Synthetic Electric Utility Systems – Expansion to 2000

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Prepared by
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Schenectady, New York

ELECTRIC POWER RESEARCH INSTITUTE

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Technical Planning Study 78-766

Final Report, April 1979

Prepared by

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ABSTRACT

An earlier technology planning study resulted in an EPRI report titled Synthetic Electric Utility Systems for Evaluating Advanced Technologies, EPRI EM-285. That work developed representative scenario utility systems and data for use in evaluating the use of new technologies in the United States' electric power systems. The development of those scenario systems was limited to 1985, and contained much peripheral data relating to load curves, stability information, and transmission topology.

This report may be considered an expansion of EM-285, but is a more modest effort. The report contains sufficient information to make generation and transmission changes to the 1985 systems so as to result in representative systems for 1990, 1995 and 2000. It must therefore be used in conjunction with EM-285. Also, based on the uses to which the synthetic systems have been put, it was deemed not required to provide system schematic diagrams of the expanded systems. Data listings and load flow output are available from this office on magnetic tape.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

It is important that EPRI have a systematic method for assuming the value of new alternative technologies or new developments on utility systems. An approach to making systematic generic assessments is to use methods of utility system planning engineers. However, it is neither required nor feasible to apply those methods to the entire U.S. system, owing to complexity and constraints of time and money. A practical solution is to develop realistic scenario systems of reasonable size to represent the diverse characteristics of various portions of the U.S. system. To that end, a project was authorized, resulting in a report titled Synthetic Electric Utility Systems for Evaluating Advanced Technologies, EPRI EM-285. That report described the development and characteristics of six synthetic utilities as they were envisioned to exist in 1985.

When later it was found that many studies required an examination through the year 2000, an extension study was authorized, culminating in this report, which describes the characteristics of the generation and transmission system of each of the synthetic utilities as they are envisioned to exist in 2000.

PROJECT OBJECTIVE

The objective of this study was to expand the six previously developed 1985 generation and transmission systems to the years 1990, 1995, and 2000, using generally acceptable criteria of reliability and quality of service, and to document the results.

PROJECT RESULTS

The providing of synthetic utility data on six generation and transmission systems allows comparison studies of new technologies to be made in the environment of representative utility systems without the specificity and other considerations of using actual utility systems.

The broad uses to which the 1985 scenarios were put may now be extended in studies through the year 2000.

Harry W. Colborn, Project Manager
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CONTENTS

SUMMARY

The six synthetic utilities' generation and transmission systems, previously developed for 1985 and reported on in EPRI EM-285, Synthetic Electric Utility Systems for Evaluating Advanced Technologies, are expanded in this report to the year 2000. Intermediate developments are detailed for 1990 and 1995, showing changes in both generation and transmission and installations from the 1985 base. This detail is presented in tabular form, available on magnetic tape.

The expansion of the systems was done on the basis of reasonable reliability criteria and, to the extent possible, through the use of techniques and judgments which would be used by a utility system planner.

The data contained in this report will allow studies of competing technologies to be made through the year 2000.

Section 1

INTRODUCTION

This report documents the expansion of the six 1985 synthetic systems (Report EM-285) to the years 1990, 1995 and 2000.

Increased load density in all U.S. electric power systems will change the complexion of these systems over the period 1985 to 2000. The expansions documented in this report are based on present generation and transmission expansion practices. As such they will serve as a reference for comparison of proposed alternative expansion technologies or strategies. Further, these systems will allow testing of technologies which might have development periods extending beyond 1985 or which might have limited feasibility.

The assumptions upon which the expansions are based, the actual system additions, and the problems encountered are presented. The data listings and load flow output are available on magnetic tape.

The expansions add to the 1985 system transmission networks and installed generating capacity, but make no changes to other system parameters such as typical heat rates, forced outage rates, stability data, etc. No definition of generation type is presented beyond classifying each installation as "central" or "peaking."

Section 2

EXPANSION ASSUMPTIONS

The following assumptions were used in all three stages of expansion.

- Load growth will be a constant 5.6 percent per year. The load was scaled uniformly at all load buses in each system.
- Generation will be added to handle the new load and provide 20 percent reserve. The increase in generation will be 75 present peaking (gas turbines, pumped hydro, etc.). These generation additions will be sited largely at existing central stations, but will include some new stations.
- Transmission additions will be made such that no thermal overloads will result from single contingency outages with no generation redispatch.
- The line and transformer additions will be based on peak load conditions.
- Voltages will be maintained at 95 percent or higher at all load buses during normal peak load conditions.
- Voltage support problems will be corrected by shunt compensation except, where necessary, peaking generation will be located to improve severe voltage problems.
- Peaking generation will not be located to minimize transmission additions.
- Only one typical dispatch will be used to define transmission additions.
- No DC lines will be used in the expansions. Existing DC transmission will continue to be treated as equivalent load and generation.
- No consideration will be given to replacement of transmission equipment due to end-of-life.

Procedure

The expansions were created by the following steps:

1. Increase system load by a factor of 1.313 ($(1.065)^5$) and add generation to cover the load increase and maintain 20 percent reserve.

2. Run DC load flow.

3. Add circuits to eliminate base case overloads.

4. Repeat 2 and 3 until all base case overloads are eliminated.

5. Run 100 worst-case primary outages.*

6. Add circuits to eliminate overloads.

7. Repeat 5 and 6 until no overloads are detected.

This cycle was repeated three times to create the 1990, 1995 and 2000 systems from the base 1985 system.

Any line loading over the listed ratings is treated as an "overload" and is eliminated by adding lines and transformers to the system.

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*The 100 worst line outages are selected by PCAP by a gradient method. No redispatch was allowed

Section 3

GENERAL COMMENTS ON SYNTHETIC SYSTEM EXPANSIONS

The several systems include a variety of transmission situations. System C is a system with long lines (i.e., 50 to 200 miles) and large areas with little or no generation. At the other extreme is System F with shorter transmission distances (i.e., less than 50 miles) and generation evenly distributed. However, transmission distances and line loadings were great enough in all systems to yield some voltage control problems during the expansions.

The systems were adjusted for adequate voltage first by reducing the existing reactive load, and then, where necessary, adding shunt capacitors. Reducing reactive load implies addition of capacitors in subtransmission and distribution systems; so in effect most voltage adjustments were made by adding shunt capacitors. Some peaking units were placed to minimize voltage support problems. Most of the voltage problem areas can be identified from the lists of changes to each system.

In a number of the synthetic systems, particularly in later years, it was necessary to raise generator EHV bus voltages from 1.0 per unit to 1.02 per unit (all the original systems were based on generator EHV bus voltages held at 1.0). This was done where it was found difficult to raise a large number of load bus voltages to .95 per unit or higher by simply changing reactive load or adding shunt capacitors. In System C many loads were so far from generation that generator EHV voltages had to be raised and considerable amounts of capacitors added.

Anyone using these synthetic systems for studies of transmission contingencies should recognize that the adjustments to reactive load and capacitor additions made in their development of the scenarios

were only adequate to hold voltages above 95 percent during normal peak load conditions. There are areas in most of the scenarios where voltages will drop to very low levels (if, indeed a solution is possible) when a circuit is removed. It is likely that many systems in the U.S. will make increasing use of voltage control equipment to allow maximum use of transmission systems. Such devices will have to be put into use if line outages are to be explored in many parts of the scenarios. Also, in such studies, the load model will affect significantly the indicated voltages under contingency conditions and should be selected carefully.

A number of EHV lines of considerable length have been added to the systems without fixed shunt compensation. Most of these lines would need such compensation in an actual system. However, at peak load, most such lines are close enough to surge impedance loading that any shunt reactors would have to be switched off or supplied reactive current from nearby generation or capcitor banks. So, where addition of shunt reactors was not necessary to control voltages, they were not added explicitly to the models (i.e., they were assumed to be lumped with nearby capacitors). Studies using the systems in such a way that long-line shunt compensation may be a factor in study results should include assumptions of line compensation and associate sources of reactive current for this shunt compensation.

In a number of the systems there appear to be substations where there are two separate HV or EHV buses of the same voltage, and an interconnection at some lower voltage. These are equivalents of urban areas where impedance of multiple, low voltage circuits often including cable circuits, have been neglected.

The system design procedures used in this work were necessarily simplified from those in actual use in the industry. Hence, there may be some differences between the systems developed here and actual systems. A later project, "Approximate Transmission of Savings Resulting From Dispersing New Generation," required an accurate expansion of one of the scenarios. As part of this work, Scenario F was re-expanded using a more detailed design procedure. The results of this expansion work and a discussion of the procedures are included with this report

Section 4

SYSTEM A CHANGES AND ADDITIONS

TABLE

Table A-1

GENERATION ADDITIONS*

BUS LOC/VOLT	BUS NO.	1985-1990	1990-1995	1995-2000
A3-765	118	1000		2000
C2-345	123	1000		
D1-345	131		1000 PK	
D1-345	133		1000	
D4-138	142	1000		970
C4-138	145	1000		
C3-345	149	1000 PK		
C4-138	158	2000		1500
C4-345	159			2000
D5-345	163	1000		1000
D5-345	165		2000	
D6-138	167			1500
D5-345	168	1000		
D5-345	171		1000	
C6-345	173		1000	
D4-345	179		2000	
A4-345	184	1000		1600
B5-345	186		2000	
B6-138	190			900
B5-345	191		1000 PK	
A4-138	193	1000 PK		
A4-138	194			200
A6-345	195		2000 PK	
A5-345	197			1380 PK
A5-345	199	1000		1000
B5-345	201	1000		1000 PK
C3-345	205			2000
E2-345	209	1000		
E2-500	211			1000
E5-345	214		2000 PK	
E4-138	219	1000 PK		1000
E3-138	222			1000
E4-138	229	1000 PK		
C3-345	305		2000	750 PK
B1-345	405		2000	1000 PK
B2-765	406		2000	1000 PK
C3-765	407		1000	2000 PK
C3-765	407			1000
A1-345	501			700
A3-345	503			2000
		12000MW Central 4000MW Peak	16000MW Central 6000MW Peak	21370MW Central 7130MW Peak

Total system generation at end of period:

1985			
53,350	69,350	91,350	119,850 MW

*All capacity is "central" unless labeled as "peaking" (PK). Unit size for central is 1000 MW except where added capacity is not an integral of 1000 MW. Maximum unit size is 1000 MW.

Table A-2

1990 SYSTEM A LINE AND TRANSFORMER CHANGES

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION*	1985	1990
101	188	20	3-345 KV	0	3
101	201	10	2-345 KV	2	4
103	305		400 MVA	1	2
110	111		500 MVA	1	2
114	405		600 MVA	0	1
116	119		500 MVA	3	4
118	303	40	765 KV	1	2
122	123		500 MVA	3	4
123	405	50	345 KV	0	1
126	131	60	345 KV	1	2
127	128	30	138 KV	1	2
132	133		750 MVA	2	3
134	135		500 MVA	2	3
136	138	10	138 KV	1	2
140	142	60	138 KV	3	4
149	151	30	2-345 KV	1	3
151	152		1000 MVA	1	3
157	160	30	230 KV	5	3
158	159		2500 MVA	4	8
163	164		2000 MVA	4	8
165	166		500 MVA	2	3
167	168		700 MVA	6	8
168	169		1000 MVA	1	2
172	173		500 MVA	3	4
176	177		1000 MVA	3	5
178	179		500 MVA	3	4
179	186	60	2-345 KV	2	4
184	185		1000 MVA	1	3
184	401	40	345 KV	0	1
186	187		300 MVA	1	2
186	191	30	2-345 KV	2	4
190	202	10	138 KV	3	4
191	401	20	2-345 KV	0	2
193	401		1000 MVA	0	2
196	197		500 MVA	1	2
197	199	110	345 KV	1	2
197	401	40	345 KV	0	1
198	199		1000 MVA	1	3
199	201	120	345 KV	1	2
108	209		500 MVA	2	3
213	402	70	345 KV	0	1
227	229	40	138 KV	1	2
227	403		500 MVA	0	1
229	402		500 MVA	0	1
303	503		2000 MVA	0	1
503	504	20	345 KV	2	3
122	124	10	1-138 KV	3	4

*MVA indicates transformer, kV indicates line

Table A-3

1990 SYSTEM A MISCELLANEOUS CHANGES

1) No additional changes needed after line and generation additions.

Table A-4

1995 SYSTEM A LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1990	1995
102	216		200 MVA	1	2
104	141	50	345 KV	0	1
104	213	100	345 KV	0	1
105	222		500 MVA	2	3
110	405	30	345 KV	0	1
110	420		2000 MVA	0	2
114	121	40	138 KV	4	5
114	405		500 MVA	1	2
119	406		2000 MVA	0	2
119	423	60	345 KV	0	1
121	423		1000 MVA	0	2
128	129		500 MVA	1	2
131	133	50	345 KV	1	2
131	134	110	345 KV	0	1
132	133		750 MVA	3	4
140	219	50	138 KV	2	3
143	144		500 MVA	2	3
155	231		200 MVA	1	2
165	166		500 MVA	3	4
167	168		700 MVA	8	9
172	173		1000 MVA	4	6
176	177		500 MVA	5	6
178	179		500 MVA	4	5
179	181	20	345 KV	3	4
180	406	120	765 KV	0	1
190	424		500 MVA	0	1
196	197		500 MVA	2	3
202	424	10	345 KV	0	1
205	407		3000 MVA	0	3
208	209		500 MVA	3	4
209	210		500 MVA	1	2
209	408	30	345 KV	0	1
210	211	30	500 KV	1	2
212	408		500 MVA	0	1
213	217		1000 MVA	1	3
215	230		300 MVA	1	2
220	223		500 MVA	1	2
222	409		500 MVA	0	1
223	408	70	345 KV	0	1
223	409	60	345 KV	0	1
224	403	110	345 KV	0	1
228	422	110	500 MVA	0	1
303	425	100	765 KV	0	1
402	422	30	345 KV	0	1
403	422	50	345 KV	0	1
405	234	40	345 KV	0	1
406	407	60	765 KV	0	1
406	420	150	765 KV	0	2
109	422	70	345 KV	0	1
501	502		400 MVA	2	3

Table A-5

1995 SYSTEM A MISCELLANEOUS CHANGES

1) No additional changes needed after line and generation additions.

Table A-6

2000 SYSTEM A LINE AND TRANSFORMER CHANGES

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION*	1995	2000
116	119		500 MVA	5	6
165	166		500 MVA	4	5
501	502		400 MVA	3	4
303	503		1000 MVA	4	5
110	111		500 MVA	3	4
157	159		450 MVA	3	4
178	179		500 MVA	5	6
163	164		800 MVA	5	6
145	146		500 MVA	2	3
198	199		500 MVA	3	4
184	185		500 MVA	3	4
134	135		500 MVA	3	4
102	216		200 MVA	2	3
229	402		500 MVA	1	2
220	223		500 MVA	2	3
176	186	50	1-345 KV	2	3
179	181	20	1-345 KV	4	5
119	406		1000 MVA	1	2
227	403		500 MVA	1	2
131	134	110	1-345 kv	1	2
103	305		400 MVA	1	2
110	420		500 MVA	1	2
205	305	10	1-345 KV	2	3
172	173		500 MVA	6	7
116	119		500 MVA	4	5
157	159		450 MVA	2	3
176	177		500 MVA	6	7
205	305	10	1-345 KV	1	2
187	192	30	2-138 KV	2	4
213	421	30	1-345 KV	1	2
197	401	40	1-345 KV	1	2
191	401	40	1-345 KV	1	2

*MVA indicates transformer, kV indicates line

Table A-7

2000 SYSTEM A MISCELLANEOUS CHANGES

1) Remove reactive load from the following buses:*

BUS NO.	AMOUNT REMOVED (MVAR)
155	22.6
161	90.6
228	22.6

2) Add capacitors at the following buses:

BUS NO.	AMOUNT (MVAR)
120	25
125	25

*In all cases the reactive load removed is the total reactive load on the bus.

Table A-8

1985 SYSTEM A TRANSFORMER MVA SIZES

FROM BUS	TO BUS	NO. OF TRANSFORMERS	SIZE (MVA)
101	202	2	600
102	216	1	200
103	305	1	400
104	219	2	500
105	222	2	500
110	111	1	500
116	119	3	500
118	504	1	1000
122	123	3	500
123	203	2	400
126	127	2	450
128	129	1	500
128	204	1	500
130	131	1	500
132	133	2	750
133	206	1	500
134	135	2	500
136	137	1	600
140	141	4	500
142	218	2	250
143	144	2	500
145	146	2	500
146	148	1	500
149	150	3	500
151	152	1	500
154	231	1	200
155	231	1	200
157	159	2	450
158	159	5	500
160	161	4	250
162	163	2	900
163	164	4	500
165	166	2	500
167	168	6	350
168	169	1	1000
170	171	1	300
172	173	3	500
176	177	3	500
178	179	3	500
180	181	1	1000
182	183	2	1500
184	185	1	500
186	187	1	300
188	189	2	600
191	192	1	500
196	197	1	500
198	199	1	500
200	201	2	400
207	209	1	500
208	209	2	500
209	210	1	500
211	212	1	500
213	217	1	500
215	230	1	300
220	223	1	500
224	225	1	500
303	503	1	1000
503	505	5	500

Section 5

SYSTEM B CHANGES AND ADDITIONS

TABLE

Table B-1

GENERAL ADDITIONS*

BUS LOC/VOLT	BUS NO.	1985-1990	1990-1995	1995-2000
A5-500	105		1000 PK	1000
A3-500	113	2000	600 PK	
B5-500	130		725 PK	1000
C6-230	133	500	1000	
C4-230	135	1000 PK		1000
B2-500	144	600 PK	1000	1000
A1-500	147			1000 PK
A1-230	152			1000
B2-500	157		1000	1600
D2-230	175		1000	1000
C3-230	192	2000	500 PK	1000 PK
E4-230	208		900 PK	1000 PK
E2-230	215		500 PK	
E1-230	221			1000
F5-500	229	2000		
F1-138	234			500 PK
F2-230	237	1500		
F2-138	238			500 PK
F4-500	244	1000	2000	1000 PK
E5-230	248		1000	1000
E6-230	249		600	
F5-500	252	1000	400	2000
G5-500	253	1000 PK	1000	
F6-500	256		1000	1000
F6-500	256			1200 PK
G4-230	258	600	1000	
G4-230	259		500 PK	
G4-230	262		1000	
G3-500	410			4000
E3-500	501		1175	
E3-500	503	1000 PK	1000	2000
		10600MW Central 3600 Peak	14175MW Central 4725 Peak	18600MW Central 6200 Peak

Total system generation at end of period:

1985			
46,100	60,300	79,200	104,000

*All capacity is "central" unless labeled as "peaking" (PK). Unit size for central is 1000 MW except where added capacity is not an integral of 1000 MW. Maximum unit size is 1000 MW.

Table B-2

1990 SYSTEM B LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES	DESCRIPTION	1985	1990
129	130		2000 MVA	4	8
134	138		500 MVA	3	5
120	122		300 MVA	3	4
181	182		200 MVS	1	2
228	229		1200 MVA	4	6
253	254		500 MVA	6	7
171	192		1000 MVA	3	5
162	163		600 MVA	2	4
151	152		400 MVA	3	4
114	115	10	1-500 kV	1	2
130	132	10	1-500 kV	1	2
501	503	30	1-500 kV	1	2
237	242	40	1-230 kV	3	4
104	105		300 MVA	3	4
108	109		500 MVA	4	5
115	116		500 MVA	2	3
136	137		250 MVA	3	4
190	191		500 MVA	2	3
142	143		333 MVA	1	2
160	162		500 MVA	1	2
229	504	20	2-500 KV	1	3
259	262	40	2-230 KV	1	3
258	259	20	1-230 KV	2	3
237	242	40	1-230 KV	2	3
235	236		1000 MVA	1	3
157	158		500 MVA	3	5
168	169		600 MVA	2	4
134	138		500 MVA	3	5
253	257		400 MVA	2	3
244	246		1000 MVA	3	4
242	244		1000 MVA	4	5
503	504	30	1-500 KV	1	2
225	503		400 MVA	2	3
237	401		1000 MVA	0	2
244	401	40	1-500 KV	0	1
214	215		200 MVA	2	3
209	208		200 MVA	2	3
160	162		500 MVA	2	3
138	140	40	1-500 KV	1	2
128	130	20	1-500 KV	1	2
137	136		250 MVA	4	5
105	120	30	1-500 KV	2	3
107	113	30	1-500 KV	1	2
120	128	60	1-500 KV	0	1
131	132		500 MVA	3	4
174	175		500 MVA	2	3
170	177		500 MVA	2	3
115	116		500 MVA	3	4
236	402	70	1-500 KV	0	1
221	402		1000 MVA	0	2
109	110		500 MVA	3	4
190	191		500 MVA	3	4
171	192		500 MVA	5	6
155	156		300 MVA	1	2
153	154		500 MVA	1	2
113	114	10	1-500 KV	2	3
401	237		500 MVA	3	4
228	229		600 MVA	6	7
503	504	30	1-500 KV	2	3
160	166	30	1-500 KV	0	1

Table B-3

1990 SYSTEM B MISCELLANEOUS CHANGES

1) Remove reactive load at the following buses:*

BUS NO.	AMOUNT (MVAR)	BUS NO.	AMOUNT (MVAR)
124	26.3	177	39.4
125	26.3	178	26.3
127	13.1	181	26.3
155	26.3	183	26.3
-	-	189	39.4

*In all cases, the reactive load removed was the total reactive load on the bus.

Table B-4

1995 SYSTEM B LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1990	1995
253	254		1000 MVA	5	6
204	207		250 MVA	3	4
221	402		500 MVA	2	3
220	503		500 MVA	3	4
228	229		600 MVA	7	8
190	191		500 MVA	4	5
162	163		300 MVA	4	5
109	110		500 MVA	4	5
142	143		250 MVA	3	4
127	128		250 MVA	4	5
108	109		500 MVA	5	6
181	182		200 MVA	2	3
153	154		500 MVA	2	3
128	136	40	1-500 KV	1	2
157	160	20	1-500 KV	1	2
144	149	80	1-500 KV	1	2
503	504	30	1-500 KV	3	4
217	221	30	1-230 KV	2	3
501	503	30	1-500 KV	2	3
131	133	20	1-230 KV	2	3
134	138		250 MVA	5	6
261	262		500 MVA	5	6
249	250	30	1-230	3	4
208	209		200 MVA	3	4
157	158		250 MVA	5	6

Table B-5

1995 SYSTEM B MISCELLANEOUS CHANGES

1) Add capacitors at buses

BUS NO.	AMOUNT (MVAR)
124	25
125	25
139	50
181	25

2) Remove reactive load from the following buses:

BUS NO.	ORIGINAL LOAD (MVAR)	FINAL LOAD (MVAR)
129	396.6	150
131	189.7	95
134	155.2	77.5
163	155.2	77.5

Table B-6

2000 SYSTEM B LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1995	2000
253	254		1000 MVA	7	8
109	110		500 MVA	5	6
171	192		500 MVA	7	8
151	152		400 MVA	4	5
108	109		500 MVA	6	7
129	130		500 MVA	10	11
127	128		250 MVA	5	6
136	137		250 MVA	6	7
208	209		200 MVA	4	5
140	160	10	1-500 KV	1	2
261	262		1500 MVA	6	9
501	502		500 MVA	3	4
214	215		300 MVA	3	4
244	504	40	1-500 KV	2	3
205	206		500 MVA	2	3
220	503		500 MVA	4	5
262	410		1000 MVA	2	3
217	221	30	1-230 KV	3	4
220	505	20	1-230 KV	3	4
167	192	50	1-230 KV	1	2
169	178	40	1-230 KV	1	2
177	178	20	1-230 KV	2	3
183	184	10	1-230 KV	1	2
175	177	10	1-230 KV	2	3
137	139	30	1-138 KV	1	2
410	411	60	2-500 KV	0	2
262	410		2000 MVA	0	2
258	411		1000 MVA	0	2
253	411	10	1-500 KV	0	1
162	163		300 MVA	5	6
171	192		500 MVA	6	7
143	144		400 MVA	2	3
135	136		500 MVA	1	2
129	130		500 MVA	8	10
136	137		250 MVA	5	6
157	158		250 MVA	6	8
140	163		250 MVA	3	4
228	229		600 MVA	8	9
253	254		1000 MVA	6	7
220	505	20	1-230 KV	2	3
205	206		500 MVA	1	2

Table B-7

2000 SYSTEM B MISCELLANEOUS CHANGES

1) Remove reactive load from the following buses:*

BUS NO.	AMOUNT (MVAR)
111	22.6
131	124.8
167	67.9
190	158.52
214	90.6
505	268.8

2) Add capacitors at the following buses:

BUS NO.	AMOUNT (MVAR)
169	100
176	25
180	25
181	50
189	150
190	100
505	100

3) Raise generator p.u. bus voltage to 1.02 at bus 133.

4) Change tap ratio on the following transformers (FROM bus is tap side)*.

FROM BUS NO.	TO BUS NO.	NEW TAP
108	109	.975
503	220	1.025

Table B-8

1985 SYSTEM B TRANSFORMER MVA SIZES

FROM BUS	TO BUS	NO. OF TRANSFORMERS	SIZE (MVA)
103	104	3	300
104	105	3	500
106	107	3	500
108	109	4	500
109	110	3	500
111	112	1	200
115	116	2	500
118	119	1	500
119	186	1	300
120	122	3	300
127	128	3	250
129	130	4	500
131	132	3	500
134	138	3	250
135	136	1	500
136	137	3	250
140	163	3	250
142	143	2	333
143	144	2	400
151	152	3	400
153	154	1	500
155	156	1	300
157	158	3	250
160	162	1	500
162	163	2	300
166	167	1	500
168	169	2	300
170	177	2	500
171	192	3	500
174	175	2	500
176	187	1	200
179	180	1	200
181	182	1	200
190	191	2	500
204	207	2	250
205	206	1	500
208	209	2	200
210	211	2	500
212	213	1	300
214	215	2	200
220	503	2	500
225	503	2	400
227	504	1	500
228	229	4	600
229	230	1	500
232	234	1	300
235	236	1	500
237	238	1	300
240	241	2	250
242	244	1	500
243	244	1	500
244	246	1	500
251	252	2	300
253	254	6	500
253	257	2	400
255	256	4	500
259	260	4	500
261	262	4	500
501	502	3	500

Section 6

SYSTEM C CHANGES AND ADDITIONS

TABLE

NOTE: The expansion of Scenario C is based on the 1985 base systems without the 2000 MW increment in load (buses 501-505) necessary to accommodate the plug-in subtransmission model (see page 3-33 EM-285). Note also that the generation listed in Table 3-8 of EM-285 includes the extra generation for the plug-in.

Table C-1

GENERATION ADDITIONS

BUS LOC/VOLT	BUS NO.	1985-1990	1990-1995	1995-2000
A1-230	104		1000	
A2-230	110		700 PK	
A2-230	112			1000
B6-345	148	1000		2000
B5-138	152			100
B4-138	156	800		400
C1-230	170			900 PK
D2-345	182		750 PK	1000
D4-345	193		1000	
C5-138	196	200		800 PK
C5-345	200	1000	1000	
D5-138	203	300 PK		
D6-345	206			1000
E5-345	207	500		1000 PK
E5-345	207	300 PK		
D4-138	215		1000	
E4-345	220			1000
E2-345	221	600	1000	600
B6-345	501	200 PK*		1000
B6-230	502	600	600 PK	
B6-345	503	800 PK*	1150	
		4700MW Central 1600MW Peak	6150MW Central 2050MW Peak	8100MW Central 2700MW Peak

Total system generation at end of period:

1985			
19,900	26,200	34,400	45,200

*This capacity is included in Table 3-8 in EM-285. It was added in 1985 (along with 2-400 MW units on bus 505 and another 200 MW unit on 501) to supply the 2000 MW plug-in load.

Table C-2

1990 SYSTEM C LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES	DESCRIPTION	1985	1990
109	111		300 MVA	2	4
129	138	20	1-138 KV	1	2
194	212	80	1-138 KV	1	2
203	212	60	1-138 KV	3	4
125	126		400 MVA	2	3
501	505		500 MVA	2	3
159	227		250 MVA	2	3
170	171		200 MVA	2	4
172	173		100 MVA	2	3
184	185		250 MVA	2	3
191	193		250 MVA	3	4
205	206		500 MVA	2	3
207	208		250 MVA	2	3
221	222		400 MVA	3	4
222	223		250 MVA	4	5
131	161	40	1-138 KV	1	2
152	153	60	1-138 KV	1	2
153	154	30	1-138 KV	1	2
119	120		100 MVA	2	3
123	124		250 MVA	2	3
122	129	40	1-138 KV	1	2
154	156	40	1-138 KV	1	2
156	185	90	1-138 KV	1	2
156	157		250 MVA	2	3
501	504	10	1-345 KV	2	3
129	138	20	1-138 KV	2	3
155	157	50	1-230 KV	1	2
166	167		200 MVA	2	3
191	192		400 MVA	2	3
200	206	110	1-345 KV	1	2
222	223		250 MVA	5	6
221	222		400 MVA	4	5
207	208		250 MVA	3	4
501	505		500 MVA	3	4
156	157		250 MVA	3	4
101	102		150 MVA	2	3
104	114	200	1-230 KV	1	2
110	126*	180	1-230	0	1
134	136	50	1-230	1	2
200	201		250 MVA	3	4
109	111	40	1-138 KV	3	4
200	201		250 MVA	4	5
195	196	30	1-138 KV	1	2
148	504	10	1-345 KV	2	3

*345 kV line operating at 230 KV

Table C-3

1990 SYSTEM C MISCELLANEOUS CHANGES

1) Add capacitors at:

BUS NO.	AMOUNT (MVAR)
125	100
172	20

2) Remove reactive load:

BUS NO.	AMOUNT (MVAR)
119	13.1
131	13.1
139	13.1
150	13.1
171	26.3
172	26.3
179	13.1
194	13.1
185	78.8

3) Raise generators voltage to 1.02 p.u. at buses:

156	193
166	196
175	203
192	206
	207

4) Add shunt reactors at buses:

112	80
158	40
164	40
219	40

Table C-4

1995 SYSTEM C LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES	DESCRIPTION	1990	1995
191	193		500 MVA	4	6
192	193		250 MVA	3	4
201	203		1-138 KV	4	5
110	226	40	1-230 KV	1	2
123	124		250 MVA	3	4
158	159		250 MVA	2	3
180	181		150 MVA	2	3
501	505		500 MVA	4	5
184	185		250 MVA	3	4
200	201		250 MVA	5	6
104	401		1000 MVA	0	1
112	401	210	1-345 KV	0	1
222	223		500 MVA	6	8
221	222		400 MVA	5	7
205	206		1000 MVA	3	5
127	128		100 MVA	2	3
200	501	80	1-345 KV	1	2
207	208		250 MVA	4	5
166	167		200 MVA	3	4
172	173		100 MVA	3	4
220	221	80	1-345 KV	1	2
164	165		250 MVA	2	3
107	108		150 MVA	2	3
105	106		150 MVA	2	3
105	108	80	1-230 KV	0	1
202	205	40	1-138 KV	1	2
181	182		300 MVA	1	3
110	402		1000 MVA	0	2
402	403	180	1-345 KV	0	1
126	403		1000 MVA	0	1
103	104		150 MVA	4	5
109	110		150 MVA	2	3
110	116	100	1-230 KV	1	2
115	116		100 MVA	2	3

Table C-5

1995 SYSTEM C MISCELLANEOUS CHANGES

1) Add capacitors at buses:

BUS NO.	AMOUNT (MVAR)
124	100
126	50
131	25
172	50

2) Generator voltages all increased to 1.02 p.u. expect.

BUS NO.	VOLTAGE
112	1.03
156	1.03
174	1.03
192	1.03
193	1.03

3) Remove reactive load at bus 118.

4) Change transformer taps (From bus is tap side):

FROM BUS NO.	TO BUS NO.	NEW TAP
158	159	.975
159	227	.975

5) New load at buses 179, 172, and 171 is shifted to nearby low voltage (138 kV) buses which were previously without load. Concentrated load at 179, 172 and 171 caused voltage problems, and an assumption that new load would appear at these nearby stations seemed reasonable.

Table C-6

2000 SYSTEM C LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1995	2000
170	171		300 MVA	4	7
180	181		300 MVA	3	5
181	182		600 MVA	3	5
191	193		250 MVA	6	7
224	225		100 MVA	2	3
207	208		500 MVA	5	6
501	505		500 MVA	5	6
200	201		250 MVA	6	7
148	503	10	1-345 KV	2	3
123	124		250 MVA	4	5
123	132	70	1-230 KV	0	1
164	165		250 MVA	3	4
191	192		400 MVA	3	4
222	223		500 MVA	8	9
221	222		400 MVA	7	8
200	420	70	1-345 KV	0	1
203	420		1000 MVA	0	2
420	421	60	1-345 KV	0	1
205	206		500 MVA	5	6
212	421		1000 MVA	0	2
207	421	60	1-345 KV	0	1
184	185		500 MVA	4	6
119	120		100 MVA	3	4
103	104		150 MVA	5	6
108	170	210	1-230 KV	1	2
112	226		750 MVA	2	5
215	216		500 MVA	3	5
105	108	80	1-230 KV	1	2
125	126		400 MVA	3	4
158	159		250 MVA	3	4
174	175		250 MVA	2	3
193	422	80	1-345 KV	0	1
422	501	180	1-345 KV	0	1
213	422		500 MVA	0	1
421	422	60	1-345 KV	0	1
143	146	30	1-230 KV	1	2

Table C-7

2000 SYSTEM C MISCELLANEOUS CHANGES

1) Remove MVAR load at buses:

165	195
167	227
502	503

2) Add shunt reactors at buses

BUS NO.	AMOUNT (MVAR)
501	40
422	80
105	

3) Generator voltages changed to control voltages

BUS NO.	P.U. VOLTAGE
200	1.01
201	1.01
203	1.01
207	1.01
501	1.017

4) Adjusted generator voltage to balance generator reactive loading at:

BUS NO.
148
501
502
503
504

Table C-8

1985 SYSTEM C TRANSFORMER MVA SIZES

FROM BUS	TO BUS	NO. OF TRANSFORMERS	SIZE (MVA)
101	102	2	150
103	104	2	150
105	106	2	150
107	108	2	150
109	110	2	150
111	226	3	300
112	226	2	250
115	116	2	100
119	120	2	100
121	122	2	100
123	124	2	250
125	126	2	400
127	128	2	100
129	130	2	100
131	132	2	150
134	135	2	100
136	137	2	150
139	140	2	250
141	142	2	400
143	144	2	150
145	146	2	150
154	155	2	150
156	157	2	250
158	159	2	250
159	227	2	250
162	163	2	100
164	165	2	250
166	167	2	200
168	169	2	100
170	171	2	100
172	173	2	100
174	175	2	250
180	181	2	150
181	182	1	300
184	185	2	250
188	189	2	250
191	192	2	400
191	193	3	250
192	193	3	250
200	201	3	250
205	206	2	500
207	208	2	250
213	214	2	250
215	216	3	250
221	222	3	400
222	223	4	250
224	225	2	100
501	502	2	400
501	505	2	500
502	505	2	250

Section 7

SYSTEM D CHANGES AND ADDITIONS

TABLE

Table D-1

GENERATION ADDITIONS

BUS LOC/VOLT	BUS NO.	1995-1990	1990-1995	1995-2000
B2-230	103	1000 PK	1000 PK	
C2-230	106			1000
D2-230	111			1000 PK
D2-500	114	1000	1000	1000
D3-500	124	400 PK	2000	2000
F3-230	134			500
F3-230	136		700	500 PK
F3-230	137		500 PK	
F4-230	140			750 PK
E4-230	147	600 PK		
E4-500	148	2000	1000	1000
B5-230	154		1000 PK	
B5-230	155			1000
D7-230	162			1000 PK
D7-230	163		1000	
D6-230	166	1000		
C6-500	180	1000	2000	1000
D7-230	183			1000
C8-230	189	2000		
B8-230	190		1000	
B8-230	192		250 PK	1000 PK
A5-230	210	400 PK		
A3-230	216		500 PK	1000
D4-500	501		1000	2000
D4-230	502			750
D5-230	504			500
		7000MW Central 2400MW Peak	9700MW Central 3250MW Peak	12750MW Central 4250MW Peak

Total system generation at end of period:

1985			
32,000MW	41,400MW	54,350MW	71,350MW

Table D-2

1990 SYSTEM D LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES	DESCRIPTION	1985	1990
101	106	10	1-230 KV	3	4
102	114	30	1-500 KV	1	2
109	111	10	1-230 KV	1	2
110	111	10	1-230 KV	3	4
126	127	10	3-230 KV	1	3
127	141	30	2-230 KV	1	3
162	163	10	2-230 KV	1	3
165	166	10	1-230 KV	1	2
166	178	20	1-230 KV	1	2
189	190	10	1-230 KV	1	2
189	197	10	2-230 KV	1	3
197	198	10	2-230 KV	2	4
101	102		600 MVA	2	3
125	126		800 MVA	2	4
131	132		750 MVA	2	5
147	149		2000 MVA	2	6
156	157		900 MVA	2	5
174	175		600 MVA	2	4
179	180		300 MVA	2	3
194	195		500 MVA	2	3
161	162	30	1-230 KV	2	3
180	195	20	1-500 KV	1	2
163	178	30	1-230 KV	1	2
198	199	10	1-230 KV	1	2
101	102		600 MVA	3	4
156	181	50	1-500 KV	1	2
189	197	10	1-230	3	4
166	178	20	1-230	2	3
200	201	10	1-230	1	2
146	147	10	1-230	2	3
155	167	20	1-230	1	2
150	231		250 MVA	2	3
129	131	10	1-230 KV	2	3
181	182		250	2	3
147	231	50	1-230 KV	1	1
147	153	50	1-230 KV	1	2
194	195		500 MVA	3	4
123	124		400 MVA	2	3
167	505	10	1-230	1	2

Table D-3

1990 SYSTEM D MISCELLANEOUS CHANGES

1) Removed reactive load:

BUS NO.	AMOUNT (MVAR)	BUS NO.	AMOUNT (MVAR)
101	39.4	142	39.4
129	52.5	218	26.3

2) Raise generator voltages to 1.03 p.u. at buses:

103	134
111	136
114	137
123	
124	

3) Adjust transformer taps:

FROM BUS NO.	TO BUS NO.	NEW TAP
501	502	1.0
501	502	1.0
503	505	

Table D-4

1995 SYSTEM D LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1990	1995
174	175		300 MVA	4	6
124	125	10	1-500 KV	1	2
179	180		300 MVA	3	5
101	102		1200 MVA	4	6
101	106	10	1-230 KV	4	6
124	132	60	1-500 KV	1	2
162	163	10	1-230 KV	3	4
146	147	10	1-230 KV	3	4
148	156	50	1-500 KV	2	3
148	149	10	1-500 KV	1	2
102	114	30	1-500 KV	2	3
501	502		500 MVA	2	3
162	185	20	1-230 KV	2	3
185	186	10	1-230 KV	2	3
216	221	20	1-230 KV	1	3
198	199	10	1-230 KV	2	3
148	149	10	1-500 MVA	1	2
501	502		500 MVA	1	2
125	126		400 MVA	4	5
194	195		500 MVA	4	5
189	197	10	1-230 KV	4	5
109	114		250 MVA	2	3
131	132		250 MVA	5	6
115	116		250 MVA	2	3
181	182		250 MVA	3	4

Table D-5

1995 SYSTEM D MISCELLANEOUS CHANGES

1) No additional changes needed after line and generation additions.

Table D-6

2000 SYSTEM D LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1995	2000
163	164		500 MVA	2	4
179	180		600 MVA	5	8
194	195		1000 MVA	5	7
156	157		600 MVA	5	7
174	175		1200 MVA	6	10
109	114		250 MVA	3	4
131	134	10	1-230 KV	1	2
181	182		500 MVA	4	6
180	195	20	1-500 KV	2	3
192	195	10	1-230 KV	1	2
175	220	20	1-500 KV	0	1
501	503	10	1-500 KV	1	3
126	127	10	1-230 KV	3	4
136	139	10	1-230 KV	2	3
109	113	10	1-230 KV	1	2
167	505	20	1-230 KV	0	1
146	154	10	2-230 KV	1	3
219	220		500 MVA	3	5
131	132		250 MVA	6	7
125	126		400 MVA	5	7
129	130	10	1-230 KV	1	2
179	198	50	1-230 KV	2	3
210	211	10	1-230 KV	1	2
193	194	10	1-230 KV	1	2
182	188	40	1-230 KV	1	2
216	217		250 MVA	2	3
123	144	40	1-230 KV	1	2
150	231		250 MVA	3	4
129	131	10	1-230 KV	3	4
147	149		500 MVA	6	7
121	122	10	1-230 KV	1	2
116	122	10	1-230 KV	1	2
142	143	10	1-230 KV	1	2
174	219	20	1-230 KV	1	2
174	206	20	1-230 KV	1	2

Table D-7

2000 SYSTEM D MISCELLANEOUS CHANGES

1) Remove reactive load from the following buses:*

BUS NO.	AMOUNT (MVAR)	BUS NO.	AMOUNT (MVAR)
113	67.9	194	203.8
128	67.9	199	67.9
150	67.9	200	90.6
152	67.9	208	90.6
161	113.2		
192	67.9	219	135.9

2) Add 25 MVAR of capacitors to bus 215.

*Represents total removal of reactive load on these buses.

Table D-8

1985 SYSTEM D TRANSFORMER MVA SIZES

FROM BUS	NO. OF TO BUS	SIZE TRANSFORMERS	(MVA)
101	102	2	600
109	114	2	250
115	116	2	250
123	124	2	400
125	126	2	400
131	132	2	250
147	149	2	250
150	231	2	250
151	227	2	100
152	228	2	100
153	232	2	100
156	157	2	300
163	164	2	250
174	175	2	300
176	177	2	250
179	180	2	300
181	182	2	250
194	195	2	500
216	217	2	250
219	220	2	250
501	502	1	450
305	505	6	450

Section 8

SYSTEM E CHANGES AND ADDITIONS

TABLE

Table E-1

GENERATION ADDITIONS

BUS LOC/VOLT	BUS NO.	1985-1990	1990-1995	1995-2000
A1-138	101		500	
A1-138	101		1000 PK	
A2-138	105	500	1000	1000
A2-345	106	1000		1500
B2-138	107		500	500
B2-138	107			800 PK
A4-345	109	1200	1000	500
B3-345	111	2000	800	1700
A5-138	116		200	100
A6-138	121			500
C7-138	128			500 PK
B6-500	130	2000	2000	1500
E7-230	138	1200	1000 PK	1000 PK
F7-138	142	1200 PK	1000	2000
F6-138	143	1800		500 PK
F5-138	146		1300 PK	
D3-138	156	1000		300
D3-138	156			700 PK
D4-138	164	1000		
E3-138	166		1000 PK	
F2-345	174		1000	1000
E2-138	181		1000	900
D2-138	183			100
D1-138	184		200 PK	
D1-345	186	1000 PK	800	500
D3-345	197		1000	1000
D2-345	198			500 PK
C1-345	199			1000 PK
F2-345	501		2000	2000
E3-138	502			1000
F3-345	503	1000 PK		2000
F4-138	505		1000	1000 PK
		9700 MW Central 3200MW Peak	13800MW Central 4500MW Peak	18100MW Central 6000MW Peak

Total generation at end of 5-year period:

1985			
45,700	58,600	76,900	101,000

Table E-2

1990 SYSTEM E LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1985	1990
105	106		600 MVA	5	6
111	188	60	1-345 KV	1	2
108	109		1200 MVA	3	5
110	403		500 MVA	2	3
130	131		1000 MVA	2	4
122	123		500 MVA	2	3
131	132		500 MVA	3	4
188	204		300 MVA	2	5
181	182		1500 MVA	4	7
138	139		250 MVA	2	3
203	502		500 MVA	2	4
161	162		500 MVA	2	3
126	201		250 MVA	2	3
156	157		400 MVA	3	5
158	159		500 MVA	2	3
185	186		500 MVA	3	4
118	119		500 MVA	2	3
171	172		300 MVA	2	3
109	118	90	1-345 KV	1	2
140	141	30	1-138 KV	3	4
165	167	40	1-345 KV	1	2
177	178	20	1-138 KV	3	4
170	171	20	1-345 KV	1	2
184	185	60	1-138 KV	1	2
180	184	30	1-138 KV	1	2
151	152	40	1-138 KV	2	3
153	154	20	1-138 KV	1	2
147	148		1500 MVA	5	8
103	105	60	1-138 KV	1	2
105	107	60	1-138 KV	1	2
143	144		1200 MVA	3	5
135	136		250 MVA	2	3
122	123		500 MVA	1	2
164	166	40	1-138 KV	1	2
152	153	40	1-138 KV	1	2
147	149		500 MVA	2	4
156	157		800 MVA	2	4
164	165		250 MVA	2	3
185	186		500 MVA	2	3
154	155		250 MVA	2	3
107	401		1000 MVA	0	2
111	401	60	1-345 KV	0	1
113	402		1000 MVA	0	2
111	402	30	1-345 KV	0	1
111	403	40	1-345 KV	0	1
110	403		1000 MVA	0	2
149	203	70	1-230 KV	1	2
145	148	30	1-500 KV	2	3
144	145	30	1-500 KV	1	2
169	405	30	1-345 KV	0	1
405	406	60	1-345 KV	0	1
152	405		1000 MVA	0	2
154	406		1000 MVA	0	2
178	179		400 MVA	2	3
176	177		300 MVA	2	3
113	115	60	1-138 KV	2	3
148	404	40	1-500 KV	0	1
404	505		1000 MVA	0	2
164	165		250 MVA	3	4
138	155	40	1-230 KV	1	2
187	191	50	1-138 KV	1	2
187	204	40	1-138 KV	1	2

Table E-3

1990 SYSTEM E MISCELLANEOUS CHANGES

1) Remove reactive load at bus 105 (328 MVAR).

BUS NO.	ORIGINAL (MVAR)	FINAL (MVAR)
148	26.3	0
234	26.3	0
235	26.3	0
501	197	97
502	170.7	70.7

2) Add capacitors at the following buses:

BUS NO.	AMOUNT (MVAR)
101	50
120	50
144	50
168	50
188	50
190	50
213	50
233	50
263	50

3) Add shunt reactors at the following buses:

BUS NO.	AMOUNT (MVAR)
199	50
202	100
217	100

4) Raise generation p.u. bus votages to 1.02 at all generator buses.

Table E-4

1995 SYSTEM E LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES	DESCRIPTION	1990	1995
130	131		500 MVA	4	5
122	123		1000 MVA	3	5
131	132		1000 MVA	4	6
141	142		250 MVA	2	3
145	146		1000 MVA	5	7
174	175		1000 MVA	5	7
102	107	60	1-138 KV	1	2
402	410	60	1-345 KV	0	1
115	401		1000 MVA	0	2
157	410	30	1-345 KV	0	1
186	411	60	1-345 KV	0	1
184	411		1000 MVA	0	2
182	411	60	1-345 KV	0	1
160	161	30	1-138 KV	1	2
146	153	40	1-138 KV	1	2
110	116	60	1-138 KV	1	2
121	124	50	1-138 KV	2	3
171	172		300 MVA	3	4
111	402	30	1-345 KV	1	2
188	204		100 MVA	5	6
108	109		600 MVA	5	6
147	149		250 MVA	4	5
203	502		250 MVA	4	5
185	186		500 MVA	4	5
192	193		100 MVA	2	3
146	152	90	1-138	0	1
137	154	20	1-138 KV	2	3
157	159	60	1-345 KV	2	3
180	412		1000 MVA	0	2
411	412	30	1-345 KV	0	1
162	197	20	1-345 KV	2	3
149	203	70	1-230 KV	2	3
402	410	60	1-345 KV	1	2
187	204	40	1-138 KV	1	2

Table E-5

1995 SYSTEM E MISCELLANEOUS CHANGE

1) Add capacitors to the following buses:

BUS NO.	AMOUNT (MVAR)
109	100
502	50

Table E-6

2000 SYSTEM E LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1995	2000
130	131		1000 MVA	5	7
121	123		500 MVA	5	6
141	142		750 MVA	3	6
181	182		1000 MVA	7	9
171	172		600 MVA	4	6
174	175		1000 MVA	7	9
188	204		100 MVA	6	8
157	410	30	2-345 KV	1	3
111	402	30	1-345 KV	2	3
130	420	60	1-500 KV	0	1
126	420		1000 MVA	0	1
129	420	40	1-500 KV	0	1
142	144	50	2-500 KV	1	3
160	161	30	1-138 KV	2	3
164	166	40	1-138 KV	3	4
181	183	10	1-138 KV	3	4
111	410	70	2-345 KV	0	2
125	126	30	1-138 KV	2	3
132	190	40	1-138 KV	1	2
122	130	90	1-500 KV	1	2
157	159	60	1-345 KV	3	4
108	109		600 MVA	6	7
131	132		500 MVA	6	7
154	155		375 MVA	3	4
111	403	40	1-345 KV	1	2
138	421	30	1-230 KV	0	1
134	421		400 MVA	0	1
117	118		500 MVA	1	2
135	138	60	1-230 KV	1	2
182	411	60	1-345 KV	1	2
166	167		250 MVA	2	3
169	405	30	1-345 KV	1	2
176	177		300 MVA	3	4
405	406	60	1-345 KV	1	2
145	148	30	1-500 KV	3	4
159	197	70	1-345 KV	2	3
186	411	60	1-345 KV	1	2
168	169		250 MVA	2	3

Table E-7

2000 SYSTEM E MISCELLANEOUS CHANGES

1) Remove reactive load from the following buses:

BUS NO.
159
166
183

2) Raise generator p.u. voltage to 1.02 at buses:

BUS NO.
166
181
183
197
198

Table E-8

1985 SYSTEM E TRANSFORMER MVA SIZES

FROM BUS	TO BUS	NO. OF TRANSFORMERS	SIZE (MVA)
101	102	2	600
109	114	2	250
115	116	2	250
123	124	2	400
125	126	2	400
131	132	2	250
147	149	2	250
150	231	2	250
151	227	2	100
152	228	2	100
153	232	2	100
156	157	2	300
163	164	2	250
174	175	2	300
176	177	2	250
179	180	2	300
181	182	2	250
194	195	2	500
216	217	2	250
219	220	2	250
501	502	1	450
305	505	6	450

Section 9

SYSTEM F CHANGES AND ADDITIONS

TABLE

Note: A second expansion of System F was developed for a later report, using somewhat different criteria and techniques. That expansion, plus a discussion of the differences, is contained in Appendix A.

Table F-1

GENERATION ADDITIONS

BUS LOC/VOLT	BUS NO.	1985	1985-1990	1990-1995	1995-2000
A2-138	103		1000	1000	1000
A5-500	104				1000
A3-138	105		1000	1000	
B4-138	118		2000		800 PK
C3-138	129		1000	1000	825
C4-138	137		1300		
C5-138	138				1000
C6-138	141				800 PK
C2-138	147			1000	800 PK
C6-138	151		1200 PK		
D6-138	152		1000	475 PK	
C6-230	153		1000	1000	1000
D3-138	158			1000	1000
E1-138	161		600 PK		775 PK
E4-138	167			500 PK	500
D5-138	168			500 PK	800 PK
D7-138	173		400 PK		
G2-138	180			675 PK	1000
F7-138	194		600 PK	500 PK	
D6-230	224				800 PK
E2-230	231			925	
E5-500	238				1000
A4-500	401			1000	2000
D2-138	502	500		1000	2000
D5-345	504	2000		2000	2000
D6-138	505	1000		1000 PK	
		3500MW	18300MW	10925MW	14325MW
			Central 2800MW Peak	Central 3650MW Peak	Central 4775MW Peak

Total system generation at end of each period:

35,300MW	46,500MW	61,075MW	80,175MW

*Capacity added to supply plug-in load in 1985 base case.

Table F-2

1990 SYSTEM F LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1985	1990
117	118	30	1-138 KV	4	5
105	199		1200 MVA	3	6
191	192	30	1-138 KV	1	2
137	149	40	1-138 KV	1	2
170	238		300 MVA	1	2
150	153	60	1-230 KV	1	2
143	153	50	1-230 KV	1	2
168	170	10	3-138 KV	1	4
224	240	30	1-230 KV	1	2
223	224	20	1-230 KV	2	3
222	501		600 MVA	4	5
215	503		1500 MVA	3	6
501	502		500 MVA	2	3
255	256		250 MVA	2	3
194	253	30	1-138 KV	1	2
104	199	50	1-500 KV	1	2
202	401	40	1-500 KV	1	2
200	401	30	1-500 KV	1	2
202	212	70	1-500 KV	1	2
249	250	30	1-230 KV	1	2
115	201		250 MVA	3	4
147	218		300 MVA	3	4
212	258	20	1-500 KV	2	3
192	253	10	1-138 KV	2	3
149	154	10	1-138 KV	1	2
193	255	30	1-230 KV	1	2
137	258		200 MVA	2	6
163	164	10	1-138 KV	1	2
207	208	30	1-230 KV	1	2
224	240	30	1-230 KV	0	1
235	240	50	1-230 KV	1	2
137	208		225 MVA	2	3
140	223	60	1-230 KV	1	2
152	224		900 MVA	3	6
118	202		400 MVA	5	6
168	172	50	2-138 KV	1	3
151	152	30	1-138 KV	2	3
138	212		1000 MVA	2	4
105	114	30	1-138 KV	2	3
118	125	30	1-138 KV	4	5
208	220	40	1-230 KV	0	1
140	223	90	1-230 KV	0	1
199	202	130	1-500 KV	0	1
103	196		400 MVA	3	4
137	208		150 MVA	2	3
127	205		500 MVA	2	3
172	240		500 MVA	2	4
189	250		300 MVA	1	2
194	254		200 MVA	2	4
107	108	20	1-138 KV	1	2
235	240	50	1-230 KV	0	1
172	224	30	1-230 KV	0	1
202	401	40	1-500 KV	0	1
200	401	30	1-500 KV	0	1
112	401		1000 MVA	0	2
173	174	40	1-138 KV	1	2
188	189	20	1-138 KV	1	2
150	221		600 MVA	2	6

Table F-3

1990 SYSTEM F MISCELLANEOUS CHANGES

1) Remove reactive load from the following buses:

BUS NO.	ORIGINAL (MVAR)	FINAL (MVAR)
148	26.3	0
234	26.3	0
235	26.3	0
501	197	97
502	170.7	70.7

2) Add capacitors at the following buses:

BUS NO.	AMOUNT (MVAR)
101	50
120	50
144	50
168	50
188	50
190	50
213	50
233	50
263	50

3) Add shunt reactors at the following buses:

BUS NO.	AMOUNT (MVAR)
199	50
202	100
217	100

4) Raise generator p.u. bus voltages to 1.02 at all generator buses

Table F-4

1995 SYSTEM F LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1990	1995
158	228		250 MVA	4	5
115	201		250 MVA	4	5
127	205		500 MVA	3	4
105	199		800 MVA	6	8
137	208		225 MVA	3	4
167	234		150 MVA	2	3
228	244	50	1-230 KV	1	2
218	227	20	1-230 KV	0	1
180	260		250 MVA	2	3
105	114	30	1-138 KV	3	4
218	230	20	1-230 KV	1	2
218	226	30	1-230 KV	1	2
126	261		250 MVA	2	3
196	262	130	1-500 KV	0	1
262	263		1000 MVA	4	6
225	232	20	1-230 KV	1	2
241	255	20	1-330 KV	1	2
220	225	10	1-230 KV	0	1
108	112	30	1-138 KV	3	4
200	202	70	1-500 KV	0	1
202	259	50	1-500 KV	0	2
219	228	50	1-230 KV	1	2
158	228		250 MVA	5	6
147	218		300 MVA	5	6
147	160	30	1-138 KV	3	4
155	158	30	1-138 KV	3	4
131	137	30	1-138 KV	2	3

Table F-5

1995 SYSTEM F MISCELLANEOUS CHANGES

1) Remove reactive load from the following buses:

BUS NO.	AMOUNT (MVAR)
187	17.2
188	17.2
189	17.2
251	17.2

Table F-6

2000 SYSTEM F LINE AND TRANSFORMER ADDITIONS

FROM BUS	TO BUS	LENGTH (MILES)	DESCRIPTION	1995	2000
216	144		100 MVA	2	3
151	223		250 MVA	2	3
115	201		500 MVA	5	7
108	200		800 MVA	3	5
207	261	20	1-230 KV	1	2
163	164	10	1-138 KV	2	3
180	260		250 MVA	3	4
179	410		500 MVA	0	1
260	410	20	1-230 KV	0	1
228	441	30	1-230 KV	0	1
155	411		500 MVA	0	1
232	234	20	1-230 KV	1	2
150	232	60	1-230 KV	0	1
169	235	30	1-230 KV	0	1
142	143	20	1-230 KV	1	2
188	189	20	1-138 KV	2	3
131	209	20	1-230 KV	0	1
163	178	30	1-138 KV	1	2
228	244	50	1-230 KV	2	3
178	264	20	1-138 KV	2	3
168	235		150 MVA	2	4
233	235	50	1-230 KV	0	1
170	243	50	1-138 KV	1	2
156	158	20	1-138 KV	1	2
126	130	40	1-138 KV	1	2
178	264	20	1-138 KV	1	2
150	153	50	1-230 KV	2	3
176	243		200 MVA	2	4
190	192	60	1-138 KV	1	2
153	237	50	1-230 KV	2	3
158	228		500 MVA	6	8
127	259	40	1-500 KV	1	2
127	205		500 MVA	4	5
149	164	80	1-138 KV	1	2
262	263		500 MVA	6	7
151	152		138 KV	3	4
176	235	60	1-230 KV	0	1

Table F-7

2000 SYSTEM F MISCELLANEOUS CHANGES

1) Remove reactive load at the following buses:

BUS NO.	ORIGINAL (MVAR)	FINAL (MVAR)
102	22.6	0
205	181.2	90
216	22.6	0
263	45.3	0

2) Add capacitors at the following buses:

BUS NO.	AMOUNT (MVAR)
130	50
181	25
183	25
187	25
190	25
263	300

Table F-8

1985 SYSTEM F TRANSFORMER MVA SIZES

FROM BUS	TO BUS	NO. OF TRANSFORMERS	SIZE (MVA)
102	197	1	300
103	196	3	400
104	198	1	300
105	199	3	400
108	200	3	400
115	201	3	250
118	202	2	400
120	124	2	100
122	203	2	250
123	204	2	250
126	259	2	250
126	261	2	250
127	205	2	500
129	206	3	400
131	207	2	150
132	209	2	150
135	211	2	150
137	208	2	150
137	258	2	500
138	212	2	500
140	210	2	100
142	213	2	150
144	215	2	250
144	216	2	100
146	217	2	250
147	218	3	300
148	219	2	150
149	220	2	150
150	221	2	150
150	222	2	250
151	223	2	250
152	224	3	300
154	225	2	150
156	226	2	250
157	227	2	150
158	228	4	250
159	229	2	100
160	230	2	150
161	231	2	250
165	232	2	150
166	233	2	150
167	234	2	150
168	235	2	150
169	236	2	100
170	238	1	300
171	239	2	100
172	240	2	250
174	241	2	150
175	242	2	100
176	243	2	100
177	244	2	150
180	260	2	250
182	245	2	100
185	246	2	100
186	247	2	100
187	248	2	250
189	249	2	100
189	250	1	300
190	251	2	100
191	252	2	100
193	253	2	100
194	254	2	100
195	255	2	100
215	503	3	500
222	501	4	600
255	256	2	250
262	263	4	500
501	502	2	500
503	505	5	500

APPENDIX A

REVISED EXPANSION OF SCENARIO F

A study of transmission benefits of dispersed generation* sponsored by EPRI required an accurate expansion of one of the scenario systems based on conventional generation. The expansion was needed for comparison with similar expansions using some quantity of dispersed generation. In analyzing the expanded scenario in this report, it was observed that the miles of transmission added to the system in the period 1985 to 2000 was considerably below the historical level, and below projections and extrapolations of the historical trend. The low level of added transmission resulted in a low level of overall system miles per megawatt. A comparison of industry average miles per megawatt from one source and the results of this study are presented in Exhibit 1.

The main concern with the miles-per-megawatt trend was that whatever caused the deviation from industry average might also influence the results of the dispersed generation study.

The low miles per megawatt for the expanded system was deemed attributable to one or more of the following possible causes:

1) Replacement of equipment which is at its end-of-life is not considered.

2) Scenario F is about 65 percent 138 kV in 1985. All load increases were assumed to occur at existing load buses (most are 138 kV) so that no new load buses and associated transmission were added. The large lumped loads resulted in 230 kV additions and little 138 kV additions.

3) Radial transmission was eliminated by equivalencing in the formation of the base 1985 systems, and remains equivalenced in the expansions. Additions in these areas are neglected.

4) Many interarea interconnections were eliminated to separate the U.S. systems into the smaller scenario systems. These bulk system lines which would appear around the perimeter of the synthetic system are neglected.

5) The ratings of each voltage level (150 MVA at 138 kV; 600 MVA at 230 kV; 2000 MVA at 500 kV) are assumed constant for all circuits in the system regardless of length. No allowance is made for voltage/reactive limitations of long lines.

6) No line additions are made for purposes of transient stability.

7) The single-contingency-without-redispatch design approach used in the expansions differs from industry practice where lines have multiple ratings (cont. LTE, STE), redispatch is used, and second contingencies are considered (as well as maintenance outages).

9) The expansion procedure uses just one typical peak load generation dispatch.

The last of these possibilities was deemed to be the most significant since it might add interarea bulk transmission circuits as well as plant outlet transmission capacity. So, synthetic system F was re-expanded using four dispatches, each featuring maximum output of the plants in one area of the system. The re-expansion included only the 1985 to 1995 period and was done for the 10-year period rather than in two 5-year increments. The remainder of this Appendix presents the results of this work.

Four base load flows were set up, each with a different group of generators at full output. Each group of generators included all the plants in one area of the system. The increase was balanced by generation reduction in the remainder of the system, with most of the reduction at the more remote plants so that power transmission would be maximized. Since having all the plants in an area at full output simultaneously would not be a credible system operating condition, the line addition criteria

was modified. Instead of eliminating all overloads resulting from single line outages, only the overloads exceeding 105 percent of line ratings were eliminated by transmission additions. This turned out to be not so significant, since the number of overloads between 100 and 105 percent were small and few lines would have had to be added to eliminate them (most of these overloads were transformers).

The line additions required by the four-dispatch approach in the 1985 base system and the expansion from 1985 to 1995 are listed in the several exhibits in this Appendix. These exhibits were extracted directly from a report being prepared on the dispersed generation study. The exhibits labeled Exhibit 2 and Exhibit 3 contain the line and transformer additions made to the 1985 base system. Exhibits 4 and 5 include the line and transformer additions required during the period 1985 to 1995. The circuits added during this period are those in Exhibit 4 indicated by the heading 'conv.' and not earmarked by footnote 1, and those in Exhibit 5 indicated by the heading 'conv.'.

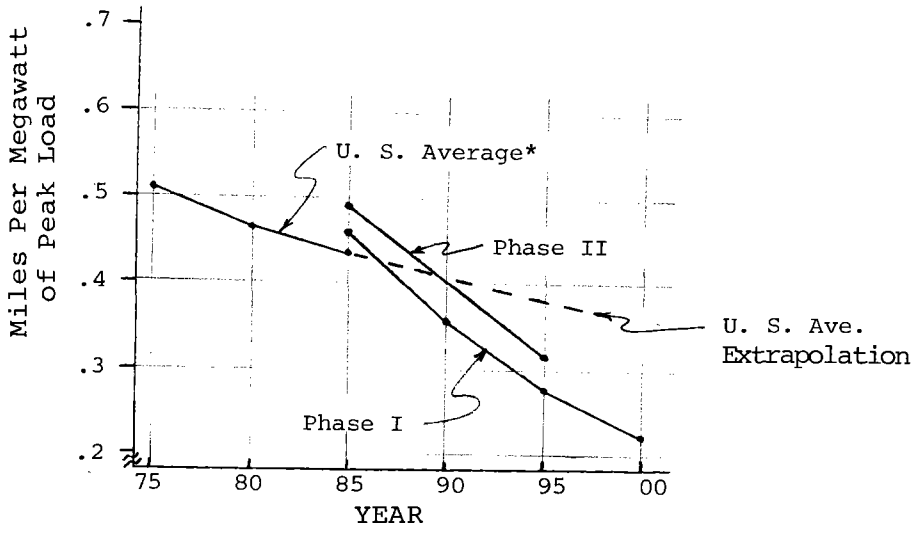
The systems resulting from the single dispatch and four dispatch approaches are compared in Exhibit 1. The curve labeled Phase I is actually derived from a single-dispatch conventional generation pattern expansion done in the dispersed generation study, but approximates the expansion of Scenario F in this report. A significant number of additional circuits were required by the four-dispatch approach, but the slope of the miles per megawatt characteristic in the range 1985 to 1995 is not changed significantly. This characteristic, labeled Phase II, is simply shifted upward. Also included in Exhibit 1 is the miles per megawatt characteristic for the U.S. for the period 1975 to 1985

(as derived from one source), and an extrapolation of this characteristic through 1995. The differences in slope are evident. Further discussion of the expansion techniques will be available in the report on dispersed generation which will be published by EPRI.

* An EPRI project now in progress.

EXHIBIT 1

MILES PER MEGAWATT COMPARISON - EXPANDED SYSTEM
VERSUS INDUSTRY AVERAGE



* Includes transmission associated with new generation and load as well as transmission constituting replacement of existing plant. Based on NEMA 1978 Industry Market Survey.

Calculations:

Year	85	90	95	00	
Phase I	$\frac{13340}{29515}$	$\frac{13630}{38759}$	$\frac{14140}{50898}$	$\frac{14695}{66840}$	$\frac{\text{Miles}}{\text{MW}}$
Phase II	$\frac{14265}{29515}$		$\frac{16055}{50898}$		$\frac{\text{Miles}}{\text{MW}}$

EXHIBIT 2

CHANGES TO 1985 SYSTEM TO ELIMINATE BASE AND PRIMARY CONTINGENCY OVERLOADS

TRANSFORMER ADDITIONS

FROM	TO	MVA	UNIT #
128	147	150	4
208	258	500 (each)	1 & 2
180	260	250	3
161	231	250	3
127	205	500	3
172	240	250	3
112	401	500	1

LINE ADDITIONS

FROM	TO	KV	MILES	CIRCUIT #
207	208	230	30	2
178	264	]38	20	2
200	401	500	30	1
202	401	500	40 (each)	1 & 2
140	223	230	60	1
			220	

EXHIBIT 3

CHANGES TO 1985 SYSTEM TO ELIMINATE
BASE AND PRIMARY CONTINGENCY OVERLOADS*

From	To	Miles or MVA	kV or X**	
130	145	30	138	
215	503	500	X	
178	268	300	X	Tap; adds xfr and 5 mi. 230
163	267	500	X	Tap; adds xfr and no miles
218	406	1500	X	
206	406	65	500	
194	254	300	X	
141	265	200	X	
141	265	200	X	
223	265	20	230	
223	265	20	230	
224	240	30	230	
235	240	50	230	
208	220	40	230	
208	219	60	230	
235	402	500	X	Tap; adds xfr, no miles
178	264	]50	X	
101	116	30	138	
127	259	40	500	
215	503	500	X	
193	252	40	230	
194	254	300	X	
230	231	60	230	
159	229	300	X	
267	268	30	230	
260	268	100	230	
105	114	30	138	
224	240	30	230	
241	255	20	230	
182	183	30	138	
206	406	65	500	
218	406	1500	X	
235	402	500	X	
161	231	500	X	
126	261	250	X	
163	164	10	138	
140	223	60	230	
125	131	20	138	
180	260	250	X	

* In addition to changes made in Phase I.
** X indicates transformer.

EXHIBIT 4

CIRCUIT ADDITIONS 1985-2000

CIRCUIT From	To	XFR or kV	MI or MVA	UNIT #		85-90 CONV.	85-90 10%	85-90 25%	90-95 CONV.	90-95 10%	90-95 25%	95-00 CONV.	95-00 10%	95-00 25%
215	503	XFR	500	4	1	X	X	X						
222	501	XFR	600	5		X								
115	201	XFR	500	4		X								
501	502	XFR	500	3		X	X	X						
215	503	XFR	500	5	1	X	X	X						
194	254	XFR	100	3	1	X								
177	244	XFR	150	3		X	X				X			
235	240	230	50	1	1	X				X				
202	212	500	70	2		X	X	X						
104	199	500	50	2		X	X				X			
235	240	230	50	2		X								
105	114	138	30	3	1	X	X	X						
193	252	230	40	1	1	X								
262	263	XFR	1000	5					X	X	X			
159	229	XFR	100	3	1				X	X	X			
132	209	XFR	150	3					X					
167	234	XFR	150	3					X	X	X			
151	234	XFR	500	3					X	X	X			
108	200	XFR	800	4					X	X	X			
115	201	XFR	500	5					X	X				
127	205	XFR	1000	5					X	X	X			
167	234	XFR	150	4					X					
235	402	XFR	500	1	1,2				X	X	X			
159	229	XFR	100	4	1				X	X	X			
138	212	XFR	500	3					X	X	X			
148	219	XFR	150	3					X					
229	230	230	20	1					X	X				X
105	114	138	30	4					X	X				
218	226	230	30	2					X	X				
150	153	230	60	2	3				X	X	X			
140	223	230	60	2					X	X				
219	228	230	50	2					X	X				
224	240	230	30	1	1				X	X	X			
249	252	230	30	2					X					
229	231	230	30	2					X	X	X			
130	145	138	30	2	1				X					
188	189	138	20	2					X					
223	224	230	20	3					X					
241	255	230	20	2	1					X	X			
197	262	500	100	3					X	X				
152	173	138	50	4						X				

1. These circuits added to 1985 system in Phase II.

2. Add 2-500 kV line terminals.

3. Removed in Phase II.

EXHIBIT 5

CIRCUIT ADDITIONS 1985-1995

From	To	Miles or MVA	kV or Xfr*	Conv.	Disp.	From	To	Miles or MVA	kV or Xfr*	Conv.	Disp.
240	266	50	230	X		219	403	20	230	X	
161	231	500	X	X	X	228	403	30	230	X	
230	231	60	230	X		155	403	300	X	X	
224	240	30	230	X	X	153	405	1000	X	X	X
224	240	30	230	X	X	153	405	1000	X	X	X
208	220	40	230	X	X	153	405	1000	X	X	X
144	215	500	X	X	X	173	266	400	X	X	
220	225	10	230	X	X	184	247	20	230	X	
234	244	50	230	X	X	247	249				
238	271	500	X	X		222	405	20	500	X	X
169	237	tap	230	X		222	405	20	500	X	X
207	209	20	230	X	X	222	405	20	500	X	
208	258	500	X	X		223	265	20	230	X	X
160	230	300	X	X		231	260	120	230	X	X
						127	258	70	500	X	X
254	255	60	230	X							
260	268	100	230	X		104	197	20	500	X	
234	267	50	230	X	X	171	239	300	X	X	X
267	268	30	230	X	X	225	232	20	230	X	X
150	222	250	X	X	X	232	234	20	230	X	X
197	262	100	500	X		140	142	20	230	X	X
227	229	20	230	X	X	129	206	600	X	X	X
						199	202	100	500	X	X
229	231	30	230	X	X						
144	216	400	X	X	X	193	251	70	230	X	
202	259	10	500 tap	X	X	193	254	30	230	X	
200	202					126	259	500	X	X	X
152	224	500	X	X	X	126	259	500	X	X	
218	227	20	230	X	X	255	256	400	X		X
227	230	20	230	X		168	235	400	X		X
219	228	tap	230	X		235	240	50	230		X

* Transformer indicated by an X in this column.

APPENDIX B

PTI CONTINGENCY ANALYSIS PROGRAM - PCAP

POWER TECHNOLOGIES INC		BULLETIN PTI/78 Page 1 of 4
P.O. BOX 1058	SCHENECTADY, NEW YORK 12301	518 374-1220

SUMMARY

PCAP is a FORTRAN IV computer program that provides the system planner with a tool to efficiently assess the adequacy of a specified transmission network for various line and generator outage conditions. Transmission adequacy is determined by comparing the power flows calculated during the various outage tests to the specified circuit capacity. If an overload or system separation is detected, the outage which caused it is considered to be a failure event. The probability and frequency of occurrence of all such failure events is calculated from historic forced outage data and accumulated to produce a final summary of the network performance. This summary allows the planner to assign a reliability index to the transmission network and, since conventional load flow analyses are performed for each outage test, the planner can identify and therefore strengthen areas of potential weakness. PCAP also calculates a system failure risk index due to generation outages. This index is based on cumulative generation outage probability and frequency tables, and allows the planner to assess the adequacy of the generation, independent of the transmission. The linearized (dc) load flow model is used to predict transmission circuit and transformer power flows and phase angles.

DESCRIPTION OF OUTAGE TESTS

A unique feature of PCAP is its ability to automatically select and test the most critical circuit and generation outages. This is accomplished by mathematically defining a system performance index based upon line flows and line capacities, and then calculating the gradient of this performance index with respect to transmission line and generation changes. This gradient allows PCAP to select the most critical components (with respect to the performance index) for outage tests. Both single component (primary contingency) and simultaneous double component (primary contingency with additional secondary contingency) outages can be selected and tested in this manner. The only contingency data that the planner is required to specify are the number of primary generator outages and circuit outages to be tested, and the number of secondary generator and circuit outages to be tested. For example, if five primary generator contingencies and three secondary circuit contingencies are specified, PCAP will select and test the five most critical generator outages, and for each of these select and test the three most critical circuit outages. A total of 20 (5 + (5x3)) outages will be tested. The planner may augment the primary contingency list by specifying (in the input data) particular generators and circuits for outage tests. In this manner, simultaneous double circuit outages may be tested which count as one primary circuit contingency. During generation outage tests, PCAP redispatches the remaining generation to minimize the performance index. This automatic dispatching can be controlled by the planner through input data parameters. Generation is also redispatched if a system separation occurs due to circuit outages. Only if overloads occur, or generation capacity constraints in either of the subsystems do not allow load demand to be satisfied, is the outage which created the separation considered to be a failure event.

APPLICATIONS

Development of comparative reliability indices for the assessment of bu[illegible] power supply system design alternatives.

SPECIFICATIONS

- Dc load flow solution by Gaussian elimination with optimal ordering.
- Efficient gradient calculation by use of an adjoint network which makes optimal use of the traingularized structure of the system.
- FORTRAN IV
- Available as batch program on IBM, UNIVAC, and PRIME computers.
- Ability to handle different types of lines along the same right-of-way.
- Up to 1500 buses, 3000 circuits (600K byte main core).

INPUT

- Standard load flow input data format
- Minimum and maximum generation for each unit
- Megawatt rating for each circuit
- Circuit and generator failure rates and repair time
- List of specified contingencies (optional)
- Number of automatically selected primary and secondary contingencies to be tested.

OUTPUT

Data listing, system failure risk index, base case load flow, detailed description of each contingency, final tabular summary.

DOCUMENTATION AND SUPPORT

Users' Manual, Program Manual, and instruction in use of program.

AVAILABILITY

- Available for purchase
- Available for problem solution at PTI.
- Modification for customer requirements is negotiable.

FOR FURTHER INFORMATION

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Power Technologies, Inc.
P.O. Box 1058
Schenectady, New York 12301

Tel. (518) 374-1220
Telex 145498 POWER TECH SCH

1/77

SAMPLE OUTPUT

```
*** SUMMARY OF RESULTS FOR SECONDARY CIRCUIT CONTINGENCY NO.  1 ***
     (CONTINGENCY TEST #    45 USED AS BASE CASE)

 ******************************
 *** CONTINGENCY TEST #    49 ***
 ******************************

 PCAP  EXAMPLE
 FAVORITE POWER COMPANY          , S.  1980
 DATE:  5/24/76


 *** DESCRIPTION OF CONTINGENCY ***

       FROM BUS             TO BUS      CKT.NO
   3 BURNS345          8 GRANT TP          1
   8 GRANT TP         20 SCOTT345          1
   8 GRANT TP         24 WILLIAMS          1

 *** NUMBER OF SUBSYSTEMS CREATED BY CONTINGENCY=  2 ***

        BUSES BELONGING TO SUBSYSTEM 1-
           1   9  16  21  25  11  12   4  18  19
           5  14   7   8   6  20  24  13  22  23
          17  10

        SUBSYSTEM LOAD= 6828.0  SUBSYSTEMCAPACITY= 7853.0

        BUSES BELONGING TO SUBSYSTEM 2-
           3

        SUBSYSTEM LOAD=    0.0  SUBSYSTEMCAPACITY= 1030.0

 *** ISOLATED UNITS TAKEN OFF LINE ***
        UNIT  NAME   BUS  PRESENT  MINIMUM  MAXIMUM
         NO              DISPATCH DISPATCH DISPATCH
           1 UNIT 1    3   1030.0    830.0   1030.0

 *** SUMMARY OF CIRCUIT OVERLOADS FOR INERTIAL DISPATCH ***
 FROM   BUS NAME     TO    BUS NAME    CKT# MW FLOW MW CAP PCNT CAP
   12 HEDMEN         19 SAGER345        1 -1640.0  1327.    123.6

 *** OVERLOAD MINIMIZATION DISPATCH USED ***

 *** SUMMARY OF CIRCUIT OVERLOADS FOR O.L. MINIMIZATION DISPATCH ***

                N O   O V E R L O A D S

 *** SUMMARY OF GENERATION DISPATCH FOR THIS CONFIGURATION ***
 UNIT  NAME   BUS CONNECTED  DISPATCH MAXGEN MINGEN INPUT
    1 UNIT 1    3 BURNS345  OFF-LINE 1030.0  830.0 1030.0
    3 UNIT 3   11 HANNET       200.0  500.0  200.0  500.0
    4 UNIT 4   11 HANNET       209.3  500.0  200.0  500.0
    8 UNIT 8   16 LEONARD      450.0  450.0    0.0    0.0
    9 UNIT 9   10 HADLEY      1288.0 1288.0    0.0  693.0
   11 UNIT11   12 HEDMEN       510.0  510.0    0.0  100.0
   12 UNIT12   17 MILLS345     165.7  600.0    0.0    0.0

 FAILURE PROBABILITY=0.7841E-09   CYCLE FREQUENCY (PER DAY) =0.2015E-08
```

*** FINAL SUMMARY OF RESULTS ***

PCAP EXAMPLE
FAVORITE POWER COMPANY , 8, 1980
DATE: 5/24/76

*** CIRCUIT OVERLOAD FAILURES ***

CIRCUIT DESCRIPTION FROM	TO	CKT NO	NO OL	TOTAL PROB	TOTAL FREQ	EXP.VAL % CAP	WORST % CAP	LOC WORST
11	4							
HARKET	CLARK345	1	2	0.2497E-03	0.2291E-03	122.7	155.1	57
4	13							
CLARK345	JOHNSON	1	3	0.2537E-03	0.2358E-03	119.6	140.8	57
4	13							
CLARK345	JOHNSON	2	4	0.2538E-03	0.2361E-03	119.7	169.8	58
12	14							
HEDMEN	LAMBERT	1	1	0.1008E-07	0.2327E-07	109.0	109.0	46
12	14							
HEDMEN	LAMBERT	2	1	0.1008E-07	0.2327E-07	109.0	109.0	46
21	20							
STEWART	SCOTT345	1	14	0.1347E-01	0.6462E-02	130.0	162.6	67
21	20							
STEWART	SCOTT345	2	15	0.1397E-01	0.6606E-02	130.2	162.6	60
16	5							
LEONARD	CLAYTON	1	14	0.1703E-01	0.7086E-02	116.4	137.6	43
16	5							
LEONARD	CLAYTON	2	14	0.1703E-01	0.7086E-02	116.4	137.6	42
16	10							
LEONARD	HADLEY	1	2	0.1578E-02	0.4633E-03	100.1	100.1	28
16	10							
LEONARD	HADLEY	2	3	0.1877E-02	0.5512E-03	102.9	117.4	30
16	10							
LEONARD	HADLEY	3	3	0.1877E-02	0.5512E-03	102.9	117.4	30
9	10							
GREEN345	HADLEY	3	2	0.5135E-03	0.7336E-04	108.5	108.5	63
9	10							
GREEN345	HADLEY	4	2	0.5135E-03	0.7336E-04	101.1	101.1	63
12	19							
HEDMEN	SAGER345	1	4	0.1519E-07	0.3695E-07	134.1	143.0	46

TOTAL NUMBER OF CIRCUIT OVERLOADS = 84
TOTAL PROBABILITY =0.2120E-01
TOTAL FREQUENCY =0.9164E-02
EXPECTED VALUE OF OVERLOADS = 120.6
CONTINGENCIES WHERE THESE EVENTS OCCURRED:

14	15	24	28	29	30	33	35	36	37	40
42	43	44	45	46	47	48	49	53	57	58
59	60	61	62	63	64	65	66	67	68	69
70	71	72								

*** OVERLOAD ELIMINATIONS ***
TOTAL NUMBER OF OVERLOADS ELIMINATED BY REDISPATCH= 23
CONTINGENCIES WHERE REDISPATCH ELIMINATED OVERLOADS

14	15	24	37	45	47	48	49	53	59	64
65	66	71	72							

*** SUMMARY OF SYSTEM SEPARATION EVENTS ***

SEPARATIONS WITH LOAD NOT SERVED:

BUS	NAME	TOTAL PROB	TOTAL FREQ	MW NOT SERVED	%MWHR NOT SERVED	NO EVENTS
9	GREEN345	0.870E-10	0.275E-09	0.437E-05	0.225E-09	1
16	LEONARD	0.870E-10	0.275E-09	0.206E-05	0.225E-09	1
21	STEWART	0.870E-10	0.275E-09	0.162E-05	0.225E-09	1
23	WILSON	0.870E-10	0.275E-09	0.306E-06	0.225E-09	1
5	CLAYTON	0.870E-10	0.275E-09	0.103E-05	0.225E-09	1
14	LAMBERT	0.870E-10	0.275E-09	0.424E-06	0.225E-09	1
20	SCOTT345	0.870E-10	0.275E-09	0.141E-05	0.225E-09	1
24	WILLIAMS	0.870E-10	0.275E-09	0.103E-05	0.225E-09	1
10	HADLEY	0.870E-10	0.275E-09	0.373E-05	0.225E-09	1

TOTAL NUMBER OF EVENTS= 1
TOTAL PROBABILITY= 0.870E-10
TOTAL FREQUENCY= 0.275E-09
TOTAL MW NOT SERVED= 0.161E-04
% OF SYSTEM MWHR NOT SERVED 0.206E-09
CONTINGENCIES WHERE THESE EVENTS OCCURRED:
51

SEPARATIONS WITH ISOLATED GENERATION:
TOTAL NUMBER OF EVENTS= 3
CONTINGENCIES WHERE THESE EVENTS OCCURRED:
49 50 56

SEPARATIONS WITH ADEQUATE GENERATION:
TOTAL NUMBER OF EVENTS= 0

*** CAPACITY DEFICIENCY FAILURES WHICH WERE TESTED ***
TOTALS: NUMBER OF CAPACITY DEFS. = 7
TOTAL PROBABILITY =0.1942E-01
TOTAL FREQUENCY =0.1202E-01
CONTINGENCIES WHERE CAPACITY DEFICIENCIES OCCURRED
11 18 25 26 27 32 39

END OF PCAP STUDY