up menu (screen ICARUS-28) will appear that shows four choices for different levels of detail. The options include a unit-level report, a fuel category aggregate report, a system totals report, and a system reliability report. One or more of these options may be selected at one time.

If you select the user-defined option, a pop-up menu (screen ICARUS-29) will prompt you to select a new report format or an existing format. The program

will then prompt you for a new or existing filename and the level of detail to be included in the report.

- The right side of screen ICARUS-27 provides four options for assembling and customizing the reports. These options include selections for units of measure, reporting years, output fields, and ordering of results. Only the first two options are available for preparing standard reports. All four options are available for creating user-defined reports.
- To view or change the reported units of measure, select the first option. This option will activate screen ICARUS-30, which allows you to choose the units of measure for variables in standard or user-defined reports.
- To select the years to include in the report, select the second option. A pop-up menu will appear (screen ICARUS-31) that lists valid simulation years. The default is to include all years that were run in the current simulation.
- The third option is active only when a user-defined report is loaded. This button will activate the field selection screen (ICARUS-32), which allows you to select the fields to include or exclude from a user-defined report.
- The fourth option is active only when a user-defined report is loaded. This button will activate the order selection screens (ICARUS-33 and ICARUS-34), which allow you to change the ordering of the selected fields in a user-defined report.

## Buttons

- |                      |   |
|----------------------|---|
| <b>&lt;Print&gt;</b> | To print the report, click on the <Print> button.                               |
| <b>&lt;View&gt;</b>  | To view the report on the screen, click on the <View> button.                   |
| <b>&lt;Exit&gt;</b>  | To exit this screen and return to screen ICARUS-08, click on the <Exit> button. |

APEX		2:39:39 pm			
<b>ICARUS Customized Report Generator</b>					
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: center;">Report Type</th> <th style="text-align: center;">Options</th> </tr> <tr> <td style="text-align: center;"> <b>Standard Reports</b>  <input type="checkbox"/> Unit Level Report  <input type="checkbox"/> Fuel Category Report  <input type="checkbox"/> System Totals Report  <input type="checkbox"/> System Reliability Report   <input type="button" value="OK"/> </td> <td style="vertical-align: top;">                 ) View/Change Reported Units                  ) Select Years To Include in Report                  ) Select Fields To Include                  ) View/Change Order of Fields             </td> </tr> </table>	Report Type	Options	<b>Standard Reports</b> <input type="checkbox"/> Unit Level Report <input type="checkbox"/> Fuel Category Report <input type="checkbox"/> System Totals Report <input type="checkbox"/> System Reliability Report  <input type="button" value="OK"/>	) View/Change Reported Units ) Select Years To Include in Report ) Select Fields To Include ) View/Change Order of Fields	<input type="button" value="Print &gt;"/>
Report Type	Options				
<b>Standard Reports</b> <input type="checkbox"/> Unit Level Report <input type="checkbox"/> Fuel Category Report <input type="checkbox"/> System Totals Report <input type="checkbox"/> System Reliability Report  <input type="button" value="OK"/>	) View/Change Reported Units ) Select Years To Include in Report ) Select Fields To Include ) View/Change Order of Fields				
		<input type="button" value="View &gt;"/>			
		<input type="button" value="Exit &gt;"/>			

**ICARUS-28**

**Purpose**

Screen ICARUS-28 contains a pop-up menu with four choices for standard reports. A standard report contains virtually all the ICARUS results for each simulation period and annual summaries. (To print specific items from available results, choose the user-defined report option from screen ICARUS-27.) One or more standard reports can be selected from screen ICARUS-28 at one time.

**Options**

- To select the unit-level report, click on the first option. This report displays generation and cost results for individual generating units.
- To select the fuel category report, click on the second option. This option displays aggregate generation and cost results for each ICARUS fuel category.
- To select the system totals report, click on the third option. This report displays total system capacity, generation, and cost results.
- To select the system reliability report, click on the fourth option. This report includes peak load, reserve margins, unserved energy, and loss-of-load probability results.

**Buttons**

**<OK>**

To exit the window and return to the custom report screen (ICARUS-27), click on the <OK> button.

```

APEX 12:34:37 pm
ICARUS Customized Report Generator

Report Type
( ) View/
( ) Create New Filename ( ) Select
Load Existing File ( ) Select ( ) View/

Report Detail
[ ] Period Results
[ ] Unit Level Results
[ ] Fuel Category Results
[ ] System Totals

<OK>

<Print > < View > < Exit >
    
```

ICARUS-29

**Purpose**

Screen ICARUS-29 provides several choices for preparing a user-defined report. You can use a previously defined format, or you can define a new report format. If you select a new report format, screen ICARUS-29 will also allow you to specify the level of detail to be included in the report. You can select as many of the four options listed as are appropriate for a given report.

**Options**

- When the pop-up menu on screen ICARUS-29 first appears, you will be given two options. The first option is to create a new user-defined report. Choose this option if you have not previously formatted a report according to the specifications you now require. If you select this option, you will be prompted for a filename for future reference. The filename must be eight or fewer characters in length and should be composed only of letters and/or numbers.

If you choose to create a new format, after providing a filename, you will be prompted with four additional checkboxes to specify the level of detail to be included. Select the first checkbox if period results (for each simulation period) are to be included in the report. Select the second checkbox if you want to include results for individual generating units. Select the third checkbox if you want to include aggregate results by fuel category (standard ICARUS fuel

categories). Select the fourth checkbox if you want to include systemwide totals in the report.

- If you choose the existing report option, another pop-up menu will display the existing file names. To choose a filename, click on the name in the pop-up menu.

### Buttons

**<OK>** To exit the window and return to the custom report screen (ICARUS-27), click on the <OK> button.

Capacity		Capacity Factors and Reserve Margins		Generation and Loads		Costs	
<input checked="" type="checkbox"/> kWh		<input type="checkbox"/> Percent		<input checked="" type="checkbox"/> kWh		<input checked="" type="checkbox"/> Dollars	
<input type="checkbox"/> MWh		<input type="checkbox"/> Fraction		<input type="checkbox"/> MWh		<input type="checkbox"/> Dollars/MWh	
<input type="checkbox"/> GWh				<input type="checkbox"/> GWh		<input type="checkbox"/> mills/kWh	
Fuel Use							
Coal	<input checked="" type="checkbox"/> BTU	<input type="checkbox"/> BOE	<input type="checkbox"/> Short Tons				
Oil	<input checked="" type="checkbox"/> BTU	<input type="checkbox"/> BOE	<input type="checkbox"/> Barrels				
Gas	<input checked="" type="checkbox"/> BTU	<input type="checkbox"/> BOE	<input type="checkbox"/> Cubic Feet				
Hydro	<input checked="" type="checkbox"/> BTU	<input type="checkbox"/> BOE					
Nuclear	<input checked="" type="checkbox"/> BTU	<input type="checkbox"/> BOE					
Other	<input checked="" type="checkbox"/> BTU	<input type="checkbox"/> BOE					
< OK >				<Cancel>			

ICARUS-30

**Purpose**

Screen ICARUS-30 allows you to select the units of measure for reported results. Defaults are marked on this screen. To change any of the units of measure, click on the required alternative. On the basis of the units of measure selected and the magnitude of results for this report, the program will determine whether a scaling factor is required (a multiple of 1000) to fit the outcomes into the columns of space allocated for each parameter. All scaling factors are noted in the headings of the report.

**Options**

- Installed capacities and peak loads can be expressed in kilowatts, megawatts, or gigawatts.
- Capacity factors and reserve margins can be expressed as percentages or as fractions.
- Generation and system energy loads can be expressed in kilowatt-hours, megawatt-hours, or gigawatt-hours.
- Units of measure for fuel use vary by fuel type. Coal use can be expressed in Btu, barrel of oil equivalents (BOEs), or short tons. Oil use can be expressed in Btu, BOEs, or barrels. Gas use can be expressed in Btu, BOEs, or cubic feet.

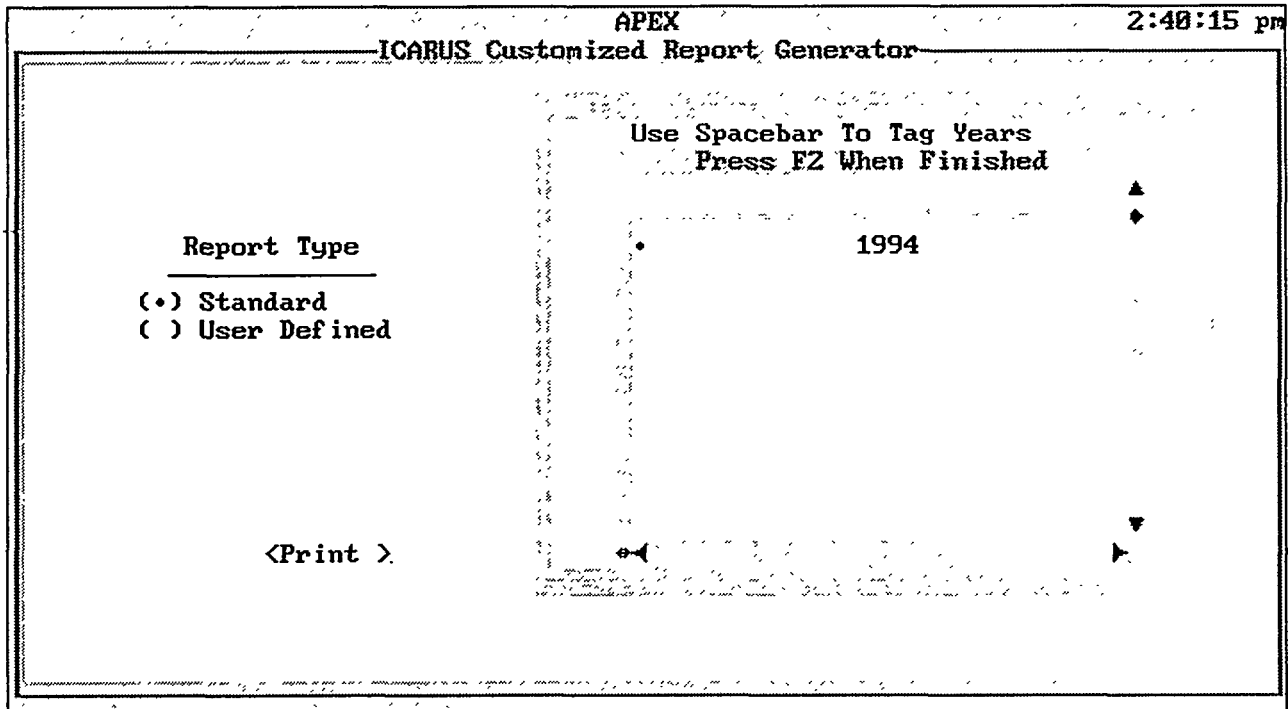


- Costs can be expressed in dollars, dollars per megawatt-hour, or mills per kilowatt-hour (equivalent to dollars per megawatt-hour).

### Buttons

**<OK>** To exit the window and return to the custom report screen (ICARUS-27), click on the <OK> button.

**<Cancel>** To cancel the changes and return to screen ICARUS-27, click on the <Cancel> button.



ICARUS-31

**Purpose**

Screen ICARUS-31 contains a pop-up window that allows you to select the simulation years to be included in the standard or user-defined reports.

**Options**

- Use the spacebar to tag the years to be included in the report. Pressing the F2 key will exit the pop-up window.

APEX		2:22:45 pm
Icarus Customized Report Generator		
Select Fields to Include		
Unit / System Information	System Reliability Information	
<input checked="" type="checkbox"/> Capacity	<input checked="" type="checkbox"/> Peak Load	
<input checked="" type="checkbox"/> Capacity Factor	<input checked="" type="checkbox"/> Installed Capacity	
<input checked="" type="checkbox"/> Generation	<input checked="" type="checkbox"/> Generation	
<input checked="" type="checkbox"/> Fuel Type	<input checked="" type="checkbox"/> Reserve Margin (Orig Peak)	
<input checked="" type="checkbox"/> Fuel Use	<input checked="" type="checkbox"/> Reserve Margin (W/Firm P/S)	
<input checked="" type="checkbox"/> Fuel Cost	<input checked="" type="checkbox"/> Unserved Energy	
<input checked="" type="checkbox"/> Fixed O&M Cost	<input checked="" type="checkbox"/> Firm Purchase/Sale Capacity	
<input checked="" type="checkbox"/> Variable O&M Cost	<input checked="" type="checkbox"/> Firm Purchase/Sale Energy	
<input checked="" type="checkbox"/> Total Variable Cost	<input checked="" type="checkbox"/> LOLP With Ties	
<input checked="" type="checkbox"/> Total Cost	<input checked="" type="checkbox"/> LOLP Without Ties	
<div style="border: 1px solid black; padding: 5px; display: inline-block;">           &lt; OK &gt;      &lt;Cancel&gt;         </div>		

ICARUS-32

### Purpose

Screen ICARUS-32 selects parameters to be included in user-defined reports.

### Options

- Screen ICARUS-32 is divided into two parts. The left side controls the output choices for individual generating unit results, aggregate fuel category subtotals, and system total results. Check each box corresponding to the outputs you would like to include in the report.
- The right side of screen ICARUS-32 controls the output choices for parameters related to system reliability. Check each item that is to appear in the report.

### Buttons

**<OK>** After completing your selections, click on the <OK> button to return to screen ICARUS-27.

**<Cancel>** To cancel the changes and return to screen ICARUS-27, click on the <Cancel> button.

APEX 9:46:51 am

ICARUS Customized Report Generator  
 Select Ordering of Fields

**Unit/System Information**

<input type="checkbox"/> 1 Capacity	<input type="checkbox"/> 2 Cap. Factor	<input type="checkbox"/> 3 Generation	<input type="checkbox"/> 5 Fuel Use
<input type="checkbox"/> 7 Fixed O&M Cost	<input type="checkbox"/> 6 Fuel Cost	<input type="checkbox"/> 8 Variable O&M Cost	<input type="checkbox"/> 4 Fuel Type
<input type="checkbox"/> 9 Variable Cost	<input type="checkbox"/> 10 Total Cost		

ICARUS-33

**Purpose**

Screen ICARUS-33 allows you to modify the ordering of results selected for user-defined reports. This screen applies to parameters selected from the left side of screen ICARUS-32, which include individual generating unit results, aggregate fuel category subtotals, and system totals. (Ordering of system reliability parameters is addressed in screen ICARUS-34, which appears as soon as you exit from screen ICARUS-33.)

**Options**

- A default ordering is displayed when a new user-defined report is created. If an existing report is loaded, the ordering used in that report will be shown. Only the fields that were checked in screen ICARUS-32 will be active, and only their ordering can be changed. Variables that are not selected for inclusion in the report will be displayed in a gray color.
- To change the order of a field, click on the pop-up box next to the field to view the ordering choices. Highlight the position you wish to select for this field and release the mouse button. No two fields should be assigned the same ordering position. If this occurs, a warning message will appear when you click on the <OK> button, and you will not be able to exit the screen until you choose a valid ordering.

**Buttons**

- <OK>** To advance to screen ICARUS-34 for continued ordering choices, click on the <OK> button.
  
- <Cancel>** To cancel the changes and return to screen ICARUS-27, click on the <Cancel> button.

APEX				2:28:27 pm			
ICARUS Customized Report Generator							
Select Ordering of Fields							
<b>System Information</b>							
<input type="checkbox"/> 1	Peak Load	<input type="checkbox"/> 2	Installed Capacity	<input type="checkbox"/> 3	Generation	<input type="checkbox"/> 4	Res.Margin Orig.Peak
<input type="checkbox"/> 5	Res.Margin With P/S	<input type="checkbox"/> 6	Unservd Energy	<input type="checkbox"/> 7	Firm Purchase/Sale Capacity	<input type="checkbox"/> 8	Firm Purchase/Sale Energy
<input type="checkbox"/> 9	LOLP With Ties	<input type="checkbox"/> 10	LOLP Without Ties				
<input style="margin-right: 20px;" type="button" value=" &lt; OK &gt; "/> <input style="margin-right: 20px;" type="button" value=" &lt;Cancel&gt; "/>							

### ICARUS-34

#### Purpose

Screen ICARUS-34 allows you to modify the ordering of system reliability results selected for inclusion in user-defined reports. This screen appears when you exit screen ICARUS-33, and it applies to parameters selected from the right side of screen ICARUS-32. (Ordering of individual generating unit results, aggregate fuel category subtotals, and system totals are addressed in screen ICARUS-33, which precedes screen ICARUS-34.)

#### Options

- A default ordering is displayed if a new user-defined report is being created. If a previously defined report is loaded, the ordering shown on this screen will reflect any changes introduced for that report. Only the data fields that were checked in screen ICARUS-32 will be active, and only their ordering can be changed. Variables not selected for inclusion in the report will be displayed in gray.
- To change the order of a field, click on the pop-up box next to the field to view the ordering choices. Highlight the position you wish to select for this field and release the mouse button. No two fields should be assigned the same ordering position. If this occurs, a warning message will appear when you click on the <OK> button, and you will not be able to exit the screen until you choose a valid ordering.

**Buttons**

- <OK>** To exit and return to screen ICARUS-27 for printing or other customization options, click on the <OK> button.
- <Cancel>** To cancel the changes and return to screen ICARUS-27, click on the <Cancel> button.

### 3.3 THE LATEST DEVELOPMENTS OF THE ICARUS MODEL

The years of extensive use of the ICARUS model by both its authors and other users, the numerous studies performed, and the experience gained by modeling various types of utility systems in the United States and around the world have helped to confirm the usefulness, practicality, and accuracy of the ICARUS simulation of utility systems operation. The broad experience gained in the use of the ICARUS model has also shown directions for further improvement of the model. The modifications and improvements introduced into the model since its introduction are summarized below.

#### 3.3.1 Output Files

ICARUS output files OUT10 and OUT14 have been renamed ICARUS.REP and AUX14.OUT, respectively. In addition, the APEX version of the ICARUS model (ICARUS-A, Version 1.1, September 1994) creates several auxiliary output files that transfer data to PACE and SMN models. The ICARUS-A output files are listed in Table 3.1.

#### 3.3.2 Number of Fuel Types

The maximum number of different thermal fuel types (input file LOADDATA, card type L3, variable name NFTY) that the ICARUS model can handle has been increased from 25 to 50 to take into account the increasing number of future generating options and the variety of existing technologies, as well as to accommodate the need for special unit representations.

#### 3.3.3 Combined Loading Order Option

Many studies have shown the need for more flexibility in defining the loading order of thermal generating units. Previously, ICARUS had two options for specifying loading order (input file LOADDATA, card type L6, variable name LOCALC): (1) the economic loading order

**TABLE 3.1 ICARUS Output Files**

File Number	Old File Name	New File Name
10	OUT10	ICARUS.REP
14	OUT14	AUX14.OUT
15	-	MAINT.OUT
16	-	UNITPERD.OUT
25	-	SYSPERD.OUT
27	-	INPACE.OUT



to be calculated by the model (LOCALC=1) and (2) the user-specified input loading order (LOCALC=0). The new version of the ICARUS model allows you to combine these two options and specify the loading order numbers for certain units in the generating system, while letting the program calculate the economic loading order for other units on the basis of their respective running costs. The loading order numbers are defined in the UNITDATA input file, card type U3; the variable names are RLOA(1) and RLOA(2). These two variables represent the loading order numbers of the first and second blocks, respectively, for the two-block unit representation. If a generating unit is described by a single-block representation, only variable RLOA(1) is used.

The request for the combined loading order is as follows. Choose the economic loading order option (LOCALC=1) in the LOADDATA input file and, in the UNITDATA file, specify the loading order numbers for units that will have a user-defined loading order and zeros for those units that should be loaded by the economic loading order. The ICARUS model checks the loading order values specified for each unit. If the unit has a RLOA value greater than zero, ICARUS will consider that value as the loading order number of that particular unit. For units that have zero input value for the RLOA variable, ICARUS calculates their running costs and assigns those values as their respective loading order numbers. This procedure for the combined loading order specification, which uses the single-block representation of generating units, is illustrated in the following example.

Consider a utility system consisting of six generating units, where you have chosen the economic loading order option (LOCALC=1) in the LOADDATA file and specified the loading order numbers for two generating units (COAL 3 and COAL 4) in the UNITDATA file, as shown in Table 3.2. The resulting loading order, which is the combination of the user input and the economic loading order, is presented in Table 3.3.

**TABLE 3.2 Sample Utility System Input Loading Order**

Unit Number	Loading Order Number (RLOA)	Running Cost [mills/kWh]	Unit Name
1	0.0	17	COAL 1
2	0.0	24	COAL 2
3	3.0	19	COAL 3
4	0.0	36	COM. CYCLE
5	1.0	21	COAL 4
6	0.0	57	GAS TURBINE

**TABLE 3.3 Resulting Combined Loading Order for Sample Utility**

Unit Number	Loading Order Number (RLOA)	Running Cost (mill/kWh)	Unit Name
5	1.0	21	COAL 4
3	3.0	19	COAL 3
1	17.0	17	COAL 1
2	24.0	24	COAL 2
4	36.0	36	COM. CYCLE
6	57.0	57	GAS TURBINE

**3.3.4 Order of Update Cards**

The update cards in the ICARUS model are used to specify the changes of system variables and unit characteristics from year to year or from period to period within a year. The update cards (card type L19) are always located at the end of the LOADDATA input file, and they are a part of the annual data set that is provided for each year of the ICARUS run. The order in which the update cards appear in the input file and are read by the program is very important. Generally, the order of update cards in the LOADDATA file should be as follows:

- Enter the annual updates that are in effect the whole year (e.g., change the annual peak load or reschedule maintenance).

- Enter the information about updates that start in the first week of the year (e.g., to schedule unit maintenance starting in period 1).
- The following updates for the first week of the year should be updates that take effect during the year; these updates should be entered in an ascending order according to the week numbers in which the changes occur.
- The last update card should have all zeros to signal the end of the annual data.

A routine has been added to ICARUS that checks whether all update cards are given in chronological order. If an update card is not in the right position in the input data file, the routine will print an error message in the output file (ICARUS.REP) and stop program execution. For example, the message given in the ICARUS.REP output file may be the following:

```
***ERROR: The following update card is not in order:
```

```
3 17 0 6 4 250.0 0 0
```

### 3.3.5 Printing of Load Duration Curve Points

Printing of the cumulative load duration curve points is now available only with the printout option (KP = 8).

### 3.3.6 Table Printouts

The INTRO "NUTYPE" DATA table in the ICARUS.REP output file has been modified to print data for all periods during the year, even if NUTYPE capacity and energy are zero in some periods. In addition, several other tables have been revised, and printing of results in columns has been realigned with the table headings.

### 3.3.7 Notation

The notation of units of measure has been completely revised. The changes can be noticed in the output files, where, for example, the new notation for kilowatt-hour is "kWh" instead of the old "KWH," and the new notation for "million British thermal units" is now "MMBtu" instead of the old "MBTU."

In addition, the output files of the ICARUS model now refer to generating "units," not to "plants." All former "PLANT" references have been converted to "UNIT" references.

### 3.3.8 Additional Output Files

In addition to ICARUS.REP and AUX14.OUT, four additional output files are created by the APEX version of the ICARUS model. The purpose of these files is to facilitate the interface and data transfer between the ICARUS model and other APEX modules (PACE and SMN). Because these files deal mainly with program-to-program interaction, the data they contain are not arranged into tables for viewing but rather into data strings to be read by other programs. However, users who are interested in viewing these auxiliary files can use an ASCII text editor to review their content. The contents and format of these additional ICARUS output files are summarized in the following sections. The variable names in the parentheses correspond to the ICARUS variable names.

**File Name: MAINT.OUT**

THERE ARE 26 PERIODS PER YEAR

1	CT1	1993	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	CT2	1993	6	1	1	1	1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	CT3	1993	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	COAL1B	1993	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	COAL2A	1993	6	1	1	1	1	1	-1	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	COAL2B	1993	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	COAL1A93	1993	6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

**Purpose**

The MAINT.OUT file contains the maintenance schedule for each unit in the given model run. This file is divided in two sections. The first section consists of a sentence describing the number of periods (NPER) followed by a blank line.

The second section consists of one detail line for each unit in the given model run. Each detail line contains the unit number (J), unit identifier (PLTID), year (NYEAR), annual unit status (NSTAT), and a unit status list containing one field for each period (ISTAT). The annual unit status (NSTAT) values are as follows:

<u>Value</u>	<u>Meaning</u>
1	Retired previously
2	Planned
3	On maintenance for entire year
4	Newly retired
5	New
6	In service

The period unit status (ISTAT) values are as follows:

<u>Value</u>	<u>Meaning</u>
1	Unit up for the period
0	Unit down for the period
-1	Unit on maintenance for the period

**File Name: UNITPERD.OUT**

```

, , ,CT1      ,1993, 1,   50.,.8971E+07,.8447E+05,.5262E+05, 23.54,  5.00
, , ,CT2      ,1993, 1,   30.,.2156E+07,.2076E+05,.8123E+04, 22.63,  7.00
, , ,CT3      ,1993, 1,   12.,.2323E+06,.2187E+04,.2326E+04, 23.54,  7.00
, , ,COAL1B   ,1993, 1,   65.,.1256E+08,.1384E+06,.1471E+06, 11.57,  3.00
, , ,COAL2A   ,1993, 1,  100.,.2601E+08,.2643E+06,.1791E+06, 18.80,  4.50
, , ,COAL2B   ,1993, 1,  100.,.3160E+08,.3192E+06,.1791E+06, 18.69,  4.50
, , ,COAL1A93,1993, 1,   30.,.5314E+07,.5883E+05,.6790E+05, 11.62,  3.00
. . .
. . .
. . . (Details omitted)
. . .
. . .
, , ,CT1      ,1993,26,  50.,.9030E+07,.8502E+05,.5262E+05, 23.54,  5.00
, , ,CT2      ,1993,26,  30.,.2012E+07,.1937E+05,.8123E+04, 22.63,  7.00
, , ,CT3      ,1993,26,  12.,.2185E+06,.2058E+04,.2326E+04, 23.54,  7.00
, , ,COAL1B   ,1993,26,  65.,.1233E+08,.1360E+06,.1471E+06, 11.58,  3.00
, , ,COAL2A   ,1993,26,  100.,.2486E+08,.2531E+06,.1791E+06, 18.84,  4.50
, , ,COAL2B   ,1993,26,  100.,.3160E+08,.3192E+06,.1791E+06, 18.69,  4.50
, , ,COAL1A93,1993,26,  30.,.5207E+07,.5771E+05,.6790E+05, 11.64,  3.00

```

**Purpose**

The UNITPERD.OUT file contains information describing the performance of each unit in the given model run. This file consists of one detail line for each unit in each year and period in the given model run. Each detail line contains three blank filler fields for database conversion, the unit identifier (PLTID), the year (NYEAR), the period (IX), the unit capacity in megawatts (YMWR), the unit generation in kilowatt-hours (UTKWH), the unit fuel usage (UTFU), the unit fixed operation and maintenance costs in dollars (UTFOM), the unit fuel costs in dollars per megawatt-hour (FURT), and the unit variable operations and maintenance costs in dollars per megawatt-hour (VOMRT).

**File Name: SYSPERD.OUT**

1993, 1,	.141729E+07,	.10871910E+00,	-15.,	.7220E+06
1993, 2,	.142031E+07,	.10890660E+00,	-15.,	.7220E+06
1993, 3,	.105627E+07,	.92226420E-01,	-15.,	.7220E+06
1993, 4,	.824782E+06,	.75709260E-01,	-15.,	.7220E+06
1993, 5,	.733362E+06,	.59782550E-01,	0.,	.0000E+00
1993, 6,	.348971E+07,	.28402820E+00,	0.,	.0000E+00
1993, 7,	.242310E+07,	.20438950E+00,	0.,	.0000E+00
1993, 8,	.106216E+07,	.79209930E-01,	0.,	.0000E+00
1993, 9,	.142021E+07,	.10566910E+00,	0.,	.0000E+00
1993,10,	.618989E+06,	.65634100E-01,	0.,	.0000E+00
1993,11,	.178591E+07,	.15419660E+00,	0.,	.0000E+00
1993,12,	.410124E+07,	.32089110E+00,	0.,	.0000E+00
1993,13,	.493358E+06,	.46819200E-01,	0.,	.0000E+00
1993,14,	.909945E+06,	.79121460E-01,	0.,	.0000E+00
1993,15,	.920060E+06,	.80164380E-01,	0.,	.0000E+00
1993,16,	.196072E+07,	.13372000E+00,	0.,	.0000E+00
1993,17,	.206640E+07,	.13873260E+00,	0.,	.0000E+00
1993,18,	.163412E+07,	.11520230E+00,	0.,	.0000E+00
1993,19,	.117522E+07,	.90833350E-01,	0.,	.0000E+00
1993,20,	.154546E+07,	.11594500E+00,	0.,	.0000E+00
1993,21,	.747533E+06,	.58851520E-01,	0.,	.0000E+00
1993,22,	.101627E+07,	.73851550E-01,	0.,	.0000E+00
1993,23,	.637888E+06,	.57896290E-01,	-15.,	.7220E+06
1993,24,	.724982E+06,	.62816890E-01,	-15.,	.7220E+06
1993,25,	.121485E+07,	.95440160E-01,	-15.,	.7220E+06
1993,26,	.123097E+07,	.96375180E-01,	-15.,	.7220E+06

**Purpose**

The SYSPERD.OUT file contains information describing the performance of the system in the given model run. This file consists of one detail line for each year and period in the given model run. Each detail line contains the year (NYEAR), the period (IX), the system unserved energy in kilowatt-hours (UEUOUT), the system loss-of-load probability (SLOLP) as a fraction of the total time, the capacity of the firm purchases or sales in megawatts (FIRM), and the energy of the firm purchases or sales in kilowatt-hours (XFIRME).

File Name: INPACE.OUT

.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.18075740E+08.00000000E+00.00000000E+00.00000000E+00.00000000E+00.25594960E+07  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00

.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.29588390E+08.00000000E+00.00000000E+00.00000000E+00.00000000E+00.63011090E+07  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00

.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.71912600E+07.00000000E+00.00000000E+00.00000000E+00.00000000E+00.14990440E+07  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
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.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00.00000000E+00  
.00000000E+00.00000000E+00

0.	0.	0.	0.	0.	0.	295.	0.
0.	0.	0.	92.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.
0.	0.						

.407836E+02 .201387E+10 .366311E+08 .191662E+00 .636785E+08

7

1975	12	.4485978000
1975	12	.2571824000
1975	12	.0591188700
1975	7	.5367563000
1975	7	.6687391000
1975	7	.8232744000
1975	7	.4982939000



## Purpose

The INPACE.OUT file contains information describing the fuel types used in the given model run. This file consists of seven distinct line types. The first six line types occur only once. The last line type is repeated once for each unit in the given system. All the line types occur contiguously, and the line type occurrences are ordered by type number:

- The first line type contains the quantities of the fuel used in million Btu (FTFU), one for each fuel type. There are 50 fuel types in the given example.
- The second line type contains a list of the fuel costs in dollars (FTF\$), one for each fuel type.
- The third line type contains a list of the variable operation and maintenance costs in dollars (FTVOM), one for each fuel type.
- The fourth line type contains a list of the system generating capacity in megawatts by fuel type (FTMW).
- The fifth line contains the system loss-of-load probability in days or year (DSLLOLP), the thermal energy generation in kilowatt-hours (THMKWH), the system unsupplied energy in kilowatt-hours (UNSUPL), the system reserve margin in the critical period (RMMIN), and the fixed energy generation in kilowatt-hours (HYDKWH).
- The sixth line type contains the number of thermal generating units (NUMPLA) for the given run.
- The seventh line type is repeated for each unit in the given run. It contains the first year of unit operation (LIFE), the unit fuel type (IFUT), and the unit capacity factor (UTCF).

### 3.3.9 Capacity Factor Constraints

Update card 16 was introduced into the ICARUS model to facilitate better representation of certain operational constraints of thermal generating units. For example, a generating unit in an electric utility system may be constrained to operate within a minimum or maximum unit utilization level. The upper limit for unit utilization may be a consequence of limited fuel supply or environmental regulations that restrict unit operation to keep the pollution levels below a maximum limit. On the other hand, technical and operational characteristics of generating units, as well as the operational needs of the electric power system, may require that a unit operate at or above a minimum output level at all times (e.g., nuclear generating units). Depending on the type and nature of the constraints, these limits can be

expressed as daily, seasonal, or annual operational limits. Very often, the operational constraints are expressed as unit capacity factor limits.

The ICARUS model is now capable of taking into account annual capacity factor limits when simulating the operation of an electric power system. The minimum, maximum, or both capacity factor limits for one or more thermal generating units in the system are input into ICARUS. These limits can be changed from year to year. Moreover, capacity factor limits can even be specified for new generating units that do not now exist in the system but are being considered as future additions.

The methodology applied in ICARUS for constraining unit capacity factors deals with the position of generating units in the loading order. If capacity factor constraints are specified by the user, the CheckCF subroutine of the ICARUS model will try to satisfy them by modifying the loading order of generating units whose capacity factors are not within the specified limits. The loading order number of these generating units will be increased or decreased, depending on whether the capacity factor of the unit should be decreased or increased, respectively. In each iteration, the unit position in the loading order is shifted up or down a step until all capacity factor constraints are satisfied or until the maximum number of iterations (specified by the user) is reached.

If the capacity factor constraints are specified for one or more units in the generating system, the ICARUS simulation of system operations is performed as follows:

- First, ICARUS simulates the annual system operation as if no capacity factor constraints are specified for any unit. The loading order used for this run is defined by the loading order option specified by the user in the LOADDATA input file (card type L6).
- After the simulation of system operation is completed, subroutine CheckCF determines whether the capacity factors of the generating units are within the specified lower and upper limits. If all capacity factors are within the specified constraints, the program stops execution at this point, and the results of the simulation are final.
- If the capacity factor constraints for one or more generating units are not satisfied, the CheckCF subroutine modifies the loading order of these units to satisfy the constraints, and ICARUS simulation of system operation will be repeated with the modified loading order.
- After the new ICARUS run is completed, the obtained unit capacity factors are checked again. If some capacity factor constraints are still not satisfied, the loading order of these units is modified again, leading to a new ICARUS simulation.

- This process is repeated until all capacity factor constraints are satisfied or until the maximum number of iterations is reached.

The CheckCF routine recognizes the difference between the single-block and two-block representation of generating units in the ICARUS model. If there are capacity factor constraints for a single-block unit, the loading order position of the whole unit is shifted up or down. In the case of a two-block unit representation, the routine always ensures that the base block is loaded before the peak block. Two cases exist for the two-block unit representation:

- If the unit position in the loading order is to be shifted downward (toward decreasing unit capacity factor), only the peak block is shifted down, and the base block remains at the same position as in the previous iteration. If, after several iterations, the peak block reaches the last position in the loading order and the unit capacity factor still exceeds the limit, the base block is shifted down until the constraint is satisfied.
- If the unit position in the loading order is to be shifted upward (toward increasing unit capacity factor), the routine checks whether the base and peak blocks were loaded immediately one after another. If that is the case, the base block is shifted one step up, and the peak block is shifted in the next iteration, if necessary. If they were not loaded immediately one after another, the peak block is shifted a step up, and the base block remains at the same position. If, after several iterations, the peak block has reached the position just after the base block, the base block is shifted a step up in the next iteration. This routine ensures that the base block is always loaded before the peak block.

The number of iterations needed to satisfy all capacity factor constraints depends strongly on the generation mix and the number of generating units in the system, as well as the type and number of capacity factor constraints. Experience has shown that all reasonable capacity factor constraints are usually satisfied in three to five iterations. Taking into account the short running time of the ICARUS model, this number is acceptable.

It is not always possible to satisfy all constraints, especially for small generating systems with few generating units. Sometimes, because of the bulk unit sizes, the problem cannot be solved if the acceptable capacity factor for a unit was specified in a very narrow range (e.g., 55-57%). You should generally start an ICARUS simulation with a low value for the maximum number of iterations (e.g., five to seven) and check the output results if the capacity constraints were satisfied. A comparison between realized unit capacity factors and the given constraints is always printed after the system's annual operation results in the ICARUS.REP output file. If the capacity factor limits for one or more generating units were not satisfied, you can check to see how close they were to the specified limits and, in the next ICARUS run, increase the number of iterations if it is likely that all capacity factors will be satisfied within a few additional iterations. The results of all iterations should be printed (CH = 0.0), and the positions of generating units in the loading order after each iteration should be checked. Because a significant amount of output can be produced, you are advised to use the most

restrictive printout options (e.g., printing of only annual results [KP = 0 to 3]) for the initial ICARUS runs. When all capacity factor limits are satisfied, you may choose to repeat the ICARUS run with more output details (KP = 4 to 8) by selecting the option for printing the results of the last capacity factor iteration only (CH = 1.0).

The methodology for adjustments of unit capacity factors is illustrated by the example of a fictitious electric power system consisting of seven generating units: four coal-fired steam units and three gas-fired combustion turbines. All seven units were represented in the ICARUS model by using the two-block representation, and the loading order option was specified as economic loading order adjusted for the spinning reserve. The capacity factor constraints were specified for all coal units, as shown in Table 3.4. It was assumed that the maximum capacity factor for the two smaller units must not exceed 70%, while the minimum capacity factor for the two 100-MW coal units must exceed 60%. Table 3.4 shows that these constraints were satisfied in four iterations.

**TABLE 3.4 Capacity Factor Constraints Imposed on Coal Units**

Unit Name	Unit Size (MW)	Running Cost (mill/kWh)	Capacity Factor Limits	Unit Capacity Factors by Iteration			
				I	II	III	IV
Coal1B	65	14.37	0.0-0.7	0.851	0.852	0.756	0.537
Coal1A93	30	14.37	0.0-0.7	0.832	0.496	0.497	0.498
Coal2A	100	23.23	0.6-1.0	0.687	0.776	0.548	0.669
Coal2B	100	23.41	0.6-1.0	0.498	0.531	0.823	0.823
CT1	50	31.40	-	0.455	0.401	0.401	0.449
CT2	30	33.17	-	0.257	0.273	0.266	0.257
CT3	12	35.12	-	0.059	0.059	0.059	0.059

After each ICARUS simulation, the CheckCF routine compares unit capacity factors with the specified constraints. This comparison and the changes in the loading order for the units that do not satisfy the capacity factor limits are printed in the ICARUS.REP output file. In addition, the CheckCF routine prints a table that lists all thermal generating units in service in the current simulation year and their current positions in the loading order. This loading order table is available with the printout option ( $KP \geq 3$ ). Sample output pages produced by CheckCF routine for the above example are presented in Appendix 3A.

Input data defining the unit capacity factor constraints should be specified in the LOADDATA input file by using update card 16, followed by a set of cards specifying unit capacity factor limits (one line for each unit that has capacity factor constraints). Types of data used for specifying capacity factor limits and their respective input formats are given in Table 3.5.

**TABLE 3.5 Data Used in Specifying Capacity Factor Limits**

Update 16:	Annual Capacity Factor Limits	Card Columns	Variable Format
LY	Year in which the change is to occur		I
LW	= 1		I
LSS	= 0		I
LPLT	= 0		I
IV	= 16		I
CH	Option for printing capacity factor iterations in the ICARUS.REP file. If CH = 0.0, the program will print the results for all capacity factor iterations. If CH = 1.0, the program will print simulation results for the last capacity factor iteration only.		F
IC	Number of units with capacity factor constraints.		I
JC	Maximum number of capacity factor iterations.		I
NUNIT	[1-600] (none) Generating unit number. This is the order number assigned to the unit in the UNITDATA input file.	1-4	I
KYEAR	[≥1] (none) First year in which the capacity factor constraints for this unit are in effect.	11-15	I
LYEAR	[≥1] (none) Last year in which the capacity factor constraints for this unit are in effect.	16-20	I
MINCF	[0-1] (none) Minimum capacity factor required for this unit.	21-30	F
MAXCF	[0-1] (none) Maximum capacity factor allowed for this unit.	31-40	F

Note: The following data must follow this update. The number of input cards (lines) must correspond to the IC value.

Variable IC defines the total number of units for which the capacity factor limits are specified or the total number of input lines with capacity factor limits that follow the update card. Variable JC represents the maximum number of capacity factor iterations to be performed in an ICARUS run in a single simulation year. When the iteration counter reaches the value of JC, the program will stop execution even if some of the capacity factor constraints have not been completely satisfied. This variable limits the number of iterations in cases in which it is difficult or impossible to satisfy given capacity factor limits. For the initial ICARUS run, a maximum of five to seven iterations is recommended. After examining the output results, you may increase the maximum number of iterations and repeat the ICARUS run to satisfy capacity factor constraints.

If the ICARUS model is used to simulate system operation over several years, it is not necessary to repeat input data for capacity factor constraints in each year. The CheckCF routine uses the KYEAR and LYEAR variables to determine which of the capacity factor constraints are in effect in the current simulation year. If capacity factor limits for some generating units change from year to year, it is enough to use update card 16 in later years only for those units that have changes. The capacity factor limits for other units will remain the same as entered in the first simulation year. The capacity factor constraints for a generating unit may either expire after the year LYEAR or be redefined with a new update card 16. To reset and discontinue all capacity factor constraints, an update card 16 with zero values for variables IC and JC should be used.

**APPENDIX 3A**

**OUTPUT PAGES PRODUCED BY CHECKCF ROUTINE**





CHECKING CAPACITY FACTOR CONSTRAINTS:

=====

ITERATION= 1

CURRENT YEAR: 1993

CURRENT LOADING ORDER (BY UNIT AND BLOCK):

-----

LOADING ORDER	LOAD NUMBER	UNIT NUMBER	UNIT NAME (AND BLOCK NUMBER)
1	14.361	4	COAL1B BLOCK: 1
2	14.361	4	COAL1B BLOCK: 2
3	14.361	7	COAL1A93 BLOCK: 1
4	14.361	7	COAL1A93 BLOCK: 2
5	23.185	5	COAL2A BLOCK: 1
6	23.185	5	COAL2A BLOCK: 2
7	23.185	6	COAL2B BLOCK: 1
8	23.185	6	COAL2B BLOCK: 2
9	28.540	1	CT1
10	29.630	2	CT2
11	30.540	3	CT3

CHECK UNITS WITH CAPACITY FACTOR CONSTRAINTS:

-----

UNIT NUMBER	UNIT NAME	CAPACITY FACTOR	LOWER LIMIT	UPPER LIMIT
-------------	-----------	-----------------	-------------	-------------

4	COAL1B	.8513	.0000	.7000
---	--------	-------	-------	-------

LOADING ORDER OF UNIT COAL1B (BLOCK: 2) WILL BE CHANGED IN ORDER TO DECREASE CAPACITY FACTOR

7	COAL1A93	.8318	.0000	.7000
---	----------	-------	-------	-------

LOADING ORDER OF UNIT COAL1A93 (BLOCK: 2) WILL BE CHANGED IN ORDER TO DECREASE CAPACITY FACTOR

5	COAL2A	.6866	.6000	1.0000
---	--------	-------	-------	--------

6	COAL2B	.4976	.6000	1.0000
---	--------	-------	-------	--------

LOADING ORDER OF UNIT COAL2B (BLOCK: 1) WILL BE CHANGED IN ORDER TO INCREASE CAPACITY FACTOR

\*\*\* SIMULATION OF YEAR 1993 WILL BE REPEATED USING THE NEW LOADING ORDER \*\*\*

CHECKING CAPACITY FACTOR CONSTRAINTS:

=====

ITERATION= 2

CURRENT YEAR: 1993

CURRENT LOADING ORDER (BY UNIT AND BLOCK):

-----

LOADING ORDER	LOAD NUMBER	UNIT NUMBER	UNIT NAME (AND BLOCK NUMBER)
1	14.361	4	COAL1B BLOCK: 1
2	14.361	5	COAL2A BLOCK: 1
3	14.361	7	COAL1A93 BLOCK: 1
4	14.362	4	COAL1B BLOCK: 2
5	23.184	6	COAL2B BLOCK: 1
6	23.185	5	COAL2A BLOCK: 2
7	23.185	6	COAL2B BLOCK: 2
8	23.186	7	COAL1A93 BLOCK: 2
9	28.540	1	CT1
10	29.630	2	CT2
11	30.540	3	CT3

CHECK UNITS WITH CAPACITY FACTOR CONSTRAINTS:

-----

UNIT NUMBER	UNIT NAME	CAPACITY FACTOR	LOWER LIMIT	UPPER LIMIT
-------------	-----------	-----------------	-------------	-------------

4	COAL1B	.8518	.0000	.7000
---	--------	-------	-------	-------

LOADING ORDER OF UNIT COAL1B (BLOCK: 2) WILL BE CHANGED IN ORDER TO DECREASE CAPACITY FACTOR

7	COAL1A93	.4958	.0000	.7000
---	----------	-------	-------	-------

5	COAL2A	.7764	.6000	1.0000
---	--------	-------	-------	--------

6	COAL2B	.5307	.6000	1.0000
---	--------	-------	-------	--------

LOADING ORDER OF UNIT COAL2B (BLOCK: 2) WILL BE CHANGED IN ORDER TO INCREASE CAPACITY FACTOR

\*\*\* SIMULATION OF YEAR 1993 WILL BE REPEATED USING THE NEW LOADING ORDER \*\*\*

CHECKING CAPACITY FACTOR CONSTRAINTS:

=====

ITERATION= 3

CURRENT YEAR: 1993

CURRENT LOADING ORDER (BY UNIT AND BLOCK):

-----

LOADING ORDER	LOAD NUMBER	UNIT NUMBER	UNIT NAME (AND BLOCK NUMBER)
1	14.361	4	COAL1B BLOCK: 1
2	14.361	5	COAL2A BLOCK: 1
3	14.361	7	COAL1A93 BLOCK: 1
4	14.362	6	COAL2B BLOCK: 1
5	23.184	6	COAL2B BLOCK: 2
6	23.185	4	COAL1B BLOCK: 2
7	23.185	5	COAL2A BLOCK: 2
8	23.186	7	COAL1A93 BLOCK: 2
9	28.540	1	CT1
10	29.630	2	CT2
11	30.540	3	CT3

CHECK UNITS WITH CAPACITY FACTOR CONSTRAINTS:

-----

UNIT NUMBER	UNIT NAME	CAPACITY FACTOR	LOWER LIMIT	UPPER LIMIT
4	COAL1B	.7560	.0000	.7000
7	COAL1A93	.4973	.0000	.7000
5	COAL2A	.5481	.6000	1.0000
6	COAL2B	.8230	.6000	1.0000

LOADING ORDER OF UNIT COAL1B (BLOCK: 2) WILL BE CHANGED IN ORDER TO DECREASE CAPACITY FACTOR

\*\*\* SIMULATION OF YEAR 1993 WILL BE REPEATED USING THE NEW LOADING ORDER \*\*\*

CHECKING CAPACITY FACTOR CONSTRAINTS:

=====

ITERATION= 4

CURRENT YEAR: 1993

CURRENT LOADING ORDER (BY UNIT AND BLOCK):

-----

LOADING ORDER	LOAD NUMBER	UNIT NUMBER	UNIT NAME (AND BLOCK NUMBER)
1	14.361	4	COAL1B BLOCK: 1
2	14.361	5	COAL2A BLOCK: 1
3	14.361	7	COAL1A93 BLOCK: 1
4	14.362	6	COAL2B BLOCK: 1
5	23.184	6	COAL2B BLOCK: 2
6	23.185	5	COAL2A BLOCK: 2
7	23.186	4	COAL1B BLOCK: 2
8	23.186	7	COAL1A93 BLOCK: 2
9	28.540	1	CT1
10	29.630	2	CT2
11	30.540	3	CT3

CHECK UNITS WITH CAPACITY FACTOR CONSTRAINTS:

-----

UNIT NUMBER	UNIT NAME	CAPACITY FACTOR	LOWER LIMIT	UPPER LIMIT
4	COAL1B	.5368	.0000	.7000
7	COAL1A93	.4983	.0000	.7000
5	COAL2A	.6687	.6000	1.0000
6	COAL2B	.8233	.6000	1.0000

\*\*\* ALL UNIT CAPACITY FACTORS ARE WITHIN SPECIFIED LIMITS \*\*\*

\*\*\* END OF CAPACITY FACTOR ITERATIONS \*\*\*

**APPENDIX 3B**

**WEEKS TO PERIODS CONVERSION TABLES**



**TABLE A2.1 Weeks to Periods Conversion for  
ICARUS Run with 26 Periods per Year**

Month	ICARUS Period	Weeks	Beginning Date	Ending Date
January	1	1, 2	January 1	January 14
January	2	3, 4	January 15	January 28
February	3	5, 6	January 29	February 11
February	4	7, 8	February 12	February 25
March	5	9, 10	February 26	March 11
March	6	11, 12	March 12	March 25
April	7	13, 14	March 26	April 8
April	8	15, 16	April 9	April 22
April	9	17, 18	April 23	May 6
May	10	19, 20	May 7	May 20
May	11	21, 22	May 21	June 3
June	12	23, 24	June 4	June 17
June	13	25, 26	June 18	July 1
July	14	27, 28	July 2	July 15
July	15	29, 30	July 16	July 29
August	16	31, 32	July 30	August 12
August	17	33, 34	August 13	August 26
September	18	35, 36	August 27	September 9
September	19	37, 38	September 10	September 23
October	20	39, 40	September 24	October 7
October	21	41, 42	October 8	October 21
October	22	43, 44	October 22	November 4
November	23	45, 46	November 5	November 18
November	24	47, 48	November 19	December 2
December	25	49, 50	December 3	December 16
December	26	51, 52	December 17	December 31



**TABLE A2.2 Weeks to Periods Conversion for  
ICARUS Run with 24 Periods per Year**

Month	ICARUS Period	Weeks	Beginning Date	Ending Date
January	1	1, 2, 3	January 1	January 16
January	2	4, 5	January 17	January 31
February	3	6, 7	February 1	February 16
February	4	8, 9	February 17	March 3
March	5	10, 11	March 4	March 18
March	6	12, 13	March 19	April 2
April	7	14, 15, 16	April 3	April 18
April	8	17, 18	April 19	May 3
May	9	19, 20	May 4	May 18
May	10	21, 22	May 19	June 2
June	11	23, 24	June 3	June 17
June	12	25, 26	June 18	July 2
July	13	27, 28, 29	July 3	July 18
July	14	30, 31	July 19	August 2
August	15	32, 33	August 3	August 17
August	16	34, 35	August 18	September 1
September	17	36, 37	September 2	September 16
September	18	38, 39	September 17	October 1
October	19	40, 41, 42	October 2	October 17
October	20	43, 44	October 18	November 1
November	21	45, 46	November 2	November 16
November	22	47, 48	November 17	December 1
December	23	49, 50	December 2	December 16
December	24	51, 52	December 17	December 31

**APPENDIX 3C**

**A USER'S GUIDE TO ICARUS: A MODEL FOR INVESTIGATING  
COST AND RELIABILITY IN UTILITY SYSTEMS**



ANL/EAIS/TM-19

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# **A Users' Guide to ICARUS: A Model for Investigating Cost and Reliability in Utility Systems**

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February 1990

Work sponsored by United States Department of Energy, Assistant Secretary for Fossil Energy



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## FOREWORD

The ICARUS code and this documentation were prepared under the sponsorship of the U.S. Department of Energy. Any distribution of the software package or other data therein except to DOE offices or other DOE contractors, unless otherwise specifically provided for, is prohibited without the approval of the National Energy Software Center. Requests from outside DOE for DOE-developed computer software should be directed to Director, National Energy Software Center, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439.

## ACRONYMS

ANL	Argonne National Laboratory
CPU	central processing unit
DOE	U.S. Department of Energy
ECAR	East Central Area Reliability
EIA	Energy Information Administration
ELDC	equivalent load duration curve
EPRI	Electric Power Research Institute
ERCOT	Electric Reliability Council of Texas
ERM	expected reserve margin
EUE	expected unserved energy
FCE	firm capacity equivalent
GURF	Generating Unit Reference File
ICARUS	Investigation of Costs and Reliability in Utility Systems
LCC	load correlation curve
LDC	load duration curve
LOEP	loss-of-energy probability
LOLP	loss-of-load probability
MAAC	Mid-Atlantic Area Council
MAIN	Mid-America Interpool Network
MAPP	Mid-Continent Area Power Pool
MEC	marginal energy cost
NERC	North American Reliability Council
NPCC	Northeast Power Coordinating Council
NRC	U.S. Nuclear Regulatory Commission
O&M	operation and maintenance
REC	replacement energy cost
RELCOMP	Reliability and Cost Model for Electrical Generation Planning
SERC	Southeastern Electric Reliability Council
SPP	Southeast Power Pool
SRMC	short-run marginal cost
SYSREL	System Reliability Code
WASP	Wien Automatic System Planning Package
WSCC	Western System Coordinating Council

# A USERS' GUIDE TO ICARUS: A MODEL FOR INVESTIGATING COST AND RELIABILITY IN UTILITY SYSTEMS

by

K.A. Guziel, J.C. VanKuiken, and W.A. Buehring

## ABSTRACT

ICARUS is an energy system planning tool for assessing the reliability and economic performance of alternative expansion patterns of electric utility generating systems. Input information includes capacity, forced outage rate, number of weeks of scheduled maintenance, and economic data for individual units, along with expected utility load characteristics. The model calculates (1) a system maintenance schedule, (2) the loss-of-load probability, (3) unserved demand for electrical energy, (4) required capacity reserve to meet a specified reliability criterion, (5) the effects of emergency interties, (6) expected energy generation and cost from each unit and block, (7) total generating system costs, and (8) fuel use. Firm purchases and sales of electricity can be included in the analysis. ICARUS uses a modified probabilistic simulation technique that produces an acceptable level of accuracy while significantly reducing computation requirements. It has been used to determine the replacement energy costs for short-term shutdowns, to calculate time-of-day tariffs that are based on short-run marginal cost of energy, and to show the effects of new technologies on system reliability. This report documents the personal computer version of the ICARUS model and provides guidance in preparing data input.

## 1 INTRODUCTION

### 1.1 BACKGROUND

The basic modeling framework for the Investigation of Costs and Reliability in Utility Systems (ICARUS) model evolved from two earlier utility simulation tools developed at Argonne National Laboratory (ANL). The original model, the System Reliability Code (SYSREL), was developed in the early 1970s for electric utility investigations (Hub et al., 1975). Subsequently, SYSREL was significantly enhanced to expand its simulation capabilities. By 1979, it was renamed the Reliability and Cost Model for Electrical Generation Planning (RELCOMP) (Buehring, Guziel, and Mullen, 1981).

The next major revision focused on improving the computationally intensive segment of RELCOMP. The new methodology reduced computer execution time while

preserving the model's accuracy, numerical stability, and usefulness (VanKuiken, 1983). In 1982, the model was renamed ICARUS.

The computational improvements in ICARUS were required for a project sponsored by the U.S. Nuclear Regulatory Commission (NRC). The project involved determining, with reasonable accuracy, the unit-specific replacement energy costs for potential short-term shutdowns of more than 100 commercial nuclear reactors (VanKuiken, Buehring, and Guziel, 1984). Detailed dispatching and production-cost analyses were made for more than 20 power pools\* containing a diverse assortment of technology types, unit sizes, and fuel mixes. Some of the power pools contained more than 200 generating units. The large number of simulations required application of an efficient and realistic modeling technique.

## 1.2 REPORT ORGANIZATION

Section 2 (Methodology) describes how ICARUS represents its main modeling features (e.g., maintenance, unit representation, and dispatch). Section 3 (Guidelines for Use) explains the main parameters that affect model run time and accuracy. Section 4 (Model Applications) contains case studies and describes a special system representation that was developed to simulate hourly loads.

The appendixes present detailed information on executing the model and its output. Appendix A contains detailed descriptions of the input formats. Appendix B discusses how to construct the input data files, and App. C consists of sample output. Appendix D describes the format of an auxiliary output file that can be used for postprocessing. Finally, App. E details the computer requirements for the model.

---

\*A power pool is a group of utilities that coordinate their generation of electric power.

## 2 METHODOLOGY

To understand and evaluate a production-cost model, the user must know how the model represents an electric utility system. Section 2 covers some of the key representations in ICARUS.

### 2.1 OVERVIEW

ICARUS is a production-cost model, written in FORTRAN, that simulates operation of electric utility systems. It can model systems as large as 600 dispatchable thermal units, each having two blocks of capacity and a composite limited-energy unit. The simulation can be for up to 52 periods per year for any number of years. An efficient probabilistic simulation algorithm determines the production costs and capacity factor for each unit.

In performing its four major functions, ICARUS (1) calculates economic loading order, (2) schedules maintenance, (3) calculates expected energy generation and costs, and (4) calculates reliability indices. Figure 2.1 provides an overview of the program flow in ICARUS.

There are three major categories of input data: load data, unit data, and economic data (see Table 2.1). There are two input files: LOADDATA and UNITDATA (see Fig. 2.2). Appendixes A and B discuss the inputs and input file construction in detail.

ICARUS generates two output files: REPORT, which contains the standard output results, and AUXILIARY, which contains system and unit-specific information that can be used in a postprocessor. (A postprocessor can be used to determine marginal energy costs, summarize results, and calculate subtotals.) There are six major categories of output:

1. Unit generation.
2. Fuel use.
3. Costs (i.e., capital, fixed operating and maintenance [O&M], variable O&M, and fuel costs).
4. Reliability indices.
5. Reserve deficit. (Reserve deficit is the amount of dependable capacity needed to meet a specified loss of load probability level.)
6. System maintenance schedule.

The generation, fuel use, and cost information is available on a unit-specific basis, but can be aggregated by fuel category and for the entire system. Appendix C presents output for a sample case, and App. D covers auxiliary output file formats.

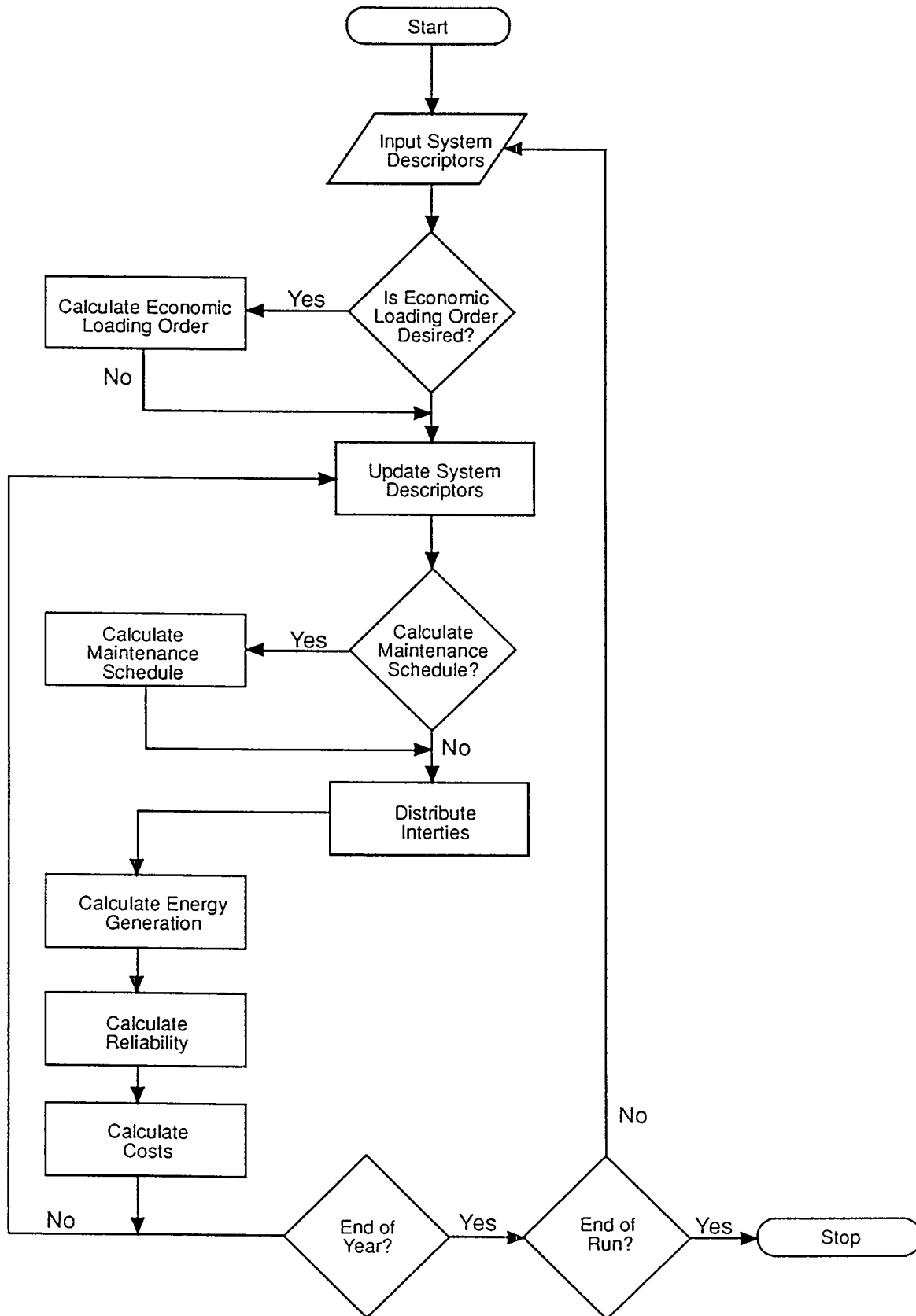


FIGURE 2.1 ICARUS Program Flow

**TABLE 2.1 Input Requirements for ICARUS**


---

 Load data

Load duration curves  
 Annual peak load  
 Period peak load ratios  
 Firm purchase requirements  
 Firm sales requirements  
 Emergency intertie capacity

## Unit data (for each thermal unit)

Year on line  
 Week on line  
 Year retired  
 Week retired  
 Unit name  
 Unit forced outage rate (%)  
 Unit fuel cost ( $\text{¢}/10^6$  Btu)  
 Unit maintenance requirement (weeks per year)  
 Unit maintenance start week (optional)  
 Unit fixed operating and maintenance (O&M)  
   cost ( $\text{\$/kW-yr}$ )  
 Unit variable O&M cost (mills/kWh)  
 Unit capital cost ( $\text{\$/kW}$ )  
 Size by capacity block (MWe)  
 Heat rate by capacity block ( $10^3$  Btu/kWh)  
 Loading order number by capacity block  
 Spinning reserve contribution by  
   capacity block (%)

## Unit data (for energy-limited unit)

Period capacity for base and peak block (MWe)  
 Capacity factor of peak block by period (%)

## Economic data

Costs for firm purchases and sales  
 Costs for emergency purchases  
 Discount rate

---



## 2.2 SYSTEM LOAD REPRESENTATION

The energy demanded of an electric generating system is defined in ICARUS by specifying the annual peak load, period peak loads, and load duration curves (LDCs). The year can be represented by up to 52 simulation periods and by up to 52 unique demand seasons. Each season can be assigned to one or more periods of the year. System dispatch is done for each period.

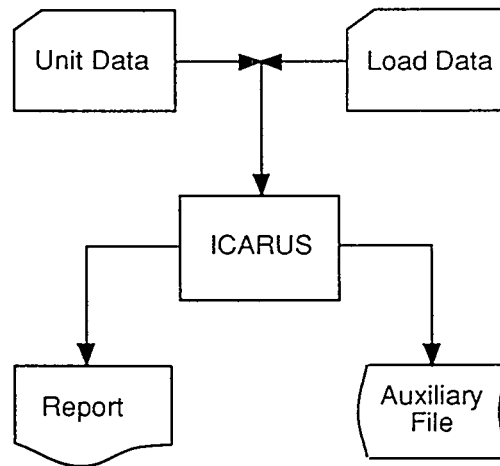


FIGURE 2.2 ICARUS File Structure

### 2.2.1 Peak Load Data

Peak load data are defined by the annual peak load and period peak load ratios. The annual peak load can be changed yearly by specifying a new annual peak load (in megawatts-electric) or by specifying a multiplier to apply to the previous year's annual peak load.

A period peak load ratio is defined, for each period, as the ratio of the period peak load to the annual peak load (both in megawatts-electric). At least one period during the year will have a period peak load ratio equal to 1.0. Although several periods may use the same LDC, each period can have a unique peak load. The period peak load ratios can be updated yearly, but they are usually held constant for the study period.

### 2.2.2 Load Duration Curve (LDC) Representation

ICARUS allows up to 52 seasonal LDCs to be defined. They can be entered as incremental or cumulative curves, and can be built up from actual or projected data. (Figure 2.3 illustrates chronological load data for a sample week, whereas Fig. 2.4 shows the cumulative LDC associated with the data in Fig. 2.3.) If no historical data are available, other techniques can be used to generate LDCs. For example, the Snyder (1973) method uses the minimum load and load factor to generate the coefficients for a fifth-degree polynomial. These coefficients are used to determine the x,y coordinates for a cumulative LDC. Cumulative LDCs are defined by specifying the duration of the load (normalized to the total hours in the period) and the load magnitude (normalized to the period peak load). Table 2.2 gives the chronological loads for one day and the corresponding normalized load and time that define the associated LDC.

If the LDCs are defined as incremental, they represent the frequency distribution of the system load. Incremental LDCs are defined by specifying the lower boundary of the load interval and the time that the load falls within that load interval. Any time unit can be specified (e.g., hours, days, or fractional periods), and time units need not sum to unity. Load intervals must be entered in descending order from the largest to the smallest load. The load intervals do not have to be equal.

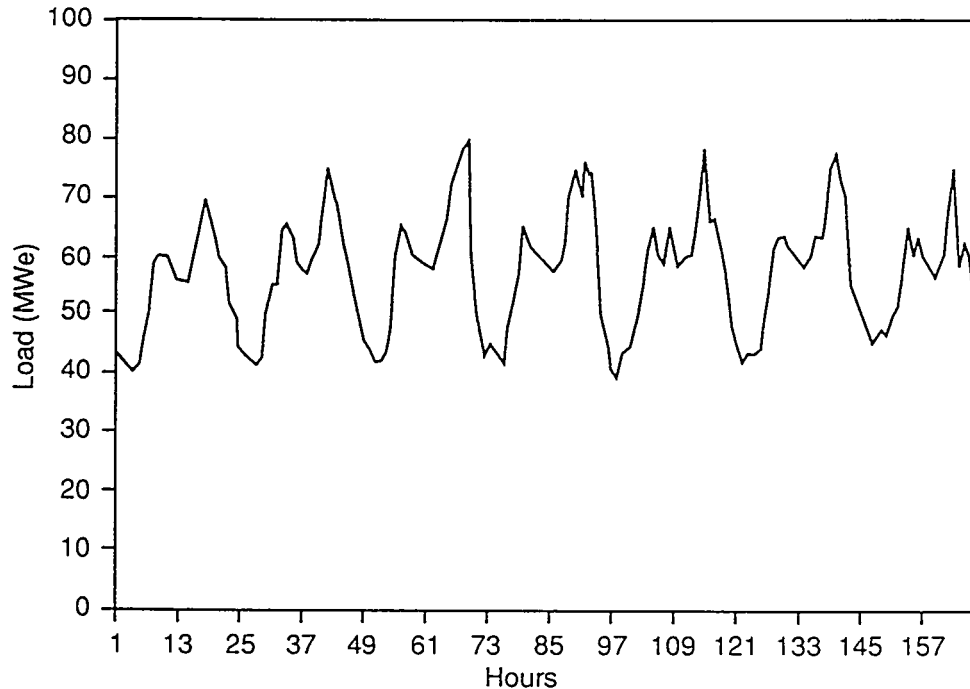


FIGURE 2.3 Sample Hourly Load for One Week

When using either incremental or cumulative LDCs, the point 1,0 should not be entered. ICARUS defines the first interval range from the boundary (i.e., 1,0) to the first entered point.

### 2.3 GENERATING SYSTEM REPRESENTATION

ICARUS can simulate an electric utility system with as many as 600 generating units. To simulate realistic loading behavior, each unit can be divided into a maximum of two capacity blocks: the first is referred to as the base block and the second as the peak block. This feature allows ICARUS to represent generating units that can operate at partial capacities. It can also account for other system limitations (see Sec. 3.3).

Table 2.3 lists the optional and required input data for each generating unit. ICARUS does not provide nonzero default values for optional inputs. Because fixed format reads are used for the generating unit input data, any input value not defined is read as zero. If calculated by ICARUS, the loading order number is a function of fuel cost, heat rate, and variable O&M cost. If users do not

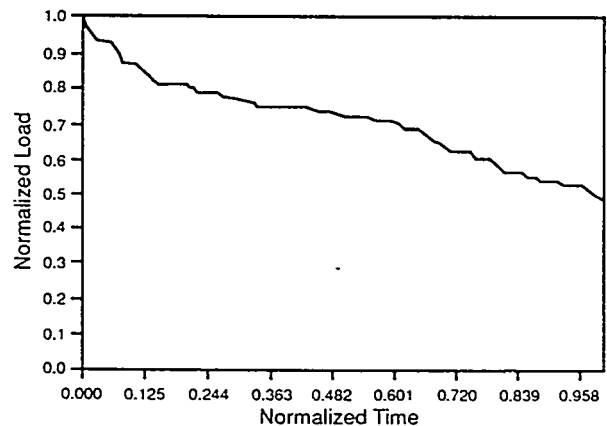


FIGURE 2.4 Cumulative Load Duration Curve for Sample Week

**TABLE 2.2 Chronological Load and Associated Load  
Duration Curve for One Day**

Hours	Load (MWe)	Sorted Load (MWe)	(Y) Normalized Load	(X) Normalized Time
1	43	70	1.000	0.042
2	42	68	0.971	0.083
3	40	65	0.929	0.125
4	40	63	0.900	0.167
5	41	60	0.857	0.208
6	45	60	0.857	0.250
7	50	60	0.857	0.292
8	58	60	0.857	0.333
9	60	58	0.829	0.375
10	60	58	0.829	0.417
11	58	58	0.829	0.458
12	57	57	0.814	0.500
13	56	57	0.814	0.542
14	55	56	0.800	0.583
15	57	55	0.786	0.625
16	60	52	0.743	0.667
17	65	50	0.714	0.708
18	70	49	0.700	0.750
19	68	45	0.643	0.792
20	63	43	0.614	0.833
21	60	42	0.600	0.875
22	58	41	0.586	0.917
23	52	40	0.571	0.958
24	49	40	0.571	1.000

input values for these three variables, the unit's capacity factor will be affected, unless an input loading order number is entered.

Although the generating units usually represent thermal generating units, they can be used to represent other technologies. In one example, pumped storage was represented as a two-block unit, with 10% of the unit's capacity in the base block and 90% in the peak block. The base block was assigned a heat rate of 0 Btu/kWh and the peak block a heat rate representative of the unit that supplied the pumping energy. The pumping energy was assumed to be accounted for in the LDC.

#### 2.4 MAINTENANCE

The maintenance schedule for an electric utility system affects both its reliability and cost. In ICARUS, system maintenance can be specified in one of three

**TABLE 2.3 Generating Unit Input Data**


---

Year on line	Required
Week on line	Optional
Year retired	Required
Week retired	Required
Unit forced outage rate (%)	Required
Unit fuel cost (¢/10 <sup>6</sup> Btu)	Optional
Unit maintenance requirement (weeks per year)	Optional
Unit maintenance start week	Optional
Unit fixed O&M cost (\$/kW-yr)	Optional
Unit variable O&M cost (mills/kWh)	Optional
Unit capital cost (\$/kW)	Optional
Size by capacity block (MWe)	Required
Heat rate by capacity block (10 <sup>3</sup> Btu/kWh)	Optional
Loading order number by capacity block	Optional

---

ways: (1) it can be entered by the user; (2) it can be partially specified by the user; or (3) it can be completely determined by the model.

Generating unit input data include the number of weeks per year of maintenance for each unit and the week in which that maintenance begins. The unit's maintenance requirement and start week, if specified, are converted from weeks to periods. For example, if 24 periods per year are specified, each period represents 15.21 days. A unit that requires two weeks of maintenance would be unavailable for one period during the year, while a unit with three weeks of maintenance would be unavailable for two periods during the year. If the week to begin maintenance is not specified, ICARUS will schedule the unit so that the effect on the system's expected capacity is minimized. In each case, the maintenance time is assumed to occur in consecutive periods.

In alternatives 2 and 3 above, the following additional assumptions are made:

1. The expected capacity of firm purchases and sales of the system is considered in determining the maintenance schedule for individual units, but not the system's emergency interties.
2. No unit is scheduled for maintenance in its first year of operation.
3. Units for which no beginning maintenance week has been specified are scheduled for maintenance in descending order, on the basis of their MW-periods. The "MW-periods" is calculated by multiplying the expected capacity (i.e., rated capacity times one minus the forced outage rate) by the number of maintenance periods required.

ICARUS uses the expected reserve margin (ERM) to evaluate the effect of the maintenance schedule on the system. Although the ERM can reasonably predict generating system reliability, it does not consider costs. The ERM is calculated as follows:

$$\text{(expected system capacity minus peak load)/peak load,}$$

where the expected system capacity includes the capacity from firm purchases or sales and the contribution from the fixed-energy technology (e.g., hydro). The expected system capacity is calculated by summing, over all the units, the result of the rated capacity of the unit times one minus the forced outage rate.

In summary, ICARUS determines which unit to schedule next for maintenance by calculating the MW-periods for each unit not yet scheduled for maintenance and selecting the unit with the largest value. Table 2.3 shows the maintenance requirements for a system with two nuclear units, one coal unit, and two oil units. Although oil-1 has a higher expected capacity than oil-2, oil-2 would be scheduled for maintenance before oil-1 because its MW-periods value is larger.

For the sample system presented in Table 2.4, assume that maintenance has already been scheduled for the two nuclear units. In Table 2.5, then, columns 2 and 3 show expected system capacity and peak load for each period. From these two values, the ERM for each period is calculated and displayed in column 4.

Coal-1 is the next unit scheduled for maintenance. On the basis of the maintenance information in Table 2.4, ICARUS calculates the ERM for each period in the year during which maintenance for coal-1 could occur. Columns 5 and 6 in Table 2.5 show the expected system capacity if maintenance for coal-1 is scheduled in each period and the resulting ERM. The period to begin maintenance is selected from the MAX[MIN(Resultant ERM)], where the MIN is taken over all possible periods in the maintenance interval, and the MAX is taken over all possible periods in which the maintenance interval could begin.

**TABLE 2.4 Maintenance Requirements for a Sample System**

Unit Name	Rated Capacity (MW)	Forced Outage Rate (%)	Expected Capacity (MW)	Number of Periods of Maintenance	Expected MW-Periods	Order in Which Maintenance Is Scheduled
Nuclear-1	1100	20	880	2	1760	1
Nuclear-2	1100	20	880	2	1760	2
Coal-1	800	15	680	2	1360	3
Oil-1	200	12	176	1	176	5
Oil-2	140	15	119	2	238	4

TABLE 2.5 Maintenance Scheduling Information for Coal-1

Period	Expected System Capacity (MW)	Peak Load (MW)	Period ERM	Expected System Capacity without Coal-1	Adjusted Period ERM	Minimum Resultant ERM
1	2280	1200	0.9	1600	0.33	0.13
2	2040	1200	0.7	1360	0.13	0.13
3	2200	1100	1.0	1520	0.38	0.38
4	2750	887	2.1	2070	1.33	1.23
5	2660	886	2.0	1980	1.23	0.78
6	2640	1100	1.4	1960	0.78	0.71
7	3080	1400	1.2	2400	0.71	0.71
8	3080	1400	1.2	2400	0.71	0.71
9	2860	1020	1.8	2180	1.14	0.98
10	2860	1100	1.6	2180	0.98	0.45
11	2860	1505	0.9	2180	0.45	0.33
12	2280	1200	0.9	1600	0.33	0.33

Column 7 shows the minimum ERM associated with each period. The minimum for period 1 is determined by looking at the ERMs in each period that would be affected if the maintenance for coal-1 were to begin in period 1. If maintenance for coal-1 were to begin in period 1, periods 1 and 2 would be affected because the unit requires two periods of maintenance. The minimum ERM value between period 1 (ERM = 0.33) and period 2 (ERM = 0.13) is 0.13. Therefore, period 1 is assigned a minimum resultant ERM of 0.13. This comparison procedure is repeated for each period.

The final step is to select the maximum value from among the minimum resultant ERMs. In this example, coal-1 would be scheduled to start maintenance in period 4. For periods in which the minimum resultant ERM is the same, ICARUS selects the starting period such that the average ERM will be maximized. If there are still ties, the period earlier in the year would be chosen.

ICARUS automatically schedules maintenance for the first year of a study period. As new units are brought on line, maintenance for the entire system should be rescheduled. This rescheduling can be done with update 7 of card type L19 (see App. A). When maintenance is rescheduled for the system, units that had been prescheduled keep the same maintenance information.

When a new unit is added to the system, the unit is never scheduled for maintenance during its first year of operation, even if a maintenance start week is specified. In addition, the new unit will not be scheduled for maintenance during the second and later years, even if prespecified, unless the user reschedules maintenance for the entire system.

Output from the maintenance scheduler includes a list of all units with each unit's maintenance requirements and beginning maintenance period. The units are listed in the order in which maintenance is scheduled. (See App. C for a sample maintenance schedule.)

## 2.5 HYDRO AND ENERGY-LIMITED TECHNOLOGIES

ICARUS has a generating unit category dedicated to representing energy-limited technologies. Called NUTYPE, this composite category is typically used for hydro representation, but can be used for other fixed-energy technologies such as wind, district heating, and other nondispatchable technologies.

The NUTYPE unit, which represents the capacity and energy of all units in the NUTYPE category, is made up of two blocks: base and peak. The capacity (in megawatts-electric) of the base and peak blocks, and the capacity factor for the peak block, must be specified for each demand period. By specifying a capacity factor rather than an actual quantity of energy, no adjustment is needed when the length of a period is changed.

The base block of the NUTYPE unit is assumed to generate at full load throughout the year. The peak portion is loaded to meet the specified energy demand in the period. Maintenance requirements and forced outages are not explicitly specified for the NUTYPE unit; however, maintenance for the NUTYPE unit can be modeled by adjusting its capacity or capacity factor in selected periods.

In addition, the user can specify a fuel cost, heat rate, fixed O&M cost, variable O&M cost, and capital cost associated with the NUTYPE unit. When scheduling maintenance for the generating units, ICARUS recognizes the NUTYPE capacity available.

## 2.6 PRODUCTION-COST MODEL

As a production-cost model, ICARUS can be used to look at the detailed operations of an electric utility system. It calculates system costs and generating-unit assignments over time. It also considers system reliability, which is an important factor in evaluating system performance.

Many factors must be considered in a production-cost model; therefore, tradeoffs between accuracy and computer run-time are inevitable. ICARUS has been designed to address some of these tradeoffs. For example, ICARUS has been used in several studies that required hundreds of computer runs for different systems in a short period of time (Vankuiken, Buehring, and Guziel, 1984; VanKuiken et al., 1987). The recent improvements in computational efficiency proved especially important for these studies.

The ICARUS model uses a probabilistic simulation approach (see Sec. 2.7) to determine the capacity factor for each block of each unit. It uses detailed unit and system data to determine period and annual energy generation and costs associated with each generating unit and the entire generating system.

Production-cost models are often used in conjunction with a long-term expansion planning model. ICARUS allows a closer look at the detailed operation of the system expansion plan prepared by the long-term model. Although ICARUS was designed for annual simulations, with up to 52 periods per year, a specialized representation has been developed to represent hourly analysis (see Sec. 4.2.1).

## 2.7 ICARUS DISPATCH METHODOLOGY

When calculating production costs, the effects of forced outages (unscheduled failures) in generating units should be accounted for. The costs and reliability of an electric utility system can be significantly affected by the failure of single units as well as by the simultaneous failure of more than one unit. However, enumerating all possible combinations of unit availabilities would be impractical, even for small systems. For this reason, special techniques have been used to examine unit outage probabilities in combination with system load variations.

The principles underlying the ICARUS generating unit dispatching logic are based on a technique referred to as the Baleriaux-Booth method (Baleriaux, Jamouille, and Linard de Guertechin, 1967; Booth, 1972). This approach represents the outage capacity from unit failures as though it were equivalent to additional loads that must be served by other units. The resulting equivalent load duration curve (ELDC) portrays the original system loads together with probabilistically determined outage capacities.

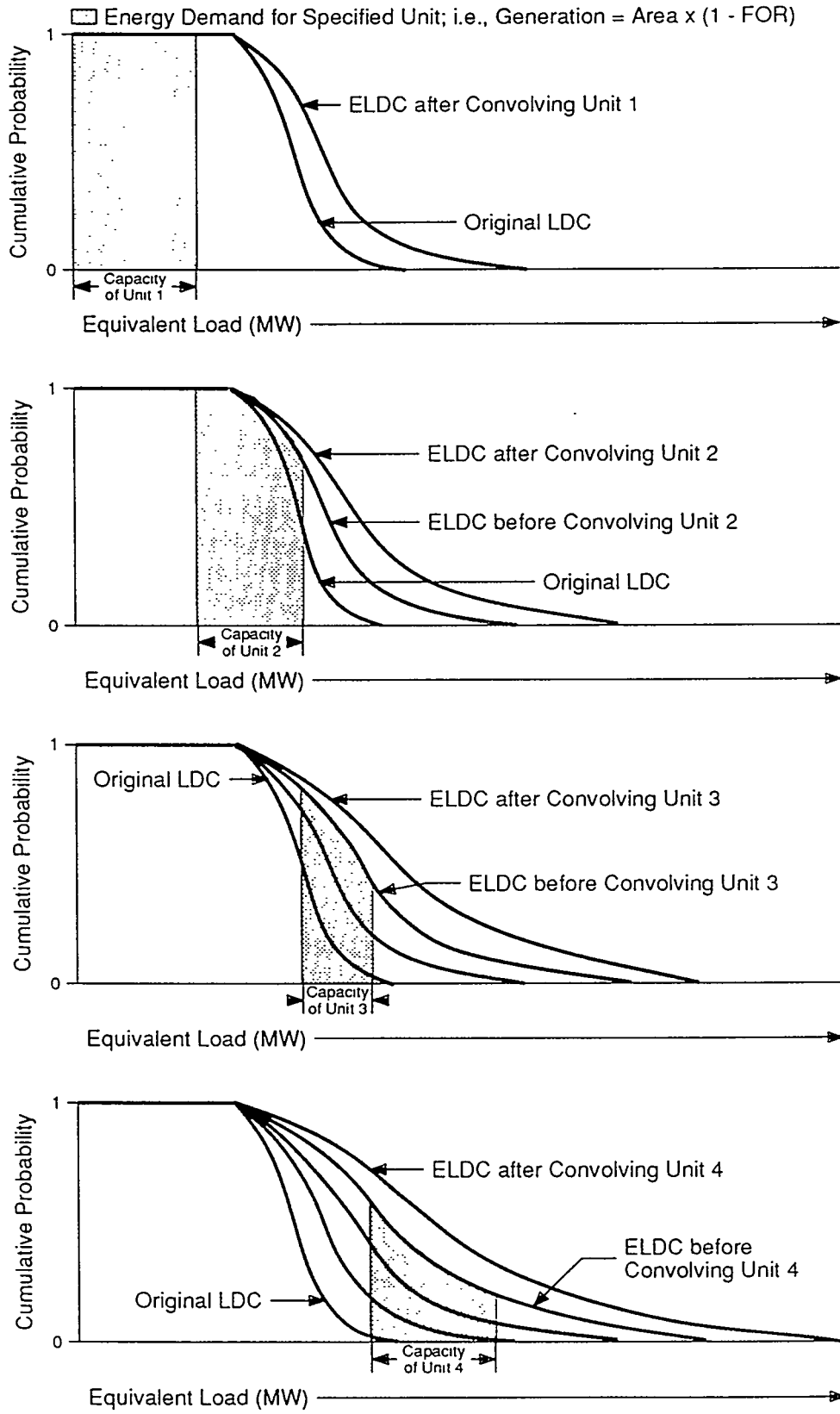
A sequence of ELDCs is constructed by dispatching each unit to determine its generation, that is, the amount of electricity it is generating. Each unit is convolved into the LDC to determine the net effect of its forced outages on the equivalent loads. Each successive ELDC consists of a weighted average between the previous load curve and the same load curve displaced by the capacity (in megawatts-electric) of the unit being dispatched. Figure 2.5 portrays a simplified view of the dispatching/convolution sequence for a four-unit system.

The Baleriaux-Booth method provides a consistent mathematical framework for determining unit generation assignments (based on unit failure probabilities), without enumerating all outage combinations. However, for systems with large numbers of generating units, the convolution procedure can constitute a computational burden.

The ELDCs are divided into small intervals, which results in convolution calculations being made at many points. This approach results in the ELDC shape being portrayed accurately. However, if units are blocked to simulate spinning reserve constraints, numerical instabilities may be introduced by the required deconvolutions and reconvolutions of partial and combined unit capacities.

The ICARUS model uses a unit dispatching algorithm that parallels the Baleriaux-Booth method, but reduces the number of convolutions and deconvolutions required. VanKuiken (1983) describes the details of the procedure, which is an approximation technique guided by the initial load curve and the final ELDC, which is determined by convolving all units with no blocking. Intermediate load curves are estimated through an interpolation procedure that uses key parameters (e.g., unit outage





**FIGURE 2.5** Sequential Loadings and Convolutions for an Example Four-Unit Generating System (Source: VanKuiken, 1988)

rates, unit sizes, and estimated load curve shapes) to determine unit energy commitments. Energy balance equations are used to ensure that system generation matches the net system loads (i.e., demand minus unserved energy).

The interpolation procedure eliminates the need for deconvolutions, even when units are blocked, to simulate dispatching constraints. Typical computational requirements for ICARUS represent about 5-15% of those associated with conventional convolution methods, and only minor differences in unit energy generation assignments have been observed.\* Furthermore, the technique does not exhibit the instabilities sometimes encountered with analytical techniques like polynomial expansion or cumulants.

Once the unit's generation level is determined, fuel use, fuel costs, and variable O&M costs can be calculated for each unit. Final results are aggregated over all fuel types and for the entire generating system.

## 2.8 SYSTEM RELIABILITY

The ELDC method provides a means of determining system reliability parameters. Once all generating units are fully convolved into the load curve, the final ELDC portrays the characteristics necessary for calculating loss-of-load probability (LOLP), expected unserved energy (EUE), and loss-of-energy probability (LOEP). For period-by-period reliability calculations, units on scheduled maintenance for a particular period are not included in the dispatching or reliability calculations for that period.

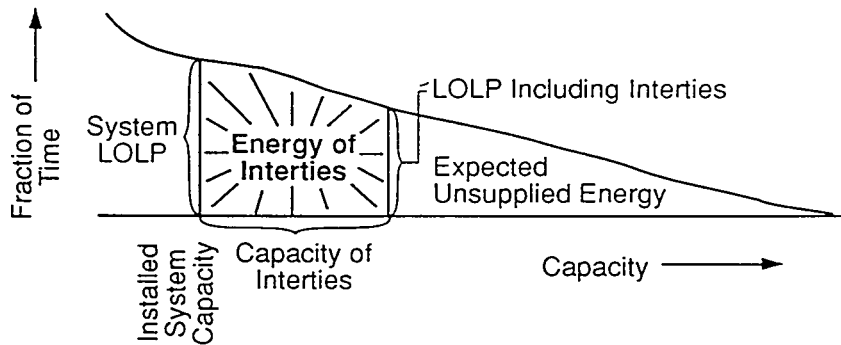
The system LOLP is determined from the height of the ELDC at the point at which the last unit is dispatched (i.e., where total megawatts-electric equals installed capacity) (see Fig. 2.6). In the figure, the ELDC is portrayed with some emergency interties available after the installed capacity. The energy required from emergency interties is the area under the final ELDC beyond the installed capacity. The height of the ELDC at the end of the intertie capacity is the system LOLP with interties.

In Fig. 2.6, the EUE is represented by the area in the tail of the final ELDC between the end point of installed capacity plus interties and the curve end point. The LOEP is calculated by dividing the EUE by the original energy demand, that is, the total area under the original load curve. Annual reliability performance is determined by weighting the outcomes for period results.

The reserve deficit is an additional reliability parameter that indicates the additional "firm" capacity that must be added to achieve a particular LOLP target. As with the other reliability parameters, the reserve deficit can be determined by examining the final ELDC. By locating the point on the curve (height) at which the target LOLP

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\*Unit-by-unit outcomes in test cases have matched results from conventional algorithms within a few percentage points.



**FIGURE 2.6** Equivalent Load Curve for Emergency Interties (Source: Buehring, Guziel, and Mullen, 1981)

occurs, the required difference in installed capacity (in megawatts-electric) can be found. The difference between this point and the system capacity plus interties is the firm capacity equivalent (FCE).

The FCE indicates how much additional capacity is needed such that the system can operate at the specified LOLP. When comparing the FCE to conventional technologies, the outage rate and maintenance requirement must be included. The FCE value may be negative if system reliability is better than the LOLP target. This value can be used when comparing alternative system configurations to account for differences in system reliability.

Reliability performance measures, such as those described above, can play an important role in utility investigations. For example, in comparing alternative generating technologies, the forced outage characteristics and generating unit sizes may create observable differences in LOLP or EUE. For consistent comparisons, the simulations should be adjusted (by adding or subtracting capacity) so that the reliability parameters are approximately equal. Alternatively, some cost adjustments (e.g., a penalty cost associated with the amount of unserved energy) can be included to reflect the differences in the value of overall system performance. Including these types of adjustments can influence the relative competitiveness of alternative generating technologies.

## 2.9 ENERGY TRANSFER REPRESENTATION

An electric utility with excess capacity will often contract with neighboring utilities to sell energy at a prespecified cost, level, and time. Such nonemergency transfers are known as firm purchases or firm sales. If actual system hourly loads are available, the firm purchase or sale capacity can be accounted for directly by building new LDCs from the adjusted hourly loads. However, this level of detail is not often available. ICARUS accounts for these activities by adjusting the original LDC.

### 2.9.1 Firm Purchases and Sales

To represent a firm purchase or sale, the following input data are required: (1) the number of days per week the transfer is available, (2) the number of hours per day the transfer is available, (3) the amount of transfer capacity available for each period, and (4) the degree to which the firm transfer occurs at times of highest demand, or EXTENT.

ICARUS constructs a load correlation curve (LCC), subject to the following criteria:

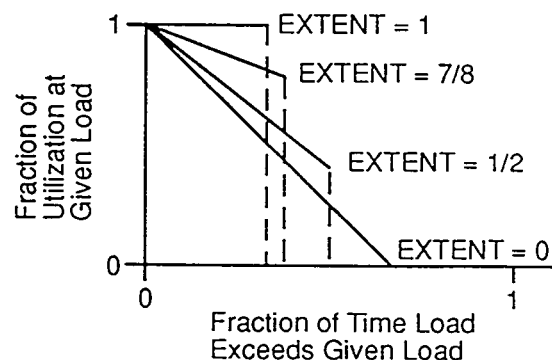
1. The correlation at peak demand is 100%.
2. The energy associated with firm purchases or sales is the capacity of firm purchases or sales multiplied by the amount of time during which firm purchases or sales are in effect.
3. The correlation curve is linear.

For example, suppose that firm purchases and sales are contracted for eight hours per day and for seven days per week, or for one-third of the total time. The LCC could take several forms, depending of the value of EXTENT (see Fig. 2.7). When EXTENT is close to 1.0, the correlation is nearly perfect; that is, power is transferred only at times of highest demand. When EXTENT is near zero, the correlation between the energy transfer and the times of highest loads is much less, but still positive. The height at minimum load is determined such that the area under the curve equals the fraction of time that firm purchases or sales are in effect. The appropriate LCC is used to adjust the demand curve to reflect firm purchases or sales.

Firm purchases and sales are considered perfectly reliable. In other words, the energy of firm purchases is always available, and the energy of firm sales is always sold. However, if demand is lower than the amount of firm purchases, the full amount of firm purchases is not used. The economic calculations assume that none of the unserved demand coincides with firm sales.

### 2.9.2 Emergency Interties

Many utilities in the United States have agreements with neighboring utilities to provide energy if a severe power outage occurs. The input to ICARUS allows users to specify the level of emergency interties available throughout the year and how that power is available throughout the year.



**FIGURE 2.7** Load Correlation Curves When Firm Purchases and Sales Occur One-Third of Total Time (Source: Buehring, Guziel, and Mullen, 1981)

There are two ways to specify the availability of emergency interties throughout the year. Option 1 is to specify that each period has an average level (in megawatts-electric) of interties available. If this is not acceptable, option 2 is to distribute available capacity of the emergency interties throughout the year. This distribution is based on a user-defined expected reserve margin target. Option 2 provides for more emergency capacity to be available in periods when it is most needed. This option can be used to represent the possibility that utilities will arrange for different levels of emergency backup over the year. Option 2 can be used for utilities having sharp seasonal peaks.

When using option 2, the user should keep in mind that any system changes that affect the expected reserve margin (e.g., the addition or retirement of a unit) could change the emergency intertie capacity distribution.

The intertie capacity is listed for each period when period output is requested. This value should be reviewed whenever option 2 is used to ensure that a reasonable system representation is being modeled.

## **2.10 LOADING ORDER**

The demand on an electric generating system can change quickly. As demand changes, the system dispatcher calls on units that can start up or change loading levels quickly to meet the rapid changes in demand. The order in which the units are called on to generate is called the system loading order. This order affects system operating costs.

### **2.10.1 Thermal Unit Loading Order**

In ICARUS, the thermal unit loading order can be specified in three ways: (1) it can be defined by the user; (2) it can be calculated on the basis of economic considerations; or (3) it can be calculated on the basis of spinning reserve considerations.

In the first option, a loading order number is assigned to each block of each unit. The units are then loaded in ascending loading order number. This option is used when the system is very small or when special system operating constraints must be represented.

The second option is calculated within ICARUS. The model calculates a loading order number for each block of each unit on the basis of the unit's heat rate, fuel cost, and variable O&M cost. As in the user-defined option, after the loading order numbers are assigned, the system loads the units in ascending loading order number. This representation produces the lowest operating costs for the system and typically results in a loading order that has a unit's peak block of capacity loaded immediately after its base block.

Although the second option (economic loading order) produces the lowest operating costs, this representation fails to account for various system constraints. For

example, most units have "ramp rates" that limit the rate of capacity addition. Also, transmission constraints may limit the response of units in some locations to loads in other locations. Finally, a utility may have a policy concerning the required amount of available fast spinning reserve. These considerations and other operating constraints interfere with the pure economic loading order. To represent these constraints, ICARUS uses a spinning reserve constraint to perturb the option 1 (user-defined) and option 2 (economic) loading orders. The spinning reserve goal is specified in the following form:

$$\text{GOAL} = [\text{SPNMLT} \times \text{capacity of the largest unit on line (other than hydro)}] \\ + [\text{SFRACT} \times \text{period peak}] + \text{SMW}$$

where SPNMLT and SFRACT are multipliers, SMW is a constant, and any of these parameters can be zero. Table 2.6 illustrates the effect of this option on loading order for a system with a spinning reserve goal and four generating units. The spinning reserve contribution (as a percentage) is the amount of fast spinning reserve available from the total unit. In addition, this percentage multiplied by the total unit capacity should be less than or equal to the capacity in the second block. This parameter is usually defined for units with more than one block. A unit is assumed to contribute to spinning reserve only when it is loaded at a capacity level equal to its first block.

The loading order number of the second block of unit B in Table 2.6 is less than that of the first block. This difference is indicative of the operating efficiency of the unit as a whole. However, the system "knows" it cannot load the peak block of the unit before its base block. This specification compels the system to try to load block 1 of unit B (B-1) as soon as possible so it can load block B-2. If the units were loaded strictly according to their loading order number, the system loading order would be as given in column 2 of Table 2.7.

As an example, suppose that the following spinning reserve goal is imposed on the system described in Table 2.6:

$$\text{GOAL} = (0 \times \text{largest unit on line}) + [0.10 \times 400] + -20 \\ = 20 \text{ MWe}$$

**TABLE 2.6 Units in Sample System**

Unit	Block 1 (MWe)	Block 2 (MWe)	Spinning Reserve Contribution		Loading Order No.	
			%	MWe	Block 1	Block 2
A	225	25	10	25	10.5	10.6
B	135	15	10	15	15.3	15.0
C	95	5	5	5	20.5	21.0
D	50	-	-	-	35	

**TABLE 2.7 Loading Order Based on Differences in Spinning Reserve**

Loading Order Position	Economic Loading Order (by block)	Loading Order Based on Spinning Reserve (by block)
1	A-1	A-1
2	A-2	B-1
3	B-2	B-2
4	B-1	C-1
5	C-1	C-2
6	C-2	A-2
7	D-1	D-1

Block A-1 is most economic of the blocks; if loaded, the system would have 25 MWe of spinning reserve, which exceeds the requirement. So, block A-1 is loaded. The next most economic block is A-2. However, if A-2 were loaded, the system would lose the 25 MWe of spinning reserve associated with block A-1 and would violate the desired spinning reserve goal.

The next step is to determine if any other units can be loaded without violating the spinning reserve goal. The next most economic block is B-2. However, block B-1 has not been loaded yet, so B-2 cannot be loaded. Block B-1 is the next most economic block and has a positive spinning reserve of 15 MWe. If block B-1 were loaded, the system spinning reserve would be 40 MWe (25 + 15). So, block B-1 is loaded next.

The next preference is to try again to load block A-2. If A-2 were loaded, the spinning reserve would be less than the goal (i.e.,  $40 - 25 < 20$  MWe). Therefore, block A-2 cannot be loaded. Block B-2 is the next best candidate. If block B-2 were loaded, the system would still have adequate spinning reserve (i.e.,  $40 - 15 > 20$  MWe). So, Block B-2 is loaded next.

Following this process, blocks C-1 and C-2 would be loaded next. Blocks A-2 and D-1 are the only ones left. If either block were loaded, the system would not have adequate spinning reserve. When there is no block left that can be used to meet the spinning reserve goal, the remaining blocks are loaded according to their loading order number.

The final loading order for the system is given in column 3 in Table 2.7. This changed loading order is likely to significantly affect unit capacity factors and system costs, but not system reliability. Whenever this option is used, the detailed system operation should be reviewed carefully to be sure that units are operating within their expected capacity factor ranges.

When running a large system, the spinning reserve goal criterion is especially helpful, as it provides a convenient mechanism for recognizing many of the complex factors that prevent economic loading from occurring. The net effect is to offload generation from baseload units and redistribute it over intermediate and peaking units.

### 2.10.2 NUTYPE Unit Loading Order

If a NUTYPE unit is defined, the base block of the NUTYPE unit is always loaded before any of the thermal unit blocks. The peak block of the NUTYPE unit has no defined loading order position. ICARUS must load it such that the amount of energy generated "best" matches that defined by the input parameters. To determine the best position, the peak block is simulated sequentially as being loaded in each position in the loading order.

If the amount of energy specified for the peak NUTYPE block exceeds the amount that can be used, the block will spill some energy. This spillage is reported through a warning message in the output file. However, if the amount of energy specified for the peak NUTYPE block is not big enough to fit anywhere, a message is printed, and the available energy is used, but with the amount of energy shortage added to unserved energy.

In most cases, peaking NUTYPE fits between two blocks in the loading order. It is loaded in each of the two positions for appropriate fractions of time so that the energy will exactly match the specified peak NUTYPE energy. For example, suppose that the desired capacity factor of the peak block of NUTYPE is 0.10. If the block were loaded 25th, it would have a capacity factor of 0.11; if loaded 26th, it would have a capacity factor of 0.08. So, the block is loaded 25th two-thirds of the time and 26th one-third of the time. The resulting capacity factor is the desired 0.10.



### 3 GUIDELINES FOR USE

Extensive use at ANL of the ICARUS model and its ancestors SYSREL and RELCOMP has resulted in identification of several areas critical to accurate system representation and reasonable execution time. Section 3 discusses these key considerations; inputs are discussed further in App. B.

#### 3.1 LOADING ORDER

The implications of using spinning reserves to perturb the economic loading order are not always intuitive. As discussed in Sec. 2.10, a loading order based on achieving a spinning reserve goal can produce unexpected results. This is especially true during runs for many years. As the system retires old units and brings new units on line, it is very important to carefully review system operations.

If spinning reserve parameters are defined improperly, new units may be loaded after older, less efficient units. Also, spinning reserve goals, if defined by constant megawatts-electric, should probably be updated as the system expands.

#### 3.2 SPINNING RESERVE

The term "spinning reserve" is interpreted differently by utility operations personnel and modelers. A utility dispatcher may be required to maintain a specified amount of fast spinning reserve to respond to unexpected system outages. This requirement is not a major concern of production-cost models, which deal with aggregated LDCs, each of which may represent a week, month, or season. The term "spinning reserve," as used in the ICARUS model, refers to a modeling technique used to account for some of the daily operational considerations that are not explicitly represented in the model. Two data groups determine how the spinning reserve goal affects the system: the unit spinning reserve and the system spinning reserve goal.

##### 3.2.1 Unit Spinning Reserve

The unit spinning reserve refers to the percentage of spinning reserve assigned to each block of each unit. The unit spinning reserve is considered only when a system spinning reserve goal is defined. (If a unit is blocked, a spinning reserve percentage should be assigned; however, the percentage assigned does not have to correspond to physical limits associated with the unit.) If a blocked unit has no spinning reserve, it will not be loaded until the system spinning reserve criterion has been met. Units able to contribute to the system spinning reserve goal will be loaded first, even if the unit with no spinning reserve is the most economic unit in the system. If the spinning reserve percentage is small for all units, the system may be unable to build up the necessary system spinning reserve. This inability would result in a loading order in which all the base blocks would be loaded before peak and single-unit blocks. This loading order would result in very high operating costs for the system.

### 3.2.2 System Spinning Reserve Goal

The system spinning reserve goal may reflect actual operational criteria or may be used to represent the less-than-perfect operating conditions in the utility environment. The system spinning reserve goal represents a target level of capacity that is available for quick response to changing demand levels and unexpected outages. In the Mid-Continent Area Power Pool (MAPP), the spinning reserve portion of the operating reserve cannot be lower than 75% of the capacity of the largest unit on line (MAPP, 1989). The East Central Area Reliability (ECAR) coordination pool requires that the daily spinning reserve equal 3% of the projected internal peak load (ECAR, 1989).

### 3.3 BLOCKING UNITS

The blocking of units is an important consideration when defining a system. In particular, the number of blocks affects the ICARUS execution time. A large number of blocks results in slower execution times, but gives more control over loading priorities and constraints. The base block should represent the average level of operation of the unit, when it is not operating at full capacity. The blocking capacities do not have to reflect operational limitations. For example, the base block capacities can be larger than the lowest operational level specified by the manufacturer.

Unit blocking can produce unexpected results when a system spinning reserve goal is defined. The loading of a relatively large peak block may be delayed because of the spinning reserve goal resulting in the unit's overall capacity factor being lower than expected.

### 3.4 STEP SIZE IN THE LOAD DURATION CURVE

The number of steps (NSTEPS) parameter represents the area of the LDC beyond minimum load. The NSTEPS used to define the LDC affects the model's execution time and the accuracy of the LDC representation. The main factors affecting the execution time for ICARUS are (1) the number of steps used to define the LDC in energy calculations, (2) the number of periods per year, (3) the number of units, and (4) the loading order criteria. The sample case presented in App. C was run on a COMPAQ 286 (12 MHz) personal computer having a math coprocessor. Figure 3.1 shows the increase in execution time as a function of NSTEPS. Users should perform test runs to determine a reasonable NSTEPS level for their systems.

NSTEPS also affects how accurately the tail of the ELDC is represented. Figure 3.2 shows the effect of NSTEPS on annual LOLP for the sample case presented

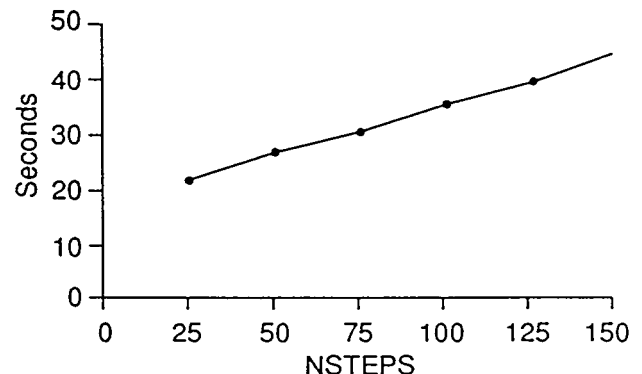


FIGURE 3.1 Increase in Execution Time as a Function of NSTEPS

in App. C. Again, users should perform several test runs with different NSTEPS to determine an appropriate level for their systems. Extensive use of ICARUS at ANL indicates that an NSTEPS value of 75-150 is normally adequate for representation of generation and reliability. However, if reliability indices are not critical, a value of 25 will produce reasonable results for total system costs and reduce execution time substantially.

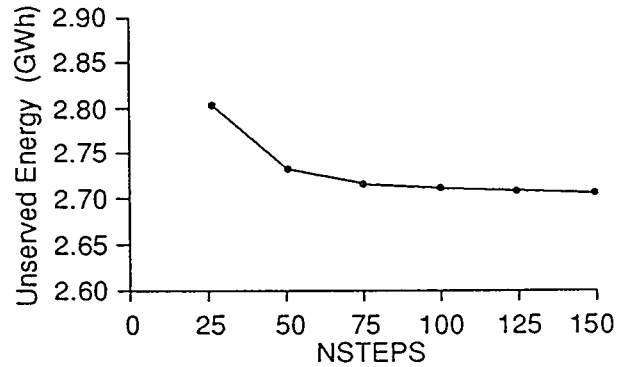


FIGURE 3.2 Effect of NSTEPS on Annual LOLP for the Sample Case Presented in App. C

### 3.5 OUTPUT CONTROL (KP)

There are nine levels for the print indicator KP. The higher the KP level, the more output is produced. Annual output should always be requested, and period output should be requested for at least the first period. The update option allows users to selectively change the KP level for each period of each year of the simulation. The danger in requesting detailed output for all periods is that the output file grows so quickly that it could fill the disk and cause the system to crash. An output level of three or four is sufficient for most studies. An output level of nine is generally reserved for debugging.

### 3.6 NUMBER OF PERIODS

The number of periods specified per year affects the ICARUS execution time; however, because of period duplication checks, the execution time is not a direct function of the number of periods. The period duplication checks determine whether the previous period's maintenance schedule, interties, fixed energy technology, and firm purchases and sales are the same. If all these components are the same, the program does not resimulate the period. The ICARUS output simply states that period X is identical to period (X - 1).

Although using a large number of periods per year (e.g., 52) lengthens the execution time, it does improve the accuracy in scheduling maintenance. For example, explicit outages can be scheduled in one-week increments. At ANL, 24 or 26 periods have typically been adopted.

## 4 MODEL APPLICATIONS

The ICARUS model has proven to be a very useful tool in electric utility system analysis projects for the NRC, the U.S. Department of Energy (DOE), The World Bank, and other organizations. ICARUS has recently been incorporated into the ARGonne Utility Simulation (ARGUS) model, which is a long-term planning package that can take coal depletion, repowering of units, and pollutant emissions into account. ICARUS is also being incorporated into the ENergy and Power Evaluation Program (ENPEP) model, which is an integrated energy planning package that considers demand side planning, resource allocation, long-term expansion planning, and environmental impacts.

### 4.1 REPLACEMENT ENERGY COST

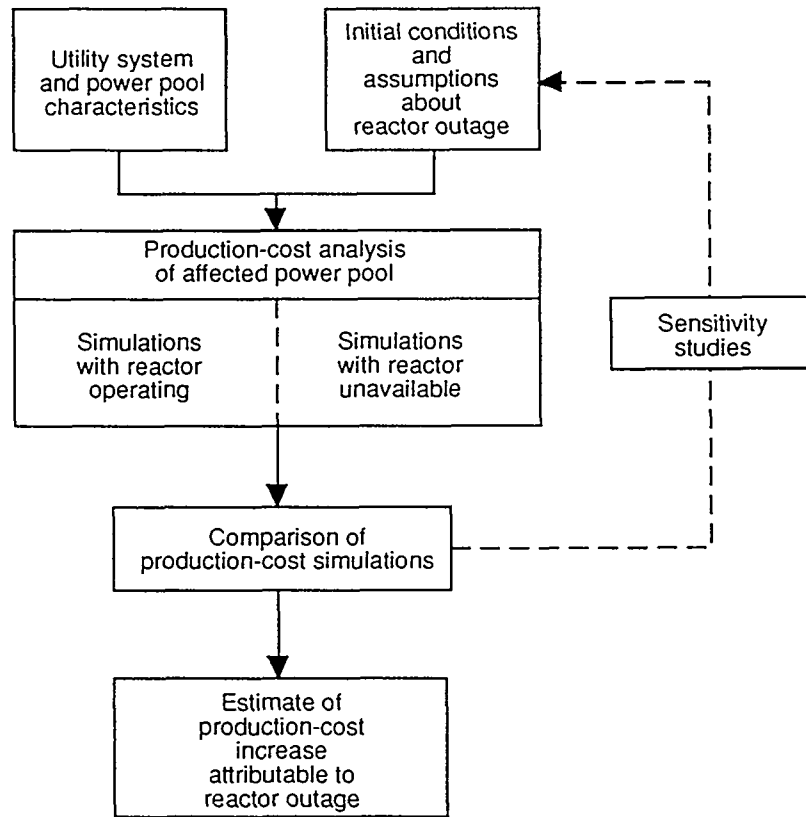
The ICARUS model has played an important role in previous studies for the NRC. The studies have focused on estimating the cost of replacing the electricity generated by nuclear power plants in the event of short-term shutdowns (VanKuiken, Buehring, and Guziel, 1984; VanKuiken et al., 1987). Such estimates are being used to help the NRC establish regulatory policies, particularly those that might necessitate temporary reactor shutdowns.

#### 4.1.1 Methodology

Replacement energy costs (RECs) arise from increased fuel requirements and variable O&M costs in other generating units when a nuclear unit is removed from service. Costs resulting from increases in emergency purchases from outside the interconnected power pools are also included. These costs can be estimated for a given reactor by conducting two production-cost simulations: one with the reactor and other units operating as usual and the other with the reactor removed from service (see Fig. 4.1). Replacement energy costs are then determined from the differences in total variable costs. Only variable costs are included in these calculations because the results are applied only to short-term (less than one year) shutdowns. Longer-term utility responses that would affect fixed costs are not considered.

In the first study (VanKuiken, Buehring, and Guziel, 1984), replacement energy costs were estimated on a seasonal basis for the two-year study period beginning with the fall of 1984 and ending with the summer of 1986. The second study (VanKuiken et al., 1987) extended the analysis to the five-year period starting in 1987 and ending in 1991.

In both studies, the analysis was conducted and reported separately for each reactor expected to be in operation during the study period (i.e., for 108-116 reactors). To best represent the groups of utilities that would be likely to respond first to short-term reactor shutdowns, the production-cost simulations were performed at the power pool level. Twenty-one power pools were found to include operating or planned nuclear reactors.



**FIGURE 4.1 Procedure for Determining Production-Cost Increases Caused by Reactor Outages**

#### 4.1.2 Data Sources

To accurately track seasonal changes in production costs, each simulation year was divided into 24 periods. Projections from the North American Electric Reliability Council (NERC) were used to characterize load growth and planned construction and retirement schedules within the study time frames (NERC, 1984; NERC, 1985a; NERC, 1986; NERC, 1987; NERC, 1988). The inventory of generating units was originally based on a DOE data base (GURF, 1981), but was then refined with NERC data published annually by each of the nine NERC regions (ECAR, 1989; ERCOT, 1989; MAAC, 1989; MAIN, 1989; MAPP, 1989; NPCC, 1989; SERC, 1989; SPP, 1989; WSCC, 1989).

DOE data were used to assign fuel costs and operating expenses for the generating units (EIA, 1988). These data were averaged by type of generator and power pool. Similarly, operating parameters (e.g., heat rates, maintenance requirements, and forced outage rates) were adopted from the Electric Power Research Institute (EPRI, 1981) and NERC (1985b) sources. These parameters were based on regional average values within various categories, including unit size and generator type. Grouped averages were used for many data items that were not readily available on a unit-specific basis or were better characterized by average values, as against single-year, unit-specific data points.

### 4.1.3 Algorithm Performance

The computational efficiency of ICARUS was especially important in conducting the REC simulations. For each nuclear reactor and study year, two power pool simulations were conducted: one with and one without the reactor in service. The 21 power pools ranged in size from those with about 60 to those with more than 250 generating units. With each year divided into 24 simulation periods, the execution times on an IBM 3033 computer ranged from about 3 central processing unit (CPU) seconds per year to almost 40 CPU seconds per year.

### 4.1.4 Results

The findings from these studies illustrate the sensitivity of RECs to pool-specific conditions, seasonal patterns, variations in the size of reactor units, and prices of alternate fossil fuels. Costs for 1990 ranged from a low of \$10,000 per day of outage to a high of \$820,000 per day of outage. The lowest cost occurred for the smallest reactor (48 MWe), which also happened to be located in one of the power pools exhibiting low energy costs per kilowatt-hour of generation. The highest cost figure occurred for one of the largest reactors (1300 MWe), which was located in one of the highest cost power pools.

The primary factor influencing the average cost by power pool was the fuel mix. Costs were highest in pools that used large percentages of premium fossil fuels (i.e., oil and natural gas). The pools that used larger quantities of coal exhibited lower REPs. Still, the replacement energy costs could not have been accurately predicted solely from fuel mixes. Production-cost simulations were used to determine how much each generating unit in a pool was able to contribute to the lost nuclear generation, given the complex interactions between system load profiles, unit availabilities, and system economics (i.e., loading priorities).

In addition to base case simulations for single independent shutdowns, simulations were made to determine (1) the effects of multiple simultaneous shutdowns in a given pool and (2) the influence of assuming other prices for oil and gas (i.e.,  $\pm 50\%$  relative to base values). The multiple shutdown cases required additional ICARUS runs in which all the reactors in a given pool were removed from service. The effect was to increase the cost per kilowatt-hour by as much as 53% in some pools having a large number of reactors. However, in pools having only a few reactors, the effect of multiple shutdowns was minimal.

With respect to changes in oil and gas prices, separate ICARUS runs were not made. Instead, the detailed output from the base cases was stored on disk and used as input to a post-ICARUS processor. The key assumption in deciding not to repeat the ICARUS simulations was that the changes being investigated in oil and gas prices would not affect the relative dispatching sequences or resulting capacity factors within each power pool. That is, coal units were still assumed to be dispatched before oil and gas units (except for peak blocks), even with modified fuel prices. Given the base case costs, this assumption was reasonable. However, under different conditions, the loading priorities could change, and separate ICARUS runs would be required to determine the new distribution of generating unit assignments and contributions to replacement energy.

The results of these studies revealed regional and, in some cases, seasonal patterns in the impacts from changes in oil and gas prices. In some pools, there was a nearly one to one correspondence between oil and gas price changes and changes in replacement energy costs. That is, increasing oil and gas prices by 50% caused the RECs to increase by nearly 50%. In other power pools (i.e., those with large contributions from coal-derived replacement energy), the RECs were nearly unaffected by changes in oil and gas prices.

## 4.2 MARGINAL COST ANALYSIS

ICARUS has proven useful in a number of applications involving estimation of marginal energy cost (MEC). Indeed, the REC analysis described in Sec. 4.1 is a type of marginal cost analysis. However, the general marginal cost application has involved variations smaller than the loss of generation from a nuclear power plant. The MEC, as discussed here, represents the cost, averaged over a specified time period, to meet an increase in demand when no capacity additions to the generating system are possible. Thus, the MEC consists of the increased variable cost (i.e., the fuel cost plus the variable O&M cost, divided by the increase in kilowatt-hours caused by an increase in demand). All fixed costs drop out of the MEC calculation. The time periods for estimating MECs can be as short as one hour or as long as one year.

The MEC is an important consideration in electrical generating systems. In the United States, for example, electric utilities must determine the avoided costs that result when nonutility generators supply electricity to the system. Also, setting electricity tariffs requires knowledge of the variation in cost during a day and from season to season. Time-of-day electricity tariffs provide consumers with appropriate price signals and therefore help to promote economic efficiency. If prices are based on economic costs, consumers will come to understand the savings realized by changes in their consumption patterns. Having MEC information readily available is therefore important to many utility planners.

The World Bank's Energy Planning Project, which involves 12 countries in Europe, the Middle East, and North Africa, has used ICARUS to estimate MECs in case studies of marginal costs and tariff setting in individual countries (Buehring and VanKuiken, 1987). ICARUS has also been used as a companion model to the Wien Automatic System Planning Package (WASP-III), which is the International Atomic Energy Agency's model for determining least-cost expansion plans for electrical generating systems. WASP-III is used to establish the least-cost development plan and the long-run marginal cost of capacity (McKechnie, 1985). ICARUS is then applied to examine the least-cost plan in more detail and to estimate the MEC.

Estimating the MEC with ICARUS is an ideal application. The level of accuracy inherent in the ICARUS calculations provides a satisfying consistency of results, even though the MEC is, in effect, a derivative of short-term cost with respect to demand. Nonetheless, users must prepare their assumptions and data with care to make best use of this capability. A few important considerations are outlined in Secs. 4.2.1-4.2.3.

### 4.2.1 Calculation of Marginal Energy Cost

Typically, ICARUS uses time intervals of one or two weeks for production-cost and reliability calculations. Users represent a year with a minimum of 1 and a maximum of 52 periods. After a reference case is established, ICARUS can be used to determine the average MEC for each period by increasing the loads at all times by a small, constant increment. "Small" means large enough to allow ICARUS to recognize the change; this change typically amounts to a few megawatts-electric added to all loads. ICARUS is then run to determine the results for the "increased loads" case. The MEC for each period and the year as a whole can be estimated by dividing the difference in costs by the difference in electricity generation requirements for the appropriate period of time. The steps involved for the calculation are detailed below:

1. Select a reference year in order to collect the appropriate system data. Even if the desired MEC is for a particular period or hour, annual results from ICARUS are needed to determine a maintenance schedule.
2. Run ICARUS for 12, 24, 26, or 52 periods for the year to obtain the maintenance schedule.
3. Select the time period desired for the MEC (e.g., hourly).
4. Run ICARUS with the reference load data for the time period of interest. Define the maintenance schedule for the particular time period, on the basis of the step 2 results. The LDCs may have to be reformulated from the original data. The LDC for a single hour is assumed to be completely flat; that is, the probability of the load being a particular value is 1. In practice, ICARUS uses the difference in probabilities for different loads to represent the LDC (see Sec. 2.2.2). A normalized LDC that approximates a constant load would be as follows:

Y	X
1.0	0.0
0.9999	0.997
0.9998	0.998
0.9997	0.999
0.9800	1.0

Experience has shown that approximating the flat LDC in this way gives better results than using only one or two points other than (1,0). If using a flat LDC, the value of NSTEPS should be reduced to 5-10. (NSTEPS represents the area from minimum load to peak load.) Some instabilities can arise with the flat LDC representation if the program attempts to divide the area into too many segments.



5. Assume an increase (or decrease) in loads for all time periods. The increment should be small, but not numerically insignificant. Values of 0.1% to 2.0% of peak load seem to be appropriate. Then, run ICARUS for the increased loads case.
6. Compute MEC as the difference in generating system cost between the two ICARUS runs divided by the difference in kilowatt-hours for the time period.

If an hourly MEC is desired, the flat LDCs must be used. To estimate the MEC for each hour of selected days, ICARUS can be run with 24 periods per year,\* flat LDCs, period peak loads set equal to the 24 hourly loads, and a maintenance schedule that shows all units available on the day of interest to have no maintenance and all other units to be on scheduled maintenance for all 24 periods. ICARUS will present results that assume there are 365 hours per period (8760 hours per year divided by 24 periods per year). Thus, kilowatt-hour and cost (in dollars) results can be determined by dividing by 365. However, if the MEC is the desired output, the results from this reference case and the increased loads case can be used directly (i.e., without dividing by 365) because the final result is obtained by subtracting costs and dividing by kilowatt-hours to give the MEC in cents per kilowatt-hour.

If an hourly MEC is being estimated, the hydroelectric representation needs special attention. The capacity factor of the peak block of hydro capacity might be very high during peak load hours of the day when daily peaking hydro energy is being used. On the other hand, the capacity factor of the peak hydro block might be near zero at night when hydro energy is being stored for use during peak hours the next day. The average capacity factor of the peak hydro block for the entire period is probably not appropriate for all hours of the day during a particular 24-hour period. The exact hydro distribution for a particular day depends on storage capability and on variations in MEC without hydro. In other words, hydroelectric plants with storage typically serve to levelize the MEC.

The increased loads case assumes that a constant load increment occurs at all times during the period. Thus, for MEC cases other than hourly (i.e., flat LDCs with a load factor of 1), the normalized LDC and the load factor change. Computing the new LDC can be tedious. A much simpler way of simulating a constant change in load is to assume that the base portion of the hydroelectric generation changes by the desired amount. Because base hydro is assumed to operate 24 hours per day and 7 days per week, a decrease of 5 MWe of base hydro will produce approximately the same effect as increasing loads by 5 MWe for all hours. However, the costs must be corrected to account for the O&M costs attributable to the difference in base hydro capacity and generation for the two cases.

When the increased loads case results in a change in EUE, the cost associated with the change in unserved energy must be considered as part of the MEC. If users do not want the unserved energy and associated cost to contribute to the MEC, then the

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\*ICARUS thinks this run is for the year.

number of kilowatt-hours divided into the change in costs should be the difference in actual generation, rather than the difference in generation requirements resulting from the increase in loads. Experience has shown that, in some countries, unserved energy can constitute a significant percentage of the total expected energy needed to supply the increase in load, especially at times of annual peak load.

#### 4.2.2 Contributions to MEC by Generating Units

All generating units not being used at their maximum levels contribute to the MEC because combinations of random forced outages mean that any unit may be called upon to satisfy some portion of the increase in system load. ICARUS uses probabilistic simulation to account for this phenomenon; that is, the cost of each possible circumstance is weighted by its probability of occurrence. The result is the expected value of the MEC. Because the number of combinations for any given time period is so large for most electric utility systems, an efficient, computer-based method for determining the MEC is required. (The number of combinations varies as two raised to a power equal to the number of generating units; therefore, a system of 20 unique generating units has 1,048,576 combinations of available generating units.) Also, this example shows that it is generally meaningless to think of a single generating unit as supplying the marginal energy. It is only in a real operating situation that the marginal unit can be identified with certainty.

#### 4.2.3 Example Calculations

ICARUS and the MEC procedure outlined in Sec. 4.2.1 were used to determine the short-run marginal cost (SRMC) of electricity for a country borrowing from The World Bank. Monthly results for 1987 were calculated for three hydroelectric conditions: (1) average, (2) wet (i.e., more hydro energy was available than normal), and (3) dry (i.e., less hydro energy was available than normal). Also calculated was the SRMC for the average hydro condition in 1992. (The cost of unserved energy was \$110/MWh in 1987 and \$400/MWh [1987] in 1992.) Table 4.1 shows the results; the largest monthly SRMC variation is for the dry condition.

Hourly SRMC values for 1987 were also calculated for the same generating system. Table 4.2 shows the results for selected months. In these calculations, 24 load levels were specified that spanned the range for all possible loads in each month. The SRMC for any load can be estimated by interpolation. Table 4.2 shows that, if a load of 1198 MWe were to occur in July, the SRMC would be \$110/MWh (100% unserved energy). These results were the basis for recommending time-of-day tariffs for this country.

### 4.3 CAPACITY RESPONSIBILITY

System reliability can be determined from the ICARUS results used to determine the MEC. In particular, the ICARUS run made to determine the maintenance schedule provides the LOLP and EUE for each period of the year. Examination of the variation in

**TABLE 4.1 Short-Run Marginal Cost of Electricity  
for 1987 and 1992 (\$/MWh)**

Month	1987 SRMC			1992 SRMC
	Average Year	Wet Year	Dry Year	Average Year
July	20.38	20.25	21.07	28.07
August	22.86	22.84	23.11	31.26
September	22.40	22.28	27.97	29.43
October	27.26	26.65	32.82	36.39
November	23.98	23.12	28.18	33.26
December	23.75	22.82	31.57	34.33
January	24.46	24.27	25.13	33.89
February	23.85	23.63	23.98	31.75
March	24.04	23.89	24.04	32.26
April	22.61	22.57	22.57	29.78
May	23.41	23.12	22.94	30.26
June	24.66	24.02	24.02	30.64

system reliability performance can be useful when attempting to assign the costs of generating capacity to different time periods.

Capacity responsibility is defined as the fraction of marginal capacity cost that should be allocated to particular time periods according to that time period's contribution to the probability of system failure to meet the load. Thus, an hour with a high LOLP (poor reliability) would have a greater capacity responsibility than an hour with a low LOLP. A characteristic of this method\* for obtaining capacity charges is that all hours have a nonzero capacity charge because the LOLP never goes to zero. Therefore, some capacity charges (usually a small amount of them) are associated with off-peak time periods.

Examination of capacity responsibility gives some guidance as to potential capacity charges that could be considered for tariff-setting purposes. For example, capacity charges for a summer peaking utility are likely to be higher in the summer than in the winter. This logic can be extended from seasons to months or weeks, and even hours. Although it is not now reasonable to expect that actual capacity charges could vary from hour to hour, they could vary with time of day (as do telephone charges).

\*The method was developed by I. Elwan of The World Bank and ANL staff during an early application of electrical system planning methods to marginal cost analysis.

**TABLE 4.2 Monthly Short-Run Marginal Cost of Electricity by Load Level for Selected Months**

Load Level (MW)	1987 SRMC (\$/MWh)			
	July	October	January	April
1198	110.0	110.0	109.9	84.02
1162	104.7	110.0	103.8	73.53
1126	100.2	110.0	98.83	63.21
1054	92.92	109.5	90.73	55.21
1018	70.36	101.8	67.35	49.28
1010	59.62	99.94	58.64	43.17
982.4	51.90	93.81	49.99	38.66
946.4	46.96	83.89	45.62	33.69
910.5	40.87	60.92	42.45	29.05
874.5	36.25	49.73	35.82	25.79
838.6	30.34	37.98	32.85	23.46
802.7	25.69	33.49	26.98	21.70
766.7	23.00	27.27	23.20	20.64
730.8	21.45	23.19	21.82	19.99
694.8	20.49	21.68	20.97	18.86
658.9	18.87	20.37	19.98	18.08
623.0	18.14	19.53	19.47	17.36
587.0	17.28	19.15	17.68	16.92
551.1	16.83	17.60	16.97	16.74
515.1	16.68	17.40	16.74	16.52
467.2	16.46	16.65	16.33	16.23
431.3	16.17	16.46	15.02	16.14
395.3	15.14	16.24	14.63	14.86
359.4	14.68	16.04	14.55	14.55

An example of capacity responsibility by time of day and by time of year is shown in Tables 4.3-4.5. For this analysis, the year was divided into 12 equal time periods. The peak hours occurred at 0700-1400 and 1700-2200. Table 4.3 shows the LOLP determined by ICARUS for peak hours and off-peak hours, as well as the total for each month. The LOLP, expressed as a percentage, involves multiplying a probability. (A LOLP of 0.1% is equivalent to a LOLP of 0.001.) Overall, the LOLP is the average of the peak LOLP and the off-peak LOLP because peak and off-peak each apply 12 hours per day.

Table 4.4 shows similar results for EUE, which is measured in megawatt-hours. Total EUE for a month is the sum of the EUE for peak hours and the EUE for off-peak hours.

**TABLE 4.3 Loss-of-Load Probability  
(LOLP) Results for Capacity  
Responsibility Calculations**

Month	LOLP (%)		
	Peak Hours	Off-Peak Hours	Overall
1	0.4869	0.0306	0.2588
2	0.2042	0.0244	0.1143
3	0.0315	0.0014	0.0165
4	0.0091	0.0020	0.0056
5	0.0028	0.0008	0.0018
6	0.0034	0.0180	0.0107
7	0.0077	0.0295	0.0186
8	0.0148	0.0063	0.0105
9	0.0575	0.0112	0.0344
10	0.0275	0.0019	0.0147
11	0.4512	0.0197	0.2355
12	1.7199	0.1319	0.9259
Annual	0.2514	0.0231	0.1373

The implications for capacity responsibility are illustrated in Table 4.5. The results for this dry year example are strongly affected by a shortage of hydroelectric energy during peak load hours in month 12. Therefore, slightly more than half of the capacity responsibility is associated with that time period. However, no time period has a zero capacity responsibility.

**TABLE 4.4 Expected Unserved  
Energy (EUE) Results for Capacity  
Responsibility Calculations**

Month	EUE (MWh)		
	Peak Hours	Off-Peak Hours	Total
1	436.7	20.8	457.5
2	165.6	16.6	182.2
3	9.6	0.8	10.4
4	5.6	1.1	6.7
5	1.4	0.3	1.7
6	1.6	10.1	11.7
7	3.7	15.8	19.5
8	9.5	3.3	12.8
9	42.3	6.8	49.1
10	19.8	1.1	20.9
11	430.6	13.1	443.7
12	1874.1	101.0	1975.1
Annual Total	3000.5	190.8	3191.3

**TABLE 4.5 Capacity Responsibility for the 1995 Generating System  
under the Dry Year (%)**

Month	LOLP Method			EUE Method		
	Peak Hours	Off-Peak Hours	Monthly Total	Peak Hours	Off-Peak Hours	Monthly Total
1	14.86	0.94	15.80	13.68	0.66	14.34
2	6.23	0.74	6.97	5.19	0.52	5.71
3	0.41	0.04	0.45	0.30	0.03	0.33
4	0.28	0.06	0.34	0.15	0.06	0.21
5	0.09	0.02	0.11	0.04	0.02	0.05
6	0.10	0.55	0.65	0.05	0.32	0.37
7	0.24	0.90	1.14	0.12	0.49	0.61
8	0.45	0.19	0.64	0.30	0.10	0.40
9	1.76	0.34	2.10	1.33	0.21	1.54
10	0.76	0.14	0.90	0.62	0.03	0.65
11	13.78	0.60	14.38	13.49	0.41	13.90
12	52.50	4.02	56.52	58.72	3.17	61.89
Annual Total	91.46	8.54	100.0	93.99	6.01	100.0

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**APPENDIX A**  
**INPUT FILES**



## APPENDIX A

### INPUT FILES

#### A.1 INTRODUCTION

The ICARUS program requires two input files: LOADDATA, which in broad terms contains the load data, and UNITDATA, which in broad terms contains the unit data. Appendix A, which describes the format of these two input files, helps users to construct new files. Further assistance is provided in App. B, which presents general guidelines and precautions for constructing ICARUS input files.

#### A.2 FORMAT

The input datasets are composed of free- and fixed-format input. The free format requires that all data values be separated by at least one space or comma, that all card types begin on a new line, and that all values be defined. The free format does not read a blank field as a 0 or null; therefore, each value must be defined for the dataset to be read in the proper sequence. The free format variables are assigned a variable format code of F for real, I for integer, and A for alphanumeric.

The fixed format requires the input variables to be in specific columns and interprets a blank field as a zero for numeric values and as a blank for character values. The fixed-format variables have a column range defined that specifies the exact location of the input field as well as a variable format code.

The UNITDATA and LOADDATA files complement one another. ICARUS attempts to read certain values from the UNITDATA file, depending on what it reads in the LOADDATA file. Therefore, the files must be compatible. Each card type descriptor is defined by a letter and a number: the letter U is used for the UNITDATA file, L for the LOADDATA file, and A for the auxiliary file (see App. D).

The following items apply to the input description for both input files:

- An asterisk -- \*-- indicates that multiple cards of this type may be required.
- Minimum and maximum limits for variables are noted in brackets -- [ ]. Many of these limits can be changed by redimensioning variables.
- Suggested ranges for some variables are indicated in parentheses -- ( ).

## A.3 UNITDATA INPUT DESCRIPTION

Card types U1 through U3 make up a set. A set of these cards is required to define each generating unit, with the exception of NUTYPE units (see card type U5).

	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type U1: LIFE(1,I),LIFE(2,I),IWUP(I),IWDOWN(I)</b>		
LIFE(1,I) - [none] (none)	1-4	I4
Year in which the unit is to begin commercial operation.		
LIFE(2,I) - [none] (none)	7-10	I4
Year in which the unit is to be retired.		
IWUP(I) - [1-52] (none)	15-16	I2
Week in which the unit is to begin commercial operation.		
IWDOWN(I) - [1-52] (none)	21-22	I2
Week in which the unit is to be retired.		
<b>Card Type U2: NPARTS(I),CAPCOS(I),OPE(I),FUEL(I), MTAIN(I),MWEEK(I),DPK WY(I),FOR(I),IFUT(I),PLTID(I)</b>		
NPARTS(I) - [1-2] (none)	1	I1
Number of blocks of capacity per generating unit.		
CAPCOS(I) - [>0] (none)	2-12	F11.0
Capital cost of each generating unit (in \$/kW).		
OPE(I) - [>0] (none)	13-24	F12.0
Variable operation and maintenance (O&M) cost of each generating unit (in mills/kWh).		
FUEL(I) - [>0] (none)	25-36	F12.0
Fuel cost of each generating unit (in ¢/10 <sup>6</sup> Btu).		

	<u>Card Columns</u>	<u>Variable Format</u>
MTAIN(I) - [0-52] (none)	40-41	I2
Number of weeks of maintenance required for a generating unit.		
MWEEK(I) - [0-52] (none)	44-45	I2
Week in which maintenance is to begin. A value of zero allows the program to schedule maintenance to maximize the minimum expected period reserve margin.		
DPKWY(I) - [>0] (none)	49-60	F12.0
Fixed operation and maintenance cost (in \$/kW-yr).		
FOR(I) - [none] (0.0-1.0)	62-68	F7.7
Equivalent forced outage rate for the unit; that is, the fraction of time that a generating unit will not generate when it is called upon.		
IFUT(I) - [1-NFTY] (none)	70-71	I2
Fuel type number that corresponds to the IFNAME values defined by card type L5.		
PLTID(I) - [none] (none)	73-80	A8
Eight-character identifier for a generating unit.		
<b>Card Type U3: (YMWR(M),RLOA(M),HEAT(M),SPNRES(M),M=1,NPARTS)</b>		
YMWR(1) - [>0] (none)	1-6	F6.0
Generating capacity of first block (in MWe). This value can be greater than the minimum operating level as defined by the manufacturer.		
RLOA(1) - [>0] (none)	7-12	F6.0
Loading order number of first block (not necessarily in sequence). This number is not necessary when economic loading order is to be calculated.		



	<u>Card Columns</u>	<u>Variable Format</u>
HEAT(1) - [ $>0$ ] (none)  Heat rate for the first block (in $10^3$ Btu/kWh).	13-18	F6.0
SPNRES(1) - [0.0-1.0] (SPNRES*(YMWR(1)+YMWR(2))<=YMWR(2))  Fraction of total unit capacity available as fast spinning reserve.	19-24	F6.0
<i>Note: The following values are needed only if the unit has two blocks.</i>		
YMWR(2) - [ $>0$ ] (none)  Generating capacity of second block (in MWe).	25-30	F6.0
RLOA(2) - [ $>0$ ] (none)  Loading order number of second block (not necessarily in sequence). This number is not necessary when economic loading order is to be calculated.	31-36	F6.0
HEAT(2) - [ $>0$ ] (none)  Heat rate for the second block (in $10^3$ Btu/kWh).	37-42	F6.0
SPNRES(2) - [0.0-1.0] (0.0)  Usually 0.0 for second block.	43-48	F6.0

*Note: After the last set of unit descriptor cards, there must be one card type U1 with LIFE(l,NUMPLA) = 0. This card signals the end of the unit descriptor input.*

<u>Card Columns</u>	<u>Variable Format</u>
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**Card Type U4\*:** One line for each fuel type defined by NFTY on card type L3 (maximum 25)

IFNAME - [none] (none)

1-8

A

Eight-character descriptor used to identify fuel categories.

Begin annual data (one set for each year).

*Note: Do not include card type U5 when IHYDRO=0 on card type L7.*

**Card Type U5\*:** (BHMW(K),HSR(K),PHMW(K),PHCF(K), K=1,NPER) one line for each period as defined by NPER on card type L3

BHMW - [ $\geq 0$ ] (none)

F

Capacity (in MWe) of the base block of the NUTYPE technology in its Kth period.

HSR - [0.0-1.0] (fraction of capacity that is peak)

F

Fraction of total capacity of the NUTYPE unit that is available as spinning reserve.

PHMW - [ $\geq 0$ ] (none)

F

Capacity (in MWe) of the peak block of the NUTYPE technology in the Kth period.

PHCF - [0.0-1.0] (none)

F

Capacity factor of peak block of the NUTYPE technology for the Kth period.

	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type U6*: (FUESC(N),N= 1,NFTY)</b>		
FUESC - [none] (none)		F
Annual fuel price escalator for each fuel type as defined by NFTY on card type L3. Fuel price for the current year equals the fuel price for the previous year times (1.0 + escalator).		
<b>Card Type U7*: (FOESC(N),N=1,NFTY)</b>		
FOESC - [none] (none)		F
Annual fixed O&M price escalator for each fuel type, as defined by NFTY on card type L3. Fixed O&M for the current year equals fixed O&M of the previous year times (1.0 + escalator).		
<b>Card Type U8*: (VOESC(N),N=1,NFTY)</b>		
VOESC - [none] (none)		F
Annual variable O&M price escalator for each fuel type, as defined by NFTY on card type L3. Variable O&M for the current year equals variable O&M of the previous year times (1.0 + escalator).		
<hr/>		
End of annual data. To begin data for the next year, return to card type U5.		
<hr/>		

#### A.4 LOADDATA INPUT DESCRIPTION

##### Card Type L1: CASE

CASE - [none] (none)	1-72	A
A 72-character string used as a descriptive title for the output.		

	<u>Card Columns</u>	<u>Variable Format</u>
ICURVE - [ $\geq 0$ ] (none)	73	I

Switch used to specify the format of the load duration curves. ICURVE=0 tells the program that the curve points specified on card type L11 are incremental. ICURVE=1 tells the program that the curve points specified on card type L11 are cumulative.

**Card Type L2: KP,NSTEPS**

KP - [0-9] (0-8)	I
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Print indicator.

- =0 Only annual summaries.
- =1 Above plus annual energy allocation and costs by fuel type.
- =2 Above plus annual energy allocation and costs by unit.
- =3 Above plus annual energy allocation and costs by block.
- =4 Above plus period results for reliability, system generation, and costs.
- =5 Same as above.
- =6 Above plus period energy allocation and costs by fuel type.
- =7 Above plus period energy allocation and costs by unit.
- =8 Above plus period energy allocation and costs by block.
- =9 Above plus debugging output.

	<u>Card Columns</u>	<u>Variable Format</u>
NSTEPS - [0-500] (25-250)		I
<p>Number of steps to be used in the energy calculations. When NSTEPS=0, ENCALC is not called and system dispatching is not performed.</p>		
<p><b>Card Type L3: NYR,APK,NFTY,NPER,ITIE,XLOLC,IRESER,NYEAR,IOUTPR,NDSIG</b></p>		
NYR - [>0] (NYR ≥1)		I
<p>Number of years to be simulated.</p>		
APK - [APK > 0] (none)		F
<p>Annual peak load in the initial year of the run (in MWe).</p>		
NFTY - [1-25] (1-25)		I
<p>Number of fuel types in the thermal system. The NUTYPE technology is not included here.</p>		
NPER - [1-52] (24, 26 or 52)		I
<p>Number of periods per year.</p>		
ITIE - [0 or 1] (none)		I
<p>Switch for availability of emergency interties. ITIE=0 indicates that each period receives TIEMW (as defined on card type L13) of interties. ITIE=1 allows the program to adjust the level of interties between periods to meet the period expected reserve margins (as defined by RMA on card type L13).</p>		
XLOLC - [0.0 < XLOLC ≤ 365.0] (0.05-10.0)		F
<p>System goal for loss-of-load probability (LOLP) (in days/yr). The firm-capacity equivalent (FCE) needed to meet the LOLP goal (XLOLC) calculated for the time period specified by IRESER below.</p>		

	<u>Card Columns</u>	<u>Variable Format</u>
<p>IRESER - [1-3] (2-3)</p> <p>Selects the time period for which the FCE will be calculated.</p> <p>1 - no FCE calculated.            2 - FCE based on annual LOLP, as defined by XLOLC above.            3 - FCE based on period LOLP, as defined by XLOLC above.</p>		I
<p>NYEAR - [<math>\geq 1</math>] (none)</p> <p>Calendar year run is to begin in, for example, 1990.</p>		I
<p>IOUTPR - [<math>\geq 0</math>] (0)</p> <p>Switch to control creation of the auxiliary output file. (See App. D for a description of this file.)</p> <p>=0 no auxiliary output file.            &gt;0 auxiliary output file printed.</p>		I
<p>NDSIG - [<math>\leq 20</math>] (none)</p> <p>Number of designated units to include in the auxiliary output file.</p>		I
<p><b>Card Type L4: (NPPLNM(I),I=1,NDSIG)</b></p> <p><i>Note: Do not include card type L4 when NDSIG=0 on card type L3.</i></p>		
<p>NPPLNM - [none] (none)</p> <p>Program-assigned number of the unit(s) that are to be written on the auxiliary output file. Requires initial program run to determine unit number assignments.</p>		I
<p><b>Card Type L5: NUTYPE</b></p>		
<p>NUTYPE - [none] (HYDRO)</p> <p>Name of technology with fixed energy and capacity.</p>	1-8	A

<u>Card Columns</u>	<u>Variable Format</u>
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**Card Type L6: LOCALC,ISPIN,SPNMLT,SFRACT,SMW**

LOCALC - [0 or 1] (none)

I

Use 1 if economic loading order is to be calculated and 0 if the input loading order is to be used.

ISPIN - [0 or 1] (none)

I

Use 1 if the basic loading order is to be adjusted for spinning reserve and 0 if the basic loading order is to be used.

SPNMLT - [none] (0.0-2.0)

F

Multiplier used to figure spinning reserve goal (see equation below).

SFRACT - [none] (-0.5 - +0.5)

F

Multiplier used to figure spinning reserve goal (see equation below).

SMW - [none] (0.0)

F

Constant used to figure spinning reserve goal (see equation below).

Spinning reserve goal = [(SPNMLT) \* (most MWe on line in any unit)] + [(SFRACT) \* (period peak)] + SMW

Begin annual data (one set for each year).

**Card Type L7: ISZ,IHYDRO,IPL,NSZ**

ISZ - [0 or not] (none)

I

Switch to determine whether to use the season assignments from the previous year. If ISZ=0, the program will use the season assignments from the previous year. ISZ cannot be 0 for the first year of a run.

	<u>Card Columns</u>	<u>Variable Format</u>
IHYDRO - [0 or not] (none)		I
<p>Switch to determine whether to use the NUTYPE profile from the previous year. If IHYDRO=0, the program will use the NUTYPE profile from the previous year. IHYDRO cannot be 0 for the first year of a run.</p>		
IPL - [0 or not] (none)		I
<p>Switch to determine whether to use the period peak multipliers from the previous year. If IPL=0, the program will use the period peak multipliers from the previous year. IPL cannot be 0 for the first year of a run.</p>		
NSZ - [0-52] (none)		I
<p>Number of seasonal load curves that will be defined. If NSZ=0, the program will use the same number of seasons that were assigned in the previous year. NSZ cannot be 0 for the first year of a run.</p>		
<p><b>Card Type L8*: (NDXS(I),I=1,NPER)</b></p>		
<p><i>Note: Do not include card type L8 when ISZ=0 on card type L7.</i></p>		
NDXS -[1-52] (none)		I
<p>Index for assigning each period to a load curve.</p>		
<p><b>Card Type L9*: (XMF(I),I=1,NPER)</b></p>		
<p><i>Note: Do not include card type L9 when IPL=0 on card type L7.</i></p>		
XMF - [0.0-1.0] (none)		F
<p>Relative height of the period peak load as a function of the yearly peak. XMF = 1.0 for the period(s) in which the annual peak occurs, and XMF &lt; 1.0 for other periods.</p>		



<u>Card Columns</u>	<u>Variable Format</u>
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**Card Type L10: NDP**

NDP - [0-99] (none)

I

Number of points in the seasonal incremental load curves. If NDP=0, the program will use the same number of points that was assigned in the previous year. NDP cannot be 0 for the first year of a run.

**Card Type L11\*: ((YLDC(I,J),XLDC(I,J),I=2,NDP+1),J=1,NSZ)\***

*Note: Do not include card type L11 data when NDP=0 on card type L10.*

When ICURVE=0 on card type L1, the YLDC,XLDC coordinates are for the seasonal *incremental* LDCs. (Cumulative curves are calculated internally from the incremental LDCs.) When ICURVE=1 on card type L1, the coordinates are for the seasonal *cumulative* LDCs. One pair of YLDC,XLDC values should be put on each line. This requires a total of NDP times NSZ lines. The point (1,0) should not be entered. The first interval is assumed to be from the point (1,0) up to the point specified.

YLDC - [none] (none)

F

For the cumulative and incremental LDC, YLDC is the load magnitude normalized by the season peak load. The points should be in descending order from peak to minimum load.

XLDC - [none] (none)

F

For the cumulative LDC, XLDC is the cumulative duration corresponding to all loads greater than or equal to YLDC, normalized by the hours in the period. For the incremental LDCs, XLDC is the amount of time that the load falls in the interval between YLDC(I,J) and YLDC(I-1,J).

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\*The point (1,0) should not be input. The first interval is assumed to be from the point (1,0) up to the first point specified. Cumulative load duration curves are calculated internally from the input incremental load curves.

<u>Card Columns</u>	<u>Variable Format</u>
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**Card Type L12\*: (FIRM(I),I=NPER)**

FIRM - [none] (none)

F

Capacity (in MWe) of firm power that will be bought or sold during each period to other power systems (purchases are positive; sales are negative).

**Card Type L13: HRS,TIEMW,RMA,EXTENT,FDAYS**

HRS - [0.0-24.0] (none)

F

Hours per day that power will be purchased or sold on a firm basis. Relates to firm purchases and sales only, not to emergency ties.

TIEMW - [none] (none)

F

Expected average capacity for emergencies interties (in MWe).

*Note: If ITIE=0 on card type L3, then RMA can be set to 0.0.*

RMA - [none] (0.5-1.0)

F

Target reserve margin used to distribute available intertie capacity on a period-by-period basis, according to the difference between the RMA and the calculated expected system reserve margin. When ITIE =0 on card type L3, all periods have the same amount of interties, regardless of the value of the RMA.

EXTENT - [0.0-1.0] (none)

F

Measures how well the firm purchases and sales are correlated with high loads. The highest correlation is 1.0, which means that firm purchases or sales are used most when loads are the highest. The lowest correlation is 0.0 (subject to the model's constraints). EXTENT is not related to emergency interties.

	<u>Card Columns</u>	<u>Variable Format</u>
FDAYS - [0.0-7.0] (none)		F
Number of days per week that firm purchases and sales are used.		
<b>Card Type L14: CHGRT,DISC\$,DISCE</b>		
CHGRT - [ $\geq 0$ ] (none)		F
Levelized fixed charge rate on all capital for the year.		
DISC\$ - [ $\geq 0$ ] (none)		F
Discount factor for dollars over time.		
DISCE - [ $\geq 0$ ] (none)		F
Discount factor for energy over time.		
<b>Card Type L15: FSFC,FSVC,FPFC,FPVC,TIEFC,TIEVC</b>		
FSFC - [ $\geq 0$ ] (none)		F
Fixed cost of using firm sales (in \$/kW-day).		
FSVC - [ $\geq 0$ ] (none)		F
Variable cost of using firm sales (in mills/kWh).		
FPFC - [ $\geq 0$ ] (none)		F
Fixed cost of using firm purchases (in \$/kW-day).		
FPVC - [ $\geq 0$ ] (none)		F
Variable cost of using firm purchases (in mills/kWh).		
TIEFC - [ $\geq 0$ ] (none)		F
Fixed costs of using emergency interties (in \$/kW-yr).		

	<u>Card Columns</u>	<u>Variable Format</u>
TIEVC - [ $\geq 0$ ] (none)		F
Variable cost of using emergency interties (in mills/kWh).		
<b>Card Type L16: BHFUEL,BHHEAT,BHCAP,BHDPKY,BHOPE</b>		
BHFUEL - [ $\geq 0$ ] (none)		F
Fuel cost of base block of the NUTYPE unit (in $\text{¢}/10^6$ Btu).		
BHHEAT - [ $\geq 0$ ] (none)		F
Heat rate of base block of the NUTYPE unit (in $10^3$ Btu/kWh).		
BHCAP - [ $\geq 0$ ] (none)		F
Capital cost of base block of the NUTYPE technology (in $\text{\$/kW}$ ).		
BHDPKY - [ $\geq 0$ ] (none)		F
Fixed O&M cost of base block of the NUTYPE technology (in $\text{\$/kW-yr}$ ).		
BHOPE - [ $\geq 0$ ] (none)		F
Variable O&M cost of base block of the NUTYPE technology (in mills/kWh).		
<b>Card Type L17: PHFUEL,PHHEAT,PHCAP,PHDPKY,PHOPE</b>		
PHFUEL - [ $\geq 0$ ] (none)		F
Fuel cost of peak block of the NUTYPE unit (in $\text{¢}/10^6$ Btu).		
PHHEAT - [ $\geq 0$ ] (none)		F
Heat rate of peak block of the NUTYPE technology (in $10^3$ Btu/kWh).		

	<u>Card Columns</u>	<u>Variable Format</u>
PHCAP - [ $\geq 0$ ] (none)		F
Capital cost of peak block of the NUTYPE technology (in \$/kW).		
PHDPKY - [ $\geq 0$ ] (none)		F
Fixed O&M cost of peak block of the NUTYPE technology (in \$/kW-yr).		
PHOPE - [ $\geq 0$ ] (none)		F
Variable O&M cost of peak block of the NUTYPE technology (in mills/kWh).		
<b>Card Type L18: RFUEL,RHEAT,RCAP,RDPKWY,ROPE</b>		
RFUEL - [ $> 0$ ] (NONE)		F
Reserve capacity fuel cost (in $\text{\$}/10^6$ Btu).		
RHEAT - [ $\geq 0$ ] (none)		F
Reserve capacity heat rate (in $10^6$ Btu/kWh).		
RCAP - [ $\geq 0$ ] (none)		F
Reserve capacity capital cost (in \$/kW).		
RDPKWY - [ $\geq 0$ ] (none)		F
Fixed O&M cost of the reserve capacity (in \$/kW-yr).		
ROPE - [ $\geq 0$ ] (none)		F
Variable O&M cost of the reserve capacity (in mills/kWh).		

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If there are no updates, or after the last update, there must be one card type L19 with all values = 0. This card signals the end of the updates.

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<u>Card Columns</u>	<u>Variable Format</u>
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**Card Type L19\*: LY,LW,LSS,LPLT,IV,CH,IC,JC**

Card type L19 (update card) is for changing system parameters during execution of the program. The functions of the updates are listed below, followed by the input requirements for each update.

- Update 1 - Change the annual peak demand.
- Update 2 - Add a generating unit.
- Update 3 - Change the forced outage rate of a unit.
- Update 4 - Change the fuel cost of a unit.
- Update 5 - Retire a unit.
- Update 6 - Not used at this time.
- Update 7 - Reschedule maintenance for the entire system.
- Update 8 - Change costs for a single unit.
- Update 9 - Exchange the loading order positioning of two units.
- Update 10 - Change the loading order for a block of a unit.
- Update 11 - Change maintenance information for a unit.
- Update 12 - Change block information for a unit.
- Update 13 - Change NUTYPE unit profile for one period.
- Update 14 - Change the value of the print indicator (KP).
- Update 15 - Stop execution in mid-year.

<u>Card Columns</u>	<u>Variable Format</u>
-------------------------	----------------------------

**Update 1: Change the annual peak demand.**

LY	= Year of the run in which the change is to occur.	I
LW	- Week in which the change is to occur.	I
LSS	- =0	I
LPLT	- =0	I
IV	- =1	I
CH	- Factor by which the previous year's demand is adjusted (see IC description).	F
IC	- When IC=0, CH is the factor by which the last year's annual load is multiplied by. When IC=1, CH is the new peak load (in MWe).	I
JC	- =0	I

**Update 2: Add a generating unit.**

LY	- Year of the run in which the change is to occur.	I
LW	- Week in which the change is to occur.	I
LSS	- =0	I
LPLT	- =0	I
IV	- =2	I
CH	- =0.0	F
IC	- =0	I
JC	- =0	I

*Note: Card types U1 through U3 must be inserted after an update 2 card to define the unit characteristics. If the economic loading order has been requested, it will be calculated for the new unit. This update will not schedule maintenance for the unit being added. Either reschedule maintenance for the whole system (update 7), or schedule maintenance for the new unit (update 11).*

<u>Card Columns</u>	<u>Variable Format</u>
-------------------------	----------------------------

**Update 3: Change the forced outage rate of a unit.**

LY	- Year in which the change is to occur.	I
LW	- Week in which the change is to occur.	I
LSS	- =0	I
LPLT	- The number of the unit that is to have its forced outage rate changed.	I
IV	- =3	I
CH	- New forced outage rate.	F
IC	- =0	I
JC	- =0	I

**Update 4: Change the fuel cost of a unit.**

LY	- Year in which the change is to occur.	I
LW	- Week in which the change is to occur.	I
LSS	- =0	I
LPLT	- The number of the unit that is to have its fuel cost changed.	I
IV	- =4	I
CH	- New fuel cost ( $\$/10^6$ Btu).	F
IC	- =0	I
JC	- =0	I

*Note: If the economic loading order has been requested, it will be recalculated for this unit.*



<u>Card Columns</u>	<u>Variable Format</u>
-------------------------	----------------------------

**Update 5: Retire a unit.**

LY - Year in which the change is to occur.	I
LW - Week in which the change is to occur.	I
LSS - =0	I
LPLT - Number of the unit to be retired.	I
IV - =5	I
CH - =0.0	F
IC - =0	I
JC - =0	I

**Update 6: Not used at this time.****Update 7: Reschedule maintenance for the entire system.**

LY - Year in which the change is to occur.	I
LW - Week in which the change is to occur.	I
LSS - =0	I
LPLT - =0	I
IV - =7	I
CH - =0.0	F
IC - =0	I
JC - =0	I

**Update 8: Change costs for a single unit.**

LY - Year in which the change is to occur.	I
LW - Week in which the change is to occur.	I
LSS - =0	I

	<u>Card Columns</u>	<u>Variable Format</u>
LPLT - Number of the unit to have its costs changed.		I
IV - =8		I
CH - =0.0		F
IC - =0		I
JC - =0		I

*Note: The following cost data values for the unit LPLT must follow this update. If the economic loading order has been requested, it will be calculated for the unit at this time.*

CAPCOS,OPE,FUEL,DPKWY

CAPCOS - [ $\geq$ ] (none)	2-12	F11.0
Capital cost of the generating unit (in \$/kW).		
OPE - [ $\geq$ 0] (none)	13-24	F12.0
Variable O&M cost of the generating unit (in mills/kWh).		
FUEL - [ $\geq$ 0] (none)	25-36	F12.0
Fuel cost of the generating unit (in $\phi/10^6$ Btu).		
DPKWY - [ $\geq$ 0] (none)	49-60	F12.0
Fixed O&M cost of the unit (in \$/kW-yr).		

**Update 9: Exchange the loading order positioning of two units.**

LY - Year in which the change is to occur.		I
LW - Week in which the change is to occur.		I
LSS - Block within unit LPLT to exchange loading order position with block JC in unit IC.		I
LPLT - Number of unit to exchange loading order number with unit IC.		I

	<u>Card Columns</u>	<u>Variable Format</u>
IV - =9		I
CH - =0.0		F
IC - Number of unit to exchange loading order number with unit LPLT.		I
JC - Block within unit IC to exchange loading order position with block LSS in unit LPLT.		I
<b>Update 10: Change the loading order for a block of a unit.</b>		
LY - Year in which the change is to occur.		I
LW - Week in which the change is to occur.		I
LSS - Block of unit LPLT that is to have its loading order number changed.		I
LPLT - Number of unit that is to have the loading order number of one of its blocks changed.		I
IV - =10		I
CH - New loading order number for block LSS in unit LPLT.		F
IC - =0		I
JC - =0		I
<b>Update 11: Change maintenance information for a unit.</b>		
LY - Year in which the change is to occur.		I
LW - Week in which the change is to occur.		I
LSS - =0		I
LPLT - Number of the unit that is to have its maintenance information changed.		I
IV - =11		I
CH - =0.0		F

	<u>Card Columns</u>	<u>Variable Format</u>
IC - The week that maintenance is to begin.		I
JC - The number of weeks of maintenance assigned to the unit.		I

*Note: When IC is specified, the program schedules the unit as requested; otherwise, the unit is not scheduled on the basis of the updated maintenance information until the whole system is rescheduled.*

**Update 12: Change block information for a unit.**

LY - Year in which the change is to occur.		I
LW - Week in which the change is to occur.		I
LSS - =0		I
LPLT - Number of the unit that is to have its block information changed.		I
IV - =12		I
CH - =0.0		F
IC - =0		I
JC - =0		I

*Note: Card type U3 must follow this update card. If the economic loading order has been requested, it is recalculated for the updated unit.*

**Update 13: Change NUTYPE unit profile for one period.**

LY - Year in which the change is to occur.		I
LW - Week in which the change is to occur.		I
LSS - =0		I
LPLT - =0		I
IV - =13		I

	<u>Card Columns</u>	<u>Variable Format</u>
CH - =0.0		F
IC - Period in which to make the change.		I
JC - =0		I

*Note: Card type U5 must follow this update.*

**Update 14: Change the value of the print indicator (KP).**

LY - Year in which the change is to occur.		I
LW - Week in which the change is to occur.		I
LSS - =0		I
LPLT - =0		I
IV - =14		I
CH - =0.0		F
IC - New value for KP.		I
JC - =0		I

**Update 15: Stop execution in mid-year.**

LY - Year in which the change is to occur.		I
LW - Week in which the change is to occur.		I
LSS - =0		I
LPLT - =0		I
IV - =15		I
CH - =0.0		I
IC - =0		I
JC - =0		I

---

End of annual data; to begin data for the next year, return to card type L7.

---

*Note: A line containing eight zeros must always be included, even if it is the only update. This line signifies the end of the updates.*



**APPENDIX B**  
**CONSTRUCTING ICARUS INPUT FILES**





## APPENDIX B

### CONSTRUCTING ICARUS INPUT FILES

This appendix describes the individual card types, which were defined in App. A. Most of the card types are self-explanatory; those that are more involved are discussed below, along with examples.

Many of the modeling representations used in ICARUS were adopted from an earlier model called RELCOMP (Reliability and Cost Model for Electrical Generation Planning). The main difference between the two models is the method of computing unit generation commitments and system reliability. ICARUS reduces the computational time required for simulating large electric utility systems or systems with long time horizons. The results derived from the two models are essentially the same.

The program assigns each unit in the UNITDATA file a unique unit number, regardless of whether the unit is operational at the beginning of the study. This number can then be used to identify particular units to be updated.

When simulating an electric utility system for the first time, users should limit the first simulation to one year. The results from the first year should then be examined in detail to assure that all units in the system are operating as anticipated. Such review helps to filter out initial data entry errors or misinterpretations of input specifications.

#### B.1 DESCRIPTIONS OF THE CARD TYPES IN THE UNITDATA FILE

The UNITDATA file contains the unit-specific characteristics of the generating units. Card types U1 through U4 are entered for the first year of the run only. Card types U5 through U8 are entered for each year, as detailed in the following descriptions.

*Card types U1 through U3* describe each generating unit. There must be a set of these cards for each unit that is operational during the study period, that is, those that are already on line when the study period begins, those that are retired during the study period, and those that are brought on line during the study period. After all of the units are so defined, there must be one card of type U1 with  $LIFE(1,NUMPLA) = 0$ . This card serves to signal the end of the unit descriptor input. Unit descriptors are specified only once, that is, at the beginning of the UNITDATA file.

*Card type U4* specifies the fuel name associated with each of the thermal fuel types. The number of lines must equal NPTY (as defined on card type L3); each line must contain only one name. These descriptors are used to assign a fuel category to the unit on the basis of the value assigned by the IFUT number found on card type U2. These cards are specified once at the beginning of the file.

*Card type U5* specifies the capacity and generation associated with the NUTYPE unit. The NUTYPE technology, a composite of all of the units of this type, is represented as a single unit with two blocks. The base block is always loaded first and is

considered to be available 100% of the time. The peak block generates energy on the basis of the capacity and capacity factor specified.

The NUTYPE category is generally used for simulating hydroelectric generation. Hydro is treated differently from conventional thermal units because energy generation is usually determined by water conditions rather than by forced outages and maintenance periods. To model hydro as NUTYPE, users sum the capacity for all hydro units and then split the total into two components: one that represents baseload generation and the other that represents peaking operations. The split is determined by reservoir capacity and rainfall conditions, both of which cause variations in the availability of hydro energy. In general, decisions regarding specification of base and peak components for hydro tend to be case-specific and regionally sensitive. If warranted by the system, ICARUS can be run to account for operation under various hydro generation schemes.

There must be one card of type U5 for each period, as defined by NPER on card type L3. These values must be defined for the first year of the study. For multiyear runs, these values may remain the same or may change each year, depending on what is specified by the IHYDRO parameter on card type L7. If they remain the same, card type U5 must not be included after the first year. Every period profile can be changed once at the beginning of each year (by using card type U5) or one at a time (by using update 13 of card type L19).

*Card types U6 through U8* specify annual escalation factors for fuel costs and fixed and variable O&M costs. There must be one value for each fuel type specified by the NFTY variable on card type L3. These values must be specified every year for every fuel type, even if the values are zero.

## B.2 DESCRIPTIONS OF CARD TYPES IN THE LOADDATA FILE

The LOADDATA file has 19 card types, which contain the economic and load data required to run the ICARUS model. Card types L1 through L6 are entered once for the first year of the run. Card types L7 through L19 can be entered every year, as detailed in the following descriptions.

*Card type L1* contains the title that is printed on the first page of the ICARUS output. The title should help distinguish between case studies that may be subtly different. This card also contains the load duration curve indicator (ICURVE), which specifies whether the LDC points are incremental or cumulative.

*Card type L2* contains the print indicator (KP) and step indicator (NSTEPS). KP specifies the level of detail at which ICARUS reports results. Users can request various levels of detail, from annual summaries to a detailed period-by-period, block-by-block report on the operation of the generating system. A KP of 4 is appropriate for first runs. For later runs, users should request more output to explore periods of special interest or to clarify unexpected results. A KP of 7 or 8 with 100 generating units and 26 periods per year can easily produce several thousand pages of output for a single year. Because of the large volume of output produced, a KP of 9 is only used for system debugging purposes.

The NSTEPS variable specifies the number of steps used in the LDC representation in the energy calculation routine. The cumulative LDC is divided into linear segments on the basis of the number of steps specified, but only over the portion of the curve between minimum load and peak load. Energy assignments for units loaded below the system's minimum load are determined without segmenting the curve.

As the NSTEPS value increases, the accuracy of the results increases (see Sec. 3.4), as does the time needed to run the program. A value between 75 and 150 will very likely produce reasonable results for most generating systems without excessive computer time. For very large systems (e.g., those with peak loads larger than 20,000 MW), users may want to use 200-300 steps to obtain more accurate estimates of system reliability and generation from the smallest units. Total system production costs and total fuel use are generally less sensitive to changes in the number of steps.

*Card type L3* contains the starting year of the study (NYEAR) and the number of years in the study (NYR). A LOADDATA file can be set up to run many years; however, users should run only a few years at first to ensure that the base years are properly defined. The beginning year of the study (NYEAR) must be specified accurately because all unit availabilities are checked against this value for every year of the run. APK is the annual peak load of the system in the initial year (NYEAR) in megawatts-electric.

NFTY is the number of fuel types represented in the system. This number includes neither the NUTYPE unit, which is assigned a name in card type L5, nor firm purchases and sales, emergency interties, or reserves. A maximum of 25 fuel types can be defined. These fuel types are used to report operating statistics by major fuel category.

NPER is the number of periods per year. When choosing this value, users should consider the minimum maintenance interval and the frequency of output results required. Fifty-two periods should be specified if maintenance requires exact representation (see Sec. 2.4). The value of NPER depends on the level of detail required for specific case studies. Values of 12, 24, 26, or 52 are recommended so that the period results can be related to the time intervals of weeks, months, or simple multiples of these basic time intervals. However, the execution time increases as the number of periods increases (see Sec. 3.6).

The XLOLC and IRESER variables control the calculation of the firm capacity equivalent (FCE). The FCE is specified in terms of the megawatts-electric required to meet the LOLP. IRESER is used to specify whether reserve costs are based on the annual or period LOLP, or if they are not to be calculated at all. With annual reserves, the amounts of required capacity, energy, and costs are calculated at the end of each year. The period reserve option calculates the amount of reserve capacity needed from period to period. In this case, the annual reserve is calculated by averaging the period reserves. The costs associated with reserves, as defined on card type L18, are applied to the calculated firm capacity equivalent and energy.

The IOUTPR and HDSIG parameters allow simulation results to be stored in an auxiliary output file whose format is described in App. D. If requested, the program creates an output file containing the period and annual results for the major fuel types

plus information on up to 20 individual units. The auxiliary output file is called OUT14. The file has a fixed-block format, with a record length of 133. This file can be accessed by other programs to provide postsimulation analyses. If IOUTPR equals zero, NDSIG must be set equal to zero, and card type L4 is not required. If the output file is requested and NDSIG is greater than zero, there must be at least one card of type L4.

*Card type L4* contains NDSIG unique unit numbers if NDSIG is greater than zero on card type L3. In addition to the system information, the program will write period and annual information for each unit specified on card type L4 onto the auxiliary file (OUT14).

*Card type L5* contains the name of the technology, which has fixed energy and capacity. This unit, usually called HYDRO, is generally used for representing conventional hydroelectric generation. However, it can be used to control generation from other energy-limited technologies (e.g., from wind machines or pumped storage facilities).

*Card type L6* contains the parameters that control calculation of the economic loading order, selection of spinning reserve options, and definition of the system spinning reserve goal. The program calls on units to generate on the basis of program-calculated or user-defined loading order. If assignments are based on user input, a loading order number must be assigned to each thermal block by using RLOA on card type U3.

The system can also call on units to generate to meet a defined spinning reserve goal. The following three parameters are used to specify this goal: SPNMLT, SFRACT, and SMW. The spinning reserve goal is calculated as follows:

$$\text{GOAL} = \text{SPNMLT} \times (\text{most MWe on line in any unit}) \\ + \text{SFRACT} \times (\text{period peak}) + \text{SMW}.$$

This equation provides a flexible range of alternatives for representing various utility practices.

The spinning reserve criterion functions as a constraint that is used to modify the loading order of the units. Each block of generating capacity is assigned a potential contribution to spinning reserves on the basis of the value of SPNRES, as defined on card type U3. Typically, a unit is divided into base and peak blocks. The peak block, which is usually on the order of 10-30% of the total unit capacity, can be held in reserve (after the base block is loaded) until the spinning reserve criterion is met or until loads are too high to satisfy the specified spinning reserve (see Sec. 2.10).

The spinning reserve option can also be used as a controlling parameter to approximate other types of unit loading restrictions (see Sec. 3.2.2). By carefully selecting the unit blocking conventions and spinning reserve specifications, users can approximate the effects of factors like load-following limitations and transmission constraints.

*Card types L7 through L19* must be specified for every year, unless noted otherwise.

**Card type L7** contains the parameters used to minimize input data in multiyear runs. For the first year of a run, ISZ, IHYDRO, and IPL must each equal one. For later years, each variable for which new data are being specified must equal one. If new data are not being specified, that variable must equal zero. A zero prompts the program to use the data values from previous years.

ISZ specifies whether to use period assignments from previous years. Whenever IHYDRO equals one, there must be a NUTYPE data profile for every period.

IPL determines whether to use period peak multipliers from previous years, and NSZ is the number of load curve shapes to be specified. NSZ must be greater than zero for the first year of a run. For multiyear runs, an NSZ equal to zero prompts the program to use the same number of seasonal load curves defined for the previous year.

**Card type L8** contains the index that assigns each period a seasonal load shape. For instance, if 12 periods (NPER) and 4 load shapes (NSZ) that correspond to 1-spring, 2-summer, 3-fall, and 4-winter are specified, the card of type L8 might look like:

```
4 4 1 1 1 2 2 2 3 3 3 4
```

These indices must be assigned for the first year of a run. They can then remain constant over the entire study period. If the remaining years of the study are to have the same load curve shapes, ISZ on card type L7 must equal zero in all remaining years. In this case, card type L8 must not be entered.

**Card type L9** contains the period peak load multipliers, which specify the relative height of each period's peak load with respect to the annual peak load. There can be more than one period containing the annual peak load. These multipliers must be specified for the first year of a run. If the remaining years are to have the same multipliers, then IPL on card type L7 must equal zero in all subsequent years, and card type L9 data are entered for the first year of the run only.

**Card type L10** contains the number of data points in each of the seasonal load curves (NDP). Each curve must have the same number of points. For the first year of a run, NDP must not equal zero. For subsequent years, if NDP equals zero, the program uses the curves for the previously defined year.

**Card type L11** contains YLDC and XLDC data, which define the load curve shape for each of the seasons. When ICURVE = 0, the curves are incremental; when ICURVE = 1, the curves are cumulative. For the cumulative LDCs, XLDC is the cumulative duration corresponding to all loads greater than or equal to YLDC, normalized by the hours in the period. For the incremental LDCs, XLDC is the amount of time that the load falls in the interval between YLDC(I,J) and YLDC(I-1,J). For the cumulative and incremental LDCs, YLDC is the load magnitude, normalized by the season peak load. The points should be in descending order from peak to minimum load. The point (1.0,0.0) must not be entered. The program assumes the first interval is from the point (1.0,0.0) up to the first point specified. Specifying one x,y pair on each line allows for easy review of the data.

**Card type L12** contains the net amount of firm purchases or sales capacity (in megawatts-electric) available for each period of the year. Purchases are represented as positive numbers and sales as negative numbers. This card type must be entered for every year of the run.

**Card type L13** contains values that further define firm purchases and sales, emergency interties, and reserves. The variables HRS, FDAY, and EXTENT apply to firm purchases and sales only. They specify how many hours per day (HRS) and days per week (FDAY) the firm purchases and sales are available. The EXTENT variable defines how firm purchases and sales affect the load curve (see Sec. 2.9.1). When EXTENT is close to 1.0, the program adjusts the load curve such that the firm energy transfers are fully correlated with peak loads (usually for purchases). As EXTENT approaches zero, the effect of firm energy transfers is more equally distributed throughout the load curve, which is usually modeled as sales.

TIEMW specifies how much capacity is available for emergency interties. This capacity can be constant for every period or adjusted to improve the period reserve margin. ITIE on card type L3 specifies whether the emergency interties are constant or adjusted. If they are adjusted, RMA on card type L3 is used to determine the distribution of the interties. The program distributes the interties on the basis of the difference between the original expected reserve margin (without interties) and the reserve margin goal (RMA).

**Card type L14** contains the fixed charge rate and discount factors. The discount factors for energy and dollars are usually set to the same value.

**Card type L15** contains the fixed and variable costs of firm purchases and sales, as well as emergency interties. These values must be defined every year, even if they are zero.

**Card types L16 through L18** contain the fuel costs, capital costs, heat rates, and fixed and variable O&M costs for the peak and base blocks of the NUTYPE technology and for emergency reserves. These values must be specified every year, even if they are zero. Each card type must begin on a new line.

**Card type L19** is used to change input parameters during a run. Each update card must contain all eight variables. There must always be a card of type L19 that contains eight zeroes for every year of the run. This card follows card type L18 (if there are no updates), or it follows the last update card.

The update cards should be used with caution. ICARUS processes one update at a time; therefore, updates within a year should be in strict chronological order. The year (LY) and week (LW) in which the change is to occur must always be specified. Because of rounding, the algorithm used to convert weeks to periods may result in the update being scheduled in a period different from the one desired. Users should carefully review the output from the updates to assure that the change is being made correctly and is occurring in the proper period.

*Update 1* is used to change the system's annual peak load. This change can be made at any time during the run by specifying a multiplier that is applied to the current peak load or by specifying the new annual peak load in megawatts-electric. The following example increases the annual peak load by 10% in year 1, week 26:

```
1 26 0 0 1 1.10 0 0
```

The following example decreases the annual peak load by 25% in year 1, week 14:

```
1 14 0 0 1 .75 0 0
```

The following update changes the new annual peak load to 10500.0 MWe in week 25:

```
1 25 0 0 1 10500.0 1 0
```

*Update 2* is used to add a thermal unit to the generating system.\* *Update 2* specifies the year and week in which the unit is to be added to the system, followed by a set of card types U1 through U3. The week and year up of the unit should correspond to the week and year of the change. The following update adds a thermal unit with the following characteristics to the system in week 3, year 1: YEARUP = 1998, YEARDOWN = 2038, WEEKUP = 26, WEEKDOWN = 0, NPARTS = 1, CAPCOS = 0.0, OPE = 8.64, FUEL = 670.62, MTAIN = 0, MWEK = 0, DPKWY = 8.07, FOR = 0.472, IFUT = 11, PLTID = PEAK OIL, YMWRA = 1.2, RLOA = 0.0, HEAT = 10.500, and SPNRES = 0.0.

```
1 3 0 0 2 0.0 0 0
```

```
1998 2038 26 0
```

```
1 0.00 8.64 670.62 0 0 8.07 0.472 11 PEAK OIL
```

```
1.2 0.0 10.500 0.00
```

*Update 3* is used to change the forced outage rate of an individual unit. The following update changes the forced outage rate of unit 35 to 20% in week 16, year 1:

```
1 16 0 35 3 .20 0 0
```

*Update 4* is used to change the fuel cost of an individual unit. If an economic loading order is requested on card type L6, it is recalculated for the updated unit. The following update will change the fuel cost of unit 46 to 100¢/10<sup>6</sup> Btu in week 29, year 1:

```
1 29 0 46 4 100.0 0 0
```

---

\*As an alternative to using update 2, all units can be included in the UNITDATA file, even those that are unavailable at the beginning of the run. This approach avoids possible errors or confusion. Startup dates can be used to bring new units on line during a simulation.



*Update 5* is used to change the specified year and week of retirement previously assigned to a unit. The unit's new retirement year is the calendar year associated with LY; the retirement week is LW. The following update retires unit 6 in week 19 of the first year of the run:

1 19 0 6 5 0.0 0 0

*Update 6* is not used at this time.

*Update 7* is used to reschedule maintenance for the entire system. The program automatically schedules maintenance for the first year of a run. When doing a multiyear run, users are responsible for requesting the program to reschedule maintenance every year, or as needed. Consideration should be given to updates that affect maintenance, such as changing the system load or adding or retiring a unit. If maintenance is not rescheduled in a year, the same schedule is used as in the previous year. The following update reschedules maintenance at the beginning of year 2 of a run:

2 1 0 0 7 0.0 0 0

*Update 8* is used to change the operating costs of an individual unit. Following the update 8 card type, there must be a card containing the new capital cost, the variable O&M cost, the fuel cost, and the fixed O&M cost. If an economic loading order has been requested on card type L6, the updated unit has its economic loading order number recalculated. The following update changes the cost parameters associated with unit 39 in week 2 of the first year of the run. The new costs of this unit are as follows: CAPCOS = 0.0, OPE = 8.64, FUEL = 670.62, and DPKWY = 8.07.

1 2 0 39 8 0.0 0 0

0.00 8.64 670.62 8.07

*Update 9* is used to change the loading order of two blocks. The following update switches the loading order number of unit 10, block 2, and unit 22, block 1, in week 13 of the first year of the run.

1 13 2 10 9 0.0 22 1

*Update 10* is used to change the loading order number of an individual unit. This update can be used, after new costs have been assigned to a unit, to manually update the loading order number of the unit, but only when the economic loading order has not been requested. The following update changes the loading order number of unit 85, block 2, to 125.5 in week 46 of the first year of the run.

1 46 2 85 10 125.5 0 0

*Update 11* is used to change the maintenance information for an individual unit. With this update, both the number of weeks and the week to begin must be specified. If the week to begin is not zero, the program automatically preschedules the unit to begin in the specified week (IC) for the specified number of weeks (JC). The following update, effective in week 5, reschedules maintenance for unit 3 to begin in week 10 for four weeks:

```
1 5 0 3 11 0.0 10 4
```

However, if the week to begin is not specified (IC = 0), the unit retains the start week of its current maintenance schedule even though its maintenance requirements may have changed. That is, the new number of weeks of scheduled maintenance is not applied to the unit until maintenance for the entire system is rescheduled.

The following update changes the maintenance requirement for unit 40 to 12 weeks in week 16 of the first year. However, unit 40 will still operate on the basis of its old maintenance assignment until maintenance for the entire system is rescheduled.

```
1 16 0 40 11 0.0 0 12
```

*Update 12* is used to change the block characteristics associated with a particular unit. After the update 12 card, there must be one card containing the new block characteristics. The following update changes the block information in week 15 of unit 98, a one-block unit, in the first year of the run. The new values correspond to: YMWRA = 50.0, RLOA = 0.0, HEAT = 13.450, and SPNRES = 0.10.

```
1 15 0 98 12 0.0 0 0
```

```
50.0 0.0 13.450 0.10
```

*Update 13* is used to change the NUTYPE technology profile for one period. The NUTYPE profile can be changed for every period (at the beginning of every year, by using card type U4) or one period at a time (by using update 13). The following update changes the NUTYPE profile associated with period 10 in week 2 of the first year of the run to the following: BHMW = 1200.0, HSR = .15, PHMW = 350.0, and PHCF = .35.

```
1 2 0 0 13 0.0 10 0
```

```
1200.0 .15 350.0 .35
```

*Update 14* is used to change the value of the print indicator (KP), which changes the level of detail of output results. A large value is often specified for KP at the beginning of the year in the run. After a few periods, KP can be reduced before being increased in the last period of the year. The following updates change KP to 4 in week 6 and then increases it to 8 in week 52:

```
1 6 0 0 14 0.0 4 0
```

```
1 52 0 0 14 0.0 8 0
```

*Update 15* is used to stop a run in mid-year. This update is useful for runs in which not all the results from the final year are required. However, if the program stops in mid-year, no annual summary tables are produced. Any results for the final year must be tallied manually. The following update stops the program in week 12 of the third year of the run:

```
3 12 0 0 15 0.0 0 0
```

**APPENDIX C**  
**SAMPLE OUTPUT**



PROGRAM ICARUS INITIATED

CASE NAME: BASE CASE FOR LRMC CASE 1-YEAR 1996

..... POWER SYSTEM RELIABILITY ANALYSIS .....

CALCULATING...LOSS-OF-LOAD PROBABILITY  
TOTAL ENERGY GENERATION  
UNSERVED ENERGY  
RESERVE CAPACITY REQUIREMENTS  
GENERATION BY UNIT AND BLOCK  
CAPACITY FACTORS  
COSTS

THE PRINT OPTION FOR THIS RUN IS: 4

THERE WILL BE 3 FUEL TYPES CONSIDERED IN THIS RUN

THERE ARE 24 PERIODS PER YEAR

NUMBER OF YEARS IN THIS PROBLEM: 1

NUMBER OF DIVISIONS (STEPS) FOR LOAD CURVE IN CALCULATIONS: 100  
THE ECONOMIC LOADING ORDER WILL BE CALCULATED

SPINNING RESERVE GOAL = .500 \* MOST MW ON LINE IN ANY UNIT + .000 \* PERIOD PEAK + 1.000

RESERVES WILL NOT BE USED.

\*\*\* CHANGE OF STATUS FOR UNIT 2 NAME: MONI02  
NOT AVAILABLE FOR GENERATION -- STARTUP YEAR: 1997 RETIREMENT YEAR: 2093

\* \* \* \* \*  
\* \* \* \* \*  
\* \* \* \* \*

YEAR 1996

\* \* \* \* \*  
\* \* \* \* \*  
\* \* \* \* \*

----- UNIT STATUS CHANGES -----

>> NOTE: CHECK FIRST PAGE OF SIMULATION OUTPUT FOR CHANGES THAT WERE INITIALIZED PRIOR TO FIRST YEAR <<

\*\*\* THIS PAGE WILL BE BLANK IF NO STATUS CHANGES OCCUR \*\*\*

-----  
\*\*\* CHANGE OF STATUS FOR UNIT 1 NAME: MONI01  
AVAILABLE FOR GENERATION IN PERIOD: 12 STARTUP YEAR: 1996 RETIREMENT YEAR: 1999

\*\*\* CHANGE OF STATUS FOR UNIT 17 NAME: GT30-03  
AVAILABLE FOR GENERATION IN PERIOD: 12 STARTUP YEAR: 1996 RETIREMENT YEAR: 2016

LOAD DURATION CURVE USED IN EACH PERIOD (SEASON NUMBER):  
 1 1 2 2 3 3 4 4 5 5 6 6 7 7 8 8 9 9 10 10 11 11 12 12

INTRO HYDRO DATA

(MAXIMUM VALUES -- SOME HYDRO ENERGY MAY NOT BE DEMANDED)

PERIOD	BASE				PEAK				OVERALL				SPINNING RESERVE	
	MW	KWH	CF	MW	KWH	CF	MW	KWH	CF	MW	KWH	CF	MW	MW
1	10.0	.36500E+07	1.0000	5.0	.18250E+06	.1000	15.0	.38325E+07	.7000	.8	0.0			
2	10.0	.36500E+07	1.0000	5.0	.18250E+06	.1000	15.0	.38325E+07	.7000	.8	0.0			
3	10.0	.36500E+07	1.0000	3.0	.32850E+06	.3000	13.0	.39785E+07	.8385	.7	0.0			
4	10.0	.36500E+07	1.0000	3.0	.32850E+06	.3000	13.0	.39785E+07	.8385	.7	0.0			
5	10.0	.36500E+07	1.0000	3.0	.32850E+06	.3000	13.0	.39785E+07	.8385	.7	0.0			
6	10.0	.36500E+07	1.0000	3.0	.32850E+06	.3000	13.0	.39785E+07	.8385	.7	0.0			
7	10.0	.36500E+07	1.0000	5.0	.18250E+06	.1000	15.0	.38325E+07	.7000	.8	0.0			
8	10.0	.36500E+07	1.0000	5.0	.18250E+06	.1000	15.0	.38325E+07	.7000	.8	0.0			
9	10.0	.36500E+07	1.0000	5.0	.27375E+06	.1500	15.0	.39238E+07	.7167	.8	0.0			
10	10.0	.36500E+07	1.0000	5.0	.27375E+06	.1500	15.0	.39238E+07	.7167	.8	0.0			
11	10.0	.36500E+07	1.0000	5.0	.18250E+06	.1000	15.0	.38325E+07	.7000	.8	0.0			
12	10.0	.36500E+07	1.0000	5.0	.18250E+06	.1000	15.0	.38325E+07	.7000	.8	0.0			
13	15.0	.54750E+07	1.0000	5.0	.36500E+06	.2000	20.0	.58400E+07	.8000	1.0	0.0			
14	15.0	.54750E+07	1.0000	5.0	.36500E+06	.2000	20.0	.58400E+07	.8000	1.0	0.0			
15	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
16	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
17	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
18	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
19	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
20	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
21	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
22	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
23	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			
24	15.0	.54750E+07	1.0000	5.0	.27375E+06	.1500	20.0	.57488E+07	.7875	1.0	0.0			

ANNUAL SUMMARY FOR HYDRO

	AVERAGE MW	TOTAL KWH	ANNUAL AVERAGE CAPACITY FACTOR
BASE:	.12500E+02	.10950E+09	.10000E+01
PEAK:	.46667E+01	.64240E+07	.15714E+00
OVERALL:	.17167E+02	.11592E+09	.77087E+00



CUMULATIVE LOAD DURATION CURVE POINTS

SEASON 1		SEASON 2		SEASON 3		SEASON 4	
FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME
1.0000	.0000	1.0000	.0000	1.0000	.0000	1.0000	.0000
.9960	.0007	.9960	.0007	.9960	.0007	.9910	.0021
.9570	.0128	.9440	.0089	.9690	.0134	.9580	.0104
.9250	.0309	.9120	.0283	.9420	.0323	.9340	.0389
.8940	.0699	.8800	.0588	.9150	.0551	.9060	.0813
.8630	.1157	.8490	.0983	.8880	.0760	.8820	.1216
.8310	.1560	.8170	.1578	.8620	.1110	.8540	.1939
.8000	.2118	.7850	.2100	.8350	.1641	.8250	.2745
.7690	.3033	.7530	.2844	.8080	.2078	.7970	.3537
.7370	.3719	.7210	.3462	.7810	.2744	.7960	.3940
.7060	.4486	.6890	.4229	.7540	.3349	.7410	.4705
.6750	.5010	.6570	.4862	.7230	.4075	.7120	.5219
.6430	.5454	.6250	.5413	.6920	.4607	.6840	.5671
.6120	.5723	.5940	.5949	.6610	.5145	.6560	.6115
.5800	.6059	.5620	.6277	.6290	.5555	.6270	.6539
.5490	.6389	.5300	.6701	.5940	.6147	.5990	.6942
.5180	.6752	.4980	.7230	.5630	.6557	.5710	.7255
.4860	.7303	.4660	.7662	.5310	.7081	.5420	.7762
.4550	.7740	.4340	.8369	.5000	.7666	.5140	.8436
.4240	.8460	.4020	.9598	.4510	.9126	.4760	.9562
.3690	1.0000	.3590	1.0000	.4060	1.0000	.4390	1.0000

SEASON 5		SEASON 6		SEASON 7		SEASON 8	
FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME
1.0000	.0000	1.0000	.0000	1.0000	.0000	1.0000	.0000
.9910	.0007	.9960	.0007	.9920	.0013	.9920	.0020
.9580	.0047	.9700	.0153	.9570	.0087	.9640	.0175
.9300	.0215	.9450	.0327	.9340	.0202	.9400	.0484
.9020	.0464	.9190	.0549	.9110	.0424	.9170	.0767
.8740	.0928	.8940	.0938	.8880	.0821	.8930	.1029
.8510	.1372	.8690	.1626	.8600	.1710	.8690	.1648
.8230	.2125	.8390	.2356	.8330	.2545	.8450	.2186
.7950	.2818	.8090	.3078	.8060	.3353	.8610	.2885
.7670	.3389	.7800	.3843	.7790	.4020	.7980	.3551
.7400	.4028	.7500	.4461	.7520	.4680	.7740	.4149
.7120	.4707	.7200	.5045	.7250	.5178	.7500	.4707
.6840	.5259	.6910	.5545	.6980	.5562	.7260	.5124
.6560	.5716	.6610	.5976	.6710	.6007	.7260	.5474
.6280	.6147	.6310	.6414	.6430	.6283	.6980	.5985
.5950	.6638	.6060	.6963	.6160	.6741	.6710	.6590
.5670	.7075	.5760	.7602	.5890	.7320	.6430	.7303
.5400	.7713	.5510	.8270	.5620	.8074	.6150	.8104
.5070	.8769	.5080	.9458	.5350	.8896	.5870	.9011
.4560	.9650	.4790	.9840	.5000	.9737	.5280	.9670
.4090	1.0000	.4450	1.0000	.4650	1.0000	.4840	1.0000

SEASON 9		SEASON 10		SEASON 11		SEASON 12	
FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME	FRAC PEAK	FRAC TIME
1.0000	.0000	1.0000	.0000	1.0000	.0000	1.0000	.0000
.9920	.0007	.9960	.0020	.9920	.0007	.9960	.0007
.9680	.0188	.9680	.0087	.9120	.0090	.9630	.0155
.9430	.0528	.9400	.0148	.8810	.0347	.9300	.0384
.9190	.1209	.9070	.0249	.8500	.0632	.9010	.0700
.8950	.1842	.8750	.0417	.8190	.1105	.8720	.1090
.8660	.2724	.8470	.0612	.7880	.1445	.8390	.1528
.8380	.3641	.8190	.0935	.7540	.2043	.8060	.2355
.8100	.4392	.7900	.1466	.9190	.2696	.7730	.3015
.7810	.4899	.7620	.2381	.6850	.3516	.7400	.3795
.7530	.5316	.7340	.3410	.6500	.4552	.7070	.4563
.7250	.5829	.7060	.4183	.6150	.5344	.6590	.4677
.6960	.5969	.6770	.4734	.5810	.5886	.6410	.5585
.6680	.6261	.6490	.5151	.5460	.6393	.6080	.5955
.6400	.6748	.6170	.5689	.5120	.6859	.5750	.6305
.6110	.7255	.5850	.6261	.4770	.7429	.5420	.6729
.5830	.7922	.5520	.6839	.4420	.8200	.5090	.7207
.5430	.9110	.5200	.7364	.4190	.8978	.4800	.7571
.5020	.9826	.4880	.8050	.3880	.9632	.4510	.8156
.4860	.9896	.4440	.9475	.3620	.9882	.4100	.9509
.4620	1.0000	.4030	1.0000	.3350	1.0000	.3700	1.0000

ESCALATION RATE BY FUEL TYPE

FUEL TYPE	FUEL ESCALATION	FIXED O&M ESCALATION	VARIABLE O&M ESCALATION
FUEL OIL	.0000	.0000	.0000
COAL	.0000	.0000	.0000
GASTURB	.0000	.0000	.0000

LEVELIZED CHARGE RATE FOR CAPITAL IS .0000

DISCOUNT FACTOR FOR DOLLARS IS .0000  
 FOR ENERGY IS .0000

FIXED COSTS(\$/KW-DAY)	FIRM SALES	FIRM PURCHASES
VARIABLE COSTS(MILLS/KWH)	.000	.000

BASE HYDRO	FUEL(CENTS/MBTU)	HEAT RATE(KBTU/KWH)	CAPITAL(\$/KW)	FIXED O&M(\$/KW-YR)	VARIABLE O&M(MILLS/KWH)
PEAK HYDRO	0.	.00	.00	.00	.00
RESERVE DEFICIT	0.	.00	.00	.00	.00

EMERGENCY INTERTIES: FIXED COSTS(\$/KW-YR) .000 VARIABLE COSTS(MILLS/KWH) .000

\*\*\*\*\* MAINTENANCE SCHEDULE \*\*\*\*\*

NOTE:	PLANT	1	(MON101 )	NOT SCHEDULED FOR MAINTENANCE	>BROUGHT UP	RETIRED OR NOT UP	THIS YEAR<
NOTE:	PLANT	2	(MON102 )	NOT SCHEDULED FOR MAINTENANCE	>BROUGHT UP	RETIRED OR NOT UP	THIS YEAR<
NOTE:	PLANT	17	(GT30-03 )	NOT SCHEDULED FOR MAINTENANCE	>BROUGHT UP	RETIRED OR NOT UP	THIS YEAR<
SCHEDULE:	PLANT	7	(DH8001 )	FOR 3 PERIODS STARTING PERIOD	19		
SCHEDULE:	PLANT	8	(DH8002 )	FOR 3 PERIODS STARTING PERIOD	22		
SCHEDULE:	PLANT	9	(DH8003 )	FOR 3 PERIODS STARTING PERIOD	16		
SCHEDULE:	PLANT	10	(DH8004 )	FOR 3 PERIODS STARTING PERIOD	19		
SCHEDULE:	PLANT	11	(DH8005 )	FOR 3 PERIODS STARTING PERIOD	1		
SCHEDULE:	PLANT	12	(DH8006 )	FOR 3 PERIODS STARTING PERIOD	22		
SCHEDULE:	PLANT	13	(VSC001 )	FOR 3 PERIODS STARTING PERIOD	14		
SCHEDULE:	PLANT	14	(VSC002 )	FOR 3 PERIODS STARTING PERIOD	17		
SCHEDULE:	PLANT	3	(MON103 )	FOR 3 PERIODS STARTING PERIOD	1		
SCHEDULE:	PLANT	4	(MON104 )	FOR 3 PERIODS STARTING PERIOD	4		
SCHEDULE:	PLANT	5	(MON105 )	FOR 3 PERIODS STARTING PERIOD	20		
SCHEDULE:	PLANT	6	(MON106 )	FOR 3 PERIODS STARTING PERIOD	1		
SCHEDULE:	PLANT	15	(GT30-01 )	FOR 1 PERIODS STARTING PERIOD	13		
SCHEDULE:	PLANT	16	(GT30-02 )	FOR 1 PERIODS STARTING PERIOD	4		

\*\*\*\*\*  
 ANNUAL PEAK: 540.7 MWE  
 TOTAL CAPACITY WITHOUT HYDRO 720.0 MWE  
 SYSTEM CAPACITY WITH ANNUAL AVERAGE HYDRO 737.2 MWE  
 \*\*\*\*\*

LOAD FACTOR TABLE

PERIOD- SEASON	PK LOAD (MWE)	DEMAND (KWH)	LOAD FACTOR	CONTRIBUTION TO ANNUAL LF
1- 1	378.5	.89097E+08	.6449	.4515
2- 1	389.3	.91643E+08	.6449	.4644
3- 2	405.5	.94070E+08	.6355	.4767
4- 2	432.6	.10034E+09	.6355	.5084
5- 3	443.4	.10711E+09	.6619	.5427
6- 3	459.6	.11103E+09	.6619	.5626
7- 4	486.6	.12543E+09	.7061	.6355
8- 4	497.4	.12821E+09	.7061	.6497
9- 5	513.7	.12829E+09	.6843	.6501
10- 5	540.7	.13505E+09	.6843	.6843
11- 6	524.5	.13637E+09	.7123	.6910
12- 6	502.9	.13074E+09	.7123	.6625
13- 7	486.6	.12694E+09	.7146	.6432
14- 7	470.4	.12270E+09	.7146	.6217
15- 8	448.8	.11945E+09	.7292	.6053
16- 8	432.6	.11514E+09	.7292	.5834
17- 9	427.2	.11615E+09	.7450	.5885
18- 9	416.3	.11321E+09	.7450	.5736
19-10	405.5	.95786E+08	.6471	.4853
20-10	394.7	.93231E+08	.6471	.4724
21-11	405.5	.93465E+08	.6315	.4736
22-11	416.3	.95958E+08	.6315	.4862
23-12	427.2	.10206E+09	.6546	.5171
24-12	432.6	.10335E+09	.6546	.5237
ANNUAL	540.7	.26748E+10	.5647	

## UNIT DESCRIPTION TABLE

UNIT-BLOCK	UNIT NAME	RATED MWE	MW ADDED	SR OUTAGE	FORCED NUMBER	LOAD NUMBER	HEAT RATE KBTU/KWH	FUEL COST \$/MBTU	FUEL TYPE	VAR O&M \$/MWH	FIX O&M \$/KWE/YR	CAP COST \$/KWE	MAINT. PERIOD LENGTH	STATUS
-1		18.	3.			31.34	12.14	30.1				31.75		
-2		12.	-3.			31.34	11.73	29.1				30.73		
1	MON101	30.		.1200			11.98	247.70	FUEL OIL	1.67	19.20	0.	3	0 UPTHISYR
-1		18.	3.			31.34	12.14	30.1				31.75		
-2		12.	-3.			31.34	11.73	29.1				30.73		
2	MON102	30.		.1200			11.98	247.70	FUEL OIL	1.67	19.20	0.	3	0 PLANNED
-1		18.	3.			31.34	12.14	30.1				31.75		
-2		12.	-3.			31.34	11.73	29.1				30.73		
3	MON103	30.		.1200			11.98	247.70	FUEL OIL	1.67	19.20	0.	3	0 IN SRVCE
-1		18.	3.			31.34	12.14	30.1				31.75		
-2		12.	-3.			31.34	11.73	29.1				30.73		
4	MON104	30.		.1200			11.98	247.70	FUEL OIL	1.67	19.20	0.	3	0 IN SRVCE
-1		18.	3.			31.34	12.14	30.1				31.75		
-2		12.	-3.			31.34	11.73	29.1				30.73		
5	MON105	30.		.1200			11.98	247.70	FUEL OIL	1.67	19.20	0.	3	0 IN SRVCE
-1		18.	3.			31.34	12.14	30.1				31.75		
-2		12.	-3.			31.34	11.73	29.1				30.73		
6	MON106	30.		.1200			11.98	247.70	FUEL OIL	1.67	19.20	0.	3	0 IN SRVCE
-1		30.	6.			27.21	10.60	26.3				27.46		
-2		30.	-6.			27.21	10.40	25.8				26.97		
7	DHB001	60.		.1200			10.50	247.70	FUEL OIL	1.20	24.48	0.	3	0 IN SRVCE
-1		30.	6.			27.21	10.60	26.3				27.46		
-2		30.	-6.			27.21	10.40	25.8				26.97		
8	DHB002	60.		.1200			10.50	247.70	FUEL OIL	1.20	24.48	0.	3	0 IN SRVCE
-1		30.	6.			24.19	9.53	23.6				24.80		
-2		30.	-6.			24.19	9.04	22.4				23.58		
9	DHB003	60.		.1200			9.28	247.70	FUEL OIL	1.20	24.48	0.	3	0 IN SRVCE
-1		30.	6.			24.19	9.53	23.6				24.80		
-2		30.	-6.			24.19	9.04	22.4				23.58		
10	DHB004	60.		.1200			9.28	247.70	FUEL OIL	1.20	24.48	0.	3	0 IN SRVCE
-1		30.	6.			24.19	9.53	23.6				24.80		
-2		30.	-6.			24.19	9.04	22.4				23.58		
11	DHB005	60.		.1200			9.28	247.70	FUEL OIL	1.20	24.48	0.	3	0 IN SRVCE



PERIOD NUMBER	PERIOD LOAD	BUY/SELL	SCHEDULED CAPACITY	SCHEDULED MAINT	PERIOD RESERVE	EXPECTED CAPACITY	EXPECTED RESERVE	EMERGENCY INTERTIES
1	378.5	.0	555.0	120.0	.4664	484.8	.2809	.0
2	389.3	.0	553.0	120.0	.4205	482.8	.2402	.0
3	405.5	.0	553.0	120.0	.3637	482.8	.1906	.0
4	432.6	.0	615.0	60.0	.4218	538.5	.2449	.0
5	443.4	.0	645.0	30.0	.4548	564.0	.2721	.0
6	459.6	.0	645.0	30.0	.4034	564.0	.2272	.0
7	486.6	.0	680.0	.0	.3974	595.4	.2235	.0
8	497.4	.0	680.0	.0	.3670	595.4	.1969	.0
9	513.7	.0	680.0	.0	.3238	595.4	.1591	.0
10	540.7	.0	680.0	.0	.2576	595.4	.1012	.0
11	524.5	.0	680.0	.0	.2965	595.4	.1352	.0
12	502.9	.0	740.0	.0	.4716	647.3	.2873	.0
13	486.6	.0	695.0	30.0	.4282	606.8	.2469	.0
14	470.4	.0	665.0	60.0	.4137	581.3	.2357	.0
15	448.8	.0	665.0	60.0	.4818	581.3	.2953	.0
16	432.6	.0	605.0	120.0	.3986	528.5	.2218	.0
17	427.2	.0	605.0	120.0	.4164	528.5	.2373	.0
18	416.3	.0	605.0	120.0	.4531	528.5	.2694	.0
19	405.5	.0	555.0	180.0	.3686	485.7	.1977	.0
20	394.7	.0	585.0	150.0	.4821	510.3	.2928	.0
21	405.5	.0	585.0	150.0	.4426	510.3	.2584	.0
22	416.3	.0	585.0	150.0	.4051	510.3	.2257	.0
23	427.2	.0	615.0	120.0	.4398	536.7	.2565	.0
24	432.6	.0	615.0	120.0	.4218	536.7	.2408	.0

FIRM PURCHASES/SALES WILL BE AVAILABLE .00 HOURS PER DAY --- .00 DAYS PER WEEK  
 FIRM PURCHASES/SALES CORRELATION WITH HIGH LOADS = .00



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 YEAR 1996 PERIOD 1  
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PEAKING HYDRO IS LOADED WITH BLOCK 14

PERIOD ENERGY AND COST SUMMARY TABLE

COMPONENT	CAPACITY MWE	GENERATED KWH	LOAD/CAP FACTOR	MILLION BTU FUEL	FUEL COST \$/MWH	O&M COST \$/MWH	VARIABLE COST DOLLARS	FIXED COST DOLLARS	TOTAL COST DOLLARS	TOTAL COST \$/MWH
DEMAND	378.	.8910E+08	.644935							
HYDRO	15.	.3833E+07	.700000	.0000E+00	.00	.00	.000000E+00	.000000E+00	.000000E+00	.00
THERMAL	540.	.8523E+08	.432420	.8508E+06	21.55	1.37	.195337E+07	.686400E+06	.805263977E+07	30.97
UNSUPPLIED		.3564E+05								
TOTAL COST				.8508E+06	20.62	1.31	.195337E+07	.686400E+06	7.71263977E+07	29.64

PERIOD SYSTEM RELIABILITY TABLE

INDICATOR	UNITS	WITHOUT TIES	WITH TIES
LOLP PROBABILITY		.34600850E-02	.34600850E-02
LOLP DAYS/YEAR		.12629310E+01	.12629310E+01
UNSERVED KWH		.35642773E+05	.35642773E+05
LOEP PROBABILITY		.40003930E-03	.40003930E-03
RESERVE MARGIN (FRACTION); ORIGINAL PEAK LOAD:		.466353E+00	W/ FIRM P/S: .466353E+00

THE FOLLOWING UPDATES WERE MADE WITHIN THE PERIOD LOOP

KP HAS BEEN RESET TO 6

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 YEAR 1996 PERIOD 2  
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PEAKING HYDRO IS LOADED WITH BLOCK 12

PERIOD ENERGY AND COST TABLE BY FUEL TYPE

FUEL NO	FUEL TYPE	RATED MWE	GENERATED KWH	CAPACITY FACTOR	MILLION BTU	FUEL DOLLARS	FUEL COST \$/MWH	VAR O&M \$/MWH	FIXED O&M \$/MWH	TOTAL O&M DOLLARS	VAR COST \$/MWH	TOTAL COST DOLLARS	TOTAL COST \$/MWH	
	HYDRO	13.	.3979E+07	.838E+00	.0000E+00	.000000E+00	.0	.00	.000E+00	.000000E+00	.00	.000000E+00	.000E+00	
1	FUEL OIL	360.	.5801E+08	.442E+00	.5840E+06	.144645E+07	24.9	1.25	.798E+01	.535741E+06	.923E+01	26.18	.198220E+07	.342E+02
2	COAL	120.	.2941E+08	.671E+00	.2886E+06	.438678E+06	14.9	1.60	.551E+01	.209049E+06	.711E+01	16.52	.647727E+06	.220E+02
3	GASTURB	60.	.1921E+06	.877E-02	.2516E+04	.787033E+04	41.0	1.20	.319E+03	.614305E+05	.320E+03	42.18	.693008E+05	.361E+03
-----														
TOTAL		553.	.9159E+08	.453766	.8751E+06									
TOTAL \$						.1893003E+07	.11982E+06	.68640E+06	.8062198E+06	.8062198E+06	.20128E+07	.2699223E+07	.2699223E+07	
SYSTEM \$/MWH						20.7	1.31	7.49	8.80	8.80	21.98	29.47	29.47	

PERIOD ENERGY AND COST SUMMARY TABLE

COMPONENT	MWE	GENERATED KWH	LOAD/CAP FACTOR	MILLION BTU	FUEL DOLLARS	FUEL COST \$/MWH	O&M COST \$/MWH	VARIABLE COST DOLLARS	FIXED COST DOLLARS	TOTAL COST DOLLARS	TOTAL COST \$/MWH	
DEMAND	389.	.9164E+08	.644935									
HYDRO	13.	.3979E+07	.838462	.0000E+00	.00	.00	.000000E+00	.00	.000000E+00	.00	.000000E+00	
THERMAL	540.	.8761E+08	.444505	.8751E+06	21.61	1.37	.20128E+07	22.97	.686400E+06	7.83	.269922E+07	30.81
UNSUPPLIED		.5350E+05										
TOTAL COST				.8751E+06	20.67	1.31	.20128E+07	21.98	.686400E+06	7.49	.269922E+07	29.47

PERIOD SYSTEM RELIABILITY TABLE

INDICATOR	UNITS	WITHOUT TIES	WITH TIES
LOLP	PROBABILITY	.50915550E-02	.50915550E-02
LOLP	DAYS/YEAR	.18584180E+01	.18584180E+01
UNSERVED	KWH	.53495949E+05	.53495949E+05
LOEP	PROBABILITY	.58373750E-03	.58373750E-03
RESERVE MARGIN (FRACTION); ORIGINAL PEAK LOAD:		.420484E+00	.420484E+00
W/ FIRM P/S:			.420484E+00

THE FOLLOWING UPDATES WERE MADE WITHIN THE PERIOD LOOP

KP HAS BEEN RESET TO 7

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 YEAR 1996 PERIOD 3  
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PEAKING HYDRO IS LOADED WITH BLOCK 13

PERIOD ENERGY AND COST BY UNIT

UNIT NO	UNIT NAME	RATED MWE	GENERATED KWH	CAPACITY FACTOR	MILLION BTU	FUEL MILLION	FUEL DOLLARS	FUEL COST \$/MWH	FUEL TYPE	VAR O&M \$/MWH	FIXED O&M DOLLARS	TOTAL O&M \$/MWH	VAR COST \$/MWH	TOTAL COST DOLLARS	TOTAL COST \$/MWH
3	MONI03	13.	.3979E+07	.838E+00	.0000E+00	.0000E+00	.0000E+00	.00	HYDRO	.00	.0000E+00	.00	.00	.0000E+00	.0000E+00
					DOWN FOR MAINTENANCE				FUEL OIL		.2400E+05	*		.2400E+05	*
4	MONI04	30.	.3768E+07	.344E+00	.4571E+05	.1132E+06	.1132E+06	30.0	FUEL OIL	1.67	.2400E+05	8.04	31.72	.1435E+06	.3809E+02
5	MONI05	30.	.2730E+07	.249E+00	.3312E+05	.8203E+05	.8203E+05	30.0	FUEL OIL	1.67	.2400E+05	10.46	31.71	.1106E+06	.4050E+02
6	MONI06				DOWN FOR MAINTENANCE				FUEL OIL		.2400E+05	*		.2400E+05	*
7	DHB001	60.	.9574E+07	.437E+00	.1013E+06	.2510E+06	.2510E+06	26.2	FUEL OIL	1.20	.6120E+05	7.59	27.42	.3237E+06	.3381E+02
8	DHB002	60.	.8463E+07	.386E+00	.8962E+05	.2220E+06	.2220E+06	26.2	FUEL OIL	1.20	.6120E+05	8.43	27.43	.2934E+06	.3466E+02
9	DHB003	60.	.1288E+08	.588E+00	.1212E+06	.3001E+06	.3001E+06	23.3	FUEL OIL	1.20	.6120E+05	5.95	24.49	.3768E+06	.2924E+02
10	DHB004	60.	.1170E+08	.534E+00	.1105E+06	.2736E+06	.2736E+06	23.4	FUEL OIL	1.20	.6120E+05	6.43	24.59	.3488E+06	.2982E+02
11	DHB005				DOWN FOR MAINTENANCE				FUEL OIL		.6120E+05	*		.6120E+05	*
12	DHB006	60.	.1086E+08	.496E+00	.1029E+06	.2548E+06	.2548E+06	23.5	FUEL OIL	1.20	.6120E+05	6.84	24.66	.3290E+06	.3029E+02
13	VSC001	60.	.1562E+08	.713E+00	.1530E+06	.2326E+06	.2326E+06	14.9	COAL	1.60	.8100E+05	6.79	16.49	.3386E+06	.2167E+02
14	VSC002	60.	.1420E+08	.648E+00	.1395E+06	.2121E+06	.2121E+06	14.9	COAL	1.60	.8100E+05	7.30	16.54	.3158E+06	.2224E+02
15	GT30-01	30.	.1516E+06	.138E-01	.1986E+04	.6211E+04	.6211E+04	41.0	GASTURB	1.20	.3060E+05	203.09	42.18	.3699E+05	.2441E+03
16	GT30-02	30.	.7641E+05	.698E-02	.1001E+04	.3131E+04	.3131E+04	41.0	GASTURB	1.20	.3060E+05	401.66	42.18	.3382E+05	.4426E+03
TOTAL		553.	.9400E+08	.465724	.8998E+06		.1951E+07	20.8		.1230E+06	.6864E+06	.8094E+06	.2074E+07	.2760E+07	.2760E+07
SYSTEM										1.31	.7302E+01	8.61	.2206E+02	.2936E+02	.2936E+02



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THE FOLLOWING UPDATES WERE MADE WITHIN THE PERIOD LOOP  
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KP HAS BEEN RESET TO 8

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YEAR 1996 PERIOD 4  
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BASE HYDRO OF 10.00 MWE GENERATES .36500E+07 KWH OF A MAXIMUM POSSIBLE .36500E+07 KWH

PEAKING HYDRO WOULD GENERATE .1825000E+07 KWH IF LOADED AFTER BASE HYDRO  
BETWEEN .10000E+02 AND .15000E+02 -- PHKWH= .1825000E+06

PEAKING HYDRO IS LOADED WITH BLOCK 16

INITIAL BLOCK ENERGY NORMALIZATION FACTOR FOR THERMAL BLOCKS = .99584E+00

FINAL BLOCK ENERGY NORMALIZATION FACTOR FOR THERMAL BLOCKS = .99262E+00

PERIOD ENERGY AND COSTS BY BLOCK

LOAD	UNIT -BLK	UNIT NAME	RATED SPIN MWE RESV	SPIN GOAL MET	GENERATED KWH	CAPACITY FACTOR	VOM+FUEL MILLS/KWH	MILLION BTU FUEL	FUEL COST DOLLARS	FUEL TYPE	VAR O&M DOLLARS	TOTAL VAR DOLLARS
	BASE	HYDRO	10.	1.	.3650E+07	.1000E+01	.000	.0000E+00	.0000E+00	HYDRO	.0000E+00	.0000E+00
1	13-1	VSC001	30.	7.	.9308E+07	.8500E+00	16.806	.9311E+05	.1415E+06	COAL	.1489E+05	.1564E+06
2	14-1	VSC002	30.	13.	.9308E+07	.8500E+00	16.806	.9311E+05	.1415E+06	COAL	.1489E+05	.1564E+06
3	9-1	DHB003	30.	19.	*.9636E+07	.8800E+00	24.801	.9181E+05	.2274E+06	FUEL OIL	.1156E+05	.2390E+06
4	10-1	DHB004	30.	25.	*.9636E+07	.8800E+00	24.801	.9181E+05	.2274E+06	FUEL OIL	.1156E+05	.2390E+06
5	11-1	DHB005	30.	31.	*.9631E+07	.8795E+00	24.801	.9177E+05	.2273E+06	FUEL OIL	.1156E+05	.2389E+06
6	12-1	DHB006	30.	37.	*.9180E+07	.8383E+00	24.801	.8746E+05	.2166E+06	FUEL OIL	.1102E+05	.2277E+06
7	7-1	DHB001	30.	43.	*.8376E+07	.7649E+00	27.456	.8378E+05	.2199E+06	FUEL OIL	.1005E+05	.2300E+06
8	13-2	VSC001	30.	37.	*.6820E+07	.6228E+00	16.022	.6471E+05	.9836E+05	COAL	.1091E+05	.1093E+06
9	8-1	DHB002	30.	43.	*.6443E+07	.5883E+00	27.456	.6829E+05	.1692E+06	FUEL OIL	.7731E+04	.1769E+06
10	14-2	VSC002	30.	37.	*.5134E+07	.4688E+00	16.022	.4871E+05	.7404E+05	COAL	.8214E+04	.8225E+05
11	3-1	MONI03	18.	40.	*.2823E+07	.4296E+00	31.751	.3428E+05	.8491E+05	FUEL OIL	.4714E+04	.8963E+05
12	9-2	DHB003	30.	34.	*.3631E+07	.3315E+00	23.582	.3281E+05	.8127E+05	FUEL OIL	.4357E+04	.8562E+05
13	5-1	MONI05	18.	37.	*.1736E+07	.2642E+00	31.751	.2108E+05	.5222E+05	FUEL OIL	.2899E+04	.5511E+05
14	6-1	MONI06	18.	40.	*.1378E+07	.2097E+00	31.751	.1673E+05	.4145E+05	FUEL OIL	.2301E+04	.4375E+05
15	10-2	DHB004	30.	34.	*.1502E+07	.1371E+00	23.582	.1357E+05	.3362E+05	FUEL OIL	.1803E+04	.3542E+05
16	11-2	DHB005	30.	28.	*.8986E+06	.8205E-01	23.582	.8120E+04	.2011E+05	FUEL OIL	.1078E+04	.2119E+05
	PEAK	HYDRO	5.	27.	.1825E+06	.1000E+00	23.582	.0000E+00	.0000E+00	HYDRO	.0000E+00	.0000E+00
17	12-2	DHB006	30.	21.	*.4720E+06	.4310E-01	23.582	.4265E+04	.1056E+05	FUEL OIL	.5664E+03	.1113E+05
18	7-2	DHB001	30.	15.	*.2745E+06	.2507E-01	26.973	.2857E+04	.7076E+04	FUEL OIL	.3294E+03	.7405E+04
19	8-2	DHB002	30.	9.	*.1572E+06	.1435E-01	26.973	.1636E+04	.4052E+04	FUEL OIL	.1886E+03	.4240E+04
20	3-2	MONI03	12.	6.	*.4423E+05	.1009E-01	30.728	.5189E+03	.1285E+04	FUEL OIL	.7386E+02	.1359E+04
21	5-2	MONI05	12.	3.	*.3348E+05	.7644E-02	30.728	.3928E+03	.9729E+03	FUEL OIL	.5592E+02	.1029E+04
22	6-2	MONI06	12.	0.	*.2496E+05	.5698E-02	30.728	.2928E+03	.7253E+03	FUEL OIL	.4168E+02	.7670E+03
23	15-1	GT30-01	30.	0.	*.3493E+05	.3189E-02	42.180	.4576E+03	.1431E+04	GASTURB	.4191E+02	.1473E+04
TOTAL									.9566E+06	.2083E+07	.1308E+06	.2214E+07

PERIOD ENERGY AND COST BY UNIT

UNIT NO	UNIT NAME	RATED MWE	GENERATED KWH	CAPACITY FACTOR	MILLION BTU	FUEL COST \$/MWH	FUEL TYPE	VAR \$/MWH	O&M DOLLARS	TOTAL O&M \$/MWH	VAR COST \$/MWH	TOTAL COST DOLLARS
15.	HYDRO	.3833E+07	.700E+00	.0000E+00	.0000E+00	.0	HYDRO	.00	.0000E+00	.00	.00	.0000E+00
30.	3 MON103	.2867E+07	.262E+00	.3480E+05	.8620E+05	30.1	FUEL OIL	1.67	.2400E+05	10.04	31.73	.1150E+06
4	4 MON104						FUEL OIL		.2400E+05	*		.2400E+05
30.	5 MON105	.1769E+07	.162E+00	.2147E+05	.5319E+05	30.1	FUEL OIL	1.67	.2400E+05	15.23	31.73	.8014E+05
6	6 MON106	.1403E+07	.128E+00	.1703E+05	.4217E+05	30.1	FUEL OIL	1.67	.2400E+05	18.78	31.73	.6852E+05
7	7 DHB001	.8650E+07	.395E+00	.9164E+05	.2270E+06	26.2	FUEL OIL	1.20	.6120E+05	8.28	27.44	.2986E+06
8	8 DHB002	.6600E+07	.301E+00	.6993E+05	.1732E+06	26.2	FUEL OIL	1.20	.6120E+05	10.47	27.44	.2423E+06
9	9 DHB003	.1327E+08	.606E+00	.1246E+06	.3087E+06	23.3	FUEL OIL	1.20	.6120E+05	5.81	24.47	.3858E+06
10	10 DHB004	.1114E+08	.509E+00	.1054E+06	.2610E+06	23.4	FUEL OIL	1.20	.6120E+05	6.69	24.64	.3356E+06
60.	11 DHB005	.1053E+08	.481E+00	.9986E+05	.2474E+06	23.5	FUEL OIL	1.20	.6120E+05	7.01	24.70	.3213E+06
60.	12 DHB006	.9652E+07	.441E+00	.9173E+05	.2272E+06	23.5	FUEL OIL	1.20	.6120E+05	7.54	24.74	.3000E+06
13	13 VSC001	.1613E+08	.736E+00	.1578E+06	.2399E+06	14.9	COAL	1.60	.8100E+05	6.62	16.47	.3467E+06
60.	14 VSC002	.1444E+08	.659E+00	.1418E+06	.2156E+06	14.9	COAL	1.60	.8100E+05	7.21	16.53	.3197E+06
15	15 GT30-01	.3493E+05	.319E-02	.4576E+03	.1431E+04	41.0	GASTURB	1.20	.3060E+05	877.26	42.18	.3207E+05
16	16 GT30-02						GASTURB		.3060E+05	*		.3060E+05
DOWN FOR MAINTENANCE												
TOTAL		615.	.1003E+09	.446874	.9566E+06							
TOTAL \$						.2083E+07		.1308E+06	.6864E+06	.8172E+06	.2214E+07	.2900E+07
SYSTEM \$/MWH						20.8		1.30	.6843E+01	8.15	.2207E+02	.2891E+02

PERIOD ENERGY AND COST TABLE BY FUEL TYPE

FUEL NO	FUEL TYPE	RATED MWE	GENERATED KWH	CAPACITY FACTOR	MILLION BTU	FUEL COST \$/MWH	VAR \$/MWH	O&M DOLLARS	TOTAL O&M \$/MWH	VAR COST \$/MWH	TOTAL COST DOLLARS
15.	HYDRO	.3833E+07	.700E+00	.0000E+00	.000000E+00	.0	.00	.0000E+00	.000000E+00	.00	.000000E+00
450.	1 FUEL OIL	.6588E+08	.401E+00	.6565E+06	.162611E+07	24.7	1.24	.703E+01	.545089E+06	.827E+01	25.93
120.	2 COAL	.3057E+08	.698E+00	.2996E+06	.455460E+06	14.9	1.60	.530E+01	.210911E+06	.690E+01	16.50
30.	3 GASTURB	.3493E+05	.319E-02	.4576E+03	.143139E+04	41.0	1.20	.175E+04	.612419E+05	.175E+04	42.18
DOWN FOR MAINTENANCE											
TOTAL		615.	.1003E+09	.446874	.9566E+06						
TOTAL \$						.2083000E+07	.13084E+06	.68640E+06	.8172416E+06	.22138E+07	.2900242E+07
SYSTEM \$/MWH						20.8	1.30	6.84	8.15	22.07	28.91



PERIOD ENERGY AND COST SUMMARY TABLE

COMPONENT	CAPACITY GENERATED MWE	LOAD/CAP KWH	MILLION BTU	FUEL COST \$/MWH	O&M COST \$/MWH	VARIABLE COST DOLLARS	FIXED COST DOLLARS	TOTAL COST DOLLARS	TOTAL COST \$/MWH
DEMAND	433.	.1003E+09	.635535						
HYDRO	15.	.3833E+07	.700000	.00	.00	.000000E+00	.00	.000000E+00	.00
THERMAL	600.	.9648E+08	.440546	21.59	1.36	.221384E+07	22.95	.686400E+06	7.11
UNSUPPLIED		.2954E+05							
TOTAL COST				20.77	1.30	.221384E+07	22.07	.686400E+06	6.84

PERIOD SYSTEM RELIABILITY TABLE

INDICATOR	UNITS	WITHOUT TIES	WITH TIES
LOLP	PROBABILITY	.27286280E-02	.27286280E-02
LOLP	DAYS/YEAR	.99594900E+00	.99594900E+00
UNSERVED	KWH	.29542949E+05	.29542949E+05
LOEP	PROBABILITY	.29442360E-03	.29442360E-03

RESERVE MARGIN (FRACTION); ORIGINAL PEAK LOAD: .421768E+00 W/ FIRM P/S: .421768E+00

THE FOLLOWING UPDATES WERE MADE WITHIN THE PERIOD LOOP

KP HAS BEEN RESET TO 3



-1	30.	.2024E+09	.770E+00	.1928E+07	23.60	24.80	.5019E+07
-2	30.	.8809E+08	.335E+00	.7960E+06	22.38	23.58	.2077E+07
10 DHB004	60.	.2904E+09	.553E+00	.2724E+07	FUEL OIL	24.43	.5057E+01 .2949E+02 IN SRVCE
-1	30.	.2023E+09	.770E+00	.1927E+07	23.60	24.80	.5017E+07
-2	30.	.5635E+08	.214E+00	.5091E+06	22.38	23.58	.1329E+07
11 DHB005	60.	.2586E+09	.492E+00	.2437E+07	FUEL OIL	24.54	.5679E+01 .3021E+02 IN SRVCE
-1	30.	.2012E+09	.766E+00	.1917E+07	23.60	24.80	.4991E+07
-2	30.	.3818E+08	.145E+00	.3450E+06	22.38	23.58	.9003E+06
12 DHB006	60.	.2394E+09	.456E+00	.2262E+07	FUEL OIL	24.61	.6135E+01 .7360E+07 .3074E+02 IN SRVCE
-1	30.	.1955E+09	.744E+00	.1955E+07	15.21	16.81	.3285E+07
-2	30.	.1672E+09	.636E+00	.1586E+07	14.42	16.02	.2679E+07
13 VSC001	60.	.3626E+09	.690E+00	.3542E+07	COAL	16.44	.5361E+01 .7907E+07 .2181E+02 IN SRVCE
-1	30.	.1955E+09	.744E+00	.1955E+07	15.21	16.81	.3285E+07
-2	30.	.1418E+09	.540E+00	.1346E+07	14.42	16.02	.2272E+07
14 VSC002	60.	.3373E+09	.642E+00	.3301E+07	COAL	16.48	.5764E+01 .7501E+07 .2224E+02 IN SRVCE
15 GT30-01	30.	.3557E+07	.135E-01	.4660E+05	GASTURB	40.98	.2077E+03 .8844E+06 .2487E+03 IN SRVCE
16 GT30-02	30.	.1862E+07	.709E-02	.2440E+05	GASTURB	40.98	.3956E+03 .8129E+06 .4366E+03 IN SRVCE
17 GT30-03	30.	.5342E+06	.203E-02	.6999E+04	GASTURB	40.98	.7459E+03 .4203E+06 .7868E+03 UPTHSYR
TOTAL	734.	.2670E+10	.415558	.2600E+08			
TOTAL \$			.5791E+08	.2073E+08		.00	.6146E+08 .1718E+08 .7864E+08
SYSTEM \$/MWH			21.69	7.76		.00	23.01 6.43 29.45

\*\*\*\*\* ANNUAL ENERGY AND COST TABLE BY FUEL TYPE \*\*\*\*\*

FUEL NO	FUEL TYPE	RATED MWE	GENERATED KWH	CAPACITY FACTOR	MILLION BTU	FUEL DOLLARS	FUEL COST \$/MWH	O&M COST \$/MWH	CAP COST \$/MWH	VAR COST \$/MWH	FIX COST \$/MWH	DOLLARS	TOTAL COST \$/MWH
	HYDRO	14.	.9136E+08	.768E+00	.0000E+00	.0000E+00	.00	.0000E+00	.00	.00	.0000E+00	.0000E+00	.0000E+00
1	FUEL OIL	510.	.1873E+10	.419E+00	.1908E+08	.4727E+08	25.23	.7393E+01	.00	26.53	.6101E+01	.6112E+08	.3263E+02
2	COAL	120.	.6999E+09	.666E+00	.6842E+07	.1040E+08	14.86	.7155E+01	.00	16.46	.5555E+01	.1541E+08	.2201E+02
3	GASTURB	90.	.5953E+07	.755E-02	.7799E+05	.2440E+06	40.98	.3148E+03	.00	42.18	.3136E+03	.2118E+07	.3557E+03
-----													
TOTAL		734.	.2670E+10	.415558	.2600E+08								
TOTAL \$						.5791E+08		.2073E+08	.00	.6146E+08	.1718E+08		.7864E+08
SYSTEM \$/MWH						21.69		7.76	.00	23.01	6.43		29.45

\*\*\*\*\* ENERGY SUMMARY TABLE \*\*\*\*\*

ENERGY DEMANDED						.267161E+10	KWH						
HYDRO GENERATION						- .913595E+08	KWH						
-----													
SUBTOTAL						.258025E+10	KWH						
FUEL OIL GENERATION						.187323E+10	KWH					.190833E+08	10**6 BTU FUEL USED
COAL GENERATION						.699913E+09	KWH					.684249E+07	10**6 BTU FUEL USED
GASTURB GENERATION						.595299E+07	KWH					.779901E+05	10**6 BTU FUEL USED
-----													
TOTAL THERMAL GENERATION						- .257910E+10	KWH						
UNSERVED ENERGY						.115020E+07	KWH						
EMERGENCY INTERTIES						.000000E+00	KWH						
-----													
UNSERVED ENERGY						.115020E+07	KWH						

\*\*\*\*\*ANNUAL ENERGY AND COST SUMMARY TABLE \*\*\*\*\*

COMPONENT	CAPACITY GENERATED MWE	LOAD/CAP FACTOR	FUEL COST \$/MWH	TOTAL O&M \$/MWH	CAP COST \$/MWH	VARIABLE COST DOLLARS	FIXED COST DOLLARS	TOTAL COST DOLLARS	TOTAL COST \$/MWH
DEMAND	541.	.2672E+10	.564722	.00	.00	.00	.0000E+00	.00	.0000E+00
HYDRO	14.	.9136E+08	.767791	.00	.00	.6146E+08	.0000E+00	.666	.7864E+08
THERMAL	720.	.2579E+10	.408913	22.46	8.04	.6146E+08	.1718E+08	23.83	30.49
UNSUPPLIED	.1150E+07								
TOTAL COST			21.69	7.76	.00	.6146E+08	.1718E+08	23.01	6.43
TOTAL COST FOR THE YEAR IS									

\*\*\*\*\*ANNUAL SYSTEM RELIABILITY TABLE \*\*\*\*\*

INDICATOR	UNITS	WITHOUT TIES	WITH TIES	RESERVE MARGIN (FRACTION); ORIGINAL PEAK LOAD:	W/ FIRM P/S:
LOLP PROBABILITY		.43750970E-02	.43750970E-02	.356729E+00	
LOLP DAYS/YEAR		.15969100E+01	.15969100E+01		
UNSERVED KWH		.11501993E+07	.11501993E+07		
LOEP PROBABILITY		.43052720E-03	.43052720E-03		

PRESENT VALUE AT BEGINNING OF BASE YEAR IS 78643380. DOLLARS.

WEIGHTED AVERAGE ENERGY COST THROUGH THIS YEAR IS 29.449 MILLS/KWH.

\*\*\*\*\*ANNUAL ENERGY AND COST TOTALS THROUGH THIS YEAR \*\*\*\*\*

FIRM PURCHASES	KWH	DOLLARS	DISCOUNTED KWH	DISCOUNTED \$
	.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
GENERATION	.26704560E+10	.78643380E+08	.26704560E+10	.78643380E+08
EMERGENCY INTERTIES	.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
RESERVE	.00000000E+00	.00000000E+00	.00000000E+00	.00000000E+00
TOTALS	.26704562E+10	.78643380E+08	.26704562E+10	.78643380E+08

\*\*\*\*\*ANNUAL ENERGY AND COST TOTALS THROUGH THIS YEAR \*\*\*\*\*  
 \*\*\*\*\* END OF SIMULATION FOR YEAR 1996 \*\*\*\*\*

APPENDIX D  
AUXILIARY OUTPUT FILE FORMATS

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## APPENDIX D

## AUXILIARY OUTPUT FILE FORMATS

## D.1 INTRODUCTION

The auxiliary output file stores the results of each simulation period (as defined by NPER on card type L3) and the annual totals. The results of each simulation period and the annual totals are reported in the following major categories: (1) unit-specific information about each of the designated units (as defined on card type L4), (2) major fuel category, and (3) system totals. The file is stored in a fixed-block format and has a record length of 133.

Blank cards and other indicators are used to signal separations in the data groups; therefore, particular care must be taken when reading and interpreting the output files.

## D.2 FILE FORMATS

The following format descriptions present the information and data sequences used in the auxiliary output file. All costs reported in the output file are in current-year dollars for the year simulated.

	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type A1: NYR,NDSIG,CASE</b>		
NYR	1-2	I2
Number of years in simulation.		
NDSIG	4-5	I2
Number of units designated for individual unit output (maximum = 20 units).		
CASE	16-87	9A8
Case name.		



<u>Card Columns</u>	<u>Variable Format</u>
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**Card Type A2a: IX**

*Note: This title card reads:*

**\*\*\* RESULTS FOR PERIOD IX \*\*\***

*Columns 1 through 4 are blank unless the period results are identical to those of the previous period, in which case card type A2b is used.*

IX	.	23-24	I2
----	---	-------	----

Period number.

**Card Type A2b: IX**

*Note: This title card reads:*

**\*\*\* DUPLICATE RESULT FOR PERIOD IX FROM  
PREVIOUS PERIOD \*\*\***

*When this card is used, the period results are omitted. They should be duplicated from the previous period. This card is never used for the first period of simulation or when card type A2a is used.*

IX		36-37	I2
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Period number.

**Card Type A3: IDPN,PLTID,YMWR,UTEWH,CF,  
UTFU,UTF\$,UTVOM,UTFOM,UT\$**

*Note: Card type A3 is repeated for each of the designated units. If zero units are designated in card type A1, then no card type A3 entries should be included.*

IDPN		1-4	I4
------	--	-----	----

Unit number.

PLTID		6-13	A8
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Unit name.

	<u>Card Columns</u>	<u>Variable Format</u>
YMWR	15-21	F7.0
Unit capacity (in MWe).		
UTEWH	23-34	E12.6
Unit generation for the period (in kWh).		
CF	36-47	E12.6
Unit capacity factor for the period (fraction).		
UTFU	49-60	E12.6
Unit fuel use during the period (in 10 <sup>6</sup> Btu).		
UFT\$	62-73	E12.6
Unit fuel costs during the period (in \$).		
UTVOM	75-86	E12.6
Unit variable O&M cost during the period (in \$).		
UTFOM	88-99	E12.6
Unit fixed O&M cost during the period (in \$).		
UT\$	101-112	E12.6
Unit fuel cost + variable O&M cost + fixed O&M cost during the period (in \$).		

*Note: One blank card follows card type A3. If no cards of type A3 are included, the blank card directly follows card type A2a or A2b.*

**Card Type A4: "16"NUTYPE,(HYOUT(I),I=1,8)**

"16"	3-4	I2
Label assigned to the NUTYPE generation category.		

	<u>Card Columns</u>	<u>Variable Format</u>
NUTYPE	6-13	A8
Alphanumeric name assigned to NUTYPE generation category (usually assigned to HYDRO).		
HYOUT(1)	15-21	F7.0
Capacity of NUTYPE (in MWe).		
HYOUT(2)	23-34	E12.6
Generation of NUTYPE during the period (in MWe).		
HYOUT(3)	36-47	E12.6
Capacity factor of NUTYPE during the period (fraction).		
HYOUT(4)	49-60	E12.6
Fuel consumption of NUTYPE during the period (in $10^6$ Btu).		
HYOUT(5)	62-73	E12.6
Fuel cost of NUTYPE during the period (in \$).		
HYOUT(6)	75-86	E12.6
Variable O&M cost of NUTYPE during the period (in \$).		
HYOUT(7)	88-99	E12.6
Fixed O&M cost of NUTYPE during the period (in \$).		
HYOUT(8)	101-112	E12.6
Fuel cost + variable O&M cost + fixed O&M cost of NUTYPE during the period (in \$).		

**Card Type A5: IFTY,FNAME(IFTY),(FUOUT(IFTY,IO),IO=1,8)**

*Note: Card type A5 is repeated once for each fuel type, as defined by NFTY on card type L3.*

	<u>Card Columns</u>	<u>Variable Format</u>
IFTY	1-4	I4
Fuel type number.		
FNAME	6-13	A8
Fuel name.		
FUOUT(IFTY,1)	15-21	F7.0
Capacity of IFTY during the period (in MWe).		
FUOUT(IFTY,2)	23-34	E12.6
Generation of IFTY during the period (in kWh).		
FUOUT(IFTY,3)	36-47	E12.6
Capacity factor of IFTY during the period (fraction).		
FUOUT(IFTY,4)	49-60	E12.6
Fuel consumption of IFTY during the period (in $10^6$ Btu).		
FUOUT(IFTY,5)	62-73	E12.6
Fuel cost of IFTY during the period (in \$).		
FUOUT(IFTY,6)	75-86	E12.6
Variable O&M cost of IFTY during the period (in \$).		
FUOUT(IFTY,7)	88-99	E12.6
Fixed O&M cost of IFTY during the period (in \$).		
FUOUT(IFTY,8)	101-112	E12.6
Fuel cost + variable O&M cost + fixed O&M cost of IFTY during the period (in \$).		

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One blank card follows card type A5.

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	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type A6: "TGEN SYS", (TSYOUT(IO), IO=1,8)</b>		
"TGEN SYS"	6-13	A8
Label for total generating system results.		
TSYOUT(1)	15-21	F7.0
Total generating system capacity during the period (in MWe).		
TSYOUT(2)	23-34	E12.6
Total generating system generation during the period (in kWh).		
TSYOUT(3)	36-47	E12.6
Average generating system capacity factor during the period (fraction).		
TSYOUT(4)	49-60	E12.6
Total generating system fuel consumption in the period (in $10^6$ Btu).		
TSYOUT(5)	62-73	E12.6
Total generating system fuel cost during the period (in \$).		
TSYOUT(6)	75-86	E12.6
Total generating system variable O&M cost during the period (in \$).		
TSYOUT(7)	88-99	E12.6
Total generating system fixed O&M cost during the period (in \$).		
TSYOUT(8)	101-112	E12.6
Total generating system fuel cost + variable O&M cost + fixed O&M cost during the period (in \$).		

	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type A7: "FIRM P/S", (FXOUT(IO), IO=1,6)</b>		
"FIRM P/S"	6-13	A8
Label for firm purchases or sales results.		
FXOUT(1)	15-21	F7.0
Capacity of firm purchases (+) or sales (-) during the period (in MWe).		
FXOUT(2)	23-34	E12.6
Generation of firm purchases (+) or sales (-) during the period (in kWh).		
FXOUT(3)	36-47	E12.6
Capacity factor of firm purchases or sales during the period (fraction) (fraction is always +).		
FXOUT(4)	75-86	E12.6
Variable O&M cost of firm purchases (+) or sales (-) during the period (in \$).		
FXOUT(5)	88-99	E12.6
Fixed O&M cost of firm purchases (+) or sales (-) during the period (in \$).		
FXOUT(6)	101-112	E12.6
Total fuel cost + variable O&M cost + fixed O&M costs of firm purchases (+) or sales (-) during the period (in \$).		
<b>Card Type A8: "EMRG TIE", (TIEOUT(IO), IO=1,6)</b>		
"EMRG TIE"	6-13	A8
Label for emergency interties.		

	<u>Card Columns</u>	<u>Variable Format</u>
TIEOUT(1)	15-21	F7.0
Capacity of emergency interties during the period (in MWe).		
TIEOUT(2)	23-34	E12.6
Generation of emergency interties during the period (in kWh).		
TIEOUT(3)	36-47	E12.6
Capacity factor of emergency interties during the period (fraction).		
TIEOUT(4)	75-86	E12.6
Variable O&M cost of emergency interties during the period (in \$).		
TIEOUT(5)	88-99	E12.6
Fixed O&M cost of emergency interties during the period (in \$).		
TIEOUT(6)	101-112	E12.6
Fuel cost + variable O&M cost + fixed O&M cost of emergency interties during the period (in \$).		
<b>Card Type A9: "RESERVES",(RSVOUT(IO),IO=1,8)</b>		
"RESERVES"	6-13	A8
Label for emergency reserves.		
RSVOUT(1)	15-21	F7.0
Capacity of emergency reserves during the period (in MWe).		
RSVOUT(2)	23-34	E12.6
Generation of emergency reserves during the period (in kWh).		

	<u>Card Columns</u>	<u>Variable Format</u>
RSVOUT(3)	36-47	E12.6
Capacity factor of emergency reserves during the period (fraction).		
RSVOUT(4)	49-60	E12.6
Fuel consumption of emergency reserves during the period (in $10^6$ Btu).		
RSVOUT(5)	62-73	E12.6
Fuel cost of emergency reserves during the period (in \$).		
RSVOUT(6)	75-86	E12.6
Variable O&M cost of emergency reserves during the period (in \$).		
RSVOUT(7)	88-99	E12.6
Fixed O&M cost of emergency reserves during the period (in \$).		
RSVOUT(8)	101-112	E12.6
Fuel cost + variable O&M cost + fixed O&M cost of emergency reserves during the period (in \$).		
<b>Card 10: "UNSUPPLD",UEOUT</b>		
"UNSUPPLD"	6-13	A8
Label for unsupplied energy result.		
UEOUT	23-34	E12.6
Unsupplied energy after emergency interties and emergency reserves during the period (in kWh).		



	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type A11: "TOTALS",TTLOUT(7),TTLOUT(1),TTLCF, (TTLOUT(IO),IO=2,6)</b>		
"TOTALS"	6-11	A6
Label for system totals. Includes generation, firm purchases or sales, emergency interties, reserves, and unsupplied energy.		
TTLOUT(7)	15-21	F7.0
Total system capacity during the period (in MWe).		
TTLOUT(1)	23-34	E12.6
Total system generation during the period (in kWh).		
TTLCF	36-47	E12.6
Total system capacity factor during the period (fraction).		
TTLOUT(2)	49-60	E12.6
Total system fuel consumption during the period (in $10^6$ Btu).		
TTLOUT(3)	62-73	E12.6
Total system fuel cost during the period (in \$).		
TTLOUT(4)	75-86	E12.6
Total system variable O&M cost during the period (in \$).		
TTLOUT(5)	88-99	E12.6
Total system fixed O&M cost during the period (in \$).		
TTLOUT(6)	101-112	E12.6
Total system fuel cost + variable O&M cost + fixed O&M cost during the period (in \$).		

	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type A12: "DEMAND", (DMDOUT(IO), IO=1,4), IX</b>		
"DEMAND"	6-11	A6
Label for system demand results.		
DMDOUT(1)	15-21	F7.0
Peak load during this period (in MWe).		
DMDOUT(2)	23-34	E12.6
Energy demand after firm purchases or sales during the period (in kWh).		
DMDOUT(3)	36-47	E12.6
Energy demand prior to firm purchases or sales during the period (in kWh).		
DMDOUT(4)	49-60	E12.6
Load factor during the period (fraction).		
IX	86-87	I2
Period number.		

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One blank card follows card type A12.

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*Note: Card types A2 through A12 are repeated once for each simulation period per year. One blank card separates the last card of type A12 from the beginning of annual totals that are signaled by card type A13.*

**Card Type A13: NYEAR**

NYEAR	25-28	I4
Current simulation year number.		

*Note: Card types A14 through A23 contain annual totals for the designated units, fuel type categories, and system totals.*

	<u>Card Columns</u>	<u>Variable Format</u>
<b>CARD TYPE A14: IDPN,PLTID,YMWR,UTEWH,CF,UTFU, UTF\$,UTVOM,UTFOM,UT\$</b>		
<i>Note: Card type A14 contains annual totals for designated units (up to 20). If zero units are designated in card type A1, then no card type A14 entries should be included.</i>		
IDPN	1-4	I4
Unit number.		
PLTID	6-13	A8
Unit name.		
YMWR	15-21	F7.0
Unit capacity (in MWe).		
UTEWH	23-34	E12.6
Annual unit generation (in kWh).		
CF	36-47	E12.6
Annual unit capacity factor (fraction).		
UTFU	49-60	E12.6
Total unit fuel use during the year (in 10 <sup>6</sup> Btu).		
UFT\$	62-73	E12.6
Total unit fuel costs during the year (in \$).		
UTVOM	75-86	E12.6
Total unit variable O&M cost during the year (in \$).		
UTFOM	88-99	E12.6
Total unit fixed O&M cost during the year (in \$).		

	<u>Card Columns</u>	<u>Variable Format</u>
UT\$	101-112	E12.6
Total unit fuel cost + variable O&M cost + fixed O&M cost (in \$).		

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One blank card follows card type A14. If no cards of type A14 are included, the blank card directly follows card type A13.

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*Note: Card types A15 and A16 contain annual fuel type totals. Card type A15 is for the NUTYPE generation category; card type A16 is repeated once for each fuel.*

**Card Type A15: "16"NUTYPE,(HYOUT(I),I=1,8)**

"16"		I2
Label assigned to the NUTYPE 3-4 generation category.		
NUTYPE	6-13	A8
Alphanumeric name assigned to NUTYPE generation category (usually assigned to HYDRO).		
HYOUT(1)	15-21	F7.0
Annual capacity of NUTYPE (in MWe).		
HYOUT(2)	23-34	E12.6
Annual generation of NUTYPE (in MWe).		
HYOUT(3)	36-47	E12.6
Annual capacity factor of NUTYPE (fraction).		
HYOUT(4)	49-60	E12.6
Annual fuel consumption of NUTYPE ( in 10 <sup>6</sup> Btu).		

	<u>Card Columns</u>	<u>Variable Format</u>
HYOUT(5) Annual fuel cost of NUTYPE (in \$).	62-73	E12.6
HYOUT(6) Annual variable O&M cost of NUTYPE (in \$).	75-86	E12.6
HYOUT(7) Annual fixed O&M cost of NUTYPE (in \$).	88-99	E12.6
HYOUT(8) Annual fuel cost + variable O&M cost + fixed O&M cost of NUTYPE (in \$).	101-112	E12.6
<b>Card Type A16: IFTY,FNAME(IFTY),(FUOUT(IFTY,IO),IO=1,8)</b>		
IFTY Fuel type number.	1-4	I4
FNAME Fuel name.	6-13	A8
FUOUT(IFTY,1) Annual capacity of IFTY (in MWe).	15-21	F7.0
FUOUT(IFTY,2) Annual generation of IFTY (in kWh).	23-34	E12.6
FUOUT(IFTY,3) Annual capacity factor of IFTY (fraction).	36-47	E12.6
FUOUT(IFTY,4) Annual fuel consumption of IFTY (in 10 <sup>6</sup> Btu).	49-60	E12.6

	<u>Card Columns</u>	<u>Variable Format</u>
FUOUT(IFTY,5) Annual fuel cost of IFTY (in \$).	62-73	E12.6
FUOUT(IFTY,6) Annual variable O&M cost of IFTY (in \$).	75-86	E12.6
FUOUT(IFTY,7) Annual fixed O&M cost of IFTY (in \$).	88-99	E12.6
FUOUT(IFTY,8) Annual fuel cost + variable O&M cost + fixed O&M cost of IFTY (in \$).	101-112	E12.6

*Note: Card type A16 is repeated once for each fuel type, as defined by NFTY on card type L3.*

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One blank card follows card type A16.

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*Note: Card types A17 through A23 contain annual totals for the generating system, firm purchases or sales, emergency interties, emergency reserves, unsupplied energy, and overall totals and demands.*

**Card Type A17: "TGEN SYS",(TSYOUT(IO),IO=1,8)**

"TGEN SYS" Label assigned for total generating system results.	6-13	A8
TSYOUT(1) Annual total generating system capacity (in MWe).	15-21	F7.0
TSYOUT(2) Annual total generating system generation (in kWh).	23-34	E12.6

	<u>Card Columns</u>	<u>Variable Format</u>
TSYOUT(3)	36-47	E12.6
Annual total generating system capacity factor (fraction).		
TSYOUT(4)	49-60	E12.6
Annual total generating system fuel consumption (in $10^6$ Btu).		
TSYOUT(5)	62-73	E12.6
Annual total generating system fuel cost (in \$).		
TSYOUT(6)	75-86	E12.6
Annual total generating system variable O&M cost (in \$).		
TSYOUT(7)	88-99	E12.6
Annual total generating system fixed O&M cost (in \$).		
TSYOUT(8)	101-112	E12.6
Annual total generating system fuel cost + variable O&M cost + fixed O&M cost (in \$).		
<b>Card Type A18: "FIRM P/S", (FXOUT(IO), IO=1, 6)</b>		
"FIRM P/S"	6-13	A8
Label assigned for firm purchases or sales results.		
FXOUT(1)	15-21	F7.0
Annual capacity of firm purchases (+) or sales (-) (in MWe).		
FXOUT(2)	23-34	E12.6
Annual generation of firm purchases (+) or sales (-) (in kWh).		

	<u>Card Columns</u>	<u>Variable Format</u>
FXOUT(3)	36-47	E12.6
Annual capacity factor of firm purchases or sales (fraction is always +).		
FXOUT(4)	75-86	E12.6
Annual variable O&M cost of firm purchases (+) or sales (-) (in \$).		
FXOUT(5)	88-99	E12.6
Annual fixed O&M cost of firm purchases (+) or sales (-) (in \$).		
FXOUT(6)	101-112	E12.6
Annual total fuel cost + variable O&M cost + fixed O&M cost of firm purchases (+) or sales (-) (in \$).		
<b>Card Type A19: "EMRG TIE",(TIEOUT(IO),IO=1,6)</b>		
"EMRG TIE"	6-13	A8
Label assigned for emergency interties.		
TIEOUT(1)	15-21	F7.0
Annual capacity of emergency interties (in MWe).		
TIEOUT(2)	23-34	E12.6
Annual generation of emergency interties (in kWh).		
TIEOUT(3)	36-47	E12.6
Annual capacity factor of emergency interties (fraction).		
TIEOUT(4)	75-86	E12.6
Annual variable O&M cost of emergency interties (in \$).		



	<u>Card Columns</u>	<u>Variable Format</u>
TIEOUT(5)	88-99	E12.6
Annual fixed O&M cost of emergency interties (in \$).		
TIEOUT(6)	101-112	E12.6
Annual fuel cost + variable O&M cost + fixed O&M cost of emergency interties (in \$).		
<b>Card Type A20: "RESERVES", (RSVOUT(IO), IO=1,8)</b>		
"RESERVES"	6-13	A8
Label assigned for emergency reserves.		
RSVOUT(1)	15-21	F7.0
Annual capacity of emergency reserves (in MWe).		
RSVOUT(2)	23-34	E12.6
Annual generation of emergency reserves (in kWh).		
RSVOUT(3)	36-47	E12.6
Annual capacity factor of emergency reserves (fraction).		
RSVOUT(4)	49-60	E12.6
Annual fuel consumption of emergency reserves (in $10^6$ Btu).		
RSVOUT(5)	62-73	E12.6
Annual fuel cost of emergency reserves (in \$).		
RSVOUT(6)	75-86	E12.6
Annual variable O&M cost of emergency reserves (in \$).		
RSVOUT(7)	88-99	E12.6
Annual fixed O&M cost of emergency reserves (in \$).		

	<u>Card Columns</u>	<u>Variable Format</u>
RSVOUT(8)	101-112	E12.6
Annual fuel cost + variable O&M cost + fixed O&M cost of emergency reserves (in \$).		
<b>Card Type A21: "UNSUPPLD",UEOUT</b>		
"UNSUPPLD"	6-13	A8
Label assigned for unsupplied energy result.		
UEOUT	23-34	E12.6
Annual unsupplied energy after emergency interties and emergency reserves (in kWh).		
<b>Card Type A22: "TOTALS",TTLOUT(7),TTLOUT(1),TTLCF, (TTLOUT(IO),IO=2,6)</b>		
"TOTALS"	6-11	A6
Label assigned for system totals. Includes generation, firm purchases or sales, emergency interties, reserves, and unsupplied energy.		
TTLOUT(7)	15-21	F7.0
Total system capacity for the year (in MWe).		
TTLOUT(1)	23-34	E12.6
Total system generation for the year (in kWh).		
TTLCF	36-47	E12.6
Total system capacity factor for the year (fraction).		
TTLOUT(2)	49-60	E12.6
Total system fuel consumption for the year (in 10 <sup>6</sup> Btu).		
TTLOUT(3)	62-73	E12.6
Total system fuel cost for the year (in \$).		

	<u>Card Columns</u>	<u>Variable Format</u>
TTLOUT(4)	75-86	E12.6
Total system variable O&M cost for the year (in \$).		
TTLOUT(5)	88-99	E12.6
Total system fixed O&M cost for the year (in \$).		
TTLOUT(6)	101-112	E12.6
Total system fuel cost + variable O&M cost + fixed O&M cost for the year (in \$).		
<b>Card Type A23: "DEMAND", (DMDOUT(IO), IO=1,4), IX</b>		
"DEMAND"	6-11	A6
Label assigned for system demand results.		
DMDOUT(1)	15-21	F7.0
Annual peak load (in MWe).		
DMDOUT(2)	23-34	E12.6
Annual energy demand after firm purchases or sales (in kWh).		
DMDOUT(3)	36-47	E12.6
Annual energy demand prior to firm purchases or sales (in kWh).		
DMDOUT(4)	49-60	E12.6
Annual load factor (fraction).		

---

One blank card follows card type A23.

---

	<u>Card Columns</u>	<u>Variable Format</u>
<b>Card Type A24: "RELIABILITY",DSLOLP,DTLOLP, UNSUPL,UNSERV</b>		
"RELIABILITY"	6-13	A8
Label assigned for annual reliability results.		
DSLOLP	23-34	E12.6
Annual loss-of-load probability (LOLP) without emergency interties (in days/year).		
DTLOLP	36-47	E12.6
Annual LOLP with emergency interties (in days/year).		
UNSUPL	49-60	E12.6
Unserved energy without emergency interties (in kWh).		
UNSERV	62-73	E12.6
Unserved energy with emergency interties (in kWh).		

---

One blank card follows card type A24, serving to separate the end of results for each year from the beginning of the period results for the next year. Card type A2a follows this blank card when more than one year is simulated.

---

*Note: The sequence of card types A2 through A13 is repeated for each period; card types A14 through A24 are repeated for each year of the simulation.*



## 4 SMN (Spot Market Network)

To analyze the effects of various electric utility demand and supply alternatives on nonfirm energy transactions from a transmission network perspective, Argonne National Laboratory has developed the Spot Market Network (SMN) model. The SMN model is driven by a linear program that minimizes production costs with recognition for utility-specific minimum profit margins that trigger spot market transactions. Nodes in the network represent generating resources and load centers. Generating resources are represented as piecewise linear marginal cost curves, and load centers are represented by estimates of hourly electricity demand. Nodes are connected by links that represent transmission lines with capacity limitations and line losses for power flows between nodes. The model recognizes line rights and includes wheeling, sales-for-resale transactions, and line usage that is reserved for long-term firm (LTF) transactions. Adjustments to line capacities in one or both directions are used to compensate for inadvertent power flows. Special features for incorporating energy limited and renewable technologies have been incorporated into the model.

### 4.1 DESCRIPTION OF SPOT MARKET TRANSACTIONS

Spot market transactions between utility systems are short-term nonfirm agreements that are generally made on an hourly basis. While some spot market energy transactions are arranged one or two days in advance (referred to as "prescheduled" transactions), other transactions may be arranged only a few minutes before they occur. For many systems, spot market transactions make up a significant portion of the utility's cash flow and significantly influence the operations of generating units.

In general, a utility system will sell energy when the spot market price is higher than the utility system's incremental cost of production. On the other hand, a utility system will buy power when it is less expensive to purchase power than to produce power from its own resources. Also, sufficient transmission capability between the buyer and the seller of power must exist. Line losses for the energy transmission must also be considered. The seller transmits the power to the buyer at a specified delivery point. Delivery may involve the use of the seller's transmission lines, or the energy may be "wheeled" or transmitted through one or more other utility transmission systems.

When two utility systems are interconnected, energy is generally delivered to the buyer without the use of a third party's transmission lines (i.e., no wheeling). However, if transmission lines between the interconnected buyer and seller are fully loaded, a spot market transaction may still be possible if the energy can be routed through a third party's transmission system. Typical wheeling charges range from \$2/MWh to \$4/MWh. When two utility systems are not interconnected, another utility system that has transmission capabilities between these two systems may purchase power from one system and sell it to another system at a profit. This type of arrangement is referred to as a sales-for-resale transaction.

## 4.2 LEVEL OF MODELING DETAIL

Although the SMN model was originally designed to analyze economy transactions between utility systems, the model can also be used to perform a detailed analysis of a single utility system. In this mode, each unit or plant is represented by a generation node. For example, if local load, unit generation, and detailed transmission data are provided, the SMN model provides the capability to estimate unit-level generation for a set of interconnected units. On the other hand, when detailed utility data are not accessible, one must rely on publicly available data. As a result, the network representation may have to be configured at a more aggregated level. Also, an aggregate representation is desirable when only gross transfers between large regions (e.g., power pools or NERC regions) are under investigation.

## 4.3 METHODOLOGY

The SMN model estimates spot market activities through the use of a network of nodes and links. Nodes are used to represent generating resources, load centers, and distribution substation points. Generating resources comprise piecewise linear marginal cost curves, and load centers are represented by electricity consumption or energy "sinks." Nodes are connected by links that represent transmission limitations, ownership, and losses. Each node type has a set of constraints (described in more detail in Appendix 4A). The following subsections describe the general characteristics of each node type and the characteristics of a link.

### 4.3.1 Variable-Supply/Fixed-Demand Node Representation

A SMN variable-supply/fixed-demand node represents electric generating resources with or without an associated fixed local demand. The SMN model can be configured with up to 50 variable-supply/fixed-demand nodes. This type of node represents either a single unit or a group of interconnected units (e.g., a utility system) with minimum and maximum generation constraints. Demands associated with these nodes should be consistent with the loads that were used to construct load duration curves input into the ICARUS and PACE modules. When there are no local demands, the loads for these nodes are set equal to zero.

Each node contains a marginal cost step function in which the function represents the additional cost of increasing production by one additional unit (e.g., kilowatt-hour) of output. A maximum of 99 user-defined steps (or 52 ICARUS-derived steps) can be used to define the function. The node may simply be referred to as a supply node, which indicates that a dispatchable generation source (and its marginal cost step function) and a fixed local demand (where applicable) are both represented.

You can input the step function directly, or it can be generated by a routine contained within the APEX modeling system. In general, when the generation supply represents one or two units, you enter the curve directly into the SMN model by using the APEX menu system. When the node represents a utility system or several integrated utility systems (e.g., a power

pool), the step function is usually constructed by an APEX routine that employs the ICARUS module.

When you are representing a system or a small set of systems in detail, nodes typically represent a portion of a power plant (i.e., a unit) or an entire power plant. For a single generating unit or units at the same location with very similar characteristics, marginal production costs are a function of fuel costs, variable O&M costs, and unit heat rate curves (see Appendix 4A). You specify the status of the generating unit (i.e., on- or off-line). You must make assumptions concerning unit forced outages and maintenance schedules. You can account for forced outages with one of three methods. The first method is simply to "disable" (i.e., take off-line) units that are currently not operating because of a planned outage. To use this method, you can use real-time outage information, or you can explore different possible outage scenarios. The second method of accounting for forced outages is to perform a Monte Carlo analysis by running the module numerous times. Although this type of analysis is possible, it is very time-consuming because no routine that generates random outages is currently incorporated into the package and no automated routine to evaluate each random situation is currently available. A third method to account for random outages is to derate units on the basis of their equivalent forced outage rate.

When the marginal cost step function is generated by the automated supply function (ASF) routine contained in the APEX modeling system, the effects of forced outages, as well as variable production costs and planned outages, on the step function are accounted for via ICARUS simulations. The limits (i.e., starting and ending steps) and the shape of the marginal cost step function depend on the unit-level characteristics of the on-line generators it represents. These characteristics include maximum operating capacity, minimum operational level, forced outage rates, variable O&M costs, fuel costs, and heat rate curves. Units that are on-line during a specific time period can be determined from results produced by the PACE module. The units include existing, announced, and new units that PACE projects will be built in order to meet future loads reliably and to replace retired units. Units that have been scheduled for maintenance during a specified week are determined on the basis of user inputs and a routine contained within ICARUS. When this ASF procedure is used, units on maintenance during a specified time period are automatically excluded from the step function representation.

The ASF routine accounts for the effects of forced outages on production costs by estimating costs in terms of dollars per megawatt-hour for different load levels ranging from a minimum production level to the system on-line capacity. When ICARUS computes production costs, it implicitly includes the effects of both scheduled and unscheduled outages. Production cost estimates are made for 24 different load levels. A least-squares curve-fitting algorithm reduces the number of points in the curve and ensures that it is convex — a necessary condition for the SMN linear programming formulation. The number of points used to represent the final curve used by SMN is selected by the user. Slopes between the points represent short-run marginal costs.



### 4.3.2 Fixed Supply/Demand Node Representation

The SMN fixed supply/demand nodes are used to represent fixed electric generating resources with fixed local demands. Fixed supply/demand nodes typically represent energy sinks or areas of net energy consumption; that is, generation either is zero or exceeds local production. In other situations, this node may represent a simple generating resource that operates at a fixed energy output level specified by the user with or without local demand. For example, this node may be used to represent run-of-river hydroelectric units or a thermal solar unit where the hourly generation pattern from the unit is determined elsewhere. Most often, this node may simply be referred to as a demand node, which indicates a local demand. The model accepts up to 50 fixed supply/demand nodes. Because the SMN model is typically run on an hourly basis, fixed supply/demand nodes usually require hourly demand data. Hourly demands that are used by the SMN model should be consistent with loads that were used to construct load duration curves input into the ICARUS and PACE modules. However, longer or shorter time periods may be used at the discretion of the user.

### 4.3.3 Substation Node Representation

A substation node is analogous to a substation without generation capabilities or local demand. In an aggregated network model, the substation node may represent an equivalent effect of several underlying substations. The total power flow entering a substation node must equal the total power flow exiting the node. The purpose of this node type is to route electricity flow from one or more node input links to one or more output links. For example, power flows from one input link can branch out onto several output links that have smaller carrying capacities. Conversely, several small transmission input links can feed into one large output link.

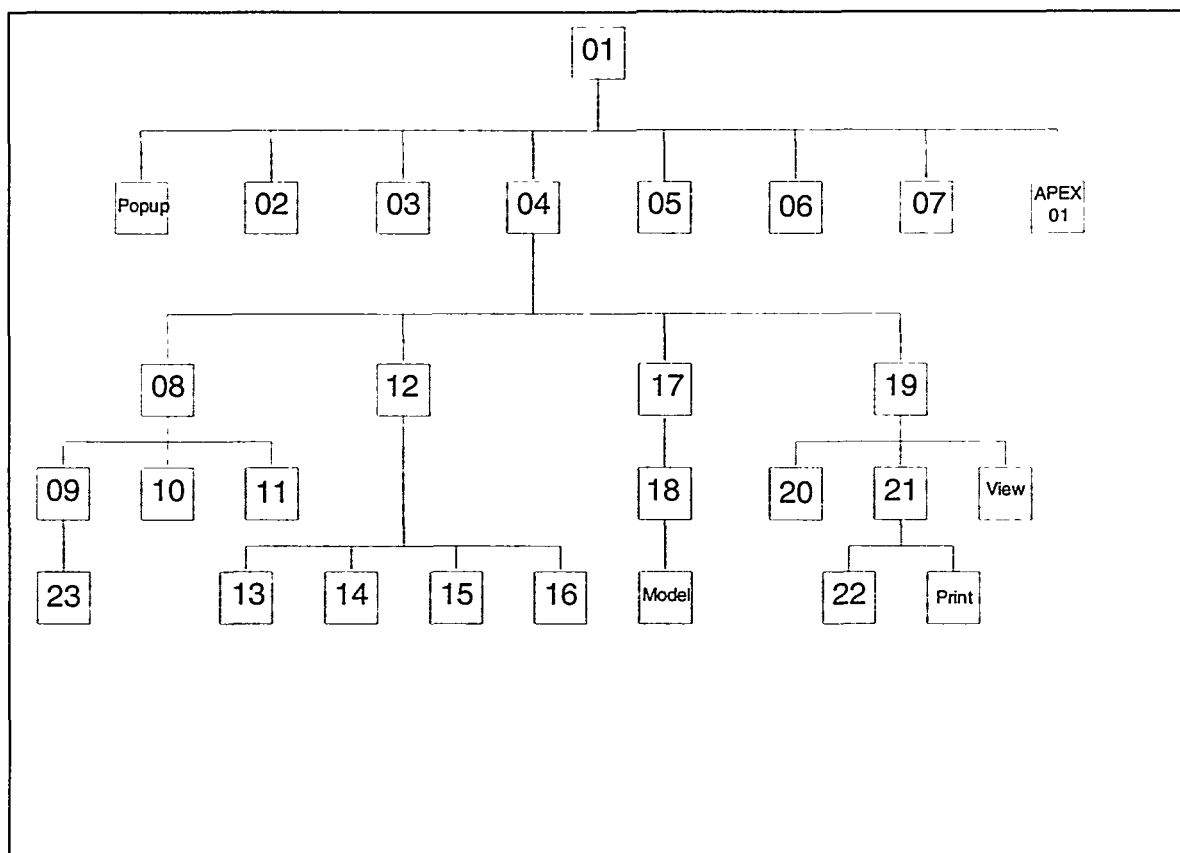
### 4.3.4 Transmission Representation

In the SMN model, transmission lines are represented as links that connect two nodes. Also, a single node can be connected with two or more links representing multiple pathways to that node. Individual lines (with an associated line capability) or composite transfer capabilities (CTCs), which consist of groups of power lines serving the same area, can be used when constructing the network. The CTCs may be used by various utility dispatchers in their daily operations. The adjusted transmission line capacity is specified in the SMN model as a maximum net hourly spot market energy transaction (expressed in megawatts) that can be made between two nodes. Transmission links can connect two similar or two different node types. The model limits only net energy transactions. That is, an energy transaction scheduled in one direction over a line can exceed the line capacity if, at the same time, there is an energy transaction scheduled in the opposite direction (i.e., back scheduling) that will reduce the net flow of energy over the line to below its capacity. Only real power flows are considered in the SMN model.

In the SMN model, transmission losses are represented by applying a loss factor to net power flows over each of the links. As a result, only a fraction (i.e., typically 92-96%) of the energy produced at a generating node is received by the demand node. The SMN model also recognizes line rights and wheeling charges that are incurred when one utility system uses another system's transmission lines. Wheeling charges typically vary between \$1/MWh and \$5/MWh, depending on utility line rights. The SMN model represents an individual transmission line that has several utility systems with line rights as several links. The sum of these links equals the total transmission line capacity. The capacities of each individual link are based on the portion of the line that a utility system has the right to use. If a utility system wants to transmit more energy over a line than it has the right to use, then energy can be wheeled over another system's link. However, wheeling charges will be incurred.

Limits can also be placed on the amount of power that can be transmitted from one set of links to a second set of links. That is, the aggregate amount of power that flows through a node can be constrained to represent internal utility transmission constraints.

4.3.5 SMN Structure

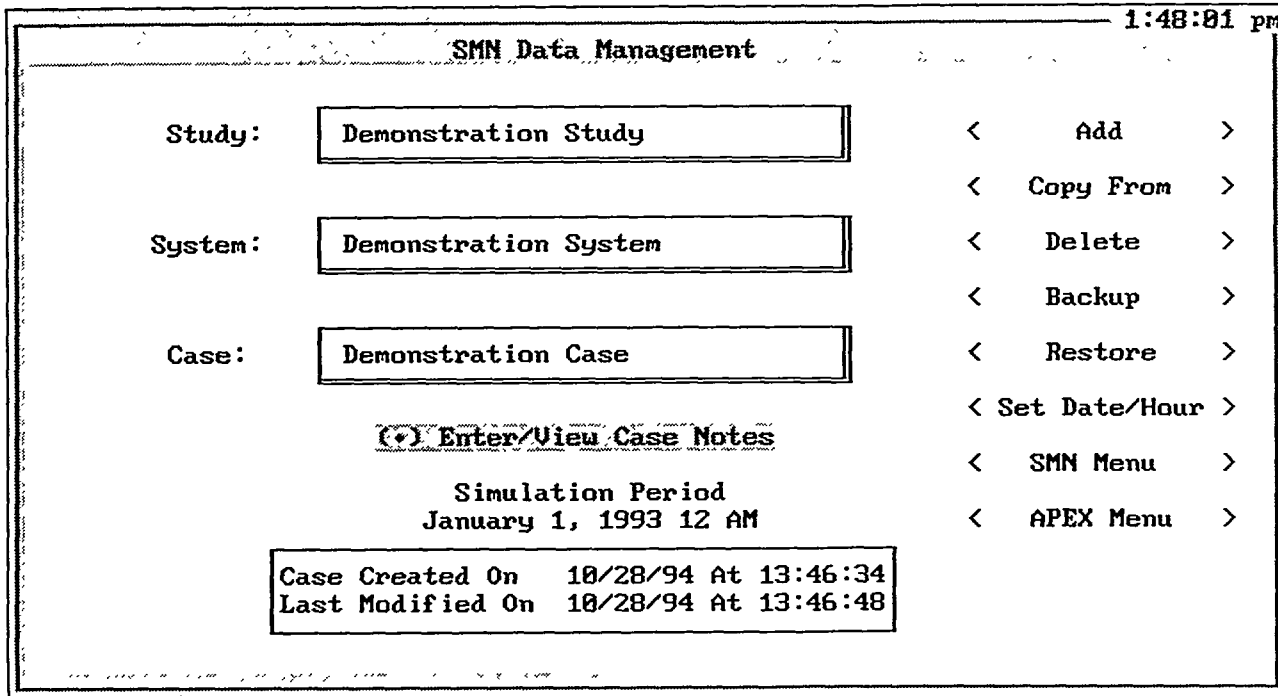


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#### 4.4 SMN SCREENS

This section provides you with a picture of each major screen in the SMN module. Following the screen image, there is a section called Purpose that describes the objective of that screen. When key options are associated with a screen, they appear in a section called Options. A third section, Data Fields, describes each data space on the screen into which you can enter data. The data screens appear with example data that can be considered typical for the SMN. Another section, Buttons, describes the button options available on that screen. The last section, Background, describes in more detail the various procedures, module functionalities, and proper module application. A list of error messages and warnings is included in Section 4.5 to assist you in solving potential problems.



SMN-01

## Purpose

The primary function of screen SMN-01 is to retrieve electronically stored SMN configurations and scenarios and to create the necessary data structures to build new configurations. Following the same conventions as used for ICARUS, data contained in SMN are organized at three different levels. The "study" level is at the top of the data management hierarchy and contains one or more systems. For example, a study of gas curtailments may be conducted for several different utility systems. The "system" level is the second level of data management. The third level allows you to define one or more cases (i.e., scenarios), for example, high, medium, and low load growth rate scenarios.

This data management screen allows you to create a new study, system, or case. You can enter notes that contain textual details describing this SMN configuration. You can also select a predefined case for editing and processing. Data associated with entire studies or systems as well as individual cases can be deleted. Also, data for one case can be copied to another, or a case can be backed up and restored in a subsequent session. A study, system, and case must be selected and the simulation year, day, and hour must be defined before you can proceed to other SMN menus.

## Options

- Screen SMN-01 is divided into two parts. The left side consists of pop-up windows that display the studies, systems, and cases that you have previously defined. The right side of the screen contains buttons that control screen functions. The buttons are either active (blue in color) or inactive (light gray). If a button is light gray, it is inactive and cannot be invoked until further selections are made. Buttons will become active or inactive as selections are made.
- To enter or view notes associated with the newly defined or selected system, click on the Enter/View Case Notes option. This button is activated only when a study, system, and case have been selected. Enter text into the window by using the keyboard. The F2 key will permanently save any user note additions and modifications made in this session and remove the user notes window. User notes are permanently associated and stored with each case and can be retrieved by using the case selection process. Notes are also saved when a case is backed up and restored when the selected case is retrieved. However, when one case is copied to another case, user notes are not copied. A separate set of user notes is associated with the backup routine. These notes are used to document backup procedures and the physical location of files.

- To exit the user notes window and disregard any changes that were made in the session, press the Esc key.
- Press the F5 key to invoke the search menu (see Section 1.2).

## Buttons

### <Add>

The <Add> button is active only if the "Add New...." prompt is displayed in one of the pop-up boxes. Once a study, system, and case have been selected, the <Add> button is deactivated, and all the other buttons on the right side of the screen are activated. After you have defined a case in the data management hierarchy, click on the button next to the Enter/View Case Notes option and enter text that describes the case in the pop-up window.

Once a case has been created in the data management hierarchy, all databases that describe a network (i.e., node and link data sets) will be created but will contain no information. Data can be input into these fields by using the SMN network or copied from an existing case. To add a study, system, or case to the data management hierarchy, select that option in the pop-up menu.

To add a study, go to the shaded rectangle next to the "Study:" prompt and select Add New Study from the pop-up list. Click on the <Add> button on the right side of the screen. A pop-up box will appear in the middle of the screen and prompt you for a new study name, a new system name, and a new case name. Press the F2 key to exit the screen and return to the data management menu.

To add a new system to the data management hierarchy, select the study to which you want to add the system. Go to the shaded rectangle next to the "System:" prompt and select Add New System from the pop-up list. Click on the <Add> button on the right side of the screen. A pop-up box will appear in the middle of the screen and display the study to which you are adding a system. The screen also prompts you for the new system name and new case names.

To add a new case to an existing study and system, select a system and study by using the study and system pop-up prompts. Select Add New Case from the "Case:" prompt pop-up.

Click on the <Add> button on the right side of the screen. A pop-up will appear in the middle of the screen and display the study and system to which you are adding and prompts you for the new case name. Once the new case has been added to the data management system, the date on which the case was created is filed and will appear on the screen every time that database is retrieved. The data management system also keeps track of the last time the case was accessed.

Note that you must select a study before selecting a system, and you must select a study and system before you can select a case. If you select a new study after a study, system, and case have already been selected, the system and case pop-up boxes become blank. You must then make new selections before proceeding.

To avoid ambiguity, the data management system will not allow you to create duplicate study, system, or case names. All names must be unique at a given hierarchy level. When you attempt to create duplicate entries, a warning appears on the screen. No two studies can have the same name; however, identical system names are permitted as long as the names are not contained in the same study. Likewise, identical case names are permitted as long as the names are not contained in the same study and system.

#### <Copy>

The <Copy> button allows you to copy the data for an existing case to another case. First, you must identify a destination case (i.e., the case to which the data will be copied) by selecting the study, system, and case by using the pop-up menus on the left side of the screen. If the destination case has not yet been created through the data management system, you must add it to the data management hierarchy by using the <Add> button.

Once you have selected a destination case, click on the <Copy> button. The copy menu will be displayed on the screen (screen SMN-02).

#### <Delete>

The <Delete> button removes the data management names and all associated data files at three different hierarchical levels (i.e., study, systems, and cases). Deletion of a study, system, or case is *permanent* (i.e., files cannot be retrieved or reconstructed). To delete a study, select the desired study from the study pop-up menu and click on the <Delete> button on the right side of the screen. The delete screen will be displayed (screen SMN-03). Answering "Y" on the delete screen will delete

all data for the study and all systems and cases under the selected study. Answering "N" will keep all data intact and active in the data management system. After you have answered the question on this screen, the delete screen is removed and you return to the data management menu.

To delete a system, select System under a specific study, select the system for deletion by using the study and system pop-up menus, and click on the <Delete> button on the right side of the screen.

To delete a specific case, select the study, system, and case from the pop-up menus and click on the <Delete> button. Answering "Y" on the following delete screen will delete only that one case and leave the system, study, and all other cases associated with that system intact. However, if there is only one case under a study and system, both the study and system labels will be removed from the data management system.

**<Backup>**

The <Backup> button allows you to save a case to a hard drive or other removable or portable storage media (e.g., 3.5-in. floppy disk, tape drive, network disk, or Bernoulli disk). To activate the <Backup> button, select a study, system, and case by using the pop-up menus. Next, click on the <Backup> button to display the backup screen (screen SMN-05).

**<Restore>**

The <Restore> button allows you to retrieve a case that was previously backed up into the list of studies, systems, and cases that can be selected through the data management menu. To restore a case, simply click on the <Restore> button (it is always activated) on the lower portion of the data management menu. This action will invoke the restore screen (screen SMN-06).

**<Set Date/Hour>**

To select the year, month, day, and hour for the currently selected case, click on the <Set Date/Hour> button. This button activates the menu shown in screen SMN-07.

**<SMN Menu>**

To advance to the SMN Main Menu (screen SMN-01), click on the <SMN Menu> button. This button is activated only when a study, system, and case have been selected.

**<APEX>**

To return to the main APEX menu (screen APEX-01), click on the <APEX> button. This button is always activated.



1:49:34 pm

**SMN Data Management**

**Copy Case**

Copy FROM:		Copy TO:	
Study	Demonstration Study	Demonstration Study	
System	Expanded US System	Demonstration System	
Case	Base Case II	Demonstration Case	

< OK >    < Exit >

SMN-02

### Purpose

The primary function of screen SMN-02 is to copy electronically stored data for one existing SMN case to another existing case. Any information that is contained in the destination data set (i.e., the case to which the data are copied) will be *permanently* deleted once this procedure is initiated. The data contained in the origin case (i.e., the case from which the data are copied) are not altered by this procedure.

### Options

- Screen SMN-02 is divided into two parts. The left side of screen SMN-02 contains pop-up windows in which you select the study, system, and case from which that the data will be copied (i.e., origin case). Click and drag on the pop-up boxes to make the desired selections. The right side of the window displays the study, system, and case to which data will be copied (destination case). This case was previously selected in screen SMN-01.

### Buttons

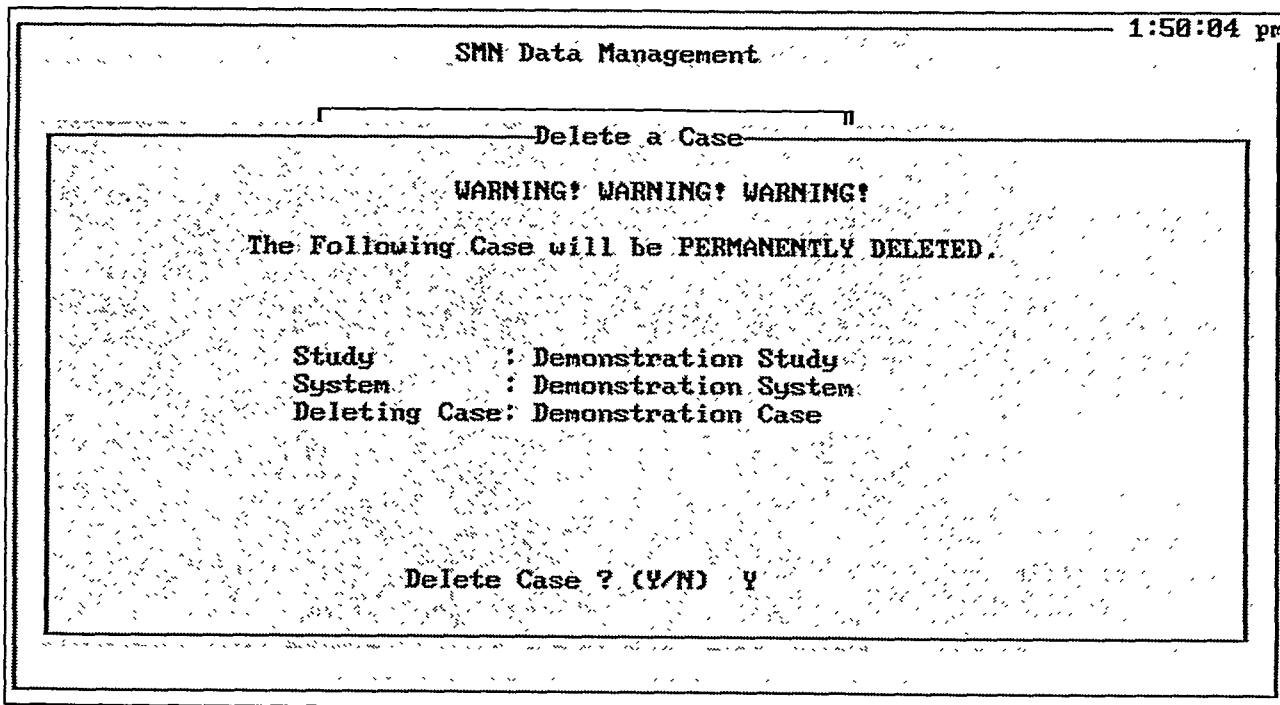
**<OK>**

After you have selected the origin case, click on the <OK> button to copy the case data. The <OK> button is active only when the destination case has been selected. Any information that was previously contained in the destination case will be destroyed

and replaced with a copy of the information contained in the origin case. Only cases can be copied; entire studies or systems *cannot* be copied. To help ensure that data are not mistakenly deleted, a verification message alerting you that data will be deleted is displayed after the <OK> button is clicked. Also, the copy procedure will not allow the destination and origin case to be identical. If you attempt to copy a set of data onto itself, a warning message will be displayed on the screen.

**<Exit>**

To cancel the copy procedure and return to the previous menu, click on the <Exit> button. The <Exit> button is always active.



SMN-03

### Purpose

The primary function of screen SMN-03 is to inform you that all data associated with one or more cases will be deleted after user verification (i.e., approval). File/directory structures and database management entries associated with the cases will also be removed. Cases and associated data will be *permanently* deleted once the deletion procedure is initiated. However, data can be recovered if they are first backed up by using the backup procedures.

### Options

- Screen SMN-03 lists all cases and associated data files that will be permanently deleted (i.e., files cannot be retrieved or reconstructed). Answering "Y" to the delete query will remove all data. Answering "N" will keep all data intact and active in the data management system. After you have answered the question on this screen, the delete screen disappears and you return to the data management menu.

1:50:29 pm

**SMN Data Management**

**Backup Case to Disk**

<b>Case Being Backed Up:</b>	<b>Backup to Drive:</b> <input type="text" value="C"/>
<b>Study:</b> Demonstration Study	<b>(*) Enter Backup Notes</b>
<b>System:</b> Demonstration System	
<b>Case:</b> Demonstration Case	<b>«Backup» &lt;Cancel&gt;</b>

SMN-05

### Purpose

Screen SMN-05 lists the case you selected for backup in the database management screen (SMN-01). All data and information associated with the selected case are copied onto an electronic storage media accessed by the device you specify. Note that the case is copied; that is, the case is not deleted or altered.

### Options

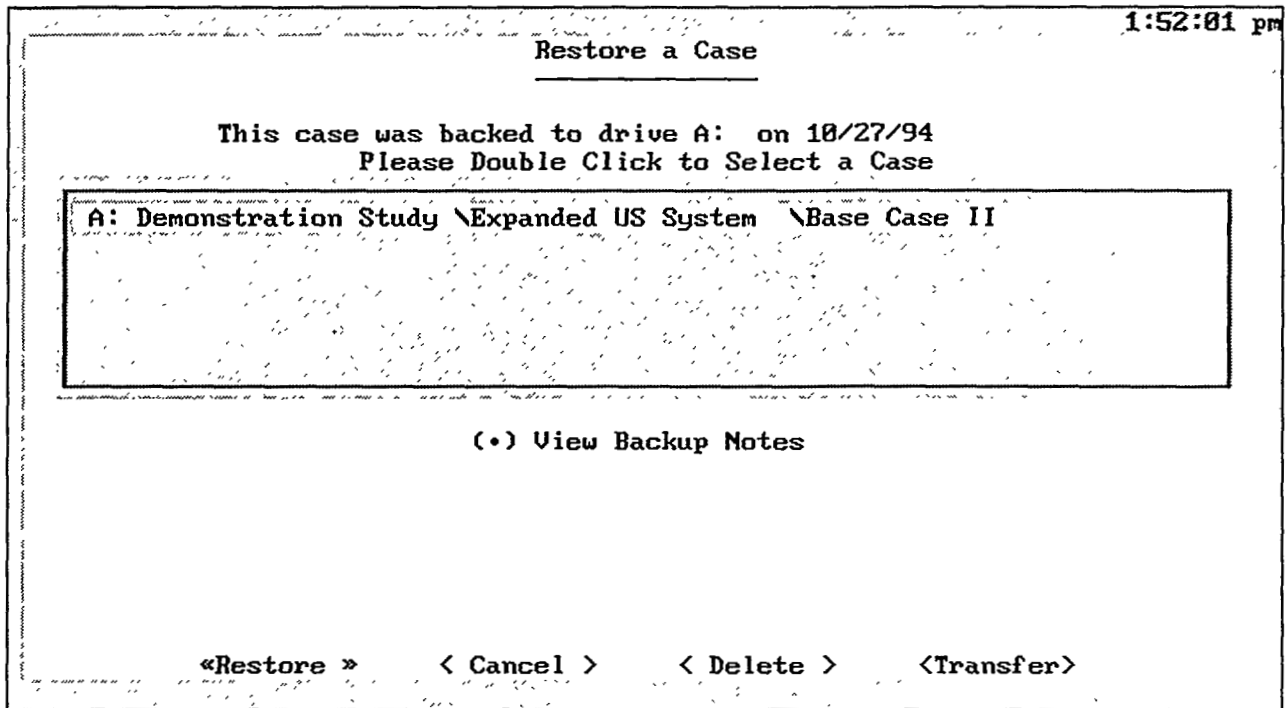
- To back up the case displayed on the left side of the screen, first select the drive on which the data will be backed up, by clicking on the pop-up menu labeled "Backup to Drive:." Only those drives that are connected to your computer are displayed in the pop-up menu. If you select drive A, B, or D, a message will appear reminding you to insert a disk into the specified drive. If you do not insert a disk into the backup drive and you invoke the backup command, a DOS error message appears at the bottom of the screen.
- To enter user notes regarding backing up the case, click on the Enter Backup Notes option. Enter text into the window by using the keyboard. User notes associated with the backup routine are usually used to document backup procedures and the physical location of files. The F2 key will permanently save any user note additions and modifications made in this session and remove the

user notes window. To exit the user notes window and disregard any changes that were made in the session, press the Esc key.

- Press the F5 key to invoke the search menu (see Section 1.1).

## Buttons

- <Backup>** To back up the case, click on the <Backup> button. If you selected a drive that is write-protected, a warning message is displayed on the screen and you are returned to the data management menu. You are also warned if there is insufficient storage space on the selected drive or if there is a problem with writing to the disk (e.g., disk segment error).
- <Cancel>** If you decide not to back up the case, click on the <Cancel> button. When you click on either the <Backup> or <Cancel> button, the backup window disappears and you return to the data management screen.



SMN-06

### Purpose

Screen SMN-06 lists all the cases that have been backed up with the backup procedure and are currently available to be restored (note that backed up cases can be deleted from this list). The screen allows you to restore backup cases, view backup notes, and transfer a case from one machine to another. This screen also allows you to view notes that were entered in the backup screen.

### Options

- To restore a case that was backed up on the current machine, select the system, study, and case combination from the middle window by highlighting the entry and pressing the Enter key. The backup drive and date will appear at the top of the screen. To restore this case, press the <Restore> button. To restore a case that was backed up on a different machine (on a removable storage medium), press the <Transfer> button.

### Buttons

- <Restore>** To restore the highlighted case, click on the <Restore> button.
- <Cancel>** If you decide not to restore the case, click on the <Cancel> button. When you click on either the <Restore> or <Cancel>

button, the restore window disappears and you are returned to the data management screen.

**<Delete>**

To delete the highlighted case from the list, click on the <Delete> button. Once a backed up case has been deleted, it cannot be recovered. This procedure only deletes the entry from the restore list and will not prompt you to insert a disk to delete the actual data files.

**<Transfer>**

To retrieve a case that has been backed up by a different machine on a removable storage medium, click on the <Transfer> button.

10:45:58 am

January						
Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Hour:

Year:

< Next Month >

<Previous Month>

« OK »

Selected Month    Selected Day

January                    5

To Select the Day Click on the Number in the Calendar

SMN-07

### Purpose

Screen SMN-07 allows you to define the time period in which the current case will be simulated. You select a simulation year, month, day, and hour. The SMN is designed to simulate a relatively short time period in a given execution of the model (usually one hour). In its current formulation, the time period selection is used only to control the internal choice of ICARUS marginal cost curves (24 periods per year) and the choice of winter/summer network transfer limits. However, the hourly selection menu has been provided to facilitate a more detailed choice once the database had been populated with hourly data.

### Options

- To select a year, click and drag the mouse on the pop-up box next to the "Year" label. You can select the hour by using the "Hour" pop-up menu. To select a day, click on the number displayed on the calendar. The selected day and month will appear at the bottom of the screen. To change the day or month, simply click on another day on the calendar.

### Buttons

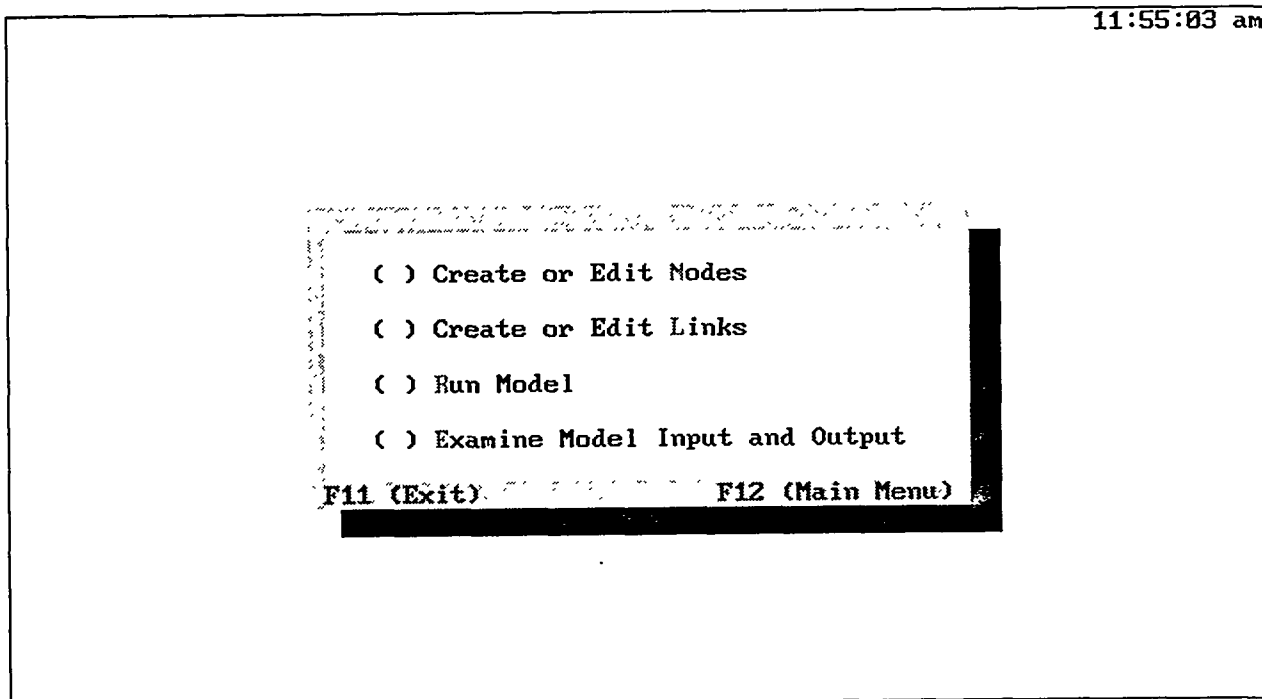
- <Next Month> To advance the calendar displayed on the screen by one month, click on the <Next Month> button. If the month selected is December, clicking on this button will set the calendar to



January of the *same* year; that is, the year does *not* advance to the next year. As you click on this button, note that the month label located on the top of the calendar changes. The month and the day can be selected by clicking on the day in the calendar or by moving the cursor to the appropriate day and by pressing the Enter key. Either of these actions will change the selected month and day displayed near the bottom of the screen. The calendar displayed in this menu is a "generic" calendar in which each year has 365 days (i.e., there are no leap years) and January 1 is always a Monday.

**<Previous Month>** To display the previous month of the calendar, click on the <Previous Month> button. If the month selected is January, clicking on this button will set the calendar to December of the *same* year; that is, the year does *not* decrease by one year. As you click on this button, note that the month label located on the top of the calendar changes. The month and the day can be selected by clicking on the day in the calendar or by moving the cursor to the appropriate day and by pressing the Enter key. Either of these actions will change the selected month and day displayed near the bottom of the screen. The calendar displayed in this menu is a "generic" calendar in which each year has 365 days (i.e., there are no leap years) and January 1 is always a Monday.

**<OK>** To store the month, day, year, and hour and return to the data management screen (SMN-01), click on the <OK> button.



## SMN-04

### Purpose

Screen SMN-04 allows you to select spot market data entry and edit menus, run the SMN model, or view the network graph.

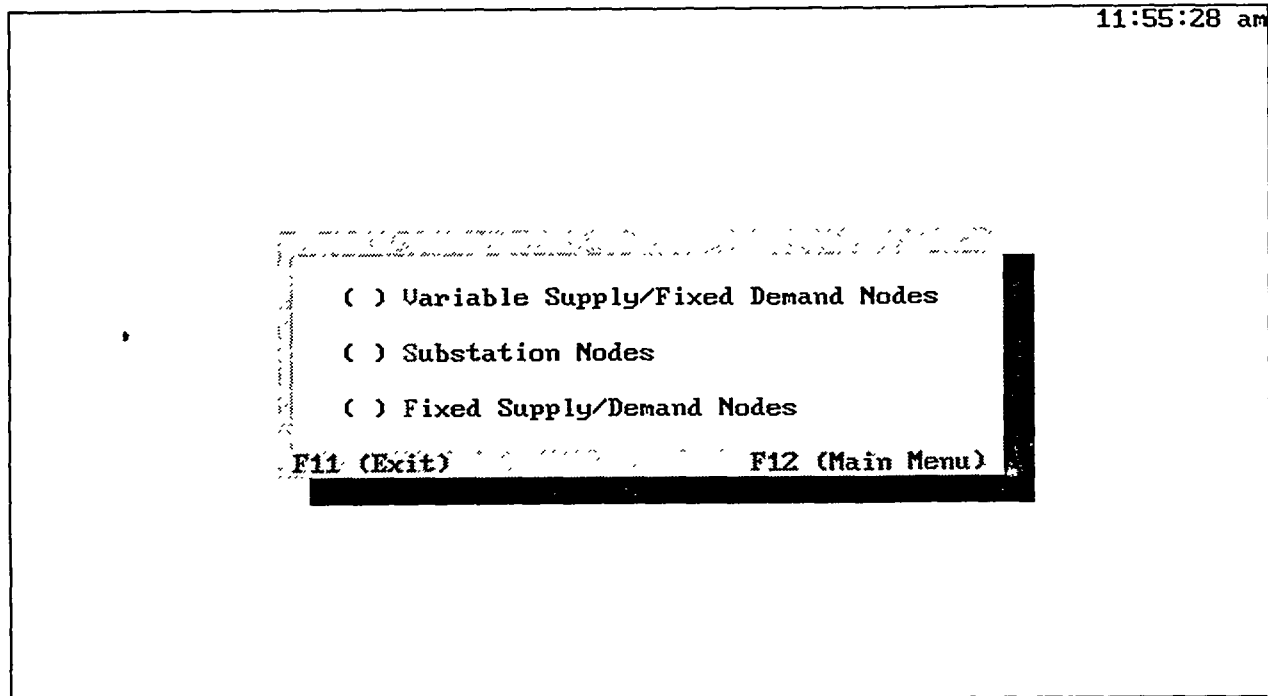
### Options

- To display a menu of options for creating or editing three different node types (variable-supply/fixed-demand nodes, substation nodes, and fixed-demand/fixed supply nodes), select the first option.
- To display a menu of various options for creating, editing, and adjusting links (i.e., transmission lines), select the second option.
- To run the current SMN case, select the third option. This option will execute five procedures. The first two procedures involve user interaction and are invoked only under a certain set of conditions. In the first procedure, SMN adjusts CTCs to account for firm energy transactions. If firm contract paths do not use any of the lines defined as CTCs, this procedure will not be invoked. When the procedure is invoked, you can override or change the adjustments made by SMN. The second procedure is very similar to the first except that SMN adjusts node transfer limits. If firm contract paths do *not* use any of the nodes that have been defined as limited, the second procedure will not be

invoked. When the procedure is invoked, you can override or change the adjustments made by SMN.

After adjustments to CTCs and node limits have been made, three other procedures are *always* invoked. First, SMN model inputs are formulated into a set of mathematical equations that are used by the Lindo LP software package. Second, the LP code is run. The last procedure copies LP model results into a database format (i.e., dbf files). Messages indicating any problems during this process are displayed on the screen. Additional messages concerning this run can be accessed by using the Examine Model Input and Output menu.

- To display a menu of options for viewing model inputs and outputs (i.e., model results), select the fourth option.



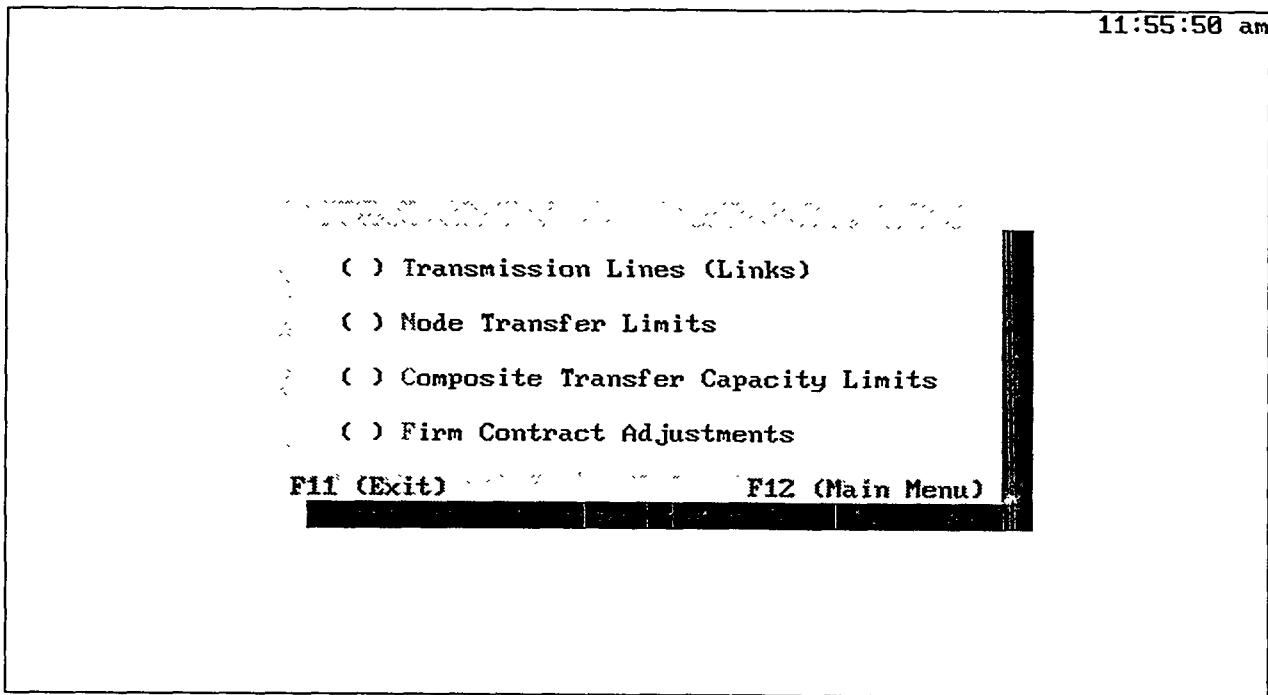
SMN-08

### Purpose

Screen SMN-08 allows you to select the type of nodes you wish to create or edit.

### Options

- To create or edit variable-supply/fixed-demand nodes (i.e., electric generating resources), select the first option.
- To create or edit substation nodes, select the second option.
- To create or edit fixed supply/demand nodes (i.e., energy sources or sinks), select the third option.



## SMN-12

### Purpose

Screen SMN-12 allows you to choose different means to define and constrain network transmission capabilities.

### Options

- To create or edit individual lines (i.e., transmission lines), select the first option. Nodes that are connected by these links must first be entered into the SMN case before this option can be used.
- To create or edit internal transmission constraints for a node, select the second option. Note that nodes and links must be created before this option can be applied.
- To create or edit CTCs (i.e., groups of lines serving the same general area), select the third option. Note that transmission lines that make up the CTC must first be entered into the current case before the CTC is created.
- To create or edit known power and energy contracts that will affect transmission lines, select the fourth option. Note that a transmission path (i.e., links and nodes) between the buyer and seller must exist before this option can be applied.

2:03:43 pm

**Variable Supply/Fixed Demand Node Descriptions**

Code	Name	Latitude	Longitude	Profit Margin	Minimum Gene
WCW	WSCC CALIF-L.NEVADA	37.0	120.0	0.0	10

Highlight Item and F4 Edit Next, F8 Edit F9 to Zoom/Unzoom

---

**Enter New Variable Supply/Fixed Demand Node**

Code Name:  Variable Supply/Fixed Demand Node Name:

Latitude(°):  Profit Margin (\$/MWh):

Longitude (°):  Minimum Generation (MW):

Load (MW):  Number of Function Steps:

Maximum Power from Grid (MW):

SMN-09

**Purpose**

Screen SMN-09 allows you to view, modify, create, delete, enable, and disable SMN variable-supply/fixed-demand nodes (also referred to as supply nodes). Supply nodes represent electric generating resources with or without an associated fixed local demand. The SMN model can be configured with up to 50 variable-supply/fixed-demand nodes. This node type represents either a single unit or a group of interconnected units (e.g., a utility system) with minimum and maximum generation constraints.

**Options**

- Screen SMN-09 is separated into two major parts. The upper browse window displays data that are contained in the energy supply file and is also used to select data records for editing. The lower half of the screen allows you to make changes to data fields for a selected energy supply and to enter new energy supply nodes into the data file.
- To view energy supply node database entries in a tabular format, activate the upper window by clicking anywhere on the window. Note that the nodes are sorted in alphabetical order by the abbreviated node name. When new entries are input into the database, the display is sorted again, and the new entries are inserted into the list at the appropriate location.

- F4** Press this key to edit the next record in the database. That is, data for the next record in the database are displayed on the lower portion of the screen for viewing or editing. If the last record in the database is in the lower half of the screen, the F4 key displays the first record in the database.
- F8** Press this key to edit the currently highlighted record in the database. The information for that record will be displayed in the lower portion of the screen for viewing or editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned on a record in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Code Name: Enter the three-character identifier for the current record.

Variable-Supply/Fixed-Demand Node Name: Enter the character description for the energy source currently being entered.

Latitude: Enter the latitude of the current energy supply (in degrees). If a data value larger than 90 is entered in this field, a warning message appears. Data entries smaller than 25 or larger than 50 produce a warning that the specified coordinate is outside the contiguous United States.

Longitude: Enter the longitude of the current energy supply (in degrees). If a data value larger than 180 is entered in this field, a warning message appears. Data entries smaller than 65 or larger than 130 produce a warning that the specified coordinate is outside the contiguous United States.

Load: Enter the electricity demand for local loads associated with this supply node. When the supply node is used to represent an aggregate set of resources for a power pool, NERC region, or load control, the hourly load value represents the demand that must be met by the system through generation or spot purchases. The hourly load can be set to zero if a single generator or power plant is represented by the supply node and no local loads are present.

Profit Margin: Enter the profit margin for the current energy source (in \$/MWh). Note that \$/MWh is equivalent to mills/kWh. The profit margin represents the minimum profit a supply source must receive before it will sell energy to the grid, where profits are defined as the difference between the spot market price and the marginal cost of production. This value must be greater than or equal to 0.0.

**Minimum Generation:** Enter the minimum generation (in megawatts) for the current energy source, that is, the lowest generation level that is physically possible without shutting the unit down.

**Number of Function Steps:** Enter the number of steps that will be used to represent the short-run marginal cost step function, as described below. This number must be between 1 and 99. Default values in the range of 2-24 steps are recommended, depending on size of system (single unit to large pool).

**Maximum Power from Grid:** Enter the maximum allowable power that can be purchased from the grid (in megawatts). This number must be a value greater than or equal to 0.0.

## Buttons

### <Add>

### <Change>

To add a new energy supply node, enter information into the fields on the lower half of the screen and press the <Add> button to save the data. The <Add> button adds the new record to the database and also sorts records alphabetically by the Abbreviated Code field. The <Add> button appears on the screen only if a record has not been selected for editing. When a record has been selected, the <Change> button is activated. Click on the <Clear> button to clear the current entry and return to the add mode. Before the new supply node is entered into the database, an error check for invalid data entries is performed. If the minimum generation level is less than the capacity of the first step of the supply function, you are informed that the minimum generation level will be reset to the capacity of the first step. Once a new node has been added, it appears in the upper window.

The following steps allow you to edit energy supply node data. First, activate the upper window and select the energy supply node to edit. When the F8 key is pressed, data for the selected record appear on the lower half of the screen. You may also press the F4 key to advance one record in the upper screen and display the data for that record in the lower screen for editing. After the selected record is displayed on the lower screen, click anywhere on the lower half of the screen, and the cursor will move to the Code Name field. Use the Tab or arrow keys or the mouse to move between fields and enter the new information. Click on the <Change> button to save the information. Once the lower half of the screen is active, you can display the next record in the database by pressing the F4 key. If new information was



entered, pressing the F4 key instead of the <Change> button will not save the new information before you advance to the next record.

### <Edit Steps>

To modify the supply step function data for the currently selected node, use the <Edit Steps> button. Enter a number greater than zero in the Number of Steps field. Once you press the <Edit Steps> button, a window that contains supply step function data is activated, and the cursor is located on the first record. Edit the data, as required. Data records (i.e., supply steps) must be entered in order of increasing capacity. Note, however, that before a value for a data entry is *temporarily* saved, you must exit the data entry field by pressing the Enter key or by some other means, such as by pressing the down arrow key. To *permanently* save changes, you must press the <Change> button located on the lower half of the menu (see below). To exit this window, press the F2 key.

After you exit the supply step function window, a data error check is performed. The SMN model requires that the production cost curve on which the step function is based be convex upward for all generation levels with values larger than the minimum generation level. If the entered data are incorrect, you are informed by warning messages that appear on the screen.

You must input the number of steps that are used to represent short-run marginal costs next to the "Number of Steps:" prompt. If you enter a number that is greater than the number of steps currently in the database, blank records will be added to the end of the database. If you enter a number that is less than the number of steps currently in the database, a warning will be displayed on the screen that informs you that records will be temporarily deleted from the end of the database. You must then confirm this entry by pressing the "Y" key in order to proceed. Pressing the "N" key will ignore the modification and reset the entry to its original value. At least one step must be used to define the cost step function. When you manually enter the step function by using this menu, the maximum number of steps is currently limited to 99. However, the maximum number of steps that can be created by ICARUS is 52.

To save modified data or to move to another record if you do not want to save the edits, click on the <Change> button. Data modifications to the supply step function (including the number

of steps and lost records) become permanent only after the <Change> button has been pressed. Changes to the current record displayed on the lower half of the menu will not be saved when you click on the <Quit> or <Clear> button. The <Quit> button also returns you to the previous screen.

- <Delete>** To delete an existing energy supply node and all links to that node, click on the <Delete> button to activate the Delete screen. The delete option will *permanently* delete records from the file.
- <Disable>** The disable feature allows you to temporarily "remove" supply nodes from the SMN or to return them to use. To disable a node, click on the <Disable> button. This action will activate the disable screen, which displays all energy supply nodes. This button is also used to enable previously disabled nodes by removing tags from the list of nodes.
- <Clear>** To clear the input fields of all data and return to the Add mode, click on the <Clear> button.
- <Quit>** To exit from the supply node screen without saving any information displayed in the screen fields, click on the <Quit> button.
- <Curve>** For ICARUS curve generation (screen SMN-23), click on the <Curve> button.

Function Steps			
Function Step	Generation Level (MW)	Cost (\$/MWh)	
1	500.00	10.00	
2	550.00	20.00	
3	600.00	30.00	
4	1000.00	40.00	
F2 to Continue			

Step Function Input Screen

## Purpose

The step function input screen allows you to manually input short-run marginal cost step functions. It is typically used to input cost function data for a single generating unit. However, it can also be used to input data for a multi-unit or power pool supply node representation. Alternatively, screen SMN-23 can be used to automatically create a step function for power pools if supporting ICARUS runs have been made.

## Options

- F2** Press this key to close the current browse input menu and activate the supply node screen (SMN-09). The data input into this screen will not be permanently saved until the <Change> button on the supply node screen is pressed.

## Data Fields

**Function Steps:** This data field contains a counter that labels the step number. The counter starts at number 1 and ends at the number you specified in the "# of Supply Steps" data field displayed on the supply curve screen (SMN-09). Note that you cannot change the values in this data field.

**Generation Level:** Data entered in this field define the ranges of generation levels for which generation costs are applicable. Enter the generation level (in megawatts) for the ending point of the step (on the x axis). The value entered is for the highest generation level (i.e., the maximum for the range) for which the generation costs specified in the Cost field are to be applied. For the first function step in this menu, it is assumed that the smallest generation (i.e., the minimum for the range) equals zero. For all other steps, it is assumed that the minimum value is infinitesimally larger than the maximum range of the previous step.

**Cost:** Data entered in this field define generation costs that are applied to the ranges of generation levels defined in the Generation field. Generation costs (in dollars per megawatt-hour) represent the average marginal cost of electricity production over the generation range of the step. Marginal costs are measured in terms of increased generation costs relative to the generation cost at the highest generation level of the previous step.

## Background

When supply nodes are used to represent individual generating units, the step function can be approximated by computing incremental generation costs at various production levels. Costs are a function of the unit heat rate curve, fuel costs, and variable O&M costs. Because unit heat rates typically decrease (i.e., the unit becomes more efficient) as a function of increasing unit generation, the production cost curve is usually not convex. The first step of the cost function may have a marginal cost that is greater than one or more of the steps that follow it. However, the maximum generation level assigned to the first block must be less than the overall minimum generation level assigned to the node. Also, the marginal cost for all steps after the second step must increase; that is, the cost curve is convex after the minimum generation level. In general, units are split into two blocks (i.e., steps); the first block represents the base capacity (minimum generation level), and the second block represents the peaking or load following portion of the unit. Where applicable, a third block may also be used to represent costs associated with increasing generation levels above the optimum design capacity or to represent spinning reserves. When the third block represents spinning reserves, the price of this block must be set artificially high so that it is used only in emergency situations.

If you input data that do not conform to the convexity and minimum generation rules, a warning message will appear on the screen. Also, you cannot exit screen SMN-09 until the node has been deleted or all step function errors have been corrected.

2:20:54 pm

Data Transfer from ICARUS to Spot Market Network

Select the ICARUS case:

Study:	Demonstration Study	Associated Energy Source Node:	ECR
System:	P1 - American Electric Power		
Case:	Base Case	Max. # Of Function Steps:	24

(•) Edit Cost Curve Data                      <Generate> < Exit >

SMN-23

### Purpose

Screen SMN-23 allows you to run an ASF procedure that creates short-run marginal cost step functions. This procedure can be used instead of manually entering the function data into the step function input screen. The ASF uses results from a previous run of the ICARUS model and invokes additional ICARUS runs that are executed in the hourly mode. Appendix 4C gives more details. To select the ICARUS results to be used as the basis for constructing the short-run marginal cost step function, use the three pop-up menus on the left side of the screen. As documented in Chapter 3, ICARUS data are saved in a hierarchical data management structure. The study level is at the top of the data management hierarchy and contains one or more systems. The system level is the second level of data management. At the third level of the hierarchy, you define one or more cases (i.e., scenarios).

It is recommended that ASF be used only for multi-unit representations, such as large plants with several generating units or power pools. When a supply node is used to represent only one unit, you should enter the step function manually by using screen SMN-09.

### Options

- Screen SMN-23 is divided into two parts. The left side consists of pop-up menus that display the studies, systems, and cases defined by the user in the ICARUS menu (screen ICARUS-01). Choose the ICARUS run you want to use as the basis for generating the short-run cost step function.

- The right side of the screen contains a pop-up menu that allows you to associate an variable supply/fixed demand node with the selected ICARUS module run; that is, the short-run marginal cost curve that is created by ASF will be assigned to the selected node. Note that only those energy source nodes that were "created" in screen SMN-09 appear in the pop-up menu. Beneath the energy source pop-up are an input field and buttons that control screen functions. The buttons are either active (blue in color) or inactive (light gray). If a button is light gray, it is inactive and therefore cannot be invoked until further selections are made. Buttons will become active or inactive as selections are made.
- Once the curve is generated for the selected system, it can be viewed by clicking on the View Cost Function Data option. Note that this button is activated only when you have selected an energy source node and the node contains cost curve data. The cost curve data may have been either entered manually or created by the ASF. For a detailed explanation of the interpretation of the data fields in this table, see the step function input screen.

## Data Fields

Max. # of Function Steps: Input the maximum number of function steps to be generated by this procedure. You must input an integer value in the range of 2-52 (a value of 24 is recommended for ICARUS-derived curves). The number of supply steps the program generates will be less than or equal to this input value. If the supply curve generated by ICARUS has points in the curve that are not convex, some points are omitted by the curve transformation algorithm.

Unservd Energy Cost Multiplier: After you click on the <Generate> button, the incremental operating costs for the most expensive peak block are displayed on the screen. You are then prompted to input a multiplier that is applied to the displayed operating costs. The resultant cost (i.e., peak block operating costs times the Multiplier) is assigned to the unserved energy cost rate. These costs are accounted for in the calculation of the marginal cost curves.

## Buttons

### <Generate>

The <Generate> button is active only when you have selected both the ICARUS case and an associated energy source node. Click on this button to run the automated step function procedure.

If the procedure did not generate a step function because of incomplete ICARUS data, a message is displayed on the screen. After the step function has been created by ASF, additional error checks on the cost function are performed. If any problems are

detected, one or more error messages are displayed on the screen. After the cost step function has been created, it can be viewed by using the View Cost Function Data button. After you exit this screen (to screen SMN-09), the value in the minimum generation field will be set to the generation level of the first step of the short-run marginal cost step function. To make manual changes to the step function, exit this screen and press the <Edit Steps> button on the supply node screen (SMN-09).

**<Exit>**

To return to the previous SMN screen (SMN-09), click on the <Exit> button. This button is always activated.

**Background**

Generation costs at a supply node are represented as a short-run marginal cost step function in the SMN. It comprises the individual segments that define the cost step functions. Refer to Appendix 4C for additional background material on the automated procedures used to prepare step functions for SMN from ICARUS data.

8:38:20 am

**Delete Entries**  
Use the SPACEBAR to Tag/Untag Entries

Press F2 When Finished

Disabled	Node	Code	Name	Latitude	Longitude	P_margin	M
F	1	ECR	ECAR	37.5	82.5	2.0	◆
F	2	ERC	ERCOT	32.0	100.0	2.0	
F	3	MAC	MAAC	39.8	75.0	2.0	
F	4	MAN	MAIN	43.0	91.5	2.0	
T	5	MPU	MAPP-US	42.0	99.0	2.0	
F	6	NYU	NPCC-US(NEW YORK)	43.0	76.0	2.0	
F	7	SRF	SERC-FLORIDA	28.0	81.5	2.0	
F	8	SRS	SERC-SOUTHERN	32.5	84.5	2.0	
F	9	SRT	SERC-TVA	35.8	86.5	2.0	
F	10	SRV	SERC-VACAR	37.5	78.0	2.0	
F	11	SPP	SPP	38.5	98.0	2.0	
F	12	WCU	WSCC-US	42.0	114.0	2.0	
F	13	MPC	MAPP-CANADA	52.0	95.0	2.0	
F	14	NPM	NPCC-MARITIMES	46.5	66.5	2.0	
F	15	NPQ	NPCC-QUEBEC	46.5	71.5	2.0	▼

Delete Screen

**Purpose**

The Delete screen allows you to permanently delete records from the database. The following types of SMN data can be deleted: (1) variable-supply/fixed-demand nodes, (2) substation nodes, (3) fixed-demand nodes, (4) links, (5) CTCs, (6) firm contracts, and (7) node transfer limits.

**Options**

- To mark (tag) a record for deletion, highlight the entry and press the spacebar. A diamond character (◆) will appear next to the record entry. To unmark entries, highlight the entry and press the spacebar. The diamond character will then disappear; the record is no longer tagged for deletion. When all desired records have been marked, press the F2 key to delete the records.

When you delete a node, all links that are connected to the node are automatically deleted. You will be informed of all links that are associated with the marked nodes that will be deleted. You must confirm the deletion by typing "Y" before the node and associated links are removed from the database.



When information is deleted from the database, it will be *permanently* removed; that is, the data cannot be retrieved, recreated, or restored. To temporarily remove information from the database, use the disable feature.

**F2** Press this key to delete marked nodes and return to the previous screen.

8:24:12 am

**Disable Entries**  
Use the SPACEBAR to Tag/Untag Entries

Press F2 When Finished

Disabled	Node	Code	Name	Latitude	Longitude	P_margin	M ▲
F	1	ECR	ECAR	37.5	82.5	2.0	◆
F	2	ERC	ERCOT	32.0	100.0	2.0	
F	3	MAC	MAAC	39.8	75.0	2.0	
F	4	MAN	MAIN	43.0	91.5	2.0	
T	5	MPU	MAPP-US	42.0	99.0	2.0	
F	6	NYU	NPCC-US(NEW YORK)	43.0	76.0	2.0	
F	7	SRF	SERC-FLORIDA	28.0	81.5	2.0	
F	8	SRS	SERC-SOUTHERN	32.5	84.5	2.0	
F	9	SRT	SERC-TVA	35.8	86.5	2.0	
F	10	SRV	SERC-VACAR	37.5	78.0	2.0	
F	11	SPP	SPP	38.5	98.0	2.0	
F	12	WCU	WSCC-US	42.0	114.0	2.0	
F	13	MPC	MAPP-CANADA	52.0	95.0	2.0	
F	14	NPM	NPCC-MARITIMES	46.5	66.5	2.0	
F	15	NPQ	NPCC-QUEBEC	46.5	71.5	2.0	▼

### Disable Screen

### Purpose

The Disable screen allows you to temporarily remove information from the SMN model without permanently deleting the data. This feature allows you to preserve previously entered data for later use. The following types of SMN data can be disabled: (1) variable-supply/fixed-demand nodes, (2) substation nodes, (3) fixed-demand nodes, (4) links, (5) CTCs, (6) firm contracts, and (7) node transfer limits.

### Options

- To disable a record, highlight the record with the cursor and press the spacebar. This action will change the disable flag for that record or group of records to "T," which indicates that the record or group of records is now disabled. Setting the flag to "F" will enable the record or group of records.

When you disable a node, all links connected to the node are automatically disabled. However, when a node is enabled, all links that were previously connected are *not* automatically enabled. You must enter the links screen in order to enable the appropriate links. Other types of information may also be disabled if the data are affected by disabling a node or link. These include firm contracts, CTCs, and node transfer limits. For example, if a link that is part of a firm contract is disabled, then the contract is also disabled. Attempts by the user to override disabled information that would result in a mathematical error are overridden by SMN. For example, if a node is disabled, the links connected

to the node are also disabled. If you attempt to enable any of these connected links, SMN will override the attempt and leave them disabled.

**F2** Press this key to disable or enable data as marked and return to the previous screen.

2:21:58 pm

**Substation Node Description**

Items Entered:

Code	Name	Latitude	Longitude	Disabled

Highlight Item, F4 Edit Next, and F8 Edit, F9 to Zoom/Unzoom.

---

**Enter Substation Node**

Code Name:      Substation Node Name:

Latitude (°):      0.0      Longitude (°):      0.0

« Add »    <Delete >    <Disable>    < Clear >    < Quit >

SMN-10

### Purpose

Screen SMN-10 allows you to view, modify, create, enable, disable, and delete substation node data. A substation node is analogous to a supply node without generation capabilities or local demand. In an aggregated network model, the substation node may represent the equivalent of one or more individual substations. The total power flow entering a substation node must equal the total power flow exiting the node. The purpose of this node type is to route electricity flow from one or more node input links to one or more output links. For example, power flows from one input link can branch out into several output links that have smaller carrying capacities. Conversely, several small transmission input links can feed into one large output link.

### Options

- Screen SMN-10 is separated into two major parts. The window in the upper portion of the screen displays data contained in the substation node file. This window is also used to select data records for editing. The lower half of the screen allows you to make changes to data fields for a selected substation node and to enter new substation nodes into the database.
- To view existing substation node data, activate the upper window by clicking anywhere on the data view window. Use the Tab and arrow keys as described below to view the information.

- F4** Press this key to edit the next record in the database; that is, data for the next record in the database are displayed on the lower portion of the screen for viewing or editing. If the last record in the database is in the lower half of the screen, press this key to display the first record in the database.
- F8** Press this key to edit the currently highlighted record in the database. The information for that record will be displayed in the lower portion of the screen for viewing or editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned on a record in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Code Name: Enter the three-character identifier for the current record.

Substation Node Name: Enter the character description for the substation node.

Latitude: Enter the latitude of the current substation node (in degrees).

Longitude: Enter the longitude of the current substation node (in degrees).

## Buttons

**<Add>/**

**<Change>**

To add a new substation node, enter information into the fields on the lower half of the screen and press the <Add> button to save the data. The <Add> button adds the new record to the database and also sorts records alphabetically by the Abbreviated Code field. The <Add> button appears on the screen only if a record has not been selected for editing. When a record has been selected, the <Change> button is activated. Click on the <Clear> button to clear the current entry and return to the add mode. Once a new node has been added, it appears in the upper window.

The following steps allow you to edit substation node data. First, activate the upper window and select the substation node to edit. Press the F8 key to display data for the selected record on the lower half of the screen, or press the F4 key to edit the next record. Click anywhere on the lower half of the screen, and the cursor will move to the Code Name field. Use either the

arrow keys or the mouse to move between fields and enter the new information. Click on the <Change> button to save the new data, or click on the <Quit> button if you do not want to save the edits.

- <Delete>** To delete an existing substation node and all links to that node, click on the <Delete> button to activate the Delete screen.
- <Disable>** The disable feature allows you to temporarily remove substation nodes from the SMN. To disable a node, click on the <Disable> button. This action will activate the Disable screen, which displays all substation nodes. Use the spacebar to toggle between enabling and disabling the highlighted node. Note that when a node is disabled, all links going to that node are also disabled.
- <Clear>** To clear the input fields of all data, and return you to the Add mode, click on the <Clear> button.
- <Quit>** To exit from the substation node screen without saving any information displayed in the screen fields, click on the <Quit> button.

2:22:09 pm

Fixed Supply/Demand

Items Entered:

Code Name	Latitude	Longitude	Production Cost	Demand	Ge

Highlight Item, F4 Edit Next, and F8 Edit. F9 to Zoom/Unzoom

---

Enter Fixed Supply/Demand Node

Code Name:      Fixed Supply/Demand Node Name:

Latitude (°):      0.0      Longitude (°):      0.0      Production Cost (\$/MWh):      0.0

Demand (MW):      0.0      Generation (MW):      0.0      Net Demand (MW):

< Add >    < Delete >    < Disable >    < Clear >    < Quit >

SMN-11

### Purpose

The SMN-11 screen allows you to view, modify, create, disable, and delete fixed supply/demand node data. The fixed supply/demand nodes are used to represent fixed electric generating resources with fixed local demands. These nodes typically represent energy sinks or areas of net energy consumption; that is, generation is either zero or exceeds local production. In other situations, this node may represent a simple generating resource that operates at a fixed energy output level specified by the user, with or without local demand. This node type is useful for representing nondispatchable electricity generating resources, such as wind and solar. It can also be used to represent generation for limited energy supply sources, such as hydroelectric power plants. However, it is often necessary to use external models to estimate appropriate input values for generation. The SMN accepts up to 50 fixed supply/demand nodes.

### Options

- Screen SMN-11 is separated into two major parts. The browse window in the upper portion of the screen displays data that are contained in the energy sink node file. This window is also used to select data records for editing. The lower half of the screen allows you to make changes to data fields for a selected energy sink node and to enter new energy sink nodes into the data file.
- To view existing energy sink node data, activate the upper window by clicking anywhere on the screen. Use the Tab and arrow keys as described below to view the information.

- F4** Press the key to edit the next record in the database, that is, data for the next record in the database is displayed on the lower portion of the screen for viewing or editing. If the last record in the database is in the lower half of the screen, the F4 key displays the first record in the database.
- F8** Press this key to edit the currently highlighted record in the database. The information for that record will be displayed in the lower portion of the screen for viewing or editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned on a record in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Code Name: Enter the three-character identifier for the current record.

Fixed Supply/Demand Node Name: Enter the character description for the energy sink node currently being entered.

Latitude: Enter the latitude of the current energy sink (in degrees).

Longitude: Enter the longitude of the current energy sink (in degrees).

Production Cost: This entry is for reference only. It does not affect simulation results and is not included in tabulated outputs.

Demand: Enter the energy demand at this node (in megawatts).

Generation: Enter the amount of generation produced at this node (in megawatts). The generation specified is a fixed value and must either be consumed at the node or transported out of the grid.

Net Demand: You cannot input this value; rather, it is calculated from the energy demand and generation inputs. It is displayed for your convenience. A net positive demand is the amount of energy that must be supplied from the grid, and a net negative demand is the amount of energy that must be transported out of the grid.

## Buttons

**<Add>/**

**<Change>**

To add a new substation node, enter information into the fields on the lower half of the screen and press the <Add> button to save the data. The <Add> button adds the new record to



the database and also sorts records alphabetically by the Abbreviated Code field. The <Add> button appears on the screen only if a record has not been selected for editing. If a record has already been selected and the <Edit> button is activated, click on the <Clear> button to clear the current entry and enter the Add mode. Once a new node has been added, it appears in the upper window.

The following steps allow you to edit energy sink node data. First, activate the upper window and select the energy sink node to edit. Press the F8 key to display data for the selected record on the lower half of the screen, or press the F4 key to edit the next record. Click anywhere on the lower half of the screen, and the cursor will move to the Code Name field. Use either the arrow keys or the mouse to move between fields and enter the new information. Click on the <Change> button to save the new data. If you do not want to save the changes, select another record by using the view data screen or click on the <Quit> button to ignore modifications and exit to the previous menu.

- <Delete>** To delete an existing energy sink node and all links to that node, click on the <Delete> button to activate the Delete screen.
- <Disable>** The disable feature allows you to temporarily remove sink energy nodes from the spot market network. To disable a node, click on the <Disable> button. This action will activate the Disable screen, which displays all fixed supply/demand nodes. Use the spacebar to toggle between enabling and disabling the highlighted node. When a link is disabled, all links connected to that node are also disabled.
- <Clear>** To clear the input fields of all data and return to the Add mode, click on the <Clear> button.
- <Quit>** To exit from the substation node screen without saving any information displayed in the screen fields, click on the <Quit> button.

10:59:33 am

**Transmission Lines (Links)**

Items Entered:

Line Name	Origin	Destination	Line Loss	Wheeling Charge	Rating	Winter Capa
LINE 9	NYU	MAC	6.00	0.00	0.0	

Highlight Item, F4 Edit Next, and F8 Edit F9 to Zoom/Unzoom

---

Origin :  Destination:

Line Name:  Line Loss (%):

Wheeling Charge (\$/MWh):  Rating (kV):

Summer Capacity (MW):  Winter Capacity (MW):

« Add » <Delete > <Disable> < Clear > < Quit >

SMN-13

**Purpose**

Screen SMN-13 allows you to view, modify, create, delete, disable, and enable transmission line data. In the SMN model, transmission lines are represented as links that connect two nodes. You can enter transmission line data for two directions of power flow. That is, you first enter data such as line capacity and wheeling charges for power that flows from node A to node B. In this case, node A is referred to as the origin node, and node B is referred to as the destination node. The first flow you enter is referred to as a power flow in direction 1. After data for direction 1 have been entered, you enter information for power that flows in the opposite direction (i.e., from node B to node A). The second flow direction you enter is referred to as a power flow in direction 2.

**Options**

- Screen SMN-13 is separated into two major parts. The upper portion of the screen displays a window that contains transmission line data. This window is used to display data and to select data records for editing. The lower half of the window allows you to make changes to data fields for a selected transmission line and to enter new transmission lines into the data file.
- To view existing transmission line data, activate the upper window by clicking anywhere on the screen. Use the Tab and arrow keys to view the information.

- F4** Press this key to edit the next record in the database; data for the next record in the database are displayed on the lower portion of the screen for viewing or editing. If the last record in the database is in the lower half of the screen, the F4 key displays the first record in the database.
- F8** Press this key to edit the currently highlighted record in the database. The information for that record is displayed in the lower portion of the screen for viewing or editing.
- F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned on a record in the upper window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Origin: Enter the starting node for this link for direction 1 (i.e., transmission line).

Destination: Enter the ending node for this link for direction 1 (i.e., transmission line).

Line Name: Enter the character description for transmission line.

Line Loss: Enter the transmission line loss (%) for direction 1. This number must be greater than or equal to 0.0.

Wheeling Charge: Enter the wheeling cost charges by the origin node (in mills per kilowatt-hour) for direction 1.

Rating: Enter the nominal operating voltage for transmission/distribution lines for both directions. (See Table 4.1.) This entry is for reference purposes only. The model relies on line capacities for simulation purposes rather than voltage ratings.

Summer Capacity: Enter the transmission line capacity in the summer months, April through September (in megawatts), for direction 1.

Winter Capacity: Enter the transmission line capacity in the winter months, October through March (in megawatts), for direction 1.

## Buttons

<Add>/

<Change>

To add a new transmission line (i.e., a link) for direction 1, enter information into the fields on the lower half of the screen and press the <Add> button to save the data. The <Add> button

adds the new record to the database and also sorts records alphabetically by the Line Name field. Pressing the <Add> button will also invoke a second screen in which you enter information for direction 2 (see the section on the Add screen). When you browse the links database, note that there is a separate data row entry for each direction (i.e., direction 1 and direction 2); however, both data rows have the same transmission line (i.e., link) name. Data entered for direction 2 either by SMN defaults or by you are added to the links database. The <Add> button appears on the screen only if a record has not been selected for editing. If a record has already been selected and the <Change> button is activated, click on the <Clear> button to clear the current entry and to enter the Add mode. Once a new node has been added, it appears in the upper window.

The following steps allow you to edit transmission line data. First, activate the upper window and select the transmission line record to edit. Press the F8 key to display data for the selected record on the lower half of the screen, or press the F4 key to edit the next record in the database. Click anywhere on the lower half of the screen, and the cursor will move to the Line Name field. Use either the arrow keys or the mouse to move between fields and enter the new information. Click on the <Change> button to save the new data, or select a new record by using the view line data screen to ignore any modifications. You can also click on the <Quit> button to exit to the previous menu without saving the edits.

- <Delete>** To delete an existing transmission line and all links to that node, click on the <Delete> button to activate the Delete screen.
- <Disable>** The disable feature allows you to temporarily remove sink energy nodes from the SMN. To disable a node, click on the <Disable> button. This action will activate the Disable screen, which displays all sink energy nodes. Use the spacebar to toggle between enabling and disabling the highlighted node.
- <Clear>** To clear the input fields of all data and return to the Add mode, click on the <Clear> button.
- <Quit>** To exit from the substation node screen without saving any information displayed in the screen fields, click on the <Quit> button.

## Background

In the SMN model, transmission line capacity is specified as a maximum net hourly spot market energy transaction (in megawatts) that can be made between two nodes. This capacity is typically physical line capacity minus base-level power flows, which are estimated through other modeling effects or empirical information and experience. The model limits only net energy transactions. That is, an energy transaction scheduled in one direction over a line can exceed the line capacity if, at the same time, there is an energy transaction scheduled in the opposite direction (i.e., back scheduling) that will lower the net flow of energy over the line below its capacity.

In the SMN model, transmission losses are represented by applying a loss factor to net power flows over each of the links. As a result, only a fraction (i.e., approximately 92-96%) of the energy produced at a generating node is received by the demand node. The SMN model also recognizes line rights and wheeling charges incurred when one utility system uses the transmission lines of another system. Wheeling charges typically vary between \$1/MWh and \$5/MWh, depending on utility line rights. An individual transmission line for which several utility systems hold line rights is represented by the SMN model as several links. The sum of these links equals the total transmission line capacity. The capacities of each individual link are based on the portion of the line that a utility system has rights to use. If a utility system wants to transmit more energy over a line than it has rights to use, energy can be wheeled over another system's link. However, wheeling charges will be incurred.

**TABLE 4.1 Approximate Power-Carrying Capability of Uncompensated AC (MW)**

Line Length (mile)	Nominal Voltage (kV)					
	138	161	230	345	500	765
50	145	195	390	1260	3040	6820
100	100	130	265	860	2080	4660
200	60	85	170	545	1320	2950
300	50	65	130	420	1010	2270
400	-- <sup>a</sup>	--	105	335	810	1820
500	--	--	--	280	680	1520
600	--	--	--	250	600	1340

<sup>a</sup> Low-voltage lines are not used for very long distance transmission, so unrealistic table entries are not included.

Note: This table is useful for estimating the amount of power a line can carry, given its rated voltage and length, but it has limitations. It is assumed that voltage drops must be limited to 5%, stability requires the line load to be no more than 65% of the theoretical maximum, and line losses can be neglected. Lines that compensate for reactance may be able to carry more, and lines that are part of an integrated network may be required to carry less than the amounts in the table.

Sources: Powel (1955), EPRI (1982), and Dunlop et al. (1979).

Direction 2 Information - Origin:SRS Dest:NYU		
Wheeling Charge (\$/MWh):	1.00	
Summer Capacity (MW) :	100.0	< OK >
Winter Capacity (MW) :	100.0	<Cancel>
Line Loss (%) :	6.0	

Add Screen

### Purpose

The Add screen appears when you click on the <Add> button in screen SMN-13. Because of inadvertent power flows, the amount of power that can be transferred on a line through a spot market transaction usually differs by direction. Assuming no parallel flows are associated with the spot market transaction, existing power flows on a line will decrease the amount of energy that can be transferred in one direction, while it increases the amount of power that can be transferred in the opposite direction.

### Options

This pop-up screen is displayed when the <Add> button is pressed. Initial default values displayed in the screen are identical to data values that you input for the first direction. You may change these values as needed.

Use the mouse and arrow keys to select the data field for modification. Next, type in the desired value. To exit the screen and save the information displayed on the screen, click on the <OK> button.

### Data Fields

Wheeling Charge: Enter wheeling costs charges by the origin node (mill/kWh).

Summer Capacity: Enter transmission line capacity in the summer months, April through September (in megawatts).

Winter Capacity: Enter transmission line capacity in the winter months, October through March (in megawatts).

Line Loss: Enter transmission line loss (%). This number must be greater than or equal to 0.0.

**Buttons**

**<OK>**

To save information and add records to the database, click on the <OK> button.

**<Cancel>**

To disregard any information entered, clear the fields, and return to the Add mode, click on the <Cancel> button.



10:27:15 am

**Composite Transfer Capacity Limits**

< Clear >

CTC Name: < Browse > < Quit >

New CTC Name: CTC MAN1

Total Capacity (Direction 1): 400.0 Total Capacity (Direction 2): 200.0

Direction 1			Direction 2		
CTC Name	Origin	Destination	CTC Name	Origin	Destination
CTC MAN1	N01	N02	CTC MAN1	N02	N01
CTC MAN1	N02	N03	CTC MAN1	N03	N02
CTC MAN1	N03	N04	CTC MAN1	N04	N03
CTC MAN1	N04	N01	CTC MAN1	N01	N04

Highlight and F5 to Flip

Press F2 When Finished

SMN-14

**Purpose**

Screen SMN-14 allows you to add, delete, or browse CTCs, which consist of groups of power lines. Through the use of a CTC, you can limit the aggregate transfer capability of a specific group of lines.

Each CTC is usually assigned a typical nonsimultaneous capacity transfer limit, which is determined by stability, thermal, or reliability limitations. These transfer limits represent typical operating limits between interacting control areas by summing up individual line capacities into a single capacity transfer limit. However, the CTC value need not be the numerical sum of individual transmission line capabilities due to parallel effects or stability concerns.

Similar to individual transmission lines, constraints or limits are bidirectional. You first enter CTC capacity for power that flows from a node (or set of nodes) to a second node or (set of nodes) as you defined in the lower portion of the screen. The node in which the power originates is referred to as the origin node, and the power is received by the destination node. You define the flow direction for each line that constitutes a CTC on the lower left side of the screen. Note that in the direction 2 window, the origin and destination node are the reverse of the direction specified in direction 1; that is, when you change the origin and destination in the direction 1 window, the origin and destination in the direction 2 window are automatically changed.

## Options

- Screen SMN-14 is separated into two parts. The upper portion of the screen initially displays only data entry headings and action buttons. Once a CTC has been selected, directional capacities are displayed on the upper portion of the screen, and the lower portion of the screen displays the links that are associated with that CTC name.
- F2** Press this key to exit and save the information displayed in the two lower windows of the CTC menu.
- F5** Press this key to swap the origin and destination nodes (i.e., directions) for a selected link. The direction of the corresponding link in the opposite direction will automatically be reversed (i.e., direction 2 is displayed in the right screen) to preserve data integrity.

## Data Fields

CTC name: Enter the character CTC name chosen from the list of existing CTC names.

New CTC Name: Enter the name of the new CTC here.

Total Capacity (Direction 1): Enter the total capacity (in megawatts) for the CTC for direction 1 you specified in the window on the lower left portion of the screen.

Total Capacity (Direction 2): Enter the total capacity (in megawatts) for the CTC for direction 2 you specified in the window on the lower right portion of the screen.

## Buttons

**<OK>**

To view a single existing CTC name, its directional capacity, and links in both directions, click on the CTC Name box and select a CTC name from the pop-up list. The directional capacity will then be shown in the appropriate fields on the screen. To view the associated links, click on the <OK> button. This action will activate the lower section of the screen, where link directions can now be changed. To exit, press the F2 key.

**<Add New>**

To add a new CTC, click on the <Add New> button. A screen will then prompt you to enter the name for this new CTC. Type the name and press the Enter key. A new window will appear, and you will be prompted to enter the directional capacities. After both capacities have been entered, another window will

appear that contains all the links that were entered in the transmission line menu (screen SMN-13). Note that at this point in the procedure, directions (i.e., origin and destinations) for links that make up the CTC are not important. Origins and destinations of lines that define CTC direction are specified by using the windows in the lower portion of the screen. Use the spacebar and arrow keys to tag the links you want to be included as part of the CTC. Tagged entries are indicated by a small diamond (◆) at the far left of the record. When all of the links have been tagged, press the F2 key. This action will activate two windows in the lower portion of the CTC screen. The left window will allow you to change the direction of the link for direction 1. The right window will display link information for direction 2. To change the direction of the link for direction 1, locate the desired link by using the arrow keys. Once the desired record is highlighted, press the F5 key. This action will change the direction of the link for direction 1. The direction of the link in direction 2 will automatically be changed in the right window. Once the desired link directions have been changed, press the F2 key to exit, save this information, and return to the beginning CTC screen.

**<Add Links>**

To add more links to an existing CTC, choose the CTC from the pop-up list and click on the <Add Links> button. This action will activate a links selection window containing the links that are available to be added to this CTC. Use the spacebar to tag additional links to be added and then press the F2 key. This action will add the links to the database. The F5 key can now be used to change the direction of the links. Once the desired link directions have been changed, press the F2 key to exit and save this information.

**<Clear>**

To clear the selected CTC names and data entered in the directional capacity fields, click on the <Clear> button.

**<Disable>**

The disable feature allows you to temporarily remove CTCs from the SMN. To disable a node, click on the <Disable> button. This action will activate the Disable screen, which displays all CTCs. Use the spacebar to toggle between enabling and disabling the highlighted node.

**<Delete>**

To delete existing CTC links, choose the CTC name from the pop-up list. A display window will appear that shows the links for this CTC for direction 1 only. Use the spacebar to tag links to be deleted and press the F2 button. Click on the <Delete>

button. This action will delete the marked links from both direction 1 and direction 2. This process causes *permanent* deletion of a CTC's links. To delete an entire CTC, tag all links associated with the CTC and press the F2 key.

**<Browse>**

To display and browse all user-defined CTC and associated capacities and links, click on the <Browse> button. Once you have finished viewing the browse screen, press the F2 key to exit and return to the main CTC screen. Note that you are not able to change any of the data when in the browse window mode.

**<Quit>**

To exit the screen without saving any information that is currently displayed, click on the <Quit> button.

Firm Contract Adjustments							2:25:10 pm
Contract Name: New Contract 1							
Seller: WCC - WSCC CALIF-L.NEVADA			Buyer: WCA - WSCC-ARIZ-N.M.AREA				
Contracted Energy (MW): 0.00			Adjust Buyer and Seller Loads? Y				
Seller Line Loss Coverage (0-100%): 0.00							
Name	Origin	Destination	Loss (%)	Energy	Adjust From	T	
WSCC/MAPP	WCC	MPC	100.00	50.00	Y	WCC M	
F8 to Edit			F9 to Zoom/Unzoom				
Next Node in Path: <input type="text"/>							
Select the destination node as the last node for the given path.							
<Update Contract> <Cancel Update> <Add Step> <Cancel Steps> <Delete Contract> <Disable Contract> <Quit >							

SMN-15

**Purpose**

The SMN-15 screen allows you to enter data on firm contracts. When a firm contract is entered into SMN, transmission line (i.e., links) transfer capabilities are adjusted in both directions accordingly. Also, at your option, demand values at demand nodes and at fixed supply/fixed-demand nodes can be modified. Sales contracts increase loads, while purchases decrease loads. This screen also allows you to edit, delete, enable, and disable a firm contract.

**Options**

- Screen SMN-15 is separated into three parts. In the top section, you input information on the seller and purchaser of firm capacity and energy. The middle section of the screen contains a window that displays the contractual transmission path from the seller to the buyer. This window is also used to select data records for editing. The bottom section of the window allows you to define the contractual transmission path. Also, buttons on the bottom portion of the screen allow you to delete, disable, enable, and update firm contract entries.
- To add a new firm contract to the database, enter the contract name located at the top of the screen. Next, click on the Seller box, and select the seller from the pop-up list. Repeat the same procedure to select the buyer. Enter the firm energy sale in the appropriate field on the screen and indicate whether load adjustments are required. Enter the seller line loss coverage in the correct

field. The <Add Step> button activates a pop-up list of nodes and allows you to define the contractual transmission path.

- To view existing contract data, activate the middle window by clicking anywhere on the middle portion of the screen. Use the Tab and arrow keys to view the information.

**F8** Press this key to edit the currently highlighted record in the database. The information for that record is displayed in the upper portion of the screen for viewing or editing.

**F9** Press this key to zoom the upper window to full screen size. This key is active only when the cursor is positioned on a record in the browse window. Pressing the F9 key a second time will restore the window to its original size.

## Data Fields

Contract Name: Enter the name of the contract that is to be stored in the database.

Seller: This field contains the seller of LTF capacity and/or energy. Select the firm power seller by clicking on the box adjacent to the Seller label. Drag the cursor on the pop-up list to select the seller. Note that only variable-supply/ fixed-demand nodes that you have previously defined appear in the pop-up list. This node defines the beginning of the firm contract path.

Buyer: This field contains the purchaser of LTF capacity and/or energy. Select the firm power buyer by clicking on the box adjacent to the Buyer label. Drag the cursor on the pop-up list to select the purchaser. Note that only variable-supply/fixed-demand nodes and fixed supply/fixed-demand nodes that you have previously defined appear in the pop-up list. This node defines end of the firm contract path.

Contracted Energy: Enter the amount of capacity (in megawatts) that is sold under the firm contract in the simulated hour.

Adjust Buyer and Seller Loads?: This flag signals whether or not SMN should automatically adjust the loads of the buyer and seller. Adjustment amounts depend on the firm sales amount, line losses, and the amount of line loss that occurs between the buyer's generating resources and the purchaser's delivery point. Answering "Y" to the question will increase the seller's load and decrease the buyer's load. Where applicable, load adjustments take into account transmission losses. For example, the demands for a utility system that sells 94 MW of power may be increased by 100 MW, while the demand for the utility system that receives the energy is reduced by only 94 MW. Furthermore, energy transfer capabilities (in both directions) are adjusted for transmission line usage that is reserved for serving firm contractual commitments. Answer "N" to the question if the loads input for each node already account for firm contracts.

**Seller Line Loss Coverage:** This field indicates the percentage of energy losses that is the responsibility of the seller. For example, if all the transmission losses are covered by the seller, enter 100 in this field. Assuming 6% losses, the seller would have to generate 106 MW of electricity to fulfill a 100-MW contractual obligation. On the other hand, if the seller is not responsible for any losses, the seller would only generate 100 MW, and the buyer would receive approximately 94 MW of electricity.

**Next Node in Path:** This pop-up box allows you to define the contractual transmission path between the seller and buyer of firm energy and/or capacity. A contractual transmission path consists of one or more transmission segments. The first time you click on this box, a pop-up list containing all nodes that are directly connected to the seller by a transmission line is displayed on the screen. Drag the cursor on the list to select the first segment of the transmission path. Note that only those nodes that are directly connected to the seller, as defined in the transmission line menu, are displayed in the pop-up list. Click on the <Add Step> button to add the link segment to the contract path database. Note that the segment will appear in the middle (i.e., browse) window. Once the first segment has been selected, all other path segments are selected by using the same click-and-drag method. Continue to define path segments until you select the buyer node in the pop-up list; that is, the entire path has been defined. If you enter a "dead end" path, a message is displayed on the screen and you must reenter the entire path. Also, you cannot "retrace" or "backtrack" when defining the contractual path. For example, when you select a path segment from node X to node Y, you cannot select a path segment from Y to X; that is, once you are at node Y, node X does not appear in the pop-up list.

## Buttons

- |                                |  |
|--------------------------------|--|
| <b>&lt;Add Step&gt;</b>        | Once you have selected a node in the Next Node in Path pop-up menu, click on the <Add Step> button to add this path segment to the database.   |
| <b>&lt;Cancel Steps&gt;</b>    | In the process of defining a contract path, you may have inadvertently entered an incorrect segment. When this occurs, press the <Cancel Steps> button to remove all path segments entered thus far and reenter the entire contract path. Note that this button is not active when a contract has been selected for editing; that is, the option can be used only when the contract path is being defined. |
| <b>&lt;Delete Contract&gt;</b> | To delete a contract, click on the <Delete Contract> button. This action will activate a screen that allows you to tag contracts for <i>permanent</i> deletion (screen SMN-03). Use the spacebar to tag or untag entries for deletion. Note that all data associated with a contract (i.e., perhaps more than one row of data) are tagged or   |

untagged for deletion when the spacebar is pressed. The delete screen will permanently remove records from the file.

**<Disable  
Contract>**

The disable feature allows you to temporarily remove contracts from the SMN. To disable a contract, click on the <Disable Contract> button. This action will activate a screen that displays all contracts. Use the spacebar to toggle between enabling and disabling the highlighted node. Note that all data associated with a contract (i.e., perhaps more than one row of data) are tagged or untagged to be disabled when the spacebar is pressed.

**<Update  
Contract>  
and  
<Cancel  
Contract>**

Four fields in the database can be modified for a single contract. Select the firm contract by clicking on the browse window located in the center of the window. Next, highlight the record for editing and press the F8 key. Note that data for the selected contract appear in the upper window. You can now modify the Contract Name, the Contract Energy, the Adjust Buyer and Seller Loads, and the Seller Line Loss Coverage fields. After you complete your modifications, press the <Update Contract> button to permanently save the changes or press the <Cancel Update> button to ignore any modifications. Note that the Seller and Buyer fields are not active (i.e., light gray) and cannot be modified. Also, the contract path cannot be changed. If you wish to change these fields, you must delete the entire contract by using the <Delete> button and reenter the contract.

**<Quit>**

To exit from the firm contract screen, click on the <Quit> button.



Spot Market Network 11:00:43 am

**Node Transfer Limits**

Node Type: Energy Supply Node: 100

Transfer Capability (MW): 0.0 Generation Fraction: 0.00

< Add > < Delete > < Disable > < Browse > < Clear > < Exit >

Currently Adding to Outgoing Links.

Available Links	Incoming Links	Outgoing Links
NYU—NPCC (NEW YORK)	▶ ECR—ECAR	▶ SRV—SERC UACAR

SMN-16

**Purpose**

At supply nodes, transfer constraints allow you to represent internal or local transmission constraints within a given utility system. Substation nodes, on the other hand, may use node transfer constraints to represent particular equipment limitations associated with a specific transmission line connected at the node. In either case, this SMN constraint can be used to represent either additional transmission or equipment limitations at any given node.

**Options**

Screen SMN-16 is divided into two main parts. The upper half of the screen contains buttons and action pop-up selection windows, while the bottom half contains three display windows. In the middle of the screen, there is an action phrase that controls what is happening in the lower three windows.

To restrict the amount of energy that can be transferred through a node from one set of links to a second set of links, you must (1) define the node, (2) specify the transmission limit, and (3) identify the links that are subject to the transfer limit. On entering the node transfer limit screen, you must select a node type (i.e., supply, demand, or substation). To select the node type, click on the Node Type pop-up box, then select the node type. Next, enter the net transfer capacity next to the Capacity label. If the node type is an Energy Supply, you will be prompted to input the generation fraction, the fraction of energy sold to the grid from the selected supply source, which will be included in the node transfer limit equation (see Appendix 4A for more details).

At this point, the Node Type pop-up box has been deactivated and you cannot change the node type again until you either save or disregard the information on the screen. Click on the Node pop-up box and select a node to constrain the transmission limit. After you select a node, you cannot select another node until you either exit from or save the node you are currently working on. If the node you selected had been previously defined and saved with information from this menu, a pop-up screen will appear that asks you to specify whether you wish to make a new node transfer limit for this node or edit an existing node transfer limit. To enter a new node transfer limit for this node, click on the <New> button. To edit an entry that is already in the database, click on the <Edit> button, and from the window below, select the node transfer record you wish to edit and press the Enter key. The information will then be recalled and displayed in the appropriate windows at the bottom and top of the screen.

After you have made the above selections and data entries, you must identify two sets of links. The first set consists of one or more links that identify the transmission lines that go *into* the node, and the second set consists of links that identify transmission lines that go *out from* the node. The transfer constraints limit the maximum amount of power that can be transferred from the set of incoming links to the set of outgoing links. Only those links included in the formulation of the node transfer limit constraint should be included in either of the two link sets. (Refer to Equation 4A.16 and examples contained in Appendix 4A for more details.) You select both incoming links and outgoing links by using the action statement in the middle of the screen and the three windows in the lower portion of the screen.

The three windows at the bottom of the screen are labeled as follows: (1) Available Links, (2) Incoming Links, and (3) Outgoing Links. The *incoming* links and *outgoing* links windows are for display only. Even though you can highlight links and scroll through the information in these windows, no actions can be performed on these windows. All actions described below are performed on the link you select in the Available Links window.

Note the action phrase in the middle of the screen that begins with "Currently" and ends with "Links." This phrase controls the actions that are taken on the item selected in the lower left window labeled "Available Links." You construct the action phrase by using pop-up lists. Two options are available in each action phrase pop-up box. After the word "Currently," the pop-up list contains the following two action phrases: (1) "Adding to" and (2) "Deleting from." Before the word "Links," the pop-up list contains the following two actions: (1) "Incoming" and (2) "Outgoing." By changing the words in the pop-up boxes, you can construct four different phrases. The phrase combinations and the actions each phrase invokes are as follows.

### **Adding to Incoming Links**

The Adding to Incoming Links option allows you to select links from the Available Links window and add them to the Incoming Links window. The links that appear in the Available Links window are determined by the node you selected earlier and the information entered in the Transmission Lines (Links) screen. You can select a link in one of two ways. You can click

twice on a link in the Available Links window, and it will move from that window into the Incoming Links window; or you can use the cursor to highlight a link, then press the Enter key to select it and move it to the other window. You can keep adding links to the Incoming Links window until you have exhausted the list of available links or the maximum number of 10 links has been reached. If the number of links added to the Incoming Links window exceeds the number of links that can be displayed in the window at one time, a scroll bar will appear in the window (refer to Section 1.1).

### **Adding to Outgoing Links**

The Adding to Outgoing Links option allows you to select links from the Available Links window and add them to the Outgoing Links window. The links that appear in the Available Links window are determined by the node you selected earlier and the information entered in the Transmission Lines (Links) screen. You can select a link in one of two ways: You can click twice on a link in the Available Links window, and it will move from that window into the Outgoing Links window; or you can use the cursor to highlight a link, then press the Enter key to select it and move it to the other window. You can keep adding links to the outgoing links window until you have exhausted the list of available links or the maximum number of 10 links has been reached.

### **Deleting from Incoming Links**

The Deleting from Incoming Links option allows you to select links from the Available Links window and, in doing so, delete them from the Incoming Links window. When this phrase appears, the contents of the Available Links window will change from unused links to the links that are displayed in the Incoming Links window. If you select a link from the Available Links window, it will be deleted from the Incoming Links window and be placed back in the general selection list. You can select a link in one of two ways. You can click twice on a link in the Available Links window and it will be deleted from the window; or you can use the cursor to highlight a link, then press the Enter key to delete it. You can keep deleting links from the Incoming Links window by clicking on the links in the Available Links window until you have deleted all links that were in the Incoming Links window. If the number of available links to delete from that window is zero or you have deleted all Available Links from the window, a blank list will be displayed in both the Available Links window and the Incoming Links window.

### **Deleting from Outgoing Links**

The Deleting from Outgoing Links option allows you to select links from the Available Links window and, in doing so, delete them from the Outgoing Links window. When this phrase appears, the contents of the Available Links window will change from unused links to the links

that are displayed in the Outgoing Links window. If you select a link from the Available Links window, it will be deleted from the Outgoing Links window and be placed back in the general selection list. You can select a link in one of two ways. You can click twice on a link in the Available Links window and it will be deleted from the window, or you can use the cursor to highlight a link, then press the Enter key to delete it. You can keep deleting links from the Outgoing Links window by clicking on the links in the Available Links window until you have deleted all links that were in the Outgoing Links window. If the number of available links to delete from that window is zero or you have deleted all available links from the window, a blank list will be displayed in both the Available Links window and the Outgoing Links window.

Once you have selected the links that you want included in this transfer node limit, click on the <Add> button to store the information to the database or click on <Exit> to disregard the changes. Either of these actions will clear the information from the screen and reactivate the Node Type pop-up list to begin selection for another node.

To delete an existing node, activate the delete screen by clicking on the <Delete> button. The delete screen will *permanently* delete records from the file.

## Data Fields

Node Type: This field determines what nodes will be displayed in the "Node:" pop-up menu. Energy nodes, substation nodes, or sink energy nodes will be displayed as possible selections.

Net Transfer Capacity: Enter the maximum amount of energy (in megawatts) that can be transferred through the node from one set of user-defined incoming links to another set of user-defined outgoing links.

Generation Fraction: Enter the fractional amount of energy from the supply node link to the grid that is included in the node transfer limitation constraint.

Node: This node is currently selected to exhibit transfer limits.

## Buttons

- |           |   |
|-----------|---|
| <Add>     | To add the currently displayed information to the node transfer database, click on the <Add> button.  |
| <Delete>  | To <i>permanently</i> delete a node's transfer limit information, click on the <Delete> button.   |
| <Disable> | The disable feature allows you to temporarily remove node transfer limits from the SMN. To disable a node, click on the <Disable> button. This action will activate the Disable screen, |

which displays all node transfer limits. Use the spacebar to toggle between enabling and disabling the highlighted node.

**<Browse>**

To display all current node transfer limits, click on the <Browse> button.

**<Clear>**

To reset all values without saving the information currently being displayed, click on the <Clear> button.

**<Exit>**

To disregard any changes or information entered about this node and return to the previous screen, click on the <Exit> button.

CTC Adjustments for Firm Contracts			
Enter New Capability Value In The "User Adjusted" Field And Press The ENTER Key			
Direction 1 Adjustments			
CTC Name	Origin	Destination	Initial Capacity
KNEW	ECR	MAN	100.
KNEW	ECR	SRT	100.
KNEW	ECR	SRV	100.
CTC TEST	SPP	MAN	100.
CTC TEST	SPP	SRT	100.
*** Press F2 To Exit ***			
Direction 2 Adjustments			
CTC Name	Origin	Destination	Initial Capacity
KNEW	MAN	ECR	100.
KNEW	SRT	ECR	100.
KNEW	SRV	ECR	100.
CTC TEST	MAN	SPP	100.
CTC TEST	SRT	SPP	100.

SMN-17

### Purpose

The SMN-17 screen displays automatic adjustments made to CTCs on the basis of contracts and allows you to confirm or change these adjustments. This screen appears after you select the Run Model option on screen SMN-04 and the program has detected that adjustments to the CTCs may be necessary because firm sales contracts affect one or more lines that make up a CTC. If contracts do not affect any of the lines in a CTC, this screen will not appear.

### Options

- Once the Run Model option has been chosen, the CTCs and the node transfer limit values are automatically adjusted. You can then view the adjustments and make changes to the capability. If there are no contracts in the contract database, screen SMN-17 is not displayed. Screen SMN-17 shows the effect of the contracts on the CTCs. The two windows on the screen show the CTC names, origins, and destination nodes; the initial capability; and the SMN-adjusted capability. The last field in each window is the User-Adjusted field. To reach this field, click on the window desired and use the Tab key, arrow keys, or position indicator to reach the last field. The initial capability of the User-Adjusted field is the SMN-adjusted number. To enter a new value, position the cursor in the User-Adjusted field of the CTC you wish to change. Enter the new capability and press the Enter key. This action will override both the initial and the SMN-adjusted capability for the entire CTC. When you are finished, press the F2 key to exit and save any changes.

**Node Transfer Adjustments for Firm Contracts**

Enter New Capability Value In The "User Adjusted" Field  
And Press The ENTER Key

Node Transfer Limit Adjustments										
Code	Initial Capacity	SMN Adjusted	User Adjusted	IN	IN	IN	IN	IN	IN	▲
SPP	100.0	80.0	80.0	SRV	SRP	MAN	ECR			◆

Press F2 to Exit

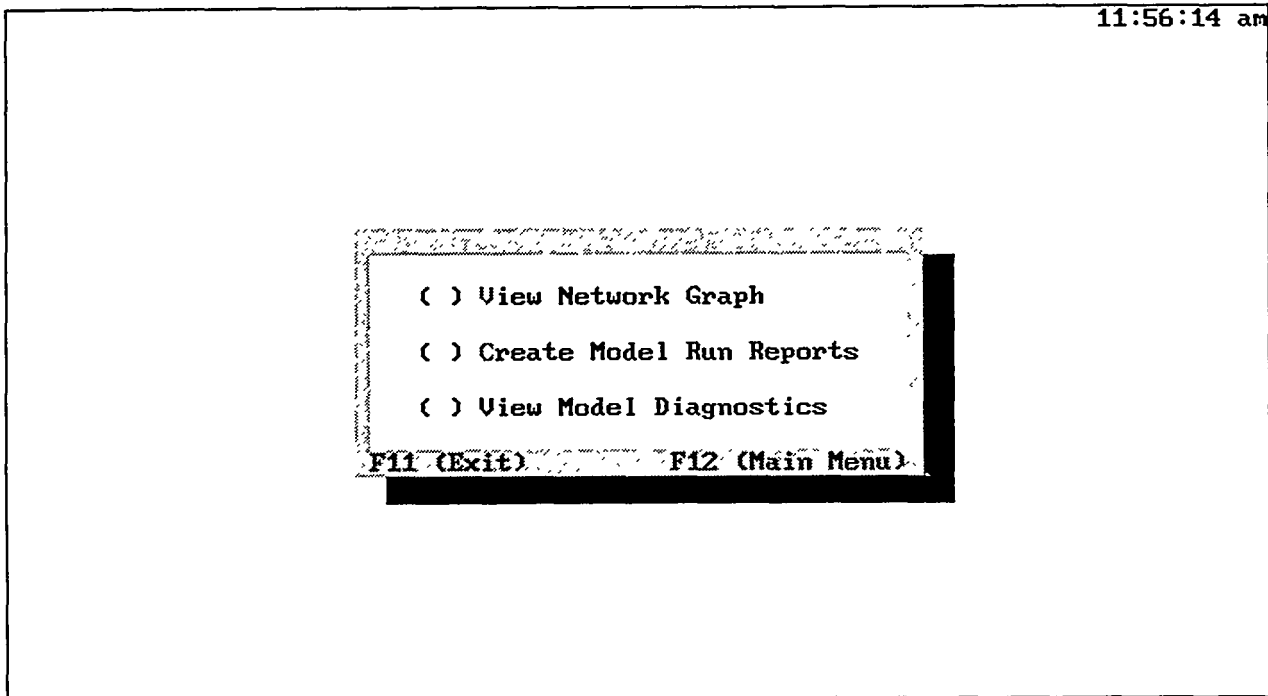
SMN-18

**Purpose**

Screen SMN-18 displays automatic adjustments to node transfer limits between contracts and allows you to confirm or change these adjustments. This screen appears after you select the Run Model option on screen SMN-04 and the program has detected that adjustments to a node flow limit may be necessary because firm sales contracts affect one or more lines that are attached to the node. If contracts do not affect any of the lines, screen SMN-18 will not appear.

**Options**

- Screen SMN-18 shows the effect of the contracts on the node transfer limit capability. If there are no contracts in the contract database, this screen is not displayed. The window in the screen shows the code, initial capacity, SMN-adjusted capacity, and all incoming and outgoing links associated with the transfer limit. The initial capability of the User-Adjusted field is the adjusted number. If a different capability is desired, it can be entered in the User-Adjusted field. To enter a new value, position the cursor in the User-Adjusted field of the node you wish to change. Enter the new capability and press the Enter key. This action will override both the initial and SMN-adjusted capability for the entire node. When you are finished, press the F2 key to exit.



## SMN-19

### Purpose

Screen SMN-19 allows you to select various options for viewing SMN case inputs and outputs.

### Options

- To view the network graph, select the first option. This option will display a map of SMN nodes and links along with state outlines. You can click on nodes and links to obtain more detailed input and output information. Also, the map indicates, by color, whether nodes and links are enabled or disabled.
- To create model run reports, select the second option. This option will display a menu of tables that can be generated by the SMN report writer (screen SMN-21). Click on various menu choices to view reports at the terminal or transmit to a printer. Menu choices include input and output data for nodes and links, including input tables for CTCs and node transfer limits.
- To view model diagnostics, select the third option.





**Buttons**

- <Print>** To send selected reports to the printer, click on the <Print> button.
- <Cancel>** To exit this screen and return to the previous screen, click on the <Cancel> button.
- <View>** To view the report on the screen, click on the <View> button.

**Short Run Marginal Cost Curve Buttons**

- <All>** This button is the default and signals that you want all short-run marginal cost curves as output.
- <Select>** Click on the <Select> button to select a subset of short-run marginal cost curves for output. A pop-up window appears that lists nodes. From this window, use the spacebar to select the nodes for which you wish to see curves.

Note: In order for the All and Select buttons to be active, you must check the box next to the phrase "Short Run Marginal Cost Curves."

Spot Market Network							9:58:39 am
Study: Demonstration Study							
System: Expanded US System							
Case: Base Case II							
Variable Supply/Fixed Demand Node							
ID	Name	Latitude	Longitude	Minimum Generation (MW)	Profit Margin (\$/MWh)		
ECR	ECAR	39.4	83.5	15030.00	2.0	9	
ERC	ERCOT	32.0	100.5	8779.00	2.0	9	
MAC	MAAC	39.8	75.0	5851.00	2.0	9	
MAN	MAIN	43.0	89.5	7839.00	2.0	9	
MEX	MEXICO	27.0	110.0	800.00	0.0	9	
MPC	MAPP CANADA	51.0	99.0	5365.31	2.0	9	
MPU	MAPP USA	47.0	99.0	4900.00	2.0	9	
NPM	NPCC MARITIMES	48.0	68.0	1222.70	2.0	9	
NPO	NPCC ONTARIO	47.0	80.5	5977.87	2.0	9	
NPQ	NPCC QUEBEC	49.0	73.5	21324.08	2.0	9	
NPU	NEPOOL	43.0	70.0	1297.00	2.0	9	
NYU	NPCC (NEW YORK)	43.0	76.0	4927.00	2.0	9	
< Done > < More >				Column: 0			

SMN-22

The preview screen (SMN-22) shows you an accurate representation of the printed report in screen format. To scroll left and right on the report screen, use the arrow keys or click and drag the position indicator on the bottom of the screen to the desired location. The column indicator displays the current most visible column on the left side of the screen. The Home and End keys can also be used to move to the far left and far right sides of the screens, respectively. To view the next page of the report, click on the More button or use the M hot key or the PageDn key. If you wish to exit, click on the Done button. Keep in mind that you can only page forward through the preview screen; you cannot page backward.



determine the map scale (i.e., geographical boundaries are displayed) and the center of the display. This automated procedure maximizes the map scale so that all node locations are displayed and the latitude/longitude aspect ratio is preserved. Note that this center is indicated not only by the crosshairs but also by an empty circle.

If the case has been viewed in previous sessions, the image last displayed on the screen will appear when the GIS is invoked. The center of the map can be changed, and the size of the image can be increased or decreased.

Click on the dot at the midpoint of a link to display transmission line information, or click on a node to display node information.

## Options

- Click on any empty area (i.e., any area except the buttons, nodes, or link dots) on the map to change the center of the map. For example, if the current display shows a map of the contiguous United States and you wish to recenter the map on the state of Maine, click on Maine. Note that the crosshairs that indicate the center of the screen are now located in the middle of Maine. The empty circle marks the center of the original map as determined by the automated mapping procedure. To recenter to the original position, click on the <Center> button. After a map is recentered, a portion of the state boundaries may not be displayed. To display all state boundaries, press the <Redraw > button.
- Click on any filled circle to display node information.
- Click on any transmission line dot to display link information.
- The graphical image currently displayed on the screen can be printed or sent to a graphics file by the <Print> button. Once the option is selected by a mouse click, three print options will be displayed in the upper left portion of the screen. Click on the <Print to Printer> button to send the image to a printer; click on the <Send to PCX> button to send the image to a PCX file; or click on the cancel button if you do not want to print.

After you click on the <Print to Printer> button, a title box will appear on the screen. Enter the title in this box by using the keyboard if you want a title to appear on the upper center portion of the printout. If you do not want a title on the printed image, the title box must be left empty (i.e., no characters, including spaces). Press the Enter key after entries in the title box are completed. Note that both the Delete key and the Backspace key are in operation in the title box.

**Buttons**

- <Done>** To return to the previous menu, click on the <Done> button.
- <Print>** To activate the print options buttons, click on the <Print> button.
- <Redraw>** To refresh the display, click on the <Redraw> button.
- <Zoom>** To activate the zoom feature, click on the <Zoom> button. To increase or decrease the size of the graphical image, click the mouse on the <Zoom> button, and a zoom selector along with a zoom scale number will appear on the screen. In addition, <Do Zoom> and <Cancel Zoom> buttons are also displayed. The first time a case is displayed, the zoom scale number is 1.0, and the zoom selector has a sliding bar at its midpoint. To enlarge the size of the image, click and hold down the mouse on the right side of the scroll selector. As you hold the button down, the sliding bar becomes longer, and the zoom scale number increases in magnitude. Once you reach the desired magnification, release the mouse button and click on the <Do Zoom> button. For example, if you want to double the size of the image, click and hold the mouse button on the right side of the scroll pop-up and release the mouse button when the zoom scale number is at 2.0. The image will be redrawn. However, part of the image may not be displayed because it can no longer fit on the screen. If you want to make the image smaller, click and hold on the left side of the zoom selector until the desired reduction is achieved and press the <Do Zoom> button. After the image is redrawn, a larger geographical area may be displayed on your screen.
- If you invoke the zoom feature a second time, either in the current or subsequent mapping sessions, the zoom indicator and the zoom scale number will reflect the current magnification relative to the initial image that was displayed the first time the mapping option was invoked for the current case. This initial image is determined by the SMN GIS.
- You can exit the zoom mode by clicking on the <Cancel Zoom> button. This button also removes the zoom selector with the sliding bar, the zoom scale number, and the two zoom buttons, namely, <Do Zoom> and <Cancel Zoom>.
- <Detailed>** To display detailed variable-supply/fixed node and link results for an SMN simulation, click on the <Detailed> button. Node

results appear around the node and include system load (upper left), generation (upper right), spot market price (lower right), and net sales (lower left). Transmission results are located at line midpoints and represent the amount of energy received by the purchaser; results include losses. The direction of the power flow is indicated by an arrow point at the end of a line segment. If no energy transactions occur on a line, no value is reported on the midpoint of the line and no arrow is displayed.

Depending on the magnitude of the power flows, numbers displayed on the map are either in megawatts or gigawatts, as indicated by the legend located in the lower left of the screen. Click on the <General> button to remove the detailed information.

#### <Center>

To return the center of the display to the geographical center of the map, click on the <Center> button. The geographical center of the map is indicated by a single gray circle located at the midrange of latitude and longitude ranges of the map.

## 4.5 ERROR MESSAGES

This section contains a listing of warnings and error messages used in SMN, with brief notations on interpretation or appropriate responses.

- **1 record is disabled**

One additional record in this database has been disabled.

- **A contract must be selected for editing!**

Select a contract first by clicking on the browse window and highlighting a contract before trying to edit it.

- **All Files Located in the Destination Directory Will be DESTROYED!**

The action you have chosen will permanently erase all files in the destination directory.

- **All nodes linked to this node are already in the path! The path must be cancelled**

A path has been created from which there is no exit via an unused node. To avoid a circular contract flow, you must re-create the path.

- **Another contract with this name already exists! Each contract must have a unique name**

Duplicate contract names are not allowed. You must enter a contract name that has not been used yet.

- **Case CANNOT be Copied onto Itself!!!**

You must select a different destination case to which to copy the files.

- **Case Name Cannot Be BLANK**

You must enter a case name. You cannot have a blank field entry here.

- **Code Cannot Be Blank**

You must enter a three-letter code in this field.

- **Default help access error, press any key to continue**

An error has occurred while the help files were being accessed. Press any key to resume.

- **Duplicate CTC Choose Another Name**

This name is already in the CTC database. You must choose a name that is not already in use.

- **Duplicate Line Name Choose Another**

This line name is already in the links database. You must choose a name that is not already in use.

- **ERROR: Check data for Node Transfer Limits!**

An undefined input or output node has been encountered in the node transfer limits input file. Check the information in the node transfer limits database and rerun.

- **ERROR: Check line path for LTF contracts!**

There is an incomplete line path in the firm contracts input file. Check the information in the firm contracts database and rerun.



- **ERROR: Generation and total capacity of incoming links at node <number> are short of satisfying the demand by <number>.**

The sum of the total potential resources of a node is less than the total demand at that node. Check the information in the energy source nodes and links databases and rerun.

- **File <filename> does not exist**

The specified file <filename> cannot be found on the disk.

- **File TABLE2.TXT not found! Check substation nodes!**

The substation nodes input file has not been found. Check the information in the substation nodes database and rerun.

- **File TABLE3.TXT not found! Check fixed supply/fixed demand nodes!**

The fixed-supply/fixed-demand nodes input file has not been found. Check the information in the fixed-supply/fixed-demand nodes database and rerun.

- **Function Step Values Must Be in Ascending Order!**

Step values must be ascending. Correct the curve so that the values are ascending.

- **Help File Access Error. Press any key to continue**

An error has occurred while the help files were being accessed.  
Press any key to resume.

- **Incomplete data entry**

Insufficient information to complete this entry is present. Enter data in the remaining fields.

- **Line Loss Has To Be  $\geq 0$**

The line loss must be greater than or equal to 0. It cannot be negative.

- **Max. Number Reached You Must Delete Before Adding Another Node**

A maximum of 50 active nodes of each type (variable-supply/fixed-demand, substation, and fixed supply/demand) are available. When this number is reached, a node must be deleted before another one can be added.

- **Need : <byte count>, Only: <byte count> Available..Press any Key**

When a case is backed up, a check is performed to determine whether the required disk space is available. If there is insufficient disk space, another disk with more space should be inserted or a new drive should be chosen.

- **No backup data found on this drive!**

When a transferred case is being restored, if the required files are not present on the disk, the restoration cannot continue.

- **No Current Entries to Browse**

No items are available to browse in this database. You must add items first.

- **No records are disabled**

No records are disabled.

- **Number Must Be  $\geq 0$**

The current entry must be a non-negative value.

- **Origin and Destination Nodes CANNOT be the Same!**

You must select different origin and destination nodes. They cannot be the same node.

- **Please Enter The Data**

Enter the required data before trying to exit or continue.

- **Please Insert Diskette or Bernoulli**

Insert the required disk into the drive you have selected before continuing with this selection.

- **Please Note The Error...You May Wish to Print Screen**

An error has occurred while the ICARUS program was running. Check model inputs and rerun the program.

- **Preliminary checking for the existence of feasible solution:**

The input data have been read and will now be subject to a basic validation process. This process identifies many common errors in network construction but does not guarantee a feasible solution.

- **Profit Margin Must Be  $\geq 0$**

The profit margin cannot be a negative number.

- **Range : <number> to <number>**

The entered value falls outside the range for this field. Enter a number within the specified range of values.

- **Records were deleted**

Records were permanently deleted from the database.

- **Records were NOT deleted**

Records were not deleted from the database.

- **SMN ERROR DETECTED: <error Message>**

An error has occurred during the execution of the SMN module.

- **Sorry..Backup Files Cannot Be Found**

The files that contain the backup information cannot be located. Make sure the correct disk is inserted in the drive.

- **Sorry, Problem With Creating Curves**

A problem has occurred while the curve files were being created.

- **Sorry, the specified files were not found**

Files could not be located on the disk.

- **Sorry, this is a read-only disk!**

The write-protect tab is preventing write-access to the disk. Insert another disk or disable the write-protect tab on the current disk.

- **Study Name Cannot Be BLANK**

You must enter a study name. You cannot have a blank field entry here.

- **System Name Cannot Be BLANK**

You must enter a system name. You cannot have a blank field entry here.

- **That Case Already Exists!!**

A case with that name already exists. You must enter a case name that is not in use under the current system.

- **That Study Already Exists!!**

A study with that name already exists. You must enter a study name that is not currently in use.

- **That System Already Exists!!**

A system with that name already exists. You must enter a system name that is not in use under the current study.

- **The above records in the Links Database will be Destroyed**

The specified records in the links database will be destroyed. This warning alerts you that more information than what was tagged will be destroyed. Because of the interdependence of this database on the information that you wish to delete, affected records in the links database will also have to be deleted in order for consistency to be maintained.

- **The above records in the CTC Database will be Destroyed**

Because of the interdependence of this database on the information that you wish to delete, the specified records in the CTC database will also have to be deleted in order for consistency to be maintained.

- **The above records in the Contract Database will be Destroyed**

Because of the interdependence of this database on the information that you wish to delete, the specified records in the contract database will also have to be deleted in order for consistency to be maintained.

- **The above records in the Node Limits Database will be Destroyed or Changed**

Because of the interdependence of this database on the information that you wish to delete, the specified records in the node limits database will also have to be deleted in order for consistency to be maintained.

- **The Following Systems and Cases will be PERMANENTLY DELETED**

When a study is selected for deletion, all systems and cases under the study are also deleted. This warning alerts you to all the items that will be deleted.

- **The formulation has been successfully created.**

The preliminary checking has been completed and a LINDO formulation has been created for the given network model.

- **The Minimum Generation Must Be  $\geq$  The First Generation Level**

When the minimum generation is entered, it must be greater than or equal to the first generation level on the step function.

- **The Minimum Generation Must Be  $\leq$  The Last Generation Level**

When the minimum generation is entered, it must be less than or equal to the last generation level on the step function.

- **The Number of points currently entered is less than the original number of points entered.**

If the number of points on the step function is changed to less than the original number of points, the values for the step function above the number entered for the number of steps will be discarded.

- **The source and destination nodes must be different**

The source and destination nodes cannot be the same. Make another selection.

- **There Are No More Links That Can Be Added**

When links are added to a CTC, if all links are currently being used on the CTC, no more additions are possible.

- **There Aren't Any Items to Delete**

No entries are available to delete in this database. Items must be added before they can be deleted.

- **There Aren't Any Items to Disable/Enable**

No entries are available to disable or enable in this database. Items must be added before they can be disabled or enabled.

- **There Must Be At Least 1 Function Step**

You must enter a step function that contains at least one step before proceeding.

- **This Line Already Exists! A Duplicate line Will NOT Be Created. Press OK To Continue.**

This line combination already exists. The information entered will be disregarded.

- **This Node is Outside the Contiguous U.S.**

The latitude or longitude value you have entered puts this node outside the United States.

- **This Node will be in Outer Space!**

The latitude or longitude value you have entered puts this node in outer space. Please check the latitude and longitude coordinates.

- **Unknown Problem with disk.**

An unknown problem with the disk or disk drive has occurred.

- **WARNING: Adjusted line capacity is less than zero! Check LTF transfer on line from node <number> to node <number>. This run will assume zero capacity of the line instead of <number> MW.**

The capacity of the line is less than the LTF contract adjustments. In the formulation, the capacity of the line has been set to zero. If this value is not desired, check the information in the links and LTF databases and rerun.

- **WARNING: Adjusted load in node <number> is less than zero! Check LTF transfer to this node. This run will assume zero load instead of <number> MW.**

The demand at the node is less than the total amount subtracted for adjustments. In the formulation, the demand of the node has been set to zero. If this value is not desired, check the information in the energy source nodes and the various contract databases and rerun.

- **WARNING!!!! A CTC Exists in Conjunction With This Link. The CTC Values Will Not Be Automatically Changed**

When a link is changed, CTC values are not automatically updated with new information.

- **WARNING!!! There Must Be At Least Two Links Associated With This Node. A Transfer Limit On This Node Is Not Possible**

A node transfer limit on this node is not possible because an insufficient number of links are available. At least two different links must be available for a node transfer.

- **Warning: This Scenario Already Exists...Restoring Will PERMANENTLY replace existing files with backed up files.**

This scenario is currently active on the disk. If you choose to restore the information, the current scenario will be permanently overwritten.

- **You Must Create LINKS first!!!**

Before you can create a CTC, you must enter links into the transmission lines (links) screen.

- **You Must Enter A Code Name**

The code name must be a unique combination of any three alphanumeric characters. The first character must be alphabetic.

- **You must enter nodes from Options 1 through 3 first!**

Before you can enter links, you must create nodes in one or more of the first three screens (variable-supply/fixed-demand, substation, or fixed supply/demand nodes).

- **You must enter At Least 1 Function Step**

Valid nodes in the variable-supply/fixed-demand node screen must have a step function. This step function must have a minimum of one step.

- **You must have at least 2 existing links!**

Before a CTC can be created, you must enter a minimum of two links.

- **You must have at least 1 link and 2 nodes!**

For a contract to be created, at least one link and two nodes must be present.

- **You must have at least 1 existing node!**

To have a node transfer limit on a node, at least one node must exist.

- **You must have at least 2 different existing links!**

A node transfer limit must have at least two different existing links to be valid.

These error messages are produced by the SMN utility and its programs. Error messages other than those listed above may occur and may be a result of FoxPro or dGE graphics error handling routines. For FoxPro error messages, refer to the *FoxPro Developers Guide*.



#### 4.6 REFERENCES

Dunlop, R.D., et al., 1979, "Analytical Development of Loadability Characteristics for EHV and UHV Transmission Lines," *IEEE Transactions on Power Apparatus and Systems*, PAS-98:607 (March-April).

EPRI, 1982, *Transmission Line Reference Book: 345 kV and Above*, 2nd ed., Electric Power Research Institute, Palo Alto, Calif.

Powel, C.A., 1955, *Principles of Electric Utility Engineering*, p. 187, The Technology Press of Massachusetts Institute of Technology, Cambridge, and John Wiley & Sons, New York.

**APPENDIX 4A**

**SPOT MARKET NETWORK MODEL  
MATHEMATICAL FORMULATION**



**APPENDIX 4A****SPOT MARKET NETWORK MODEL  
MATHEMATICAL FORMULATION**

This appendix describes the underlying structure of the SMN model. Sufficient detail is provided to allow you to draw comparisons between the physical characteristics of electricity transactions and the methodology and formulation adopted in the SMN model. Such background information is necessary to understand the assumptions and limitations of the modeled energy system and to permit proper interpretation of model results.

Several factors, in addition to production costs, must be taken into consideration in a spot market model. These factors include the following:

- Physical transfer limits on transmission lines and within network nodes,
- Line specific transmission loss factors,
- Multiple transmission routes between interconnected systems,
- Line rights and wheeling charges for transmission line usage,
- Generating resources and transmission line usage earmarked for LTF power commitments,
- Sales-for-resale transactions,
- Minimum "profit" margins, and
- Minimum system generation levels.

Each of these factors is addressed by the SMN model, either through cost factors in the objective function or through constraints designed to represent physical characteristics or limitations. The mathematical formulation for treating these parameters is described in this appendix.

A specific energy network representation comprises an arrangement of various network nodes and links. Links represent transmission capabilities, and network nodes represent generation resources, substations, and demand centers. The combination of SMN network nodes and corresponding links is used to physically model a given network topology and its operational characteristics. Furthermore, the physical limitations of the network are represented through the use of SMN constraints.

#### 4A.1 SMN OBJECTIVE FUNCTION

Because the SMN model is based on a linear programming formulation, the model description is defined in terms of an objective function and a set of constraints. Section 4.3 outlines the basic concepts of the SMN model. These concepts are expressed here as an explicit objective function and a set of constraints. The subscript notation adopted for Equation 4A.1 and the equations that follow conveys the naming conventions adopted for the FORTRAN program that prepares LINDO inputs. A footnote is provided with Equation 4A.4 to serve as an example.

The overall objective of the SMN model is to minimize the cost of serving loads. As shown in the objective function below (Equation 4A.1), costs include (1) electricity production costs, (2) wheeling costs, and (3) transaction costs (or minimum profit margin). Mathematically, the objective function is represented as follows:

$$\text{Minimize } \sum_u \sum_k c_{uk} G_{uk} + \sum_i \sum_j t_{ij} W_{ij} + \sum_u m_u X_{un} , \quad (4A.1)$$

where

$c_{uk}$  = short-run marginal cost (or incremental cost) of segment  $k$  at supply network node  $u$  (\$/MWh);

$t_{ij}$  = wheeling cost on wheeling link  $i, j$  (\$/MWh);

$m_u$  = transaction cost for the distribution component of supply network node  $u$  to transport energy to its grid connection component (\$/MWh);

$G_{uk}$  = generation level within segment  $k$  at supply network node  $u$  (MW);

$W_{ij}$  = power flow on each network wheeling link  $i, j$  (MW);

$X_{un}$  = power flow from the distribution component to the grid connection component of supply network node  $u$  (MW);

$u$  = supply network node name, where  $u_n = u \text{ } \cancel{1} \text{ } \cancel{2} \text{ } \dots \cancel{50}$  (e.g.,  $u = \text{CEC}$  for Commonwealth Edison Company) and  $n$  is the node number corresponding to this node name;

$n$  = node number corresponding to supply network node name  $u$ , where  $n = 001, 002, 003, \dots, 050$ ;

$k$  = short-run marginal cost segment for supply network node  $u$ , where  $k = 1, 2, 3, \dots, 99$ ;

$i$  = node  $i$  for a given network node, where  $i = 001, 002, 003, \dots, 150$ ; and

$j$  = node  $j$  for a given network node, where  $j = 001, 002, 003, \dots, 150; j \neq i$ .

The SMN model implementation can model up to 150 individual network nodes and all possible interconnecting link combinations. The formulation requires that the following node numbers correspond to the following network node types:

Node Numbers	Network Node Type	Reference Name
1-50	Variable-supply/fixed-demand	Supply node
51-100	Substation	Substation node
101-150	Fixed-supply/fixed-demand	Demand node

These restrictions are somewhat arbitrary and can be modified through programming changes, as required. Node limits are presented here to describe the indexing of variables in the current formulation.

The objective function is subject to several classes of constraints. Each constraint is designed to directly represent various physical power systems limitations and characteristics in the SMN model. Most of the constraints apply Kirchhoff's laws (energy balance equations) to power flow between the components that make up a given supply node and to power flow between various network nodes. In general, power flows into a node are considered to be negative, while power flows out of a node are treated as positive flows. Net power flows follow the same convention and are expressed in megawatts, and any consideration for reactive power flows is neglected. For this discussion, power flows are generally synonymous with energy flows because the SMN model is typically applied on an hourly basis so that the time component cancels out of the equations (i.e., MWh/h = MW). The following section describes detailed node characteristics and the formulation of necessary SMN constraints. The last section describes the transmission modeling capabilities incorporated in the SMN model.

#### 4A.2 NETWORK NODES

The general descriptions of the nodes and links provided in Section 4.3 do not provide detailed information on the SMN formulation. This section is intended to provide that detail to assist in accurate network development and appropriate interpretation of model results.

Network nodes comprise various internal components that facilitate the mathematical model formulation. In general, network nodes must have a corresponding grid connection component to be a functional and interactive element of the SMN model. That is, each node type by definition can interact with the rest of the system. Network nodes may also have

several other components: a supply step function, a distribution component, an energy demand, and an energy dump capability. The exact function of each node component and component configuration is discussed in the following sections. The manner in which these internal components are arranged and used distinguishes network nodes into the three distinct types: supply node, substation node, and demand node.

### 4A.2.1 Substation Node Representation

#### 4A.2.1.1 Conceptual Configuration

Conceptually, the substation node is simplest to understand. A network node configured as a substation node contains only a grid connection component (Figure 4A.1). The substation node does not contain any generation or demand components, but it does support transmission links to and from the node. Several links are required to model a transmission line. As discussed in more detail in Section 4A.3, transmission lines are composed of direct links and wheeling links, each of which is bidirectional. For now, it is sufficient to know that direct links represent transmission transfers that do not incur additional wheeling fees, whereas wheeling links are designed specifically to model wheeling transactions and to account for associated wheeling costs. All grid connection components support a complete interconnection to other interconnected network nodes. In fact, supply nodes and demand nodes each have the grid connection component as a key element of its internal structure, as described in Section 4A.2.3.

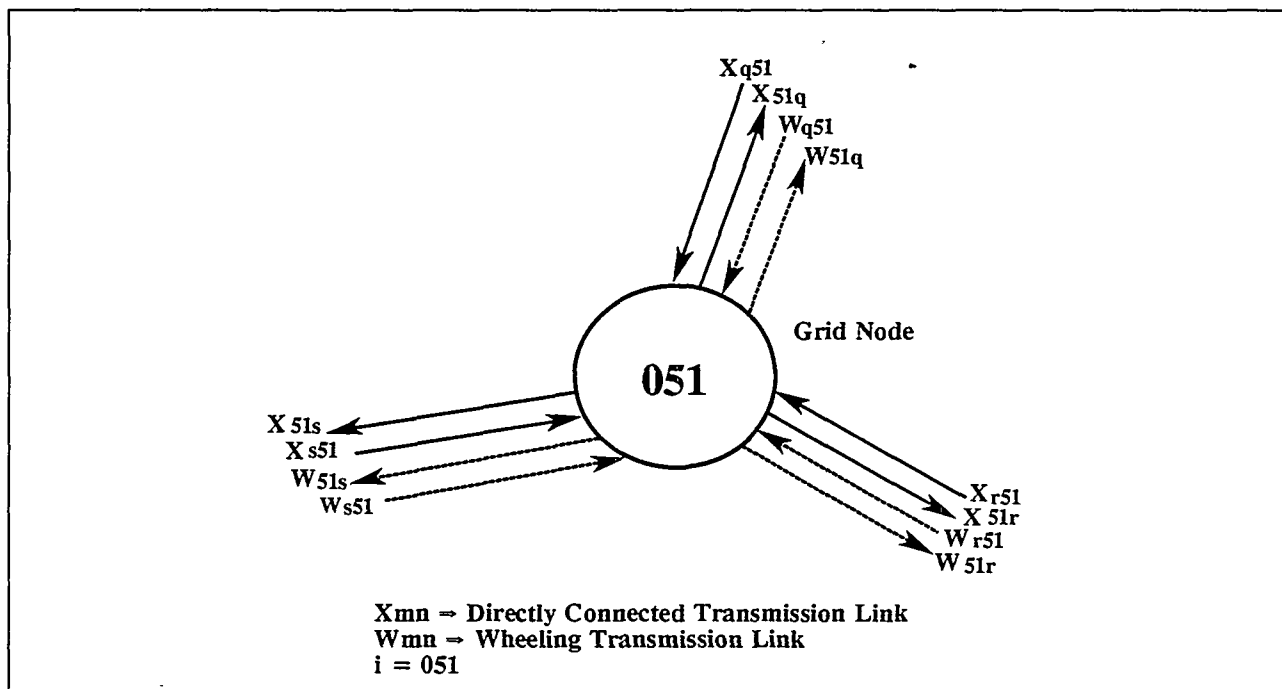


FIGURE 4A.1 Graphical Depiction of a Substation Node

### 4A.2.1.2 Substation Node Constraint

The substation node plays an integral part of the SMN transmission capabilities. Equation 4A.2 describes the energy balance at the substation node. This constraint simply applies Kirchhoff's current law at the substation node to ensure that all energy supplied to the node exits through the node (a guarantee of energy conservation). Also, power flows on transmission links are adjusted in this constraint to account for transmission line losses.

$$\sum_j \{ (1+l_{ij}) X_{ij} - X_{ji} + (1+l_{ij}) W_{ij} - W_{ji} \} = 0 \quad \text{for all } i \text{ substation nodes} \quad (4A.2)$$

where

$X_{ij}$  = power flow on the direct link from substation network node  $i$  to network node  $j$ ;

$X_{ji}$  = power flow on the direct link from network node  $j$  to substation network node  $i$ ;

$W_{ij}$  = power flow on the wheeling link from substation network node  $i$  to network node  $j$ ;

$W_{ji}$  = power flow on the wheeling link from network node  $j$  to substation network node  $i$ ;

$l_{ij}$  = transmission loss factor for the line between substation network node  $i$  and network node  $j$ ;

$i$  = substation network node index 051, 052, 053, ..., 100; and

$j$  = network node index 001, 002, 003, ..., 150,  $j \neq i$ .

## 4A.2.2 Demand Node Representation

### 4A.2.2.1 Conceptual Configuration

Next in node complexity is the demand node (Figure 4A.2). This node simulates a fixed hour demand, a fixed (nondispatchable) generation source, and an associated connection to the transmission grid. Either of the generation or demand components may be zero. If only the generation component is zero, the fixed-demand node may also be referred to as a sink node, which indicates that the node consumes energy only from the transmission grid. On the other hand, if only the local demand is zero, the demand node may be called a fixed supply node, which indicates that the node must supply a specific amount of energy to the grid at a fixed production cost (in dollars per megawatt-hour). In either case, the demand node presented in Figure 4A.2 illustrates the potential energy injection into the grid, the potential local demand, and the direct connect and wheeling interconnections to the transmission grid.



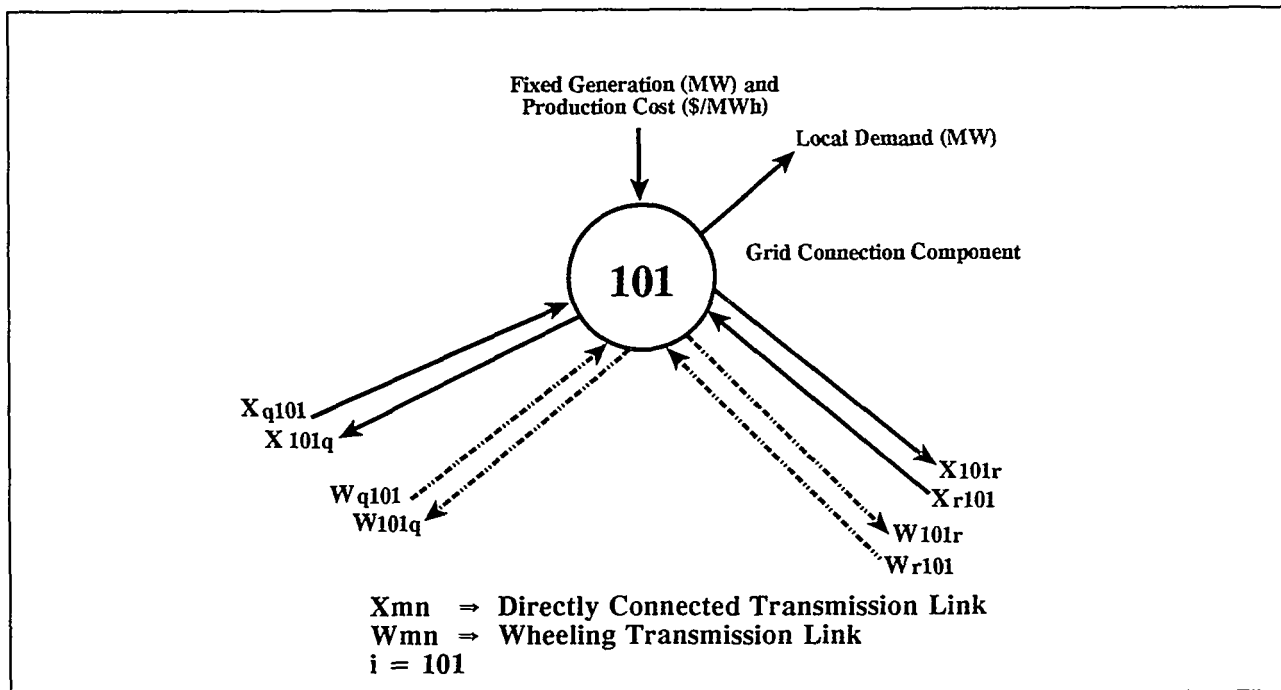


FIGURE 4A.2 Graphical Depiction of a Demand Node

#### 4A.2.2.2 Demand Node Constraint

An energy balance equation similar to the substation node is required for demand nodes (Equation 4A.3). For each demand node,  $d_i$  can represent either a net demand or a net generation surplus. If the net flow at the node is negative, it represents an energy sink node. If the net flow at the node is positive, it represents a net generation surplus that must be injected into the grid. The sign of  $d_i$  is determined by data inputs from the SMN model user interface. Note that transmission line losses are accounted for by variable  $l_{ij}$ .

$$\sum_j \{ (1+l_{ij}) X_{ij} - X_{ji} + (1+l_{ij}) W_{ij} - W_{ji} \} = d_i \text{ for all } i \text{ demand nodes} \quad (4A.3)$$

where

$X_{ij}$  = power flow on the direct link from demand network node  $i$  to network node  $j$ ;

$X_{ji}$  = power flow on the direct link from network node  $j$  to demand network node  $i$ ;

$W_{ij}$  = power flow on the wheeling link from demand network node  $i$  to network node  $j$ ;

$W_{ji}$  = power flow on the wheeling link from network node  $j$  to demand network node  $i$ ;

$l_{ij}$  = transmission loss factor for the line between demand network node  $i$  and network node  $j$ ;

$i$  = demand network node index 101, 102, 103, ..., 150; and

$j$  = network node index 001, 002, 003, ... ,150,  $j \neq i$ .

### 4A.2.3 Supply Node Representation

#### 4A.2.3.1 Conceptual Configuration

The variable-supply node is more complicated because the model requires that several energy balance equations be separable to achieve proper constraint formulation. While the variable-supply nodes are actually composed of several components, as shown in this section, the aggregate of these components is depicted as single node points in the final SMN graphical network display. Figure 4A.3 illustrates the main components of the variable-supply node: supply cost step function, distribution component, local energy demand component, dumped energy component, and grid connection component. In addition, direct connect and wheeling interconnections to the transmission grid are provided. Each of these components is designed to represent specific network characteristics. The supply cost step function represents the short-run marginal costs of all the generation resources represented by the supply node. Section A.2.3.3 and Figure 4A.4 provide a detailed discussion of the cost step function.

As shown in Figure 4A.3, there are two ways in which a node's local demand can be satisfied: either by internal generation (from the supply node) or by energy from the transmission grid (through the grid connection component). The distribution component is required to administer the various internal node energy transfer paths. Note that generated energy at the node may supply local load, be directed to the transmission grid, or be discharged at the energy dump component. The distribution component achieves this multidirectional generation allotment function.

If any of the energy produced at a supply node is not used to serve local demand or is not supplied to the grid, the energy must be dumped, as in an energy spill from a hydroelectric power plant. Energy is dumped only when the network's collective minimum generation levels (i.e., from must-run units) are greater than the collective network energy demands or when there is insufficient transmission capability between a supplier with excess generation and various network demand centers (i.e., both demand nodes and demand components of supply nodes). Although each of the supply node components has been introduced, the actual mathematical formulation further characterizes the operation and interaction of these components through additional SMN model constraints.

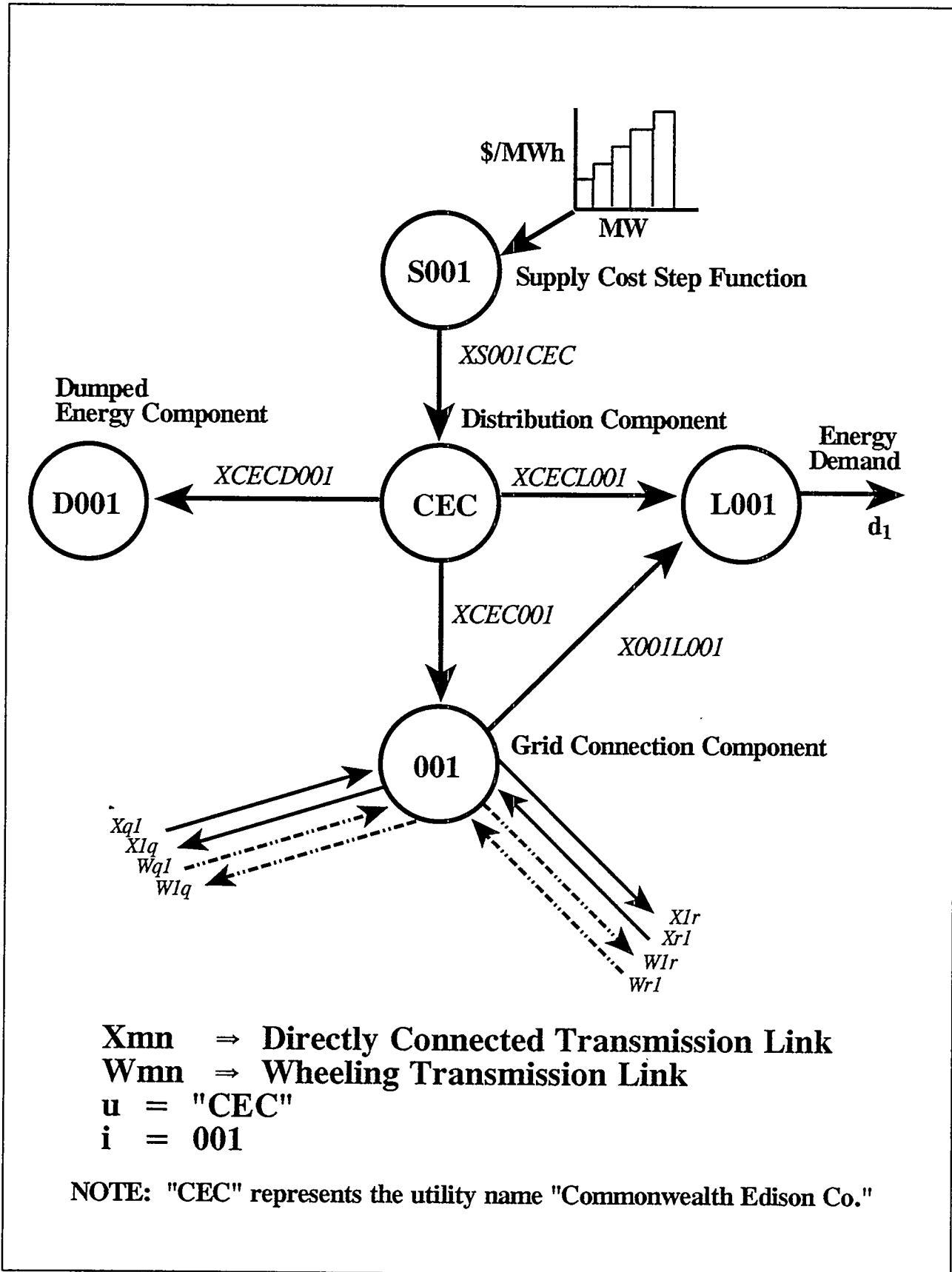
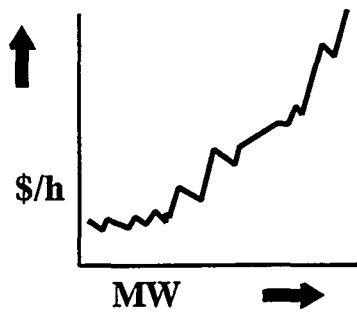
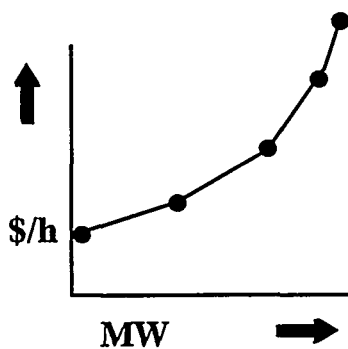


FIGURE 4A.3 Depiction of the Supply Node Configuration



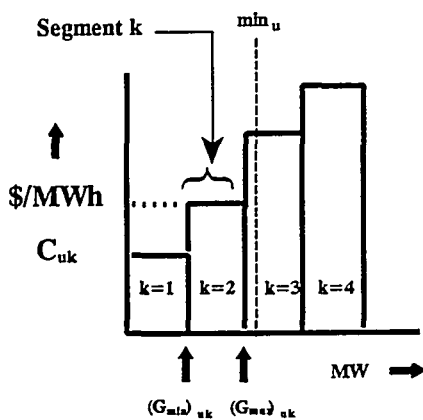
The ICARUS generated production cost curve is represented as a non-smooth curve relating \$/h to power output (MW) over the range of feasible loads for a given aggregated utility or power pool region.

Figure A4a



An intermediate program transforms ICARUS cost curves into a piece-wise linear, convex, segmented cost curve. Depending on the number of user-defined points and the shape of the curve, the algorithm attempts to reduce curve-fitting error. The resulting curve now represents a smoothed relationship between cost (\$/h) and generated output (MW).

Figure A4b



Numerical values obtained from the intermediate program are used to construct the final short-run marginal cost step function, which represents the aggregated system incremental costs. The slopes ( $C_{uk}$  in \$/MWh) and generation ( $(G_{min})_{uk}$  and  $(G_{max})_{uk}$  in MW) of each segment  $k$  are identified for a given aggregated system (at network node  $u$ ). The resulting discrete step function represents the incremental cost of generation at network node  $u$ .  $min_u$  represents the minimum generation requirement at network node  $u$ .

Figure A4c

FIGURE 4A.4 Intermediate Steps to Final Step Functions

### 4A.2.3.2 Supply Node Energy Balance Equations

Four constraints in the SMN model (Equations 4A.4, 4A.5, 4A.7, and 4A.8) are used to ensure an energy balance between the components of a supply node. Equation 4A.4 describes the energy balance at the distribution component; specifically, all energy supplied to the distribution component from the supply cost step function serves local energy demands, is dumped, or is transferred to the grid connection component. Note that  $i$  is the supply network node index (001, 002, ... 050) corresponding to a specific supply network node  $u$ .<sup>1</sup> Thus, for any given value of  $u$ , there is a single (and unique) value for the index  $i$ .

$$X_{ui} + X_u L_i + X_u D_i - X S_{iu} = 0 \quad \text{for all } u, \quad (4A.4)$$

where

$X_{ui}$  = power flow from the distribution component to the grid connection component of supply network node  $u$ ;

$X_u L_i$  = power flow from the distribution component to serve the local demand of supply network node  $u$ ;

$X_u D_i$  = power flow from the distribution component to the dumped energy component of supply network node  $u$ ;

$X S_{iu}$  = power flow from the cost step function to the distribution component of supply network node  $u$ ;

$u$  = supply network node name, where  $u_i = \mu, \nu, \xi, \dots, \theta_0$  (e.g.,  $u = \text{CEC}$  for Commonwealth Edison Company), and  $i$  is the node number corresponding to this node name; and

$i$  = node number corresponding to supply network node name  $u$ , where  $i = 001, 002, 003, \dots, 050$ .

Equation 4A.5 performs the energy balance operation for the local energy demand component. The power flow to serve demand  $d_i$  equals the sum of power flows from the distribution component and power flows from the grid connection; that is, demands are served via the systems own generation or through energy purchases from the grid.

$$- X_u L_i - X_i L_i = - d_i \quad \text{for all } u, \quad (4A.5)$$

where

---

<sup>1</sup> The variables  $X_u L_i$ ,  $X_u D_i$ , and  $X S_{iu}$  used in Equation 4A.4 do not signify multiplications. Instead, they correspond to the notation used to define variable names within the Fortran program that creates coded LINDO input for SMN. For example,  $X_u L_i$  becomes XCECL001 (a single power flow variable) when  $u = \text{CEC}$  (Commonwealth Edison Company) and  $i = 001$  (CEC is designated to be network node number 001). This labeling convention also holds for the other equations in this appendix.

$$-X_u L_i - X_i L_i = -d_i \text{ for all } u, \quad (4A.5)$$

where

$d_i$  = local electricity demand (MW) for supply network node  $u$ ;

$X_u L_i$  = power flow from the distribution component to serve the local demand of supply network node  $u$ ;

$X_i L_i$  = power flow from the grid connection to serve the local demand of supply network node  $u$ ;

$u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ , and  $i$  is the node number corresponding to this node name; and

$i$  = node number corresponding to supply network node name  $u$ , where  $i = 001, 002, 003, \dots, 050$ .

Local demands are adjusted to account for LTF purchases and sales. Sales are added to the local system demand  $d_i$  of the seller, and purchases are subtracted from  $d_i$  of the buyer.

While the local demand of a supply node can be served with energy from its corresponding grid connection component, Equation 4A.6 restricts the delivery of energy to the local demand component to be no greater than a user-specified amount:

$$X_i L_i \leq g_{ui} \text{ for all } u, \quad (4A.6)$$

where

$X_i L_i$  = power flow from the grid connection component to serve local demand node of supply network node  $u$ ;

$g_{ui}$  = maximum amount of power from the grid connection component allowed to satisfy local load at supply network node  $u$  (MW);

$u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ , and  $i$  is the node number corresponding to this node name; and

$i$  = node number corresponding to supply network node name  $u$ , where  $i = 001, 002, 003, \dots, 050$ .

Because of the grid connection constraints described below (Equations 4A.7 and 4A.8), the source of the energy transferred from the grid connection to serve local loads,  $X_i L_i$ , is guaranteed to originate from a purchase (i.e., from direct and wheeling links, as specified in Equation 4A.7). This prevents imports from the grid from flowing on links  $X_{u'}$  which are intended to represent flows out from the node to the grid (Equation 4A.8).

In addition to Equations 4A.7 and 4A.8, which ensure an energy balance relationship at the supply node's grid connection component, Equation 4A.7 also guarantees that all power flows originating from the network (i.e., all links except for link  $X_{ui}$ ) either serve local demands or are passed through the grid connection component on wheeling links (or some combination of the two). Because power that flows on wheeling links adds to objective function costs (Equation 4A.1), this relationship guarantees that transfers from the grid that do not serve local demand are treated as wheeled rather than direct transactions. Where appropriate, wheeling charge rates can be set equal to zero, in which case wheeling links will behave in the same manner as direct links. Section 4A.3 gives more details on transmission line representations in the SMN model.

$$X_i L_i - \sum_j \{ X_{ji} - (1+l_{ij}) W_{ij} + W_{ji} \} = 0 \quad \text{for all } u, \quad (4A.7)$$

where

$X_i L_i$  = power flow from the grid connection component to serve local demand at supply network node  $u$ ;

$X_{ji}$  = power flow on the direct link from network node  $j$  to the grid connection (subscript  $i$ ) of supply network node  $u$ ;

$W_{ij}$  = power flow on the wheeling link from grid connection component  $i$  at supply network node  $u$  to network node  $j$ ;

$W_{ji}$  = power flow on the wheeling link from network node  $j$  to grid connection component  $i$  at supply network node  $u$ ;

$l_{ij}$  = transmission loss factor on the line between grid connection component  $i$  at supply network node  $u$  and network node  $j$ ;

$u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ , and  $i$  is the node number corresponding to this node name;

$i$  = node number corresponding to supply network node name  $u$ , where  $i = 001, 002, 003, \dots, 050$ ; and

$j$  = network node index 001, 002, 003, ... ,150,  $j \neq i$ .

Note that energy injections into the grid connection component via  $X_{ui}$  and the direct link energy out of the grid connection component are not included in Equation 4A.7. This part of the energy balance formula is contained in Equation 4A.8.

As shown in Equation 4A.8, all energy production that originates from supply network node  $u$  for transfer to the grid connection component must be directed onto direct links. This constraint is consistent with the notion that any given system or utility cannot wheel its own

generated energy. Losses on the transmission line between the supply grid connection component and the network node  $j$  are accounted for by loss factor  $l_{ij}$ .

$$X_{ui} - \sum_j (1+l_{ij}) X_{ij} = 0 \quad \text{for all } u, \quad (4A.8)$$

where

$X_{ui}$  = power flow from the distribution component to the grid connection component of supply network node  $u$ ;

$X_{ij}$  = power flow on the direct link from supply network node  $u$  to network node  $j$ ;

$l_{ij}$  = transmission losses on the line between supply network node  $u$  and network node  $j$ ;

$u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ , and  $i$  is the node number corresponding to this node name;

$i$  = node number corresponding to supply network node name  $u$ , where  $i = 001, 002, 003, \dots, 050$ ; and

$j$  = network node index 001, 002, 003, ... ,150,  $j \neq i$ .

Equation 4A.8 also precludes a system from redirecting energy sent to the grid to serve its local demand. Also, all of the energy sent to the grid from a node is forced to flow on direct links. Wheeling occurs only when energy is passed through a node from elsewhere on the network.

#### 4A.2.3.3 Representation of Generation Costs

Generation costs at a supply node are represented in the network with short-run marginal cost step functions. Each function is made up of the individual segments that define the cost step functions, as shown in Figures 4A.3 and 4A.4. The derivation of a cost step function that represents a multi-unit system involves three phases of development. While these steps are transparent to the user when the ASF procedure is invoked (screen SMN-23), the methods are described here for documentation purposes. Figure 4A.4 illustrates the intermediate steps used to derive the final step functions, as described below.

In the first stage, the ICARUS dispatch model is run for various load levels, which range from minimum system generation to the system on-line capacity (i.e., the system peak load is set equal to system on-line operable capacity). The minimum generation is set to the larger of two values: (1) 15% of on-line capacity (i.e., summed from all units not on scheduled maintenance) or (2) the sum of base hydroelectric capacity, base block capacity for the least expensive generating unit, and firm purchase capacity. This procedure is designed to ensure that the minimum will not be set too low for a feasible ICARUS simulation to be completed.



For the special case of preparing SMN cost curves, load duration curves input into ICARUS for each period are flat, so that each period curve represents a fixed load over a short period of time (e.g., each period corresponds to one hour). ICARUS is then run for 24 periods with load levels distributed over the periods to span the range of minimum-to-maximum generation levels. The cost estimates at the various load levels are used to construct short-run marginal cost curves. Because ICARUS is coded to interpret simulation periods as portions of a year (e.g., week[s]), results for SMN must be adjusted to reflect costs for a portion of a day (e.g., hour[s]). Thus, total costs are divided by  $8760/24 = 365$  hours/period to provide the correct conversion.

Cost estimates made with ICARUS explicitly account for scheduled and unscheduled outages. Total unserved energy costs are included and priced at the user-defined rate (cost of most expensive peaking unit times a user-defined multiplier). Example results are illustrated in Figure 4A.4a. Because of scheduled maintenance requirements, the procedure uses the user-selected month and day (screen SMN-07) to determine which units are operational. The schedule is obtained from a separate standard ICARUS run that assigns maintenance outages for all units. When units are taken off-line for maintenance, the curve shape and range of viable production levels change accordingly.

The second stage of development involves transforming and smoothing the ICARUS-produced energy cost curve. A transformation algorithm modifies the number of cost curve points (as specified by the user) and guarantees that the curve is convex. The slopes of the segments of the resultant piecewise linear cost curve increase as a function of increasing generation levels. The transformation algorithm contains logic that minimizes the squared error difference between the original curve produced by ICARUS and the modified curve. The outcome is illustrated in Figure 4A.4b.

The third and final stage involves the construction of a short-run marginal cost step function. The step heights are set equal to the slopes of the convex curve segments. Thus, the marginal costs are treated as being fixed over the range of each generation level (i.e., step width) that bound each linear segment on the convex cost curve. Figure 4A.4c illustrates a hypothetical example that contains four steps. As indicated for screen SMN-09, the appropriate number of steps depends on the size of the system being modeled. Values of 2-24 steps are recommended for systems ranging from single units to large power pools.

The SMN model provides flexibility in modeling either detailed or aggregated cost data depending on the level of detail contained in available data and the type of analysis that is being conducted. When supply nodes are used to represent individual generating units, the cost curve can be approximated directly by Equation 4A.9. (That is, ICARUS does not have to be run and the curve derivation [outlined in Figure 4A.4] may be bypassed).

$$C_i = (H_k \times FC \times 1000 + V) \text{ for all generation levels } k, \quad (4A.9)$$

where

$C_k$  = production cost (\$/MWh) at generation level  $k$  (MW);

$H_k$  = unit heat rate (Btu/kWh) at generation level  $k$ ;

$FC$  = unit fuel costs (\$/10<sup>6</sup> Btu);

$k$  = number of steps from minimum generation to installed capacity; and

$V$  = unit variable O&M costs (\$/MWh).

Since unit heat rates typically decrease (i.e., the unit becomes more efficient) as a function of increasing unit generation, the production cost curve is usually not convex. To represent this general shape within the SMN model, the first step of the cost function may have a marginal cost that is greater than one or more of the steps that follow it. However, the maximum generation level assigned to the first block must be less than the overall unit minimum generation level.

Also, the marginal cost for all steps after the second step must increase; that is, the cost curve is convex after the minimum generation level. In general, units are split into two blocks (i.e., steps) where the first block represents the base capacity (minimum generation level) and the second block represents the peaking or load following portion of the unit. Where applicable, a third block may also be used to represent spinning reserves or operation above the recommended design capacity. When the third block represents spinning reserves, the price of this block must be set artificially high so that it is used only in emergency situations.

#### 4A.2.3.4 Supply Function Constraints

Several supply step function constraints are required for the proper implementation of the cost step function. The objective function (Equation 4A.1) uses the variable  $G_{uk}$  to represent the generation dispatched from the  $k$ 'th segment of supply network node  $u$ . The sum of generation from all of the  $k$  segments equals the maximum generation level of the represented unit or system. Supply function constraints, along with the marginal cost profile, ensure that the steps are "loaded" in the appropriate order: that is, generation for the first step is at its maximum before any generation is assigned to the second step, and the second step is at its maximum generation before any generation is assigned to the third step and so on. The constraints also require generation levels to be within the feasible minimum and maximum operational levels.

Equation 4A.10 states that the sum of the dispatched generation for all  $k$  segments must equal the total generation that is delivered to the system's distribution component. In essence, Equation 4A.10 in conjunction with Equations 4A.4 and 4A.7 require that the exact amount of energy produced by supply resources is dispatched by the system to satisfy local demand or is sold to the grid and distributed to any other demand center.

$$\sum_k G_{uk} - XS_{iu} = 0 \quad \text{for all } k \text{ and } u, \quad (4A.10)$$

where

- $G_{uk}$  = segment  $k$  generation level (dispatched megawatts) at supply network node  $u$ ;
- $XS_{iu}$  = power flow (MW) from the supply cost step function to the distribution component of supply network node  $u$ ;
- $u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ , and  $i$  is the node number corresponding to this node name;
- $i$  = node number corresponding to supply network node  $u$ , where  $i = 001, 002, 003, \dots, 050$ ; and
- $k$  = short-run marginal cost segment for supply network node  $u$ , where  $k = 1, 2, 3, \dots, 99$

Equation 4A.11 puts a similar bound on the generation range corresponding to a given segment  $k$ . The generation of  $G_{uk}$  must be no greater than the available generation within a given segment  $k$  at supply network node  $u$ .

$$G_{uk} \leq (G_{\max})_{uk} - (G_{\min})_{uk} \text{ for all } k \text{ and } u, \quad (4A.11)$$

where

- $G_{uk}$  = segment  $k$  generation level (dispatched) at supply network node  $u$  (MW);
- $(G_{\max})_{uk}$  = maximum generation of segment  $k$ ;
- $(G_{\min})_{uk}$  = minimum generation of segment  $k$ ;
- $u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ ; and
- $k$  = short-run marginal cost segment for supply network node  $u$ , where  $k = 1, 2, 3, \dots, 99$ .

Equation 4A.12 supplements Equation 4A.11. This constraint forces the generation of supply network node  $u$  to be greater than or equal to the minimum generation requirement at node  $u$ .

$$XS_{iu} \geq \min_u \text{ for all } u, \quad (4A.12)$$

where

- $XS_{iu}$  = power flow from the supply cost step function to the distribution component of supply network node  $u$ ;

$min_u$  = minimum generation at supply network node  $u$  (MW);

$u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ , and  $i$  is the node number corresponding to this node name; and

$i$  = node number corresponding to supply network node name  $u$ , where  $i = 001, 002, 003, \dots, 050$ .

### 4A.3 TRANSMISSION LINKS

The transmission grid is used to deliver energy from supply resources to local loads or to transport energy over longer distances to serve more remote loads. Depending on the service area boundaries, these remote loads may or may not belong to the system serving the loads. In either case, the grid connection component provides access to energy purchases and sales. As described in Section 4.3, transmission capabilities (individual lines or groups of lines) are represented in the network by links between nodes. Links that connect the supply curve to the grid connection (Figure 4A.3) are used to represent lines that transfer energy to the grid connection component for transport to other utility systems. Links from the grid connection to the local demand are used to represent the transfer of energy from a delivery point on the grid to a local load center.

When any two grid nodes are connected, the transmission capability is represented by four links, which consist of two direct connect links (one in each direction) and two wheeling links (one in each direction). The two different link types are needed to distinguish between direct transactions (spot market purchases or sales, or sales for resale) and wheeling contracts. Because utilities are often directly connected through transmission facilities that are fully or jointly owned, utilities do not need to pay wheeling fees for direct transactions across these lines. On the other hand, wheeling charges are used to capture transmission usage fees for third-party transactions. This twofold link applies to all SMN network nodes.

#### 4A.3.1 Net Transfer Capability Constraints

Specific transmission line transfer capabilities are formulated as SMN model constraints. The net flow on a line is constrained by power flow limits, as shown in the equations that follow. Additional adjustments are made to the power flow limits on each line to account for LTF contracts. The amount of the firm contracts (in megawatts) is subtracted from the transfer capability of the lines from seller to buyer and are added to the transfer capability of the lines from buyer to seller. Equations 4A.13 and 4A.14 express net flow capability limits for each link in terms of direct flows and wheeling transactions:

$$X_{ij} + W_{ij} - X_{ji} - W_{ji} \leq b_{ij} \quad \text{for all } i \text{ and } j, i \neq j,$$

and

(4A.13)

$$X_{ji} + W_{ji} - X_{ij} - W_{ij} \leq b_{ji} \quad \text{for all } i \text{ and } j, i \neq j, \quad (4A.14)$$

where

$X_{ij}$  = power flow on the direct link from network node  $i$  to network node  $j$ ;

$X_{ji}$  = power flow on the direct link from network node  $j$  to network node  $i$ ;

$W_{ij}$  = power flow on the wheeling link from network node  $i$  to network node  $j$ ;

$W_{ji}$  = power flow on the wheeling link from network node  $j$  to network node  $i$ ; and

$b_{ji}$  = power flow limit on link  $i,j$  (adjusted for firm contracts).

#### 4A.3.2 Composite Transmission Capabilities

While Equations 4A.13 and 4A.14 are used to limit flows on individual lines, another type of constraint is used to limit the net capability of several transmission lines or links. In many control areas, transmission lines are often treated as a composite "bundle" of individual transmission lines for operational purposes. The CTC may not be the numerical sum of the individual transmission line capabilities because of parallel effects or stability concerns. As a result, the following constraint is defined to model CTCs explicitly:

$$\sum_n \{ X_{ij} - X_{ji} + W_{ij} - W_{ji} \} \leq ctc_k \quad \text{for all } k \text{ CTC constraints}, \quad (4A.15)$$

where

$X_{ij}$  = power flow on the direct link from network node  $i$  to network node  $j$ ;

$X_{ji}$  = power flow on the direct link from network node  $j$  to network node  $i$ ;

$W_{ij}$  = power flow on the wheeling link from network node  $i$  to network node  $j$ ;

$W_{ji}$  = power flow on the wheeling link from network node  $j$  to network node  $i$ ;

$ctc_k$  = maximum power transfer limit for CTC  $k$  (MW);

$n$  = set of all links associated with CTC  $k$ ; and

$i,j$  = network nodes  $i$  and  $j$  connected to transmission link  $n$ ,  $i \neq j$ .

### 4A.3.3 Internal Node Transmission Constraints

One additional SMN transmission constraint is used to represent transmission limitations that may exist at a grid node. In some instances, limiting the transfer capability to or from a particular network node is not enough to capture the physical limitations that may exist within the node. For example, multiple line capacities into and out of a node may be greater than the internal equipment (e.g., transformer, substation, or internal transmission link) transfer capacities within a given node. Equation 4A.16 can represent such considerations.

An essential concept in the following constraint definition is that one set of constrained links to each transfer-limited node is treated as "incoming constrained links" and another set is considered to be "outgoing constrained links," even though the net flows on either set of links may be incoming or outgoing. Thus, flow from an incoming constrained link may be into or out of the transfer-limited node, just as flows to outgoing constrained links may be into or out of the transfer-limited node.

The remaining links are considered "unconstrained" (i.e., constrained only by the line limits, not by the node transfer limits), and the incoming flows over these links are treated in the transfer limit equation. These conventions have been adopted to conceptually represent directional constraints through a node that selectively affect some lines but affect others only indirectly. Equation 4A.16 introduces the necessary limitations by using the variables that represent (1) incoming flows and (2) outgoing flows on the outgoing constrained links, (3) incoming flows on the unconstrained links, and (4) internal generation sent to the grid (generation factor  $gf_u$  controls the effect internal generation has on transfer limits). Examples are provided, following Equation 4A.16, to help illustrate the way these limits can be applied. At any given node  $i$ , the node transfer limits are defined by the following:

$$\sum_j (1+l_{ij}) X_{ij} - \sum_j X_{ji} - \sum_k X_{ki} - gf_u X_{ui} \leq N_i \quad \text{for transfer limit at node } i, \quad (4A.16)$$

for all  $j$  and  $k, j \neq k \neq i$

where

$gf_u$  = generation factor for supply network node  $u$  (set between 0 and 1 for supply nodes [0 implies internal generation has no influence on transfer limit, 1 implies transfer limit is relaxed by full capacity of transfers to the grid]; set at 0 for all other nodes);

$N_i$  = maximum power flow for constrained transfers through network node  $i$ ;

$X_{ij}$  = outgoing power flow on the constrained outgoing links from network node  $i$  to node  $j$ ;

$X_{ji}$  = incoming power flow on the constrained outgoing links from network node  $i$  to node  $j$ ;

$X_{ki}$  = incoming power flow on the unconstrained links from network node  $k$  to node  $i$ ;

$X_{ui}$  = power sent to grid from node  $u$ ;

$u$  = supply network node name, where  $u_i = u_1, u_2, u_3, \dots, u_{50}$ , and  $i$  is the node number corresponding to this node name;

$i$  = node number corresponding to supply network node name  $u$ , where  $i = 001, 002, 003, \dots, 050$ , or other nodes, where  $i = 051, 052, 053, \dots, 150$  ( $gf_u$  and  $X_{ui}$  are ignored for nodes numbered greater than 050);

$j$  = network node index for nodes connected to constrained outgoing links; and

$k$  = network node index for nodes connected to unconstrained links.

Note that  $X_{ij}$ ,  $X_{ji}$ , and  $X_{ki}$  may represent direct links or wheeling links.

To help you gain a better understanding of the internal node transfer limit constraint, several examples are provided in this section. The first example, depicted in Figure 4A.5, shows substation network node 51, which has connections to grid nodes 1 and 8. Energy is transferred from link  $X_{8,51}$  through network node 51 to link  $X_{51,1}$ . Assume that the transfer limit on each of the two links is 200 MW, while the limit through node 51 is 100 MW. Figure 4A.5 illustrates a case in which the net power flow through the node is at the maximum limit. Note that although 100 MW is transferred through the node, node 1 receives only 94.3 (100/1.06) MW because of a 6% transmission loss.

When there are multiple links at node 51, the interpretation of the power flows through a node become more complex (Figure 4A.6). At node 51, assume that the constrained incoming link is  $X_{8,51}$  and the constrained outgoing link is  $X_{51,1}$ . The remaining links between nodes 51 and 101 and between nodes 51 and 6 are the unconstrained links: that is, these two links are physically connected to the "internal" transmission system of the node such that they do not affect the critical transmission path between nodes 8 and 1. Assuming the transfer limit at node 51 is 100 MW for flows from node 8 to node 1, Figure 4A.6 shows the maximum transfer is met by having 100 MW of link  $X_{8,51}$  flow to link  $X_{51,6}$ . The remaining 100 MW on link  $X_{8,51}$  is transferred to link  $X_{51,1}$ . An additional 6 MW of power flow on link  $X_{51,1}$  compensates for the 6% transmission losses and is supplied from link  $X_{101,51}$ . Link  $X_{101,51}$  also supplies link  $X_{51,6}$  with 6 MW of generation to compensate for losses on that link.

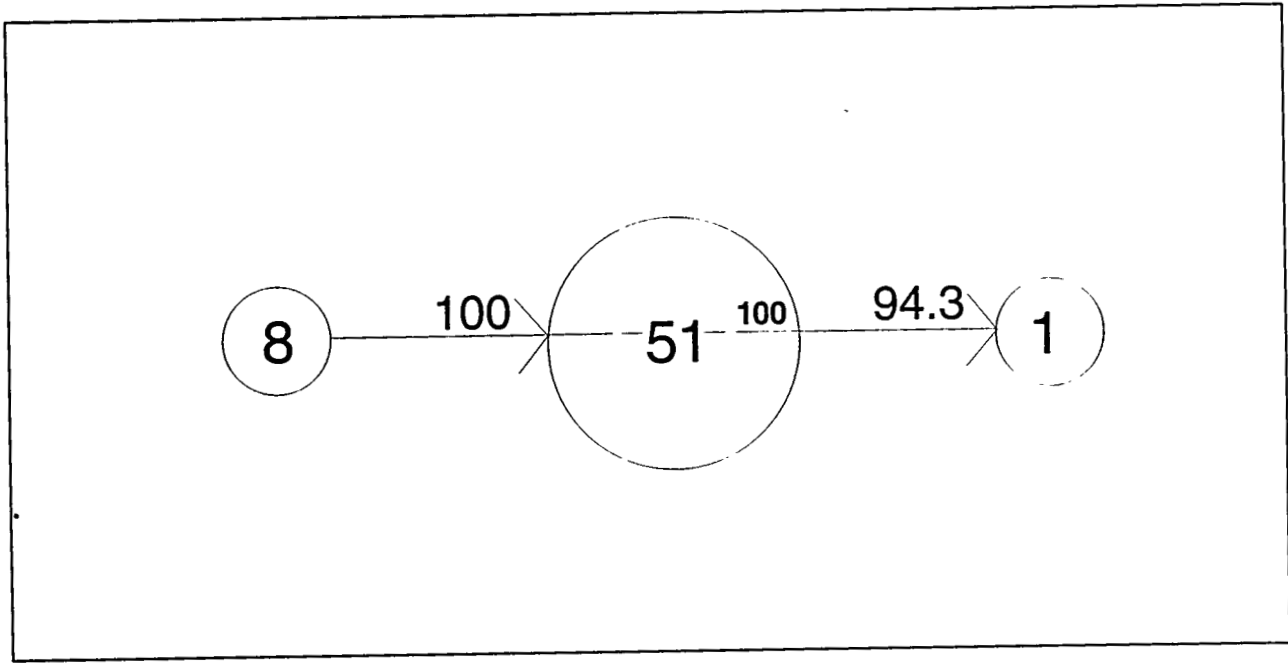


FIGURE 4A.5 Depiction of Internal Node Transmission Constraint with Two Lines

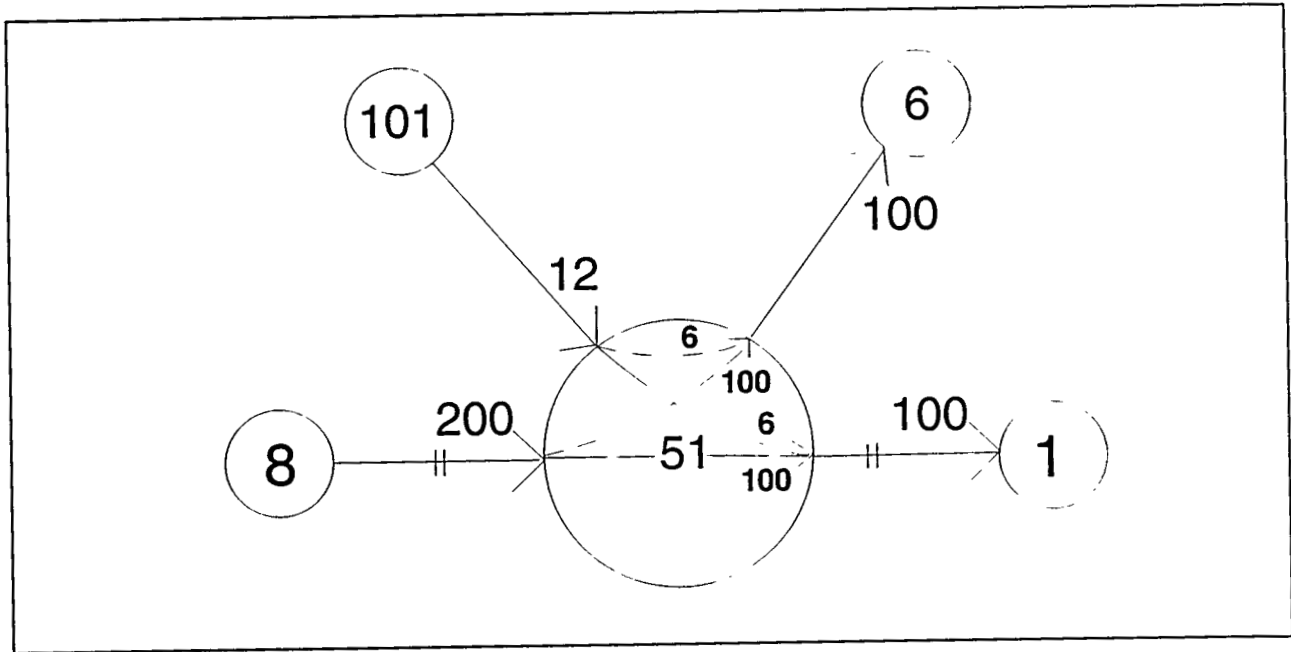


FIGURE 4.A6 Internal Transmission Limits With Several Links



When the transfer limit is reduced to 0 MW, as shown in Figure 4A.7, the 200 MW from incoming link  $X_{8,51}$  is transferred to links  $X_{51,101}$  and  $X_{51,6}$ . Node 101 receives only 88.7 MW from node 8, and it sends 106 MW back through node 51, which arrives as 100 MW at node 1. The net flow on link  $X_{101,51}$  is the difference between incoming and going generation. Link  $X_{51,1}$  receives 106 MW from link  $X_{100,51}$ , but only 100 MW reaches node 1 because of transmission losses of 6%. The transfer limit of 0 MW from link  $X_{8,51}$  to link  $X_{51,1}$  is satisfied. These examples illustrate that application of the internal node transfer limit constraints requires careful attention for proper implementation. Two or more compatible limits may be specified at a single node for more complex relationships.

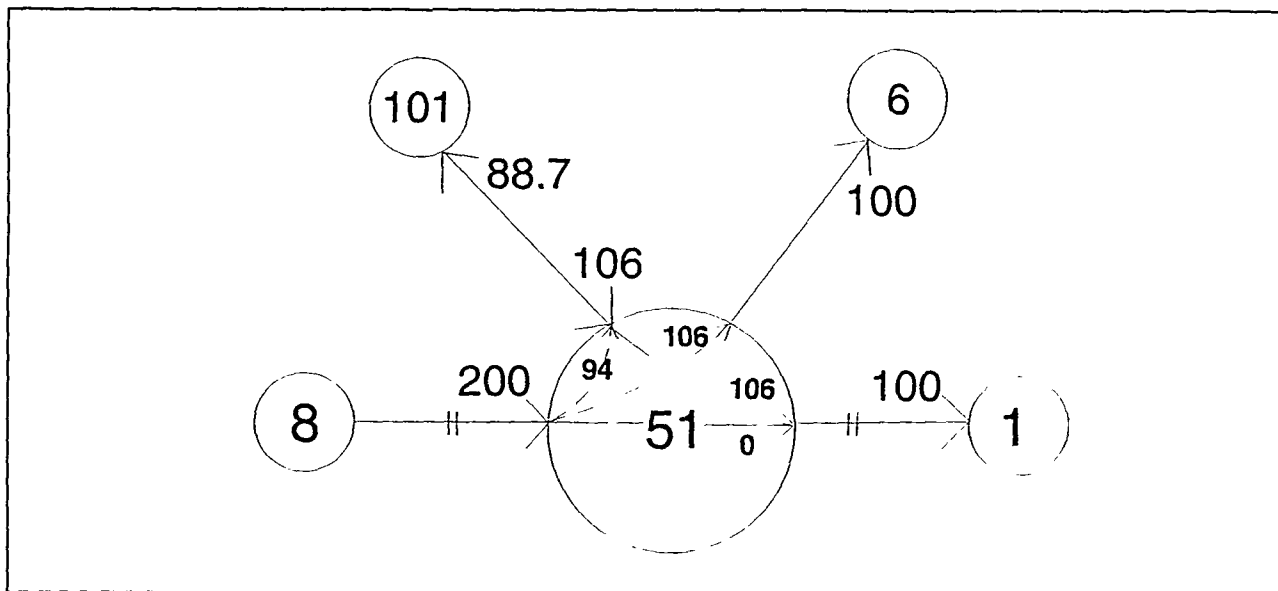


FIGURE 4A.7 Internal Transfer Limit with Several Links and a Zero Limit