Puget Sound Area Electric Reliability Plan

Transmission Reinforcement Analysis Appendix E

Received PSTI

MAY 12 1992

DOE/BP--1844

DE92 013557

**DRAFT ENVIRONMENTAL IMPACT STATEMENT
PUGET SOUND AREA ELECTRIC RELIABILITY PLAN**

**Appendix E
Transmission Reinforcement Analysis**

**Bonneville Power Administration
U.S. Department of Energy**

Prepared as part of a coordinated plan to address a power system problem in the Puget Sound Area. Utilities participating in planning include: Bonneville Power Administration, Puget Sound Power and Light, Seattle City Light, Snohomish County Public Utility District No. 1, and Tacoma City Light.

April 1992

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

PSAERP Transmission System Reinforcement Options Engineering Report

Table of Contents

Transmission System Reinforcement Options Report	page 1-3
Table 1: Comparison of Transmission System Reinforcement Options	page 4
Pre-PSAERP Transmission System Diagram	page 5
Transmission System Reinforcement Options Diagrams	page 6-11
QV Curves of Transmission System Reinforcement Options	page 12-18
Basecases of Transmission System Reinforcement Options	page 19-39
Attachment 1: Puget Sound Reinforcement Transmission Alternatives Report	
Attachment 2: New Cross Mountain Transmission Line Alternative Memo Option 5	
Attachment 3: Reactive Plan Development	
Attachment 4: Option 6 Development (Rocky Reach-Maple Valley Rebuild)	
Attachment 5: Voltage Collapse studies for the Puget Sound Area	
Attachment 6: Review of BPA Voltage Collapse Studies and Reactive Plan by Power Technologies, Inc.	
Attachment 7: Executive Summary of report by GE entitled " Voltage Stability of the Puget Sound system under Abnormally Cold Weather Loads"	

The purpose of this report is to provide an update of the latest study work done on transmission system options. Much of the development work for these options is included in the attachments of this report. Also included in the attachments are 2 reports analyzing the voltage stability of the Puget Sound transmission system (one by BPA and one by General Electric) and a review by Power Technologies, Inc. of the BPA voltage stability analysis and reactive options.

Five transmission line options and several reactive options are presently being considered as possible solutions to the PSAERP by the Transmission Team. The first two line options would be built on new rights-of way adjacent (as much as possible) to existing corridors. The reactive options would optimize the existing transmission system capability by adding new stations for series capacitors and/or switchgear. The other three line options are rebuilds or upgrades of existing cross mountain transmission lines. These options are listed below and include a preliminary assessment of the additional transmission system reinforcement required to integrate the new facilities into the existing transmission system. Plans were designed to provide at least 500 MVAR reactive margin.

The transmission line options were derived from earlier study work that was summarized in "Puget Sound Reinforcement Transmission Options" and "New Cross Mountain Transmission Line Alternative: The Crosstie", which are attached. The initial Transmission Options study report recognized the value to system performance of adding an entirely new circuit rather than rebuilding an existing one. However, siting realities require that rebuild options be considered. Typically, the most attractive rebuild options would be the lowest capacity (lowest voltage) circuits. But because of corridor location, length and terminal proximity, the rebuild options listed below appear to be the most promising. Diagrams of each option are also attached.

ASSUMED SYSTEM ADDITIONS

The following equipment is assumed to be in service: Echo Lake substation (which is referred to as Snoqualmie in the studies); 300 MVAR SVC's at Maple Valley and Keeler; LDC's at Coulee, Centralia, John Day, The Dalles and Bonneville; and new 230-kv capacitor banks at Tacoma, Olympia and Snoking and the Option 14 reactive plan (two 500-kv capacitor groups at Raver, Echo Lake and Monroe). These additions will meet the winter 1995-96 load level as shown in QV Curve-0. No local generation additions beyond 1993 or accelerated conservation programs have been added to these studies.

OPTION 1: New Chief Joseph-Monroe/Echo Lake 500-kV double circuit line

A new double-circuit 500-kV line would be built on new right-of way from Chief Joseph substation west toward Monroe following the existing Stevens Pass corridor. In the vicinity of Skykomish the double circuit line would split, with one circuit continuing on to Monroe following the existing corridor. The other circuit would head southwest on a new corridor toward Echo Lake substation. A new 500/230-kV transformer would be needed at the existing Snoking substation. The existing 230-kV line that feeds this substation from Monroe was designed for 500-kV operation and would need to be converted at that time. A second Bothell-Snoking 230-kV line would also be needed and this line could be obtained by reconnecting existing lines in the area and/or constructing

new lines. A second Chief Joseph 500/230-kV transformer will also be needed and this can be added in the existing substation. This plan is analyzed in detail in "Puget Sound Reinforcement Transmission Options" in Attachment 1.

OPTION 2: New Chief Joseph-Echo Lake 500-kV double circuit line

A new double-circuit line would be built on new right-of way from Chief Joseph substation southwest by Sickler substation to Echo Lake substation following the existing Snoqualmie Pass corridor. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1. This plan is also analyzed in detail in "Puget Sound Reinforcement Transmission Options" in Attachment 1.

OPTION 3: Reactive additions (Voltage Support-2)

This plan involves building a new substation in the vicinity of Naneum, tying all the 500-kV lines together. Series compensation would be added west of this new station on the old Coulee-Raver lines (19 ohms and 3150 amps). In the early 2000's, additional series compensation would be needed on the other two lines west of Naneum, (20 ohms and 2200 amps on the old Sickler-Raver line and 23 ohms and 2000 amps on the old Vantage-Raver line). Also an upgrade of the Columbia series capacitors to 2700 amps will be needed at this time. An alternative to the latter two capacitor banks would be to increase the 19 ohm series capacitor banks on the Coulee-Raver lines to 26 ohms and 4200 amps. With this cross mountain reinforcement, a new transformer will be needed at Snoking in 2000 (as discussed in Option 1). Also, a second Raver-Echo Lake 500-kV line or the Chief Joe-Monroe series compensation, as discussed in Attachment 3, will be needed in about 2001. A third shunt capacitor group is also needed in the vicinity of Raver in about 2001. (These later additions may not be needed until after 2003 in the PSAERP preferred option because the accelerated conservation and expected resources will reduce flows into the Puget Sound area.)

Many other options and variations were also studied. Refer to Attachment 3 for the development of these options. It should be noted that substation names of Naneum, Kittitas and Schultz are interchangeable in the Reactive Options analysis.

OPTION 4: Chief Joseph-Snohomish 345-kV upgrade with Crosstie

The existing Chief Joseph-Snohomish 345-kV double circuit line (through the Stevens Pass corridor) would be upgraded to a single-circuit 500-kV line in this option (using the existing right-of-way). This upgrade would be accomplished by replacing the top of the existing double circuit towers with new single circuit ones and adding three new conductors. The feasibility of this transmission line upgrade is still being investigated. A new single circuit line would also be needed between Columbia, Sickler and a new substation on the Stevens Pass corridor, tentatively called Mad River (near Chumstick). The rebuilt Chief Joe-Snohomish line would be connected to Monroe substation and a new 500/230-kV transformer would be added at Snohomish to replace the 345/230-kV transformers that will be removed. A third Bothell-Snohomish 230-kV line would be needed with this transformer and could be obtained by connecting one of SCL's Skagit River lines into Snohomish or by building a new circuit. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1. An additional 30% series compensation would be needed at a new site near Naneum on the existing Coulee-Raver lines. Eventually a second Raver-Echo Lake 500-kV line (adjacent to the existing line) will also be needed. This plan is analyzed in detail in the report entitled "New Cross Mountain Transmission Line Alternative: The Crosstie" in Attachment 2.

OPTION 5: Chief Joseph-Snohomish 345-kV rebuild

The existing Chief Joseph-Snohomish 345-kV line (through the Stevens Pass corridor) would be replaced by a new double-circuit 500-kV line in this option (using existing right-of-way). This new line would be connected to Monroe substation and a new 500/230-kV transformer would be added at Snohomish to replace the 345/230-kV transformers that will be removed. A second Bothell-Snohomish 230-kV line would be needed with this transformer and could be obtained by connecting one of SCL's Skagit River lines into Snohomish or by building a new circuit. One of the circuits between Monroe and Snohomish would operate at 500-kV to supply the new transformer, the other would operate at 230-kV. New transformers would also be needed at Snoking and Chief Joseph as described in Option 1.

OPTION 6: Rocky Reach-Maple Valley 345-kV rebuild with Crosstie

The existing Rocky Reach-Maple Valley 345-kV line (through the Snoqualmie corridor) would be replaced by a new double-circuit 500-kV line in this option (using existing right-of-way). This new line would be connected to Echo Lake substation and a new 500/230-kV transformer would be added at Maple Valley to replace the 345/230-kV transformer that was removed. Since Sickler substation is not a strong enough source for a new double circuit line, it will have to be reinforced. Many options exist to do this (as discussed in Attachment 4), but the following option has some desirable traits. A double circuit line would be added between a new Columbia switching station (adjacent to the existing series capacitor yard and 230/115-kV substation) and this new line following the Columbia-Rocky Reach 230-kV line. These additions would create a Sickler-Echo Lake line, a Columbia-Echo Lake line and a Columbia-Sickler line. A new single-circuit line would also be needed between Columbia and the Coulee-Hanford line, following the 115-kV right-of-way east toward the old Rocky Ford substation site. A small switching station would be required there. A second Sickler 500/230-kV transformer will also probably be needed. Eventually a Snoking 500/230-kV transformer would be needed as described in Option 1.

SUMMARY

The performance of these options is summarized in Table 1. All of these options will solve the voltage stability problems in the Puget Sound Basin beyond the 2003 study period. The two new line options (Options 1 and 2) are somewhat stronger than the other plans for outage conditions since they contain more transmission lines. The upgrade of the Chief Joseph-Snohomish line to single circuit 500-kV (option 4) is the weakest of the transmission options being investigated, however it should be the least expensive. This option would be slightly better than the Reactive Options for solving the voltage stability problems.

All of the transmission line options save a substantial amount of transmission system losses. Option 5, the rebuild of the Chief Joseph-Snohomish 345-kV to 500-kV double-circuit would save the most. The next best loss-saver is Option 1. Options 2, 4 and 6 have similar loss saving that are somewhat lower. The Reactive option saves the least amount of losses.

TABLE 1: COMPARISON OF TRANSMISSION REINFORCEMENT PLANS FOR PSAERP

<u>OPTION</u>	<u>PEAK SYSTEM LOSS SAVINGS</u>		<u>REACTIVE MARGIN</u>
	MW - 2004 BPA	PNW	MVARS - 2004 2-line/1-line/Trojan(3) margins include unused MSC QV curves are attached
1. New Chief Joe-Monroe/Echo Lake 500-kV double circuit	86	108	1100/900/900
2. New Chief Joe-Echo Lake 500-kV double circuit line	72	90	1000/900/900
3. Voltage Support 2 Switchyard and series caps 19/19/20/23 ohms	18 (1)	27 (1)	700/400/550 (2)
4. Chief Joe-Snohomish 345-kV upgrade to 500-kV single circuit	75	97	500/800/600
5. Chief Joe-Snohomish 345-kV rebuild to 500-kV double circuit	93	112	800/700/700
6. Rocky Reach-Maple Valley 345-kV rebuild to 500-kV double circuit	73	83	1200/700/800

(1) 10 MW of the BPA loss savings and 13 MW of the PNW loss savings is due to the addition of the Raver-Echo Lake #2 and Maple Valley Transformer #2 needed in early 2000's.

(2) This plan includes replacement of the third (PCB) capacitor group at Raver. Another option to this Raver group could be an MSC at Naneum.

(3) The Portland area will need to be supported in the early to mid 2000's. Cursory studies indicate that one MSC will provide this support; a 300 MVAR MSC at Marion substation near Salem. All options include this MSC.

Diagrams

PRE-PSAERP SYSTEM (Existing System plus Echo Lake Substation)

OPTION 1

OPTION 2

OPTION 3 (in circle)

Two 19 Ω capacitor banks needed initially
20 and 23 Ω capacitor banks needed in early 2000's

OPTION 4

OPTION 5

OPTION 6

QV-Curves

QV Curve - 0

PERFORMANCE OF SYSTEM WITH REACTIVE-1 INSTALLED

J97133:2C-R OUT(J9782)MSC @SNOQ(2),MON(1),TAC,OLY

J97EH65:CJ-MON OUT (J97EH63) MSC @ MON(1), OLY

J97EH66:TROJAN SCRAM (J97EH64) MSC @ MON(1), OLY

ALL MSC'S USED

22-JUL-1991

REACTIVE1.SETUP

PLAN 1: CHIEF JO-MONROE/SNOQUALMIE 500 ADDED

J04663:COUL-RAV 1&2 OUT(J04662)MSC SNOQ(2),RAV(1)
 J04EH426:COULEE-RAVER 500 OUT (J04EH422) NO MSC
 J04EH487:TROJAN SCRAM(J04EH423)MSC MON(1),OLY,MAR

MSC AVAILABLE
 MON,OLY
 MON,OLY
 None

○ J04663QV
 + J04EH487QV

△ J04EH426QV

PLAN 2: CHIEF JOE-SNOQUALMIE 500 ADDED

○ J04659:COULEE-RAVER 1&2 OUT(J04656)

MSC AT MON(1), SNOQ(1), RAV(1)

△ J04EH412:COULEE-RAVER 1 OUT(J04EH408)MSC AT MON(1)

+ J04EH413:TROJAN SCRAM (J04EH409)

MSC AT MON(1), OLY(1), MARION(1)

MSC AVAILABLE

SNOQ, OLY

OLY

None

○ J04659QV
+ J04EH488QV

△ J04EH412QV

ALL MSC'S
USED

PLAN 3: NANEUM SWYD

20% ON COULE-RAV, 30% ON SICK-RAV, 39% ON VANT-RAV
 ○ J04826: NAN-RAV 3&4 OUT, MSC 00L, SNQ, MON, RAV(J04825)
 △ J04827: GC-NAN 1&2 OUT, MSC 00L, SNQ, MON, RAV(J04825)
 + J04EH579: CJ-MON, MSC 0 OLY (J04EH577) MSC RAV
 x J04EH580: TROJAN SCRAM, MSC 0 OLY, MARION (J04EH578) MSC RAV

22-AUG-1991
 J04PLAN3-4.SETUP

PLAN 4: UPGRADE CJ-SNOHOMISH 345 TO 500 SSC
 ADD CROSSTIE: COLUMBIA-SICKLER-MAD RIVER 500 SSC
 J04651:MADRV-R-MONROE 1&2(J04650)MSC @MON1,SQ2,OLY1
 J04EH416:COLUMB-RAVER 1 OUT(J04EH406)MSC @ MON(1)
 J04EH489:TROJAN SCRAM (J04EH407) MSC @ OLY, MARION

○ J04651QV
 + J04EH489QV

△ J04EH416QV

22-JUL-1991
 PLAN4M.SETUP

PLAN 5: CHIEF JOE-SNOHOMISH REBUILT TO 500 SDC

J04653:COULE-RVR 1&2 OUT(J04652)MSC SNQ(2),MON,RAV

J04EH398:COULE-RVR 1 OUT(J04EH396)MSC @ MON(1)

J04EH490:TROJAN SCRAM (J04EH397)MSC @ OLY,MON,MAR

MSC AVAIL

OLY

OLY

None

○ J04653QV
+ J04EH490QV

△ J04EH398QV

22-JUL-1991
PLANSM.SETUP

PLAN 6: ROCKY RH-MAPLE VL 345 REBUILD TO 500 SDC

CROSSTIE ADDED: SICKLER-COLUMBIA-ROCKY FORD
 J04658:COL/SICK-SNOQ OUT(J04655)MSC @ SNOQ(2),RAV
 J04EH410:CJ-MON OUT (J04EH404) MSC @ OLY
 J04EH487:TROJAN SCRAM(J04EH423)MSC @ MARION & OLY

MSC AVAILABLE
 MON, OLY
 None
 None

○ J04658QV
 + J04EH487QV

△ J04EH410QV

22-JUL-1991
 PLAN6M.SETUP

Base Cases

19782 11/16/86 PJ V5008
CY85 P/L

1
2
3
4

INTERLIE SCHEDULE

AC= 0. AC= -288.
DC= 557. DC= 557.

LOSSES

BPA= 744.37
PNW= 1134.45
SYSTEM= 3869.11

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 971.

IDAHO TO PNW
SI= 700.
AI= 691.

500BUSNORTHWEST

J048. 8/22/91 PE V6010
CY89 ALH HJL
BASED ON J04632
NANEUM SWITCHYARD
30% COMP ON SICKLER-RAVER
20% COMP ON COULEE-RAVER
39% COMP ON VANTAGE-RAVER

500BUSNORTHWEST

INTERTIE SCHEDULE

AC= -730. AC= -949.
DC= -1710. DC= -1710.

LOSSES

BPA= 898.53
PNW= 1336.88
SYSTEM= 4169.97

NADA TO PNW
(BCH & WK001)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1029.

IDAHO TO PNW
SI= 480.
AI= 532.

J04EH396 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH333
PLAN 5

S:PD R , PLOTTED 7-MAR-81 AT 10:28:21 HOURS

PF PLOT PFP334 : REVISED 10/11/80

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= -1175.	AC= -1369.	BPA= 977.23
DC= -2000.	DC= -2000.	PNW= 1426.94
		SYSTEM= 4269.91
IADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WKOOT)	SI= 1300.	SI= 480.
SI= 450.	AI= 1044.	AI= 543.
AI= 450.		

500BUSNORTHWEST

J04EH397 6/ 4/91 PF V6010
 CY89 MJL-ALH
 BASED ON J04EH337
 PLAN 5

INTERIE SCHEDULE

AC= -1175.
DC= -2000.

ACTUAL

AC= -1370.
DC= -2000.

LOSSES

BPA= 986.84
PNW= 1441.61
SYSTEM= 4285.54

ANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1039.

IDAHO TO PNW
SI= 480.
AI= 546.

500BUSNORTHWEST

J04EH337 9/9/91 PJ V6010
CY89 MIL ALI
BASED ON J04EH337
PLAN 6D

INTERTIE SCHEDULE

AC= -730.
DC= -1710.

ACTUAL

AC= -947.
DC= -1710.

LOSSES

BPA= 918.42
PNW= 1351.50
SYSTEM= 4185.13

ANADA TO PNW

(BOH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW

SI= 1300.
AI= 1032.

IDAHO TO PNW

SI= 480.
AI= 531.

500BUSNORTHWEST

J04EH406 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH333
PLAN 4

3:50 P, PLOTTED 7-MAR-91 AT 10:21:31 HOURS

PF PLOT PFP334 ! REVISED 10/11/90

INTERLIE SCHEDULE

AC= -1175.
DC= -2000.

ACTUAL

AC= -1368.
DC= -2000.

LOSSES

BPA= 994.18
PNW= 1439.73
SYSTEM= 4282.74

CANADA TO PNW
(BCH & WKCOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1044.

IDAHO TO PNW
SI= 480.
AI= 543.

J04EH407 3/ 7/91 PF V6010
CY89 MJL-ALH
BASED ON J04EH337
PLAN 4

S:PO R , PLOTTED 7-MAR-81 AT 10:25:12 HOURS

PFPL0T PFP334 : REVISED 10/11/90

500BUSNORTHWEST

INTERIE SCHEDULE

AC= -730. AC= -947.
DC= -1710. DC= -1710.

LOSSES

BPA= 903.54
PNW= 1358.27
SYSTEM= 4169.85

ANADA TO PNW
(BCH & WK001)
SI= 450.
AI= 450.

MONI TO PNW
SI= 1300.
AI= 1032.

IDAHO TO PNW
SI= 480.
AI= 531.

J04EH422 3/25/91 PF V6010
CY89 ALH-HJL
BASED ON J04EH333
PLAN 1

INTERTIE SCHEDULE

AC= -730.
DC= -1710.

ACTUAL

AC= -955.
DC= -1710.

LOSSES

BFA= 990.42
PNW= 1446.55
SYSTEM= 4284.97

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1016.

IDAH0 TO PNW
SI= 480.
AI= 539.

500BUSNORTHWEST

10/11/97 8/22/91 FF V6010
C189 ALL 111
BASED ON J04EH333
NANEUM SWITCHYARD
30% COMP ON STICKLER-RAVEN
20% COMP ON COULEE-RAVEN
39% COMP ON VANTAGE-RAVEN

500BUSNORTHWEST

INTERIE. SCHEDULE

$$AC = -1175.$$
$$DC = -2000.$$

ACTUAL

$$AC = -1376.$$
$$DC = -2000.$$

LOSSES

$$BFA = 1077.31$$

PNW= 1544.85

SYSTEM= 4394.52

CANADA TO PNW
(RCH & WKOOT)

SI= 450.

$$AI = 450.$$

MONT TO PNW

$$SI = 1300.$$

AI= 1028.

IDAHO TO PNW

SI= 480.

AI= 551.

J0411579 8/22/91 FF V6010

CY89 ALH-11JL

BASED ON J04EH337

NANEUM SWITCHYARD

30% COMP ON SICKLER-RAVER

20% COMP ON COULEE-RAVER

39% COMP ON VANTAGE-RAVER

Attachment 1

ATTACHMENT 1

PUGET SOUND REINFORCEMENT TRANSMISSION ALTERNATIVES by Marv Landauer and Gordon Comegys - BPA 9-19-90

There is a minor omission in this document. Reinforcement is needed in the Lake Sammamish area within the study period. A Lakeside 230/115-kV transformer addition is assumed in the powerflow models after 2001 to correct these local problems. This project was inadvertently left out of Table 150, however, it is included in all options studied in this report. Projects such as this are needed in the powerflow to get accurate results from the analysis of the cross Cascade transmission capacity. The performance of the alternatives studied in this report are not dependent on the Lakeside project. This project will be studied independently by the utilities involved to determine whether this or some other option is most favorable.

PUGET SOUND REINFORCEMENT TRANSMISSION ALTERNATIVES

ASSUMPTIONS

This report uses the the same assumptions as contained in the 1-12-90 memo from Porter to Perry (Table 150).

The line ratings used in this report are included in Table 151. The assumptions include Skagit generation levels prior to and after January 6 of each year. For calculation of loss savings noted in this report, it is assumed that the high and low generation levels will each exist for half the winter peak load period and the loss savings will be the average of these two conditions.

At the time this study was started, there was some concern about the high number of unexplained outages experienced by the new 1.7 pu line designs. Therefore, a 2.0 p.u. line design was used in these studies for calculation of line parameters. Sensitivity of this assumption is tested in Table 310. Due to audible noise constraints, a 4-bittern conductor bundle is assumed.

If an SVC is used in any study, its output is assumed to be zero until a contingency occurs. From that point on, the SVC attempts to maintain the pre-contingency voltage of the bus it is connected to.

NOTE

The January 2004 cases (except Plan 5 and 6) have an error in the compensation level of the Coulee-Raver lines (45% instead of 22.5%). This error improved the performance of the EH winter outages by about 150 MVARs. It was, however, detrimental to the normal winter double line outages of the Coulee-Raver lines, since the system had to withstand the loss of this additional compensation with fewer shunt capacitors energized prior to the outage. This error will be corrected in future cases. It should not have a great effect on the comparison of these alternatives. Refer to Table 310 for more detail.

PROBLEMS

The potential for voltage instability exists in the Puget Sound area for several cross mountain line outages or loss of Trojan generation. This report will analyze the reinforcement of the Cross Mountain (CM) transmission system to relieve these problems. Modifications to the transmission system could cause increased flow in certain areas of the system and require additional facilities. Major areas with transmission problems that are affected by the CM reinforcement are the north Seattle area, Trojan area, Okanogan area and Coulee-Chief Joe area. These will be analyzed individually for each alternative studied.

Reactive support for the maingrid transmission system was studied through 2004. Not all plans are necessarily equal, since additions beyond this time (some of them may be significant) were not considered. Thermal problems in the bulk transmissions system in the Puget Sound area were studied through 2010 to ensure that the plans were equivalent. The other problems were only studied around the 1996 timeframe to measure the impact of the Cross Mountain reinforcement.

Solving the voltage stability problem in the Puget Sound area is a two-tiered problem. The voltages on the 230-kV system need to be supported to preserve the output of the large amount of shunt compensation on the lower voltage system and the reactive losses of the Cross Mountain (CM) transmission needs to be reduced.

There are also three problems that exist prior to the assumed energization of the CM reinforcement (10-96) and will not necessarily be solved by this project. They are: a breaker failure at Raver, the integration of the new PSPL line into Lake Tradition and the Massachusetts-Broadstreet 115-kV line overload.

The breaker failure at Raver could cause loss of the Raver-Snoqualmie and Raver-Tacoma lines, which, prior to the CM additions, would cause the Covington transformers to overload as shown in J96254. Reinforcement of the CM transmission would reduce the severity of this problem. It is assumed that this problem is corrected by rearranging the bus layout at Raver (somehow) and this fix will eliminate the problem in later years. However, the effect of each plan on the existing bus layout is analyzed in Table 170.

There are many line overload problems in the Lake Tradition area that are the result of poor integration of Puget's new 230-kV cross mountain circuit. The heavy loading of the 115-kV lines in this area is further aggravated by external outages. The Massachusetts-Broadstreet overload is caused by throughflow which occurs during maingrid equipment outages. Nothing is assumed to be added to correct these problems, however the effect of each CM reinforcement plan is analyzed with respect to these problems in Table 170.

ALTERNATIVES CONSIDERED

Thirty nine new line options were studied in an attempt to solve the Puget Sound Voltage Stability problem. Five of these are considered technically and economically feasible. Also discussed below are a Reactive Option (no line construction) and two rebuild options. Options that were studied and rejected are included in Tables 302 and 303. The options listed in Table 302 are considered technically feasible, but are too costly. Those options listed in Table 303 are not considered technically feasible or are technically inferior.

The performances of the 500-kV transmission line alternatives are fairly similar. Generic development of these alternatives is included in Table 310. Differences are noted with each plan.

A. Chief Joseph-Monroe 500-kV Double-Circuit Line: Plan 1

1. Puget Sound Area Voltage Stability Performance

This plan assumes a new double circuit Chief Joe-Monroe 500-kV line is built parallel to the existing circuit on new right-of-way (ROW). This new line and the 300 MVAR Static VAR Compensator (SVC) at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004, respectively. For more detail on these additions, refer to Table 310.

The voltage stability performance of Plan 1 is shown in QV-110 for 1996 and in QV-111 for 2004 for the 3 critical outages. Since this plan does not have the reactive margins for the double line outage in 2004, an additional 300 MVAR SVC is needed at Covington prior to the 2003-4 winter.

2. Puget Sound Area Thermal Overload Requirements

If the Chief Joe-Monroe 500-kV double-circuit line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These include:

- a. Loss of the Monroe-Sedro-Snohomish 230-kV three terminal line causes the Monroe-Snoking Tap 230-kV line to overload during low Skagit generation (J96M218). This overload will not occur with normal Skagit generation (J96M227).
- b. Loss of the Monroe-Snoking-Sammamish 230-kV three terminal line causes the Monroe-Sedro Tap 230-kV line to overload during low Skagit generation (J96M217). This overload will also not occur with normal Skagit generation (J96M226).
- c. Loss of the Maple Valley 500/230-kV transformer overloads the Monroe transformer beyond its emergency loading and loads the Monroe-Sedro tap line heavily (J96EH554).
- d. Loss of the double-circuit Chief Joe-Snohomish 345-kV lines during normal winter causes the Monroe-Sedro Tap 230-kV line to overload (J96235).
- e. Loss of the Monroe-Snoqualmie 500-kV line also overloads the Monroe 500/230-kV transformer (J96EH555).
- f. The Monroe transformer and the Monroe-Snohomish 230-kV line will overload during cold weather without any outages in 2001 as shown in J00EH32.

This is a difficult set of problems to solve. Since Monroe is strengthened considerably by the addition of the double-circuit CM line, the 230-kV system out of Monroe is stressed heavily as indicated by the fact that there are overloads in the base system without any outages in 2001. To correct these problems, additional 500/230-kV transformation is needed and the 230-kV system into Snohomish needs backup. Since the base system is so heavily stressed, a single reinforcement project will not be able to solve the problems through the study period (2010).

Adding a new Monroe-Snohomish 500-kV line to feed a 500/230-kV transformer at Snohomish would relieve these problems best initially. Case J96EH568 shows that a third Bothell-Snohomish 230-kV line is needed with this plan for the outage of one of the existing lines. This can be accomplished by looping-in or tapping one of SCL's Skagit lines. The worst outage for this plan appears to be the loss of the new transformer and/or the new Monroe-Snohomish 500-kV line (J00EH32) which will cause the Monroe transformer to overload in 2001.

To relieve these later problems, a transformer addition is needed in the Snoking/Snohomish area. Reinforcing Snoking with a 500/230-kV transformer looks attractive at this time since the Monroe-Snoqualmie 500-kV line can be tapped and the existing Snoking Tap 230-kV line can be converted to its design voltage of 500-kV (no new 500-kV line construction is needed). A second Bothell-Snoking 230-kV line is also needed with this transformer (case J00EH113). These additions should solve the area problems well beyond 2010.

If the Snoking transformer were added first, it would require a new circuit to Monroe and not just a tap on the Monroe-Snoqualmie line in order to correct problem 5 above. This line construction (9 miles) can be eliminated by adding the Snohomish transformer first, even though the Snoking project saves about 4

MW more losses than Snohomish.

If the Snoking 500/230-kV transformer is added first, the transmission between Monroe and Snohomish will overload in 1998 for the loss of the new Snoking transformer (J96EH565 and J00EH28). This plan is not as good as Snohomish since the conversion of the existing 230 tap line into Snoking to its design voltage of 500-kV just replaces the existing circuit with one of higher capacity. But since the new line is 500-kV, the system must serve abnormally cold weather loads during that outage instead of moderate loads as was the case prior to the change.

Additional transformation could be added at Monroe with an additional 230-kV circuit added to the Snohomish area. Loss savings would favor the addition of the transformation closer to the load, however, this could aggravate through-flow problems.

Tapping an existing Custer-Monroe 500-kV line to feed a 500/230-kV transformer at Snohomish is another possibility to relieve these problems and would save some line construction. However, loss of the Custer-Monroe line with the new transformer aggravates the overloads that would occur if only the transformer were lost. Additional support would be needed in about 1999 to eliminate the overloads of the Monroe transformer and Monroe-Snohomish line for loss of this new transformer as shown in case J00EH30. As shown above, this overload can be delayed about 2 years if an entirely new line is built from Monroe to Snohomish to supply the new transformer.

The loss savings due to the addition of the recommended Snohomish transformer project is about 13.5 MW on the BPA system and 14.9 MW total for the Northwest in 1996 (compare cases J96248, J96252, J96261 and J96262). These loss savings increase to 21.5 MW on the BPA system and 26.0 MW for the Northwest in 2000 (compare cases J0035, J0036, J0037 and J0038). Note that the 2000 cases have both the Snohomish and the Snoking transformers in service.

A 300 MVAR shunt reactor is required at Monroe to provide voltage control on the 500-kV system during lighter load periods.

Summer and spring conditions were studied (Tables 202-212). The assumed summer conditions include 2000 MW Ingledow to Custer powerflow and 8000 MW total PNW to PSW interchange schedules. The assumed spring conditions include 2000 MW Ingledow to Custer powerflow and 1800 MW Custer to Ingledow powerflow. Eleven transmission lines need upgrading to higher conductor operating temperatures (Table 201).

The Ingledow to Custer powerflow cannot exceed 1000 MW with the Monroe-Snoqualmie 500-kV line permanently out of service during summer. This applies only to Plan 1. The other plans can accommodate 2000 MW Ingledow to Custer during outages.

3. Portland Area Voltage Stability Performance

The critical outage for the Portland area is loss of the Trojan Nuclear plant with one Centralia generating unit previously out of service during abnormally cold weather loads. The addition of the new line into the Puget Sound area, with 300 MVAR SVC's at Maple Valley and Keeler will provide the necessary reactive margins in the Portland area. The Keeler SVC will need to be increased to 500 MVARs in later years to keep up with the load growth. Also, additional 500-kV shunt capacitors will be needed at Ostrander, Keeler and Pearl

substations between 1998 and 2004. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-112. For more detail on this plan, refer to Table 310.

4. Portland Area Thermal Overload Requirements

Prior to Puget Sound Reinforcement, the PGE Trojan-Rivergate 230-kV and Trojan-St. Marys 230-kV lines overload following an Allston-Keeler 500-kV line outage during summer conditions (A93194). The severity of the overload increases during off peak Seattle summer loads, very high PNW to PSW schedules over the DC and AC interties (following 3rd AC), and high BCH to PNW schedules (A93160). Adding a cross mountain line increases the severity of the overload by about 4% (A96174, A96175). However, the overload is more sensitive to high area interchange schedules during off peak summer loads than it is to the addition of a new cross mountain line. The overloads slightly decreases in future years as the Seattle summer loads increase.

5. Okanogan Valley Performance/Effects

The new cross mountain line increases loading by about 7%. The Okanogan-Brewster 115-kV line needs upgrading to a higher conductor operating temperature before and after addition of a cross mountain line to prevent overloads following an outage of either Douglas-Wells 230-kV line or Sickler 500/230-kV transformer during summer (A96170, A96176). Refer to Table 201.

6. Coulee/Chief Joseph Area Performance/Effects

Loading increases on the 500/230-kV transformers with a new CM line. A second Chief Joe 500/230-kV transformer is needed to prevent overloading the Coulee 500/230kV transformer following an outage of the existing Chief Joe 500/230-kV transformer during spring with 1800 MW Custer to Ingledow powerflow (SPG94116). Refer to Table 201.

7. Plan 1 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus;
 Add 300 MVAR SVC on Keeler 230-kV bus;
 Add 500-kV shunt capacitor bank at Ostrander.
- 1996 Add Chief Joseph-Monroe 500-kV double circuit line;
 Add 1300 MVA Snohomish 500/230-kV transformer fed from new 11 mile
 500-kV line from Monroe;
 Loop-in one SCL Eothell-Diable line into Snohomish;
 Add Monroe 500-kV shunt reactor;
 Upgrade 12 transmission lines to higher operating temperatures;
 Add second Chief Joe 500/230-kV transformer.
- 1998 Add 500-kV shunt capacitor bank at Keeler.
- 2000 Upgrade Keeler SVC to 500 MVAR;
 Add Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV
 line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV #2;
 Add MSC to one existing Raver shunt capacitor group;
 Add second 500-kV shunt capacitor bank at Ostrander.
- 2001 Upgrade Maple Valley SVC to 500 MVAR.

- 6
- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
Add second 500-kV shunt capacitor bank at Pearl;
 - 2003 Add 300 MVAR SVC on Covington 230-kV bus.
 - 2004 Add 500-kV shunt capacitor bank at Monroe;
Add third 500-kV shunt capacitor bank at Ostrander.

8. Loss savings of Plan 1

The loss savings of various options is summarized in Table 100. Plan 1 will save 58.0 MW on the BPA system and 70.2 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 67.9 MW on the BPA system and 82.0 MW in the Northwest in 2004 (compared to the Reactive Plan). This plan has some of the highest loss savings of the 500-kV options studied.

B. Chief Joseph-Snoqualmie 500-kV Double-Circuit Line: Plan 2

1. Puget Sound Area Voltage Stability Performance

This plan assumes a new Chief Joseph-Snoqualmie 500-kV double circuit line is built on new ROW paralleling the existing Chief Joe-Sickler line, on new ROW from Sickler toward the Cascades summit, then paralleling the Rocky Reach-Maple Valley 345-kV line into Snoqualmie. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on this and the additions needed through 2004, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 2 in service is shown in QV-120 for 1996 and in QV-121 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These include:

- a. Loss of the double-circuit Chief Joe-Snohomish 345-kV lines during normal winter will cause the Monroe-Sedro Tap 230-kV line to overload in 1997 (J96234).
- b. Loss of the Monroe 500/230-kV transformer causes the Maple Valley-Snoking 230-kV line to load beyond the 1275 amp limit (J96EH553).
- c. Loss of the Maple Valley 500/230-kV transformer will cause the Monroe transformer to overload in 2001 (J00EH25).

The 230-kV three-terminal line outages out of Monroe are not serious with this CM plan (J96M219 and J96M220).

Although transformation is not required until 2001, it is advantageous to add a Snoking transformer with the new CM line. This transformer addition solves both

line overloads (problems a and b above) and the eventual 500/230-kV transformer overload (problem c above). It also has loss saving benefits. The Monroe-Snoqualmie line can be tapped and the existing Snoking Tap-Snoking 230-kV line converted to its design voltage of 500-kV to supply the new Snoking transformer. A second Snoking-Bothell 230-kV line is needed with this transformer to prevent overloads during Monroe transformer outages (J00EH26).

When the Lakeside transformer is added (assumed in 2001), the unused 230-kV circuit that is parallel to the existing Bothell-Snoking-Maple Valley 230-kV line will need to be put into service at 230-kV. With the new Chief Joe-Snoqualmie 500-kV line plan, the Maple Valley-Lakeside section of this line will need to be rebuilt to about 1800 amps at -15 degrees Celcius.

The Maple Valley 500/230-kV transformer will overload in about 2007 for loss of the Snoking transformer and Monroe-Snoqualmie line (J04EH97 and 2% load growth). A parallel Maple Valley 500/230-kV transformer will be needed at this time. With these additions, this plan should provide for future load growth beyond 2010.

If a second Maple Valley-Snoking 230-kV line (25 miles) is added to correct problem #2 above instead of the Snoking transformer, it would also delay the Monroe-Snohomish overload in problem #1 until about 1999 (J96236 and J0017). If a second Maple Valley 500/230-kV transformer is then added in 1999, it would delay this overload further until about 2002 (2% load growth applied to case J0018). Additional support would then be needed into the Snohomish area. The Snoking project would be needed at this time.

If the second Maple Valley-Snoking 230-kV line is added in 10-96, followed by a Snoking transformer in 1999, the 230-kV line addition would have limited usefulness until the Lakeside transformer is added (J00EH27). The Snoking transformer addition provides substantial loss savings over the 230-kV line addition (9 MW vs 1.2 MW). If the Snoking 500/230-kV transformer is added in 1996, it would solve all the problems listed above through the year 2007 without the addition of a second Maple Valley-Snoking 230-kV line. This line would not be needed until the Lakeside transformer is added. Therefore, the Snoking transformer is the preferred option.

The loss savings due to the addition of the Snoking project is about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Snoqualmie line addition on the Portland system performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scam is shown in QV-122. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 2 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus;
 Add 300 MVAR SVC on Keeler 230-kV bus;
 Add 500-kV shunt capacitor bank at Ostrander.

- 1996 Add Chief Joseph-Snoqualmie 500-kV double circuit line;
 Add 1300 MVA Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Eight transmission line upgrades to higher operating temperatures
 Add second Chief Joe 500/230-kV transformer.

- 1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Upgrade Keeler SVC to 500 MVAR;
 Add MSC to one existing Raver shunt capacitor group;
 Add second 500-kV shunt capacitor bank at Ostrander.

- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees
 (coincides with Lakeside transformer addition).

- 2002 Upgrade Maple Valley SVC to 500 MVAR;
 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl.

- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander.

- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 2

The loss savings of various options is summarized in Table 100. Plan 2 will save 53.6 MW on the BPA system and 66.9 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 53.8 MW on the BPA system and 65.1 MW in the Northwest in 2004 (compared to the Reactive Plan).

C. Chief Joseph-Snoqualmie/Monroe 500-kV Double Circuit Line: Plan 3

1. Puget Sound Area Voltage Stability Performance

This plan includes a double circuit 500-kV line from Chief Joe west towards Puget Sound using the existing northern corridor to Monroe. At 29 miles outside Monroe, the line will split into two single circuits with one circuit extending southwest to the new Snoqualmie switchyard site and the other circuit line continuing northwest to Monroe. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic

switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004. For more detail on this and the additions needed through 2004, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 3 in service is shown in QV-132 for 1996 and in QV-133 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, the following problems will occur:

- a. The Maple Valley 500/230-kV transformer outage will cause the Monroe 500/230-kV transformer to overload by January 1997 (J96EH328).
- b. The new line addition aggravates the loadings experienced during outages of either 230-kV three-terminal line out of Monroe (J96M147 and J96M148). These lines will overload one or two years after the Cross Mountain line is added.
- c. The loss of the double-circuit Chief Joe-Snohomish 345-kV lines will cause the Monroe-Sedro Tap 230 line to overload (J96260).

The addition of a 500/230-kV transformer at Snoking will solve all the problems listed above. The existing 500-kV constructed tap line presently feeding Snoking should be used to tap the newly formed Snoqualmie-Monroe 500-kV line. A second Bothell-Snoking section is also needed for either the Maple Valley or Monroe 500/230-kV transformer outages as shown in J96EH251 and J96EH252.

The existing Monroe-Snohomish 230-kV line will overload in about 2001 for loss of the new Snoking transformer (J00EH39). A second Snoking-Maple Valley 230-kV line would delay this line overload until about 2006 (case J04EH42 and 2% load growth). This line is assumed to be added in the early 2000's with the Lakeside 230/115-kV transformer. Therefore, if Lakeside is added by 2001, no reinforcement is needed in the Monroe-Snohomish area until 2006.

At this time, additional support will be needed for Snohomish. If a Monroe-Snohomish line is added in 2006, the Monroe 500/230-kV transformer will overload in 2010 for loss of the new Snoking transformer (case J04EH110 and 2% load growth). Since additional 500/230-kV transformation is also needed, this plan will include construction of the Monroe-Snohomish line at 500-kV (operated at 230-kV initially) in 2006 and conversion of this line to 500-kV and a Snohomish 500/230-kV transformer in 2010. As shown with Plan 1, a loop-into Snohomish of one Skagit line is needed with this transformer. This reinforcement will relieve the overload problems in the area beyond 2010.

If the Lakeside transformer is delayed beyond 2001, the Monroe-Snohomish construction will have to be done earlier.

Another solution to these problems would be to reverse the order of the 500/230-kV transformers. If the Snohomish transformer is added first, additional support would be needed to relieve the Monroe transformer and Monroe-Snohomish 230 kV line loadings at about the same time as the Snoking transformer plan (case J00EH35).

Both plans would perform similarly. However, line construction between Monroe and Snohomish can be delayed with the Snoking plan, especially if Lakeside is

added as planned. The BPA loss savings for both plans are almost identical, while the Northwest loss savings favors Snoking by 2.1 MW. Therefore, the Snoking Reinforcement is preferred.

The loss savings due to the addition of the Snoking project (using the existing parallel Bothell-Snoking circuit) is about 10.6 MW on the BPA system and 15.1 MW total for the Northwest in 1996 (compare cases J96241, J96242, J96250, and J96251). The loss savings increases to 12.6 MW for BPA and 17.6 for the Northwest in 2000 (compare cases J0023, J0024, J0027 and J0028).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Snoqualmie/Monroe line addition on the Portland system performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-134. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 3 Summary

1994	Add 300 MVAR SVC on Maple Valley 230-kV bus;
Add 300 MVAR SVC on Keeler 230-kV bus;
Add 500-kV shunt capacitor bank at Ostrander.
1996	Add Chief Joseph-Snoqualmie/Monroe 500-kV double circuit line;
Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking;
Add Snoking-Bothell 230-kV line #2;
Add Snoqualmie 500-kV shunt reactor;
Add second Chief Joe 500/230-kV transformer.
Eight line upgrades.
1998	Add 500-kV shunt capacitor bank at Keeler.
2000	Upgrade Keeler SVC to 500 MVAR;
Add MSC to one existing Raver shunt capacitor group;
Add second 500-kV shunt capacitor bank at Ostrander.
2001	Rebuild Maple Valley-Lakeside 230 kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition).
2002	Upgrade Maple Valley SVC to 500 MVAR;
Add 500-kV shunt capacitor bank at Snoqualmie;
Add second 500-kV shunt capacitor bank at Pearl;
2004	Add second 500-kV shunt capacitor bank at Monroe;

Add third 500-kV shunt capacitor bank at Ostrander.

2005 Add Monroe-Snohomish 500-kV line, operate at 230-kV initially.

2010 Add Snohomish 500/230-kV 1800 MVA transformer;
Loop Bothell-Diablo 230-kV line into Snohomish;
Convert Monroe-Snohomish line to 500-kV operation.

8. Loss savings of Plan 3

The loss savings of various options is summarized in Table 100. Plan 3 will save 59.1 MW on the BPA system and 73.9 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 63.6 MW on the BPA system and 77.1 MW in the Northwest in 2004 (compared to the Reactive Plan). This plan has the highest loss savings of the 500-kV options studied.

D. Hanford-Snoqualmie 500-kV Double-Circuit Line: Plan 4

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built from Hanford to Naneum paralleling the existing 500-kV line. From Naneum to Snoqualmie, the new line will parallel the existing Rocky Reach-Maple Valley 345-kV line. The reason for including this plan is the possibility that future resources (eg. the mothballed nuclear plant at Ashe, WNP-1) may be energized in the Hanford area.

This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on the need for these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 4 in service is shown in QV-140 for 1996 and in QV-141 for 2004 for the 3 critical outages. To meet the reactive requirements for the double line outage in 2004, an additional 300 MVAR SVC is needed at Covington in 2004.

2. Puget Sound Area Thermal Overload Requirements

The thermal requirements of this plan are the same as Plan 2 above. The Snoking and Maple Valley transformer addition projects are similarly proposed to correct these problems. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Hanford-Snoqualmie line addition on the Portland system performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-142. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: No impact

6. Coulee/Chief Joseph Area Performance/Effects: No impact

7. Plan 4 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus;
Add 300 MVAR SVC on Keeler 230-kV bus;
Add 500-kV shunt capacitor bank at Ostrander.
- 1996 Add Hanford-Snoqualmie 500-kV double circuit line;
Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie 500-kV line and using existing 500-kV constructed line into Snoking;
Add Snoking-Bothell 230-kV line #2;
Add Snoqualmie 500-kV shunt reactor;
Eight line upgrades.
- 1998 Add 500-kV shunt capacitor bank at Keeler.
- 2000 Upgrade Keeler SVC to 500 MVAR;
Add MSC to one existing Raver shunt capacitor group;
Add second 500-kV shunt capacitor bank at Ostrander.
- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees (coincides with Lakeside transformer addition);
Upgrade Maple Valley SVC to 500 MVAR.
- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
Add second 500-kV shunt capacitor bank at Pearl.
- 2004 Add second 500-kV shunt capacitor bank at Monroe;
Add third 500-kV shunt capacitor bank at Ostrander;
Add 300 MVAR SVC on Covington 230-kV bus.
- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 4

The loss savings of various options is summarized in Table 100. Plan 4 will save 39.9 MW on the BPA system and 51.0 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 57.4 MW on the BPA system and 74.2 MW in the Northwest in 2004 (compared to the Reactive Plan). The increase in loss savings in 2004 is largely due to the assumption of WNP-1 operating.

E. Sickler-Snoqualmie Double-Circuit Line & Naneum Switchyard: Plan 5

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built on new ROW from Sickler to Snoqualmie. Mileage for the northern corridor was assumed in the studies, however, the southern corridor is not much longer. Also included in this plan is the development of a major Naneum switchyard (the Coulee-Raver lines will be tied into the existing station with the Sickler-Raver and Vantage-Raver lines). This switchyard development strengthens Sickler as a source for

the new line and reduces the severity of the double-line Coulee-Raver outage.

With this new line added, the three critical outages for the Puget Sound area are 1) loss of the Chief Joe-Monroe 500-kV line during abnormally cold weather, 2) loss of the Trojan nuclear plant with one Centralia unit previously out-of-service, also during abnormally cold weather and 3) simultaneous loss of both Coulee-Naneum 500-kV lines (the compensated section of the old Coulee-Raver lines) during normal winter peak loads.

These new additions and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Also, additional 500-kV shunt capacitors will be needed at Monroe and Snoqualmie substations between 2002 and 2004. For more detail on these additions, refer to Table 310.

The voltage stability performance of Plan 5 is shown in QV-150 for 1996 and in QV-151 for 2004 for the 3 critical outages. To meet the reactive requirements for the single line outage in 2004, an additional 300 MVAR SVC is needed at Covington in 2004. Performance of this plan with the Covington SVC is shown in QV-152.

A Chief Joseph-Sickler 500-kV single circuit and a 300 MVAR SVC at Sickler was investigated as alternatives to the Covington SVC to provide the required reactive margins. Neither performed as well as the Covington SVC during post-transient conditions. However, the transmission between Chief Joe and Sickler will eventually need to be reinforced.

It should be noted that in Plans 1 and 4, a Covington SVC was also proposed, but to correct the double line outage. In Plan 5 this SVC is needed for the cold weather single line outage. The development of the Naneum switchyard in Plan 5 improves the performance of the double line outages. The MSC at Raver is not needed with this plan.

2. Puget Sound Area Thermal Overload Requirements

The thermal requirements of this plan are the same as Plan 2 above. The Snoking and Maple Valley transformer addition projects are similarly proposed to correct these problems. During spring and summer conditions, the same seven line upgrades needed for Plan 2 are needed for this plan (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Sickler-Snoqualmie line and Naneum Switchyard additions on the Portland area performance is similar to the other line option plans. Identical facilities are required in the Portland area. The performance of the three critical busses in the Northwest for the Trojan scram is shown in QV-153. For more detailed information, refer to Table 310.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: No impact

6. Coulee/Chief Joseph Area Performance/Effects: No impact

Although there is no impact in the Coulee/Chief Joseph area, there may be some impact on the Sickler/Douglas transformer. This needs further study.

7. Plan 5 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus and
 Add 300 MVAR SVC on Keeler 230-kV bus.
 Add 500-kV shunt capacitor bank at Ostrander.

- 1996 Add Sickler-Snoqualmie 500-kV double circuit line;
 Expand Naneum 500-kV switchyard;
 Add 300 MVAR 230-kV shunt capacitors at Wells;
 Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Eight line upgrades.

- 1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Upgrade Keeler SVC to 500 MVAR;
 Add second 500-kV shunt capacitor bank at Ostrander.

- 2001 Rebuild Maple Valley-Lakeside 230-kV line;
 Upgrade Maple Valley SVC to 500 MVAR.

- 2002 Add second 500-kV shunt capacitor bank at Pearl;
 Add 500-kV shunt capacitor bank at Snoqualmie.

- 2003 Add 300 MVAR SVC on Covington (or Snohomish) 230-kV bus.

- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander.

- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 5

The loss savings of various options is summarized in Table 100. Plan 5 will save 49.6MW on the BPA system and 65.1 MW in the Northwest in 1996 (compared to the base system). The loss savings will increase to 56.1 MW on the BPA system and 68.7 MW in the Northwest in 2004 (compared to the Reactive Plan).

F. Reactive Alternative Plan 6

1. Puget Sound Area Voltage Stability Performance

The assumed voltage stability criteria can be achieved in 1996 with the addition of three 300 MVAR SVC's and two series capacitor stations on the Coulee-Raver lines (J96EH573QV4, J96EH575QV4, J96275QV4). A possible plan to add five series capacitor stations (one on the Chief Jo-Monroe, one on each Naneum-Raver circuit, and one on each Coulee-Raver line) to reduce the number of SVC's does not meet voltage stability criteria for the Chief Jo-Monroe outage (J96EH581QV). Therefore, reducing the number of SVC's by increasing series compensation is not an alternative.

Distributing the SVC's among different locations provides about 40MVARs of benefits in Q-V performance for the double generator outage during abnormal or double line outage during normal (J96EH573QV4, J96EH573QV5, J96275QV4,

J96275QV5). The single line outage during abnormal shows a 40MVAR disadvantage to distributing SVC's (J96EH575QV4, J96EH575QV5).

The series capacitor stations perform better when located halfway between Columbia and Raver on the Coulee-Raver lines (20% compensation, 2600A continuous). Q-V performance improves by about 30MVARS (J96EH575QV4, J96EH576QV). Voltages are about 4kv less at the stations so criteria levels are not violated when sending end voltages are held high.

System planning assumes that the SVC's can be made equally reliable to transmission lines. If assumptions change and system design assumes the failure of one SVC following the contingency, then one more 300MVAR SVC is needed (assumed at Snohomish J96275QV2, J96275QV3).

In 2000, load growth and system design for the simultaneous loss of both Coulee-Raver 500-kV lines cause the need for three additional series capacitor stations on the other three existing cross Cascades 500-kV lines (25% 3200A midline on Chief Joe-Monroe 500, 35% 2300A on each Naneum-Raver 500 line). These will be switched in service following the double Coulee-Raver line loss during normal winter or double generator loss during abnormal winter. Another 324MVAR 500-kV shunt capacitor bank is needed at Monroe. The plan for 2000 was not studied. It was estimated from 1996 and 2004 studies.

By 2004, load growth causes the need for series compensation to be in service on the Chief Jo-Monroe line (25%) and Naneum-Raver line sections (35%) with no outage during abnormal cold weather (J04EH34). More series compensation on the Chief Jo-Monroe line (25% more for 50% total) and the Naneum-Raver lines (35% more for 70% total) need to be added for the double Coulee-Raver line loss during normal winter. Two 500-kV 324MVAR shunt capacitor banks are needed at Snoqualmie (J0482QV). The assumed voltage stability criteria is achieved for the single line loss (J04EH148QV) and double generator outage (J04EH149QV) with the added series and shunt compensation.

The amounts of series compensation were calculated by considering these factors:

- > series compensation keeps the amount of needed dynamic and switched shunt compensation from dramatically increasing every year with assumed load growth. For example, about 3MVARS of dynamic shunt (SVC's) would be needed for 1MW of load growth without series compensation (3:1 ratio). With the planned series compensation, only about .5-1MVARS per MW of less expensive switched shunt compensation needs to be added. Therefore, adding the series compensation is estimated to be more cost effective than adding more dynamic shunt compensation.

- > series compensation reduces voltage sensitivity to load level (reduces the slope on a Q-V curve). This allows more shunt capacitors to be on line prior to an outage.

- > distributing series compensation along the line improves Q-V performance because reactive power cannot be transmitted over long distances on heavily loaded lines.

- > the amount of series compensation at any specific site is limited by the voltage drop (or rise) that may cause the voltage at the station to exceed 550kv steady state.

> transmission system energy efficiency is best with Coulee-Raver series compensation at about 40-50% (J96279, J96280, J96273).

> the ratio of series compensation between the Chief Jo-Monroe line and the Naneum-Raver lines was sized to keep the powerflow on the lines roughly proportional to the thermal rating of each circuit during the double Coulee-Raver outage.

> voltage stability criteria cannot be met with only series compensation and switched shunt compensation. SVC's are needed too. This is caused by the very high critical voltage (520kv, J96EH577QV). SVC'S provide voltage control in the vicinity of the critical voltage. Also, SVC's lower the critical voltage in this case and the series compensation becomes more effective in Q-V performance. Theoretically, voltage stability could be accomplished with very large amounts of SVC's and no series compensation, regardless of the critical voltage level on a constant power Q-V curve. However, the cost would be much higher with no apparent benefits.

Based on these factors, the maximum compensation is about 50% on Chief Jo-Monroe, 42% on Coulee-Raver #1 & #2, and 70% on Naneum-Raver #1 & #2.

2. Puget Sound Area Thermal Overload Requirements

The loss of both Chief Joe-Snohomish 345-kV lines overloads the Monroe-Sedro Tap 230-kV line section during a 2000 normal winter (J0049). Adding another Monroe-Sedro Tap circuit solves this.

The loss of the Maple Valley 500/230-kV transformer overloads the Covington 500/230-kV transformers during abnormal cold in 2004 (J04EH22). Adding a second Maple Valley transformer solves this.

The loss of the Snoqualmie-Raver 500-kV line overloads the PSP Christopher-O'Brien and Covington-Creston 230-kV lines with abnormal cold loads in 2004 (J04EH25). A second Snoqualmie-Raver 500-kV line solves this.

3. Portland Area Voltage Stability Performance

A 300 MVAR SVC is needed at Keeler in 1996 (J96EH573QV3,QV4) and one additional 300

MVAR SVC is needed at Ostrander in 2004 to satisfy voltage stability criteria for the Trojan outage during abnormal cold with one Centralia unit down (J04EH149QV2).

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: see Table 201 (no cross mtn line)

6. Coulee/Chief Joseph Area Performance/Effects: none

7. Reactive Plan 6 Summary

1994 300 MVAR SVC on Maple Valley 230-kV bus and
 300 MVAR SVC on Keeler 230-kV bus.
 8 line upgrades

1996 300 MVAR SVC at Snohomish
 300 MVAR SVC at Covington

- 20% more series comp on Coulee-Raver #1 and #2 between Columbia and Raver
- 2000 25% series comp on Chief Joe-Monroe 500 midline
 35% series comp on Naneum-Raver #1 and #2 between Naneum and Raver
 3rd parallel circuit from Monroe Tap to Sedro Tap
 Add 500-kV shunt capacitor bank at Monroe
 Add 500-kV shunt capacitor bank at Pearl
 Add 500-kV shunt capacitor bank at Ostrander
- 2004 Add 2-500-kV shunt capacitor banks at Snoqualmie
 Add 500-kV shunt capacitor bank at Ostrander
 25% more series comp on Chief Joe-Monroe 500
 35% more series comp on Naneum-Raver #1 and #2
 2nd Maple Valley 500/230 transformer
 2nd Raver-Snoqualmie 500 line
 300 MVAR SVC at Ostrander

8. Loss savings of Reactive Plan 6

The loss savings of all feasible options are summarized in Table 100. The Reactive Plan will save 2.4 MW in the Northwest in 1996. In the 2004 loss savings case, the reactive plan is used as the base since the powerflow will not solve with just the base system in service.

G. Coulee-Snoqualmie/Olympia 500-kV Double-Circuit Line Rebuild: Plan 7

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new 500-kV double circuit line is built, replacing existing 230-KV and 287-KV lines between Grand Coulee and the Puget Sound area. The Coulee-Columbia 230-kV line, the Columbia-Covington 230-kV line and the Columbia-Olympia portion of the Coulee-Olympia 287-kV line would need to be removed. The remaining section of 287-kV line from Coulee to Olympia would be converted to 230-kV to replace the parallel circuit that was removed. Nothing will be added at Columbia to replace the circuit to Covington, since it is a load line. The Olympia and Covington 230-kV busses will be investigated in the Puget Sound thermal overload section to determine if any reinforcement is needed at these busses to replace the facilities that were removed.

This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe substations in 2002 and 2004. A 300 MVAR SVC is needed at Snohomish in 2004 to strengthen this plan for double line outage. For more detail on these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 7 in service is shown in QV-171 for 2004 for the 3 critical outages.

2. Puget Sound Area Thermal Overload Requirements

The problem areas in the North Seattle area for Plan 7 would be very similar to

Plan 2. Since the Shelton 500/230-kV transformer has been added by this time, additional support is not needed at Olympia to replace the 287-kV circuit. However, at some future time, additional facilities will be needed in this area earlier as compared to the other plans considered (J04EH162). Although a source line was removed from Covington, the addition of the new 500-kV CM lines redistributes the powerflow so that Covington capacity is not a problem. There are no transformer overloads in the Puget Sound area for several years.

As in Plan 2, it is advantageous to add a Snoking transformer with the new CM line since this transformer addition will also alleviate the double 345-kV line outage. The Monroe-Snoqualmie line can be tapped and the existing Snoking Tap-Snoking 230-kV line converted to its design voltage of 500-kV to supply the new transformer. A second Snoking-Bothell 230-kV line is needed with this transformer to prevent overloads during Monroe transformer outages (J00EH26, from Plan 2). With the Snoking Transformer addition, the Covington transformer loadings actually decrease from the pre-CM conditions even though a 230-kV circuit was removed (compare J96EH158 and J96EH582).

When the Lakeside transformer is added (assumed in 2001), the unused 230-kV circuit that is parallel to the existing Bothell-Snoking-Maple Valley 230-kV line will need to be put into service at 230-kV. With a new Chief Joe-Snoqualmie 500-kV line in service, the Maple Valley-Lakeside section of this line will need to be rebuilt to about 1800 amps at -15 degrees Celcius.

This plan has extremely well balanced 500/230-kV transformer loading. The Covington 500/230-kV transformer will overload in about 2011 for loss of the Tacoma transformer (J04EH183 and 2% load growth) and in 2012 for loss of the parallel bank (J04EH165). The Maple Valley 500/230-kV transformer will overload in about 2012 for loss of the Snoking transformer and Monroe-Snoqualmie line (J04EH166). The Tacoma 500/230-kV transformer will overload in 2015 for loss of the Maple Valley transformer (J04EH163). A parallel Maple Valley 500/230-kV transformer will therefore be needed by 10-2010. As can be seen in these outages, the new Snoking transformer is loading in excess of 1600 MVA in these cases. This transformer will need to be a 1800 MVA bank when it is installed in 1996.

The loss savings due to the addition of the Snoking project will be similar to that of Plan 2. The loss savings for Plan 2 are about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201). The effect of the new line terminated at Olympia on intertie schedules has not been studied yet.

3. Portland Area Voltage Stability Performance

The effect of the Coulee-Snoqualmie/Olympia 500-kV line addition on the Portland system performance is similar to the other plans. Identical facilities are required in the Portland area. Refer to Table 310 for further information.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: None

6. Coulee/Chief Joseph Area Performance/Effects: Not studied yet.

7. Plan 7 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus and
 Add 300 MVAR SVC on Keeler 230-kV bus.
 Add 500-kV shunt capacitor bank at Ostrander.

- 1996 Replace the existing Coulee-Columbia 230-kV line, Columbia-Covington
 230-kV line and Columbia-Olympia portion of the Coulee-Olympia 287-kV
 line to a new 500-kV double circuit line;
 Convert remaining section of Coulee-Olympia 287-kV line to a 230-kV
 Coulee-Columbia line.
 Add 1300 MVAR Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Eight transmission line upgrades to higher operating temperatures;
 Add second Chief Joe 500/230-kV transformer.

- 1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Upgrade Keeler SVC to 500 MVAR;
 Add MSC to one existing Raver shunt capacitor group;
 Add second 500-kV shunt capacitor bank at Ostrander.

- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees
 (coincides with Lakeside transformer addition);
 Upgrade Maple Valley SVC to 500 MVAR.

- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl.

- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander;
 Add 300 MVAR SVC on Snohomish 230-kV bus.

- 2012 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 7

The loss savings of various options is summarized in Table 100. Plan 7 will save 58.2 MW on the BPA system and 69.4 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 54.6 MW on the BPA system and 63.9 MW in the Northwest in 2004 (compared to the Reactive Plan).

H. Chief Joseph-Sickler-Snoqualmie Double-Circuit Line Rebuild: Plan 8

1. Puget Sound Area Voltage Stability Performance

This plan assumes that a new Chief Joseph-Sickler-Snoqualmie 500-kV double circuit line is built replacing the existing Chief Joseph-Sickler 500-kV and Rocky Reach-Maple Valley 345-kV lines. This new line and the 300 MVAR SVC at Maple Valley will solve the voltage stability problems and have the required reactive margins for the critical outages in 1996. This SVC will need to be

increased to 500 MVARs in later years to keep up with the expected load growth. Automatic switching of one capacitor group at Raver is required by about 2000 for the double Coulee-Raver line outage. Also, additional 500-kV shunt capacitors will be needed at Snoqualmie and Monroe in 2002 and 2004. A 300 MVAR SVC is needed at Snohomish in 2002 to strengthen this plan for the double line outage. For more detail on these additions, refer to Table 310.

The voltage stability performance for the Puget Sound area with Plan 8 in service is shown in QV-180 for 2004 for the 3 critical outages (without the Snohomish SVC).

The exact timing of the need for the Chief Joe-Sickler portion of this plan has not been determined. The 2004 base case with one Centralla unit down would not solve without this reinforcement. A QV curve of this system showed that the 3 shunt capacitor groups at Raver were required to just touch the knee of the QV curve without any outage. It was therefore assumed that this line would be needed immediately.

2. Puget Sound Area Thermal Overload Requirements

If this line is added, numerous problems are aggravated in the North Seattle area during winter conditions. These are very similar but slightly worse than the problems in Plan 2 since the Maple Valley 345/230-kV transformer is removed. If the Snoking transformer is added as in Plan 2, these initial problems are relieved. This transformer will need to be an 1800 MVA bank instead of 1300 MVA as in Plan 2 to make up for the loss of the Maple Valley 345/230-kV transformer (compare cases J04EH163 and J04EH168).

The Maple Valley 500/230-kV transformer will overload in about 2006 for loss of the Snoking transformer and Monroe-Snoqualmie line (J04EH167). A parallel Maple Valley 500/230-kV transformer will be needed at this time. With these additions, this plan should provide for future load growth beyond 2010.

The loss savings due to the addition of the Snoking project will be similar to that of Plan 2. The loss savings for Plan 2 are about 9.0 MW on the BPA system and 14.3 MW total for the Northwest (compare cases J96249, J96253, J96258 and J96259). These loss savings increase to 10.6 MW on the BPA system and 17.0 MW for the Northwest in 2000 (compare cases J0021, J0022, J0025 and J0030).

A 300 MVAR shunt reactor is required at Snoqualmie to provide voltage control on the 500-kV system during lighter load periods. Seven transmission lines need upgrading to higher conductor operating temperatures to meet spring and summer loading conditions (Table 201).

3. Portland Area Voltage Stability Performance

The effect of the Chief Joseph-Sickler-Snoqualmie line rebuild on the Portland system performance is similar to all the other transmission line options. Identical facilities are required in the Portland area. Refer to Table 310 for further information.

4. Portland Area Thermal Overload Requirements: same as Plan 1

5. Okanogan Valley Performance/Effects: same as Plan 1 (Table 201)

6. Coulee/Chief Joseph Area Performance/Effects: same as Plan 1 (Table 201)

7. Plan 8 Summary

- 1994 Add 300 MVAR SVC on Maple Valley 230-kV bus and
 Add 300 MVAR SVC on Keeler 230-kV bus.
 Add 500-kV shunt capacitor bank at Ostrander.

- 1996 Rebuild the existing Chief Joseph-Sickler 500-kV and Rocky Reach-Maple
 Valley 345-kV lines to form a Chief Joseph-Sickler-Snoqualmie 500-kV
 double circuit line;
 Add 1800 MVA Snoking 500/230-kV transformer tapping Monroe-Snoqualmie
 500-kV line and using existing 500-kV constructed line into Snoking;
 Add Snoking-Bothell 230-kV line #2;
 Add Snoqualmie 500-kV shunt reactor;
 Eight transmission line upgrades to higher operating temperatures;
 Add second Chief Joe 500/230-kV transformer.

- 1998 Add 500-kV shunt capacitor bank at Keeler.

- 2000 Upgrade Keeler SVC to 500 MVAR;
 Upgrade Maple Valley SVC to 500 MVAR;
 Add MSC to one existing Raver shunt capacitor group;
 Add second 500-kV shunt capacitor bank at Ostrander.

- 2001 Rebuild Maple Valley-Lakeside 230-kV line to 1800 Amps @ -15 degrees
 (coincides with Lakeside transformer addition).

- 2002 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl;
 Add 300 MVAR SVC on Snohomish 230-kV bus.

- 2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander.

- 2006 Add Maple Valley 500/230-kV 1800 MVA transformer #2.

8. Loss savings of Plan 8

The loss savings of various options is summarized in Table 100. Plan 8 will save 50.0 MW on the BPA system and 60.1 MW in the Northwest in 1996 (compared to the base system). The loss savings will be 49.7 MW on the BPA system and 58.2 MW in the Northwest in 2004 (compared to the Reactive Plan).

19-SEPT-1990

QV CURVES

PLAN 1: CJ - MON 2&3, SNOKING, LDC,
COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER,
300MVAR SVC AT MAPLE VL

O J96EH408: COULEE-RAVER OUT (J96EH390)

Δ J96EH418: TROJAN SCRAM (J96EH394)

+ J96179: DOUBLE COULEE-RAVER OUT (J96171)

O J96EH408QV
Δ J96EH418QV
+ J96179QV

30-APR-1990

QV-110

PLAN 1: CHIEF JO-MONROE, SNOK & SNOHOMSH TX, LDC
 500 MVAR SVCS AT MAPLE VALLEY & KEELER
 J04377: DOUBLE COULEE-RAVER OUT (J04376)
 J04EH120: COULEE-RAVER OUT (J04EH119)
 J04EH121: TROJAN SCRAM (J04EH114)

Q J04377QV
 Δ J04EH120QV
 + J04EH121QV

28-JUN-1980

CV-111

PLAN 1: CHIEF JOE-MONROE
 TROJAN SCRAM (BASECASE: J04EH114)
 J04EH121: RAVEN
 J04EH141: OSTRANDER
 J04EH145: MARION

O J04EH121QV
 Δ J04EH141QV
 + J04EH145QV

PLAN 2: CJ - SNOQ, SNOKING, LDC,
 COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER
 300MVAR SVC AT MAPLE VL
 J96EH409: COULEE-RAVER OUT (J96EH391)
 J96EH419: TROJAN SCRAM (J96EH395)
 J96180: DOUBLE COULEE-RAVER OUT (J96172)

○ J96EH409QV
 ▲ J96EH419QV
 + J96180QV

5-MAR-1990

QV-120

PLAN 2: CHIEF J0-SNOQUALMIE, SNOKING, LDC
 500 MVAR SVCS AT MAPLE VALLEY & KEELER
 ○ J04373: DOUBLE COULEE-RAVER OUT (J04372)
 △ J04EH73 : COULEE-RAVER OUT (J04EH71)
 + J04EH82 : TROJAN SCRAM (J04EH81)

RAVER VOLTAGE

RAVER SHUNT REACTIVE (MVARs)

○ J04373QV
 △ J04EH73QV
 + J04EH82QV

28-JUN-1990

QV-121

PLAN 2: CHIEF JOE-SNOQUALMIE
 TROJAN SCRAM (BASECASE: J04EH81)
 J04EH82 : RAVEN
 J04EH142: OSTRANDER
 J04EH146: MARION

O J04EH82QV
 Δ J04EH142QV
 + J04EH146QV

27-JUN-1990

QV-12.2

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE ADDED
 300 MVAR SVC'S AT MAPLE VALLEY AND KEELER
 LDC'S AT COULEE, CENTRALIA, JOHN DAY, DALLES, BONN
 SNOKING 500/230 TRANSFORMER'S
 J96EH378: LDC ADDED AT CHIEF JOE } Based on J96EH332
 J96EH500: NO LDC AT CHIEF JOE

3-APR-1990

QV-130

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER, LDC, SNOKING TX
 O J96EH367:ONE COULEE-RAVER 500 LINE OUT (J96EH332)
 Δ J96154:DOUBLE COULEE-RAVER LINE OUT (J96144)
 + J96EH335: TROJAN SCRAM(J96EH333)

21-FEB-1990

6V-131

PLAN 3: CHIEF JOE - SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER & AT MAPLE VL, LDC, SNOK TXF
 O J96EH378: ONE COULEE-RAVER 500 LINE OUT (J96EH332)
 Δ J96EH378: ONE COULEE-RAVER 500 LINE OUT (J96EH332)
 + J96EH379: TROJAN SCRAM (J96EH333)

O J96EH378QV
 Δ J96EH378QV
 + J96EH379QV

QV-1272

- 26-FEB-1990

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 500 MVAR SVCS AT KEELER AND MAPLE VALLEY
 LDC AND SNOOKING TRANSFORMER
 J04166: DOUBLE COULEE-RAVER LINE OUTAGE (J04165)
 J04EH64: COULEE-RAVER #1 LINE OUT (J04EH26)
 J04EH53: TROJAN SCRAM (J04EH27)

○ J04166QV
 △ J04EH64QV
 + J04EH53QV

11-APR-1990

60-133

TROJAN SCRAM ON BASE J04EH27
 PLAN 3: CJ-S/M, LDC, SNOKING, 500MVAR SVC'S AT
 KEELER AND MAPLE VALLEY
 O J04EH51: OSTRANDER
 Δ J04EH52: MARION
 + J04EH53: RAVER

21-FEB-1990

011-127

DOUBLE COULEE-RAVER LINE OUT ON CJ-SNOQ/MON PLAN

ΔJ9642: LINE ADDITION ONLY
 OJ9668: LINE AND 2X300 MVAR SVC ADDED
 +J9663: LINE AND 35%/40% COMP ADDED
 xJ9662: LINE, 35%/40% COMP AND 2X300 MVAR SVC

27-DEC-1989

QV-135

COULEE-RAVER LINE OUTAGE ON CJ-SNOQ/MON PLAN

- O J96EH46: LINE ADDITION ONLY
- x J96EH88: LINE AND 2X300 MVAR SVC ADDED
- Δ J96EH63: LINE AND 35%/40% COMP ADDED
- + J96EH62: LINE, 35%/40% COMP AND 2X300 MVAR SVC ADD

27-DEC-1985

CV-136

PLAN 2: CJ-SNOQ, DOUBLE COULEE-RAVER OUTAGE

500 MVAR SVCS AT MAPLE VALLEY & KEELER

J04381QV: WITH SERIES COMP 35% (J04380)

J04318QV: NO SERIES COMP (J04308)

J04373: NO SERIES COMP (J04372)

RAVER VOLTAGE HIGH (549)

O J04381QV
 Δ J04318QV
 + J04373QV

19-JUN-1990

QV 137

PLAN 4: HANFORD-SNOQ 1&2, SNOKING, LDC,
 COVINGTON-BERRYDALE, 300MVAR SVC AT KEELER,
 300MVAR SVC AT MAPLE VL
 J96EH410: COULEE-RAVER OUT (J96EH392)
 ΔJ96EH420: TROJAN SCRAM (J96EH396)
 J961S1: DOUBLE COULEE-RAVER OUT (J96173)

No Aske LDC

○ J96EH410QV
 Δ J96EH420QV
 + J961S1QV

8-MAR-1990

RAVER SHUNT REACTIVE - MVAR

QU-140

PLAN 4: HANFORD-SNOQUALMIE, SNOKING, LDC
 500 MVAR SVCS AT MAPLE VALLEY & KEELER
 J04379: DOUBLE COULEE-RAVER OUT (J04378)
 J04EH122: COULEE-RAVER OUT (J04EH115)
 J04EH125: TROJAN SCRAM (J04EH116)

28-JUN-1990

PLAN 4: HANFORD-SNOQUALMIE
 TROJAN SCRAM (BASECASE: J04EH116)
 J04EH125: RAVEN
 J04EH143: OSTRANDER
 J04EH147: MARION

O J04EH125QV
 Δ J04EH143QV
 + J04EH147QV

27-JUN-1990

QV-142

PLAN 5: SICKLER-SNOQ-NANEUM SY; SNOKING,
 LDC, COV-BERYDL, 300MVAR SVC AT KEELER & MAPLE VL
 O J96182: DOUBLE COULEE-NANEUM OUT (J96174)
 Δ J96EH413: CHIEF JO-MONROE OUT (J96EH393)
 + J96EH421: TROJAN SCRAM (J96EH397)

O J96182QV
 Δ J96EH413QV
 + J96EH421QV

9-MAR-1990

PLAN 5: CHIEF JO-SICKLER-SNOQUALMIE, SNOKING, LDC
 500 MVAR SVCS AT MAPLE VALLEY & KEELER
 J04315QV: DOULBE COULEE-NANEUM OUT (J04310)
 J04EH126QV: CHIEF JO-MONROE OUT (J04EH118)
 J04EH123QV: TROJAN SCRAM (J04EH117)

O J04315QV
 Δ J04EH126QV
 + J04EH123QV

17-JUL-1990

QV-151

PLAN 5: SICKLER-SNOQUALMIE, SNOKING, LDC
 500 MVAR SVCS AT MAPLE VL & KEELER, 300 MVAR AT COV
 J04426: DOUBLE COULEE-NANEUM OUT (J04310)
 J04EH150: CHIEF JO-MONROE OUT (J04EH118)
 J04EH151: TROJAN SCRAM (J04EH117)

17-JUL-1990

CV-152

PLAN 5: SICKLER-SNOQUALMIE
TROJAN SCRAM (BASECASE J04EH117)
O J04EH151: RAVEN
Δ J04EH152: OSTRANDER
+ J04EH153: MARION

O J04EH151QV
Δ J04EH152QV
+ J04EH153QV

18-JUL-1990

QV-153

PLAN 2: CHIEF JO-SNOQUALAMIE, NORMAL WINTER

O J04198: 500-KV LINE, COULEE-RAVER OUT (J04197)
 Δ J04200: 765-KV LINE, OP e 500, C-R OUT (J04199)
 + J04203: 765-KV LINE, CHIEF JO-SNOQ OUT (J04202) } 2000 MW
 x J04208: 765-KV LINE, COULEE-RAVER OUT (J04202) } PS setting

O J04198QV.Q
 Δ J04200QV.Q
 + J04203QV.Q
 x J04208QV.Q

QV-10

10-MAY-1990

PLAN 2: CHIEF JO-SNOQUALAMIE

○ J04EH73: 500-KV LINE, COULEE-RAVER OUT (J04EH71)
 △ J04EH76: 765-KV LINE, OP @ 500, C-R OUT (J04EH74)
 + J04EH78: 765-KV LINE, CHIEF JO-SNOQ OUT (J04EH77) } 2000 MW
 × J04EH88: 765-KV LINE, PS Z=0, CH J-SNOQ OUT (J04EH87) } PS setting
 ◇ J04EH100: 765-KV LINE, COULEE-RAVER OUT (J04EH77)

○ J04EH73QV.
 △ J04EH76QV.
 + J04EH78QV.
 × J04EH88QV.
 ◇ J04EH100QV

QV-161

10-MAY-1990

PLAN 2: TROJAN SCRAM

○ J04EH82: 500-KV LINE (J04EH81)
 Δ J04EH84: 765-KV LINE, OP AT 500 (J04EH83)
 + J04EH86: 765-KV LINE (J04EH85) - 2000 MW PS setting

○ J04EH820V.
 Δ J04EH840V.
 + J04EH860V.

OSTRANDER SHUNT REACTIVE - MVARs

Rover

26-APR-1980

100-100

CHIEF JOE - SNOQUALMIE PLAN

WORST SINGLE LINE OUTAGE
 O J96EH26: 500KV LINE ADDED
 Δ J96EH141: 765KV LINE ADDED OPERATED AT 500KV
 + J96EH139: 765KV LINE ADDED
 x J96EH142: 765KV LINE ADDED WITH 35% COMP, 40% IN C-R

O J96EH26QV.
 Δ J96EH141QV
 + J96EH139QV
 x J96EH142QV

12-JAN-1990

RAVR SHUNT REACTIVE - MVAR

QV-163

CHIEF JOE - SNOQUALMIE PLAN

WORST DOUBLE LINE OUTAGE
 o J96104: 500KV LINE ADDED
 Δ J96104: 765KV LINE ADDED OPERATED AT 500KV
 + J96103: 765KV LINE ADDED
 x J96101: 765KV LINE ADDED WITH 35% COMP, 40% IN C-R

12-JAN-1990

20-164

PLAN 2: CHIEF JOE/COULEE-SNOQUALMIE 765 DOUBLE CIR

○ J04EH102: COULEE-SNOQUALMIE 765 LINE OUT (J04EH101)
 Δ J04EH103: COULEE-RAVER 500 LINE OUT (J04EH101)
 + J04EH105: TROJAN SCRAM (J04EH104)

○ J04EH102QV
 Δ J04EH103QV
 + J04EH105QV

QV-165

10-MAY-1990

COULEE - RAVER NO 1&2 OUT

O J96246: 1700MW (J96199)
 Δ J96245: 2000MW (J96191)
 + J96247: 2200MW (J96203)

O J96246QV
 Δ J96245QV
 + J96247QV

QV-161

9-MAY-1990

COULEE - RAVAR NO 1 OUT
 O J96EH548: 1800MW (J96EH547)
 Δ J96EH544: 1900MW (J96EH543)
 + J96EH460: 2000MW (J96EH458)
 x J96EH546: 2100MW (J96EH545)
 ◇ J96EH550: 2200MW (J96EH549)

O J96EH548QV
 Δ J96EH544QV
 + J96EH460QV
 x J96EH546QV
 ◇ J96EH550QV

16-APR-1990

QV-167

CHIEF JOE-SNOQUALMIE 765 LINE OUT

- J96EH559: 1800MW (J96EH547)
- △ J96EH560: 1900MW (J96EH543)
- + J96EH561: 2000MW (J96EH458)
- x J96EH562: 2100MW (J96EH545)
- ◇ J96EH563: 2200MW (J96EH549)

RAVEOLTAGE

○ J96EH559QV
 △ J96EH560QV
 + J96EH561QV
 x J96EH562QV
 ◇ J96EH563QV

RAVER SHUNT REACTIVE - MVARs

20-APR-1990

QV-162

CHIEF JOE/COULEE-SNOQ 765 DBL CKT PLAN

PHASE SHIFTED TO 2000MW IN BASE (J04EH101)
 O J04EH106:PS ANGLE DECREASED 5° FROM PRE OUTAGE
 Δ J04EH102:PS SET AT 2000MW PRE OUTAGE ANGLE
 + J04EH107:PS ANGLE INCREASED 5° FROM PRE OUTAGE

O J04EH106QV
 Δ J04EH102QV
 + J04EH107QV

RAVR SHUNT REACTIVE - MVARs

11-MAY-1990

QV-169

PLAN 7: GRAND COULEE-OLYMPIA/COVINGTON 500 (Rebuild of 230/287)
 O J04EH171: CHIEF JO-MONROE 500 OUTAGE (J04EH154)
 Δ J04EH175: TROJAN SCRAM (J04EH155)
 + J04492: DOUBLE COULEE-RAVER OUTAGE (J04438)

Smoking, LDC
 500 MVARS SVC @ Keel + 1000

8-AUG-1990

QV-171

PLAN 8: CHIEF JOE-SICKLER-SNOQUALMIE 500KV REBUILD

AND ROCKY R-MAPLE VL 345KV
 500MVAR SVCS AT MAPLE VL & KEELER
 O J04EH180: CHIEF JOE-MONROE 500 OUT (J04EH176)
 Δ J04EH179: TROJAN SCRAM (J04EH177)
 + J04495: DOUBLE COULEE-RAVER 500KV OUT (J04494)

O J04EH180QV
 Δ J04EH179QV
 + J04495QV

8-AUG-1990

QV-180

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

300MVAR SVC AT KEELER & MAPLE VALLEY

ADD 35% COMP ON ASHE-MARION

J04EH190: COULEE-RAVER 500 LINE OUT (J04EH186)

J04503: DOUBLE COULEE-RAVER 500 LINES OUT (J04500)

J04EH191: TROJAN SCRAM (J04187)

RAVER VOLTAGE

○ J04EH190QV
 △ J04503QV
 + J04EH191QV

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

TROJAN SCRAM -- BASED ON J04EH160

o J04EH161: 500 MVAR SVC AT KEELER & MAPLE VL

Δ J04EH192: 300 MVAR SVC AT KEELER, MV & OSTR

+ J04EH198: 500 MVAR AT MV, 300 MVAR AT KEELER & OSTR

x J04EH199: 500MVAR @ MV, 300MVAR @ KEELR (J04EH197) 50% comp on BE-Ostr.

PLAN 3: CHIEF JO-SNOQ/MONROE

TRAJAN SCRAM

o J04EH217:300/300 BE TAP TO HAN-OST(J04EH216)
 Δ J04EH219:300/300 BE TAP TO ASHE/MARION(J04EH218)
 + J04EH185:300MVAR SVC'S - KEELER/MAPLE VL(J04EH160)
 x J04EH161:500MVAR SVC'S - KEELER/MAPLE VL(J04EH160)

o J04EH217QV
 Δ J04EH219QV
 + J04EH185QV
 x J04EH161QV

18-AUG-1990

6V-212

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER & MAPLE VL, LDC, SNOK TXF
 ○ J00EH15: ONE COULEE-RAVER 500 LINE OUT (J00EH12)
 △ J00100: DOUBLE COULEE-RAVER LINE OUT (J0010)
 + J00EH16: TROJAN SCRAM (J00EH17)

○ J00EH15QV.
 △ J00100QV
 + J00EH16QV

8-AUG-1990

22V-220

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 5700MVAR SVC AT KEELER & MAPLE VL, LDC, SNOK TXF
 ○ J04EH159: ONE COULEE-RAVER 500 LINE OUT (J04EH158)
 △ J04441: DOUBLE COULEE-RAVER LINE OUT (J04440)
 + J04EH161: TROJAN SCRAM (J04EH160)

○ J04EH159QV
 △ J04441QV
 + J04EH161QV

8-AUG-1990

QV-221

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

--- BASED ON J04EH160

o J04EH161: 500MVAR SVC AT KEELER & MAPLE VL

Δ J04EH185: 300MVAR SVC AT KEELER & MAPLE VL

+ J04EH192: 300MVAR SVC AT KEELR, MV & OSTRNDR

x J04EH198: 500MVAR AT MV; 300MVAR AT KEELR & OSTR

RAVER VOLTAGE

o J04EH161QV
Δ J04EH185QV
+ J04EH192QV
x J04EH198QV

9-AUG-1990

RAVER SHUNT REACTIVE - MVAR

QU-2222

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE
 300MVAR SVC AT KEELER & MAPLE VL
 ~ J04EH184: ONE COULEE-RAVER 500 LINE OUT (J04EH158)
 ~ J04499: DOUBLE COULEE-RAVER LINE OUT (J04441)
 ~ J04EH185: TROJAN SCRAM (J04EH160)

O J04EH184QV
 Δ J04499QV
 + J04EH185QV

8-AUG-1990

PLAN 8: CJ-SNOQ REPLACING EXISTING LINES

DOUBLE COULEE-RAVER 500 OUTAGE
 J04495: RAVER CHARACTERISTICS
 J04496: MONROE CHARACTERISTICS
 BOTH BASED ON J04494

QV-225

2-AUG-1980

PLAN 2: CHIEF JO-SNOQUALMIE
 DOUBLE COULEE-RAVER LINE OUTAGE
 500 MVAR SVC'S AT MAPLE VALLEY AND KEELER
 OJ04318: ONE CAP GROUP ON AT RAVER (J04308)
 +J04375: TWO CAP GROUPS ON AT RAVER (J04374)
 AJ04373: THREE CAP GROUPS ON AT RAVER (J04372)

O J04318QV
 Δ J04373QV
 + J04375QV

13-JUN-1990

RAVER SHUNT REACTIVE - MVAR

RAVER SHUNT REACTIVE - MVAR

CORRECTION OF C-R SERIES COMP LEVEL

J04166, J04EH64 AND J04EH53 - 45% COMP
 J04441, J04EH159 AND J04EH161 - 22% COMP
 2-C-R 1-C-R TROJAN

O J04166QV
 Δ J04EH64QV
 + J04EH53QV
 x J04441QV
 ◇ J04EH159QV
 ★ J04EH161QV

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.

BASED ON J04EH193

O J04EH195:COULEE-RAVER 500KV LINE 1 OUT

A J04EH207:CHIEF JO-SNOQ 500KV LINE OUT

+ J04EH208:CHIEF JO-MONROE 500KV LINE OUT

RAVER VOLTAGE

O J04EH195QV
 A J04EH207QV
 + J04EH208QV

RAVER SHUNT REACTIVE - MVARs

14-AUG-1990

620-22-1

PLAN 3:CHIEF J-SNOQ/MONROE - 35% COMP.
 300MVAR SVC'S AT KEELER AND MAPLE VL
 J04505:DOUBLE COULEE-RAVER 500KV OUTAGE(J04504)
 Δ J04506:CHIEF J-SNOQ/MON 500KV LINES OUT(J04504)

○ J04505QV
 Δ J04506QV

13-AUG-1990

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE

○ J04EH195, 2196 + J04506: 35% COMP, 300 MVAR SVC'S
 x J04EH159, 161 + J04441: 500 MVAR SVC'S

○ J04EH195QV
 △ J04EH196QV
 + J04506QV
 x J04EH159QV
 ◇ J04EH161QV
 ▲ J04441QV

14-AUG-1990

QV-233

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE--35% COMP

300 MVAR SVC'S AT KEELER AND MAPLE VALLEY

○ J04EH195: COULEE HELD BY EXISTING GENERATION

△ J04506: COULEE HELD BY EXISTING GENERATION

+ J04EH220: COULEE HELD AT 548 KV

x J04507: COULEE HELD AT 548 KV

17-AUG-1990

QV-229

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.
 DOUBLE COULEE-RAVER 500KV OUTAGE
 300MVAR SVC'S AT KEELER AND MAPLE VL
 J04506:COULEE HELD BY EXISTING GENERATION
 J04507:COULEE HELD AT 548KV
 J04512: MSC 300MVAR AT COULEE

28-AUG-1990

RAVER SHUNT REACTIVE - MVAR

CV-7-55

PLAN 3: CHIEF JO-SNOQ/MON - 35% COMP.
 300MVAR SVC'S AT KEELER AND MAPLE VL
 J04EH195: COULEE HELD BY EXISTING GENERATION
 J04EH220: COULEE HELD AT 548KV
 J04EH223: MSC 300MVAR AT COULEE

O J04EH195QV
 Δ J04EH220QV
 + J04EH223QV

QV-236

27-AUG-1990

CHIEF JO-MONROE OUT FROM BASE J96EH158

Δ J96EH484A LDC ● PAUL, COULEE, JOHN DAY,
DALLAS, BONNEVILLE
○ J96EH484 ADD HOLD AT COULEE 500 E-BUS
+ J96EH484B LDC & 300 MVAR SVC ● MV & KLR
x J96EH484C LDC, SVC & HOLD AT COULEE

○ J96EH484
Δ J96EH484A
+ J96EH484B
x J96EH484C

PLAN 3: CHIEF JOE-SNOQUALMIE/MONROE

TRAJAN SCRAM -- BASED ON J04EH160

○ J04EH161: 500MVAR SVC AT MAPLE VL & KEELER

△ J04EH206: 500MVAR e MV; 300MVAR e KLR & OSTR

○ J04EH161QV
△ J04EH206QV

RAVR SHUNT REACTIVE - MVAR

15-AUG-1990

QV-240

PLAN 3: CH JO-SNOQ/MONR TROJAN SCRAM BASE J04EH1

J04EH200: 500 MVAR SVC AT KEELER & MAPLE VALLEY
 J04EH201: 300 MVAR SVC AT KEELER & MAPLE VALLEY
 +J04EH204: 300 MVAR SVC AT KLR & MV: 50% SERIES COMP
 ON BE-OSTR IN PRIOR TO OUTAGE (J04EH197)
 x J04EH205: SAME AS 204, BUT COMP SWITCHED AFTER OUTAGE

OSTRANDER VOLTAGE

O J04EH200QV
 Δ J04EH201QV
 + J04EH204QV
 x J04EH205QV

OSTRANDER SHUNT REACTIVE - MVARs

21-AUG-1990

QV-291

PLAN 3: CHIEF JO-SNOQUALMIE/MONROE COMPARISON OF 1.7PU AND 2.0PU LINE DESIGNS O J04EH159:1 COULEE-RAVER LINE OUT, 2PU (J04EH158) Δ J04EH189:1 COULEE-RAVER LINE OUT, 1.7PU (J04EH188) + J04441:DOUBLE COULEE-RAVER OUTAGE, 2PU (J04440) x J04502:DOUBLE COULEE-RAVER OUTAGE, 1.7PU (J04501)

O J04EH159QV
 Δ J04EH189QV
 + J04441QV
 x J04502QV

8-AUG-1990

24-250

ALTERNATIVE Q-V CURVES

J96EH576QV: C-J-M outage = SUC'S @ SNOB, @ MV, @ COV, @ KEELER, S-E 427, @ Columbia series comp

J96EH578QV: Trj-m outage SUC'S @ MV, @ KEELER, series comp 3530 J-M, 4260 N, 3570 N-N

J96EH579QV: C-J-M outage SUC'S @ MV, @ KEELER, series comp 4260 N, 3570 N-N

J96EH581QV: C-J-M outage SUC'S @ MV, @ KEELER, series comp 5460 J-M, 7060 N-N, 4270 C-N

J96282QV: double C-N outage, SUC'S @ MV, @ KEELER, series comp 4270

[illegible]

J96EH575QV: CJ-M entage, S-V's CE entage, KE-101
J96EH575QV4: CJ-M entage, S-V's CE entage, KE-101, C-A 42.7% comp.
J96EH575QV5: CJ-M entage, S-V's CE entage, KE-101, C-A 42.7% comp.
J96EH580QV: Tregent entage, S-V's CE entage, KE-101, C-A 42.7% comp.
J96283QV: S-V's CE entage, KE-101, C-A 42.7% comp.

PSR REACTIVE ALTERNATIVE Q-V CURVES

J96EH573QV3: Same as QV except QV at Marian
 J96EH573QV4: Trojan outage, JVC's @ Suck, (at 100, keeler, C-K 42% comp series
 J96EH573QV5: Trojan outage, Suck's @ MV (3) and keeler
 J04EH149QV: Trojan outage, series comp on 5-50KV lines, Suck's same as 196
 J04EH149QV2: Same as QV except QV at Marian

2-JUL-1990

PSR REACTIVE ALTERNATIVE Q-V CURVES

J96EH577QV: C.T. - 1.44mV, C.R. to range 42%, max 500's

~~J062750VZ~~
~~J062750V4~~
~~J062750V5~~
~~J04EH1100V~~

o J96EH577QV

2-JUL-1990

PSR REACTIVE ALTERNATIVE Q-V CURVES

J962750V2; 2000 C-10000 SUTS 10 MV, 10 C-100, 10 Keeler
 J962750V3; 2000 C-10000 SUTS 10 SPARK, 10 MV, 10 C-100, 10 Keeler
 J9R2750V4; 2000 C-10000 SUTS 10 SPARK, 10 MV, 10 C-100, 10 Keeler
 J962750V5; 2000 C-10000 SUTS 10 SPARK, 10 MV, 10 C-100, 10 Keeler
 J04EH148QV; 2000 C-10000 SUTS 10 SPARK, 10 MV, 10 C-100, 10 Keeler

○ J962750V4
 △ J962750V5
 + J962750V2
 x J962750V3
 ◇ J04EH148QV

J2004 ABNORMAL COLD ALL LINES IN SERVICE

15.5 MVA selected in order to keep 1 line in service

○ J04EH60QV - 15.5 MVA
 ▲ J04EH61QV - 15.5 MVA

DC LINE FROM COULEE TO SNOQUALMIE
 LOADED TO 1500MW PRIOR TO CONTINGENCY
 AFTER CONTINGENCY DC RAMPED TO 3000MW
 TEST OF CJ-MONROE OUTAGE AND TEST OF TROJAN
 OUTAGE (ONE CENTRALIA UNIT ALREADY DOWN)
 KEELER SYNCH CONDENSER WITH GENERATOR OUTAGE

○ J04EH62QV
 ▲ J04EH63QV

TABLES

TABLE 100: LOSS SAVINGS OF FEASIBLE ALTERNATIVES

(In peak MW's; top number is PNW losses, lower number is BPA losses)

Alternative	1996	2000	2004(1)	2004+(1)
Base System	-0- -0- J96243, J96244	-0- -0- J0037, J0038	N/A	N/A
Plan 1 Chief Joe-Monroe	70.2 58.0 J96261, J96262	91.5 73.7 J0035, J0036	82.0 67.9 J04343	82.0 67.9 J04343
Plan 2 Chief Joe-Snoqualmie 500-kV	66.9 53.6 J96258, J96259	78.3 62.2 J0022, J0021	65.1 53.8 J04226	69.3 58.0 J04347
Plan 2 Chief Joe-Snoqualmie 765-kV line op @ 500	77.7 64.3 J96271, J96272	90.6 74.0 J0046, J0047	76.9 65.0 J04227	
Plan 2 Coulee/Chief Joe- Snoqualmie 765-kV line			141.5 122.6 J04228	141.5 122.6 J04228
Plan 3 Chief Joe-Snoq/Mon 4-Bunting	73.9 59.1 J96241, J96242	86.1 68.2 J0023, J0024	77.1 63.6 J04345	84.9 70.4 J04348
Plan 3 Chief Joe-Snoq/Mon 4-Seahawk	Older J96 studies showed an additional 6.6 MW BPA and 6.9 MW PNW losses are available if 4-Seahawk conductor is used.			
Plan 4 Hanford-Snoqualmie	51.0 39.9 J96267, J96268	71.6 54.5 J0042, J0043	74.2(2) 57.4 J04344	78.7(2) 61.1 J04349
Plan 5 Sickler-Snoqualmie	65.12 49.6 J96269, J96270	77.73 59.5 J0044, J0045	68.7 56.1 J04346	73.4 60.9 J04350
Plan 6 Reactive Alternative	2.4 xxx J96273, J96273loss	10.13 xxx J0040, J0041	-0- -0- J04370	-0- -0- J04370
Plan 7 Coulee-Olympia/Snoq 500-kV	69.4 58.2 J96289, J96290	82.4 68.2 J00104, J00105	63.9 54.6 J04508	67.8 58.1 J04510
Plan 8 Chief Joe-Sickler- Snoqualmie 500-kV	60.1 50.0 J96291, J96292	73.5 59.7 J00106, J00107	58.2 49.7 J04509	63.7 53.9 J04511

(1) Loss savings for 2004 are referenced against loss of Reactive Alternative, not base system without additions as is the case for 1996 and 2000.

(2) 2004 base has WNP-1 in operation which increases the loss savings of Plan 4.

TABLE 15C.

.....1/09/90.....
PUGET SOUND VOLTAGE PLANNING ASSUMPTIONS
.....

RESOURCES

1. The Puget Sound area hydro generation will generate at median water firm peaking levels for winter prior to January 6 (reduced generation on the Skagit River). Snoqualmie Falls will be assumed frozen with no generation during abnormal cold.
2. The PSP&L combustion turbines will be generating during abnormal cold except Whitehorn unit #3 and Shuffleton units are off.
3. The PSP&L combustion turbines are off during normal winter peak load.
4. PGE's Beaver combustion turbine/combined cycle plant is off.
5. Coulee serves as a baseload generator with 4500MW generation.
6. Snake River projects provide peaking generation.

.....

INTERTIE SCHEDULES

7. BCH to PNW schedule is 250MW during normal and abnormal cold. After the BCH-WWP intertie is completed in the mid 1990's, the total BCH-PNW schedule will be 850MW. Phase shifters on the eastern BCH system will cause 600MW to flow directly to the WWP system. The Nelway phase shifter will be adjusted to minimize inadvertent flow. This assures the Ingledow to Custer powerflow will consistently be about 250MW.
8. BCH is using two Burrard units as synchronous condensers for normal and abnormal winter loads. Zero reactive is generated prior to a contingency.
9. PNW-PSW interchange is zero during abnormal cold if PNW resources are sufficient to meet the load cold weather load.
10. PNW imports from the PSW on the DC intertie if PNW resources are insufficient to meet the assumed cold weather load.
11. PNW-PSW interchange during normal peak is 1000MW DC and 2000MW AC export to PSW in 1996. Export in later years decreases to allow PNW resources to meet the assumed normal load.
12. Transmission additions to return the Canadian Entitlement (1400MW firm in 2003) will be addressed in a separate planning study.

.....

SYSTEM DESIGN

13. The operating point will be planned to provide 500MVARs shunt reactive margin from the voltage instability point.
14. The newly revised Reliability Criteria is applied.

TABLE 150

15. The system will be designed to restore full load immediately following the contingency unless a detailed system study shows the load cannot be fully restored with a 95% voltage level at BPA delivery points. The system will not be designed to use the direct load trip scheme now being installed at Intalco and Kaiser.

.....

LOAD LEVEL ASSUMPTIONS

16. The CY89 load forecasts and power factors for normal peak are reasonable.

17. The peak load level above the PNUCC forecast experienced during the February 1989 cold snap is the abnormal cold load level for planning. Snohomish PUD abnormal cold load for planning is slightly higher due to their own 1987 study. Multipliers for abnormal cold load for the four major utilities are: PSP&L 116%, SCL 111%, SPD 123%, TCL 120%. The utilities report that the February 1989 conditions reflect reduced school and business loads. The power factor for abnormal is the same as normal weather.

.....

SYSTEM ADDITION ASSUMPTIONS

Prior to 1993

Raver 500kv shunt capacitors (brings total to 952MVARs)
Columbia series capacitor upgrade (2400A, 22.5%)
Olympia-Port Angeles 230kv loop-in at Shelton
Shelton-Port Angeles 230KV loop-in at Fairmount
Port Angeles 115kv terminals in advance of added Daishowa load
(assumed schedule: phase 1 - fall 1993, phase 2 - fall 1995)
Olympia 230kv shunt capacitors (2-150MVAR banks, remove old 100MVAR bank)
Custer-Bellingham 230kv #2 line
BCH Nelway phase shifter
BCH Nicola-Meridian series capacitors (50%)
BCH Nicola-Ingledow series capacitors (50%)
TCL shunt capacitors at Southwest (100MVARs), Pearl (60MVARs), Northeast (80)
and Cowlitz (60MVARs)

Prior to 1996

Cowlitz-Olympia 230kv line
Cowlitz Falls Integration (Mayfield-Mossyrock 230kv loop-in)
Port Angeles 115kv shunt capacitors (Daishowa phase 1, 2-23.7MVAR banks)
Shelton 230kv shunt capacitors (Daishowa phase 1, 1-114MVAR bank)
Fairmount-Port Angeles 230kv line (3rd line, Daishowa phase 1)
Shelton-Fairmount 230kv line (3rd line, Daishowa phase 2)
Olympic Peninsula Reinforcement with 500kv to Shelton
Allston 500/230kv transformer #2
Ostrander 500kv shunt capacitors (1-312MVAR bank)
Keeler 500kv shunt capacitors (1-312MVAR bank)
BCH Williston-Kelly Lake 500kv #3 line with series capacitors
BCH Kelly Lake-Cheehy 500kv #2 line with series capacitors
BCH Ingledow static var device (150MVAR)
BCH-WWP intertie (600MW added import assumed for both normal and abnormal)

Prior to 2004

No assumed additions after 1996.

.....

TABLE 151: LINE AND TRANSFORMER RATINGS

The new reliability criteria requires that abnormally cold weather loads must be served during maingrid outages using -15 deg C ambient equipment limits. Main grid outages include the 500-kV system, 345-kV system and the transformers from these systems to the 230-kV grid. Moderate cold weather loads must be served during 230-kV system outages using a -10 deg C ambient. The ratings of critical lines are as follows:

	Owner	Conductr	Max Oper Temp	Rating at Ambient Temperature				
				-15 C	-10 C	-5 C	20 C	35 C
Bellingham-Sedro	BPA	Drake	60	1124	1082	1037	776	357
Berrydale-Talbot Hill	PSPL							
Bothell-Sammamish	SCL	Tern	100	1363	1333	1303	1133	1015
	PSPL	Tern	100	1363	1333	1303	1133	1015
Bothell-Snohomish #1	BPA	Drake	90	1308	1275	1271	1083	948
Bothell-Snohomish #2	BPA	Drake	100	1391	1361	1329	1156	1035
	SCL	Mallard		1377	1347	1345	1170	1048
Bothell-Snoking	SCL	Mallard	100	1377	1347	1345	1170	1048
	BPA	Drake	100	1391	1361	1329	1156	1035
Broadstreet-Massachusetts	SCL							
Christopher-Obrien*	PSPL	Bittern		1616	1567	1517	1228	1011
Cottage Br-Snoqualmie	PSPL	2/0 cu7						
Covington-Creston BPA	BPA	Drake	80	1252	1217	1180	1000	847
Covington-Obrien	PSPL							
Covington-Tacoma A	BPA	Drake	80	1252	1217	1180	1000	847
Lakeside-Talbot Hill #1	PSPL	Tern						
Lakeside-Talbot Hill #2	PSPL	4/0 cu7						
Monroe Tap-Sedro Tap #1	BPA	Drake	70	1191	1153	1113	907	728
Monroe Tap-Sedro Tap #2	BPA	Drake	70	1191	1153	1113	907	728
Monroe-Snoking Tap	BPA	Chukar	70	1942	1879	1813	1434	1139
Snohomish-Murray	BPA	Drake	50	1049	1001	952	644	357
Snohomish-Murray+	BPA	Drake	100	1391	1361	1329	1156	1035
Snoking-Maple Valley	SCL	Mallard						
Talbot Hill-Obrien	PSPL	Tern						

*Estimated using 75 deg C bittern with BPA Assumptions

+Upgraded in BPA line sag program

Transformers

Station	voltage	nominal rating	thermal summer	emergency summer	thermal winter	emergency winter
Covington #1	500/230	1008	1107	1317	1256	1512
Covington #2	500/230	1008	1087	1317	1236	1512
Maple Valley	500/230	1792	1862	2136	2089	2523
Monroe	500/230	1008	1177	1353	1325	1512
Tacoma	500/230	1344	1429	1665	1621	1983

The above emergency ratings are based on 60% load factor.
No transformer can be loaded above emergency rating at any time.
No transformer can be loaded above thermal without an outage.

TABLE 170

OTHER THERMAL PROBLEMS IN THE PUGET SOUND AREA

As mentioned in the main text, there are three problems that exist prior to the assumed energization of the CM reinforcement (10-96) and will not necessarily be solved by this project. They are: a breaker failure at Raver, the integration of the new PSPL line into Lake Tradition and the Massachusetts-Broadstreet 115-kV line overload.

A breaker failure at Raver could cause loss of the Raver-Snoqualmie and Raver-Tacoma lines, which, prior to the CM additions, would cause the Covington transformers to overload as shown in J96254. Reinforcement of the CM transmission would reduce the severity of this problem. It is assumed that this problem is corrected by rearranging the bus layout at Raver (somehow) and this fix will eliminate the problem in later years. However, the effect of each plan on the existing bus layout is analyzed below.

There are also many line overload problems in the Lake Tradition area that are the result of poor integration of Puget's new 230-kV cross mountain circuit. The heavy loading of the 115-kV lines in this area are further aggravated by external outages. The Massachusetts-Broadstreet overload is caused by throughflow which occurs during maingrid equipment outages. Nothing is assumed to be added to correct these problems, however the effect of each CM reinforcement plan is analyzed with respect to these problems below.

Plan 1

This CM line addition alleviates the breaker failure problem at Raver until about 2004 (J04232).

Terminating the new CM line at Monroe improves (but does not correct) the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

Plan 2

This CM line addition will alleviate the breaker failure problem at Raver (J96257), however, by about 2005 the problem will reoccur (J04216). The addition of the second Maple Valley 500/230-kV transformer (in 2006) will delay this even further.

Terminating the new CM line at Snoqualmie aggravates the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

Plan 3

This CM line addition will alleviate the breaker failure problem at Raver (J96255), however, by about 2003 the problem will reoccur (J04207). The addition of the Snohomish 500/230-kV transformer (in 2010) will delay this even further.

Terminating the new CM line at both Monroe and Snoqualmie does not change the Massachusetts-Broadstreet overload and Lake Tradition integration problems significantly.

Plan 4: same as Plan 2.

Plan 5: same as Plan 2.

Plan 7

This CM line addition alleviates the breaker failure problem at Raver (J96287), however, by about 2002 the problem will reoccur (J04497). The addition of the second Maple Valley 500/230-kV transformer (in 2012) will again delay the problem.

Terminating a new CM line at Snoqualmie aggravates the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

Plan 8

This CM line addition alleviates the breaker failure problem at Raver (J96288), however, by about 2003 the problem will reoccur (J04498). The addition of the second Maple Valley 500/230-kV transformer (in 2006) will again delay this problem.

Terminating the new CM line at Snoqualmie aggravates the Massachusetts-Broadstreet overload and Lake Tradition integration problems.

TABLE 201 - LINE UPGRADES

PUGET SOUND AREA LINE	Upgrade BEFORE XMTN PLAN	Upgrade AFTER XMTN PLAN	PLAN
PSP Bellingham-Sedro 230-kV	970A	1020A spring	all
PSP Blumaer-Electron Heights 115	440A	470A summer	all
PSP Electron Hgths-Krain Corner Tap (on Elct Hts-White Rv 115-kV line)	340A	360A summer	all
PSP St Clair-White River 115 line	720A	760A summer	all
PSP Obrien-Talbot Hill 230 line	700A	860A summer	all
BPA Covington-Tacoma A 230 line	600A	630A summer	all
PSP Maple Valley-Talbot Hill 230 #1&2	---	1900A summer	all
SCL Bothell-Snohomish 230 #3 (created from loopin)	---	1200A summer	plan 1
PSP Beverly Park-Hilton 115	---	600A summer	plan 1
SCL Maple Valley-Snoking 230	---	950A summer	plan 1
PSP Lakeside-Sammamish 115 #1&2	---	650A summer	plan 1
OKANOGAN AREA LINES			
BPA Brewster-Ophir Tap 115	280A	300A summer	all
	310A	330A spring	all
BPA Ophir Tap-Okanogan 115	250A	270A summer	all
	280A	300A spring	all

2002

AGENCY STUDIES

LOAD	RATING	100PERG RATING	OUTAGE	% LINE LOADING			
				250KW INCLSDOM-CRITER			
				NO PLAN	DOUBROE PLAN	DOH-SHOCK PLAN	SHOCK PLAN
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SHOCK 500	N/A	N/A	90%	92%
			TACOMA 500/230	98%	110%	112%	111%
			CHRIS-COVINGTON 230	92%	102%	104%	103%
			CHRIS-OBRIEN 230	100%	103%	105%	106%
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	151%	150%	161%	162%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	137%	144%	147%	148%

2000 2003
A960Y89 STUDIES

LOAD	RATING	LOADED RATING	OUTAGE	% LINE LOADING 1000W INCHLOW-CUTTER			
				NO PLAN	MONROE PLAN	MON-SHOCK PLAN	SHOCK PLAN
BLUMBER- ELECTRITY 115	306A	(587A)	RAVER-PAUL 500	94%	100%	102%	103%
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	93%	98%	99%	99%
O'BRIEN- TALBOT II 230	552A	(1015A)	NO OUTAGE	N/A	86%	89%	N/A
			RAVER-SHOCK 500	N/A	100%	111%	113%
			TACOMA 500/230	106%	118%	120%	120%
			CHRIS-COVINGTON 230	99%	109%	112%	111%
BREWSTER- OPHIR T 115	180A	(353A)	CHRIS-O'BRIEN 230	103%	106%	108%	109%
			DOUGLAS-WELLS 230	148%	154%	157%	158%
ORANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	134%	140%	143%	144%
HOLCOMB- NAHELE 115	420A		LONGVW-LONGVW T 230	120%	123%	125%	125%

Table 204

A96CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOW>CUSTER TROJAN OFF								A96 CASE #'S
				FO	PFLOW	FO	PFLOW	FO	PFLOW	FO	PFLOW	
				NO		MONROE		MON-SNOQ		SNOQ		
				PLAN		PLAN		PLAN		PLAN		
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	142	147	147	153	149	155	151	155	141,142,143,144
ELECTHTS- WR KC TP 115	306A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	110 97	112 96	113 100	115 99	114 102	117 100	115 102	116 100	SAME AS ABOVE 145,146,147,148
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	63 129		66 137		67 135		67 136		SAME AS ABOVE
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE RAVER-SNOQ 500 TACOMA 500/230 CHRIS-COUMGTN 230 CHRIS-OBRIEN 230	90 112 125 114		101 112 134 115		104 137 135 127		104 148 139 126		149,150,151,152 153,154,155,156 157,158,159,160
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	95	95	102	103	107	107	108	108	161,162,163,164
LAKESIDE- SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH MONROE-SNOQ 500 SNOQ TP-SNOQUALM 500	N/A 95 N/A	87 95	114 116	114 118	106 N/A 100	106 N/A 87	97 N/A	98	165,166,167,168 173,135,134,133 134
MAPLE VL- SNOKING 230	890A	(1035A)	MONROE-SNOQ 500 MAPLE VL 500/230	N/A N/A		106 N/A	108	N/A N/A		N/A N/A		SAME AS ABOVE
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	142	138	147	142	150	146	152	148	169,170,171,172
GRANOGAN- R T 115	180A	(353A)	DOUGLAS-WELLS 230	128	130	133	135	137	139	138	140	SAME AS ABOVE
ERLY PK- ILTON 115	552A		MONROE-SNOQUALM 500	N/A	87	107	107	N/A		N/A		SAME AS ABOVE
BOTHELL- SNOHOSH 3 230			MONROE-SNOQUALM 500	N/A		112	113 (N)	N/A		N/A		SAME AS ABOVE

Table 205

AOOCY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 250MW INGLEDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A			
			TACOMA 500/230	101%	110%	115%	114%
			CHRIS-COVINGTN 230	95%	109%	107%	106%
BREWSTER- OPHIR T 115	180A	(353A)	CHRIS-OBRIEN 230	106%	110%	111%	112%
			DOUGLAS-WELLS 230	152%	160%	162%	163%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	138%	146%	148%	149%
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	112%	116%	117%	117%

Table 206
A00CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1000MW INGLEDOVE-CLUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	91%	97%	98%	98%
O'BRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A	92%	N/A	N/A
			RAVER-SNOQ 500	N/A	101%	108%	111%
			TACOMA 500/230	108%	124%	122%	122%
			CHRIS-COVINGTON 230	100%	116%	113%	113%
LAKESIDE- SAMMAMISH 115	552A	(1015A)	CHRIS-O'BRIEN 230	108%	112%	112%	113%
			LAKESIDE-SAMMAMISH	N/A	102%	N/A	N/A
BREWSTER- OPHIR T 115	180A	(353A)	MONROE-SNOQ 500				
DOUGLAS-WELLS 230	150%			156%	160%	161%	
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	136%	142%	146%	147%
TROJAN- ST MARYS 230	1315A	(1507A)	ALLSTON-KEELER 500	96%	99%	100%	100%
TROJAN- RIVERGATE 230	1315A	(1507A)	ALLSTON-KEELER 500	97%	100%	101%	101%
BOTHELL- SNOHOMH 3 230			MONROE-SNOQ TAP 500	N/A	107%	N/A	N/A

Table 207
A00CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	LINE LOADING 2000MW INGLEWOOD-CUSTER TROJAN OFF			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	138	145	146	147
ELECTHTS- WR RC TP 115	306A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	109 98	114 103	114 103	115 102
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	62 128	67 134	67 134	67 135
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	93	108	108	108
			RAVER-SNOQ 500	111	138	149	153
			TACOMA 500/230	128	142	143	143
			CHRIS-COVINGTN 230	118	131	131	131
			CHRIS-OBRIEN 230	115	117	120	121
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	97	107	110	110
LAKESIDE- SAMMAMISH 115	552A	(1015A)	LAKESIDE-SAMMAMISH MONROE-SNOK TP 500 SNOK TP-SNOQ 500	93 N/A N/A	126 104 123	107 N/A 97	99 N/A N/A
MAPLE VL- SNOKING 230	890A	(1035A)	MONROE-SNOQ 500 MAPLE VL 500/230	N/A N/A			
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	144	150	153	155
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	131	136	139	141
RLY PK- DON 115	552A		SNOK TP-SNOQ 500	N/A	103	N/A	N/A
ROTHELL- SNOHOMSH 230	1,2,3		MONROE-SNOK TP 500	N/A	140	100	N/A
ROTHELL- SNOKING 230	1048A		MONROE-SNOK TP 500	92	111	N/A	N/A

Table 208
A04CY89 STUDIES

3 LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 250MW INGLENDOW>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A			
			RAVER-SNOQ 500	N/A			
			TACOMA 500/230	95%	114%	112%	111%
			CHRIS-COVINGTON 230	N/A	106%	104%	102%
			CHRIS-OBRIEN 230	102%	107%	108%	109%
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	153%	161%	164%	164%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	139%	147%	149%	150%
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	111%	115%	116%	116%

Table 209
A04CY09 STUDIES

RLOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1000MW INGLEDOVE>CUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMBER- ELECTRITS 115	306A	(587A)	RAVER-PAUL 500	N/A	96%	96%	97%
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	91%	98%	98%	98%
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE	N/A	N/A	87%	N/A
			RAVER-SNOQ 500	N/A	N/A	102%	104%
			TACOMA 500/230	104%	121%	121%	120%
			CHRIS-COVINGTON 230 CHRIS-OBRIEN 230	96% 105%	112% 108%	111% 111%	110% 111%
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	152%	159%	162%	163%
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	138%	145%	147%	148%
BOTHELL- SNOHOMH J 230			MONROE-SNOK TAP 500	N/A	113%	N/A	N/A
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	120%	124%	125%	125%

Table 210
A04CY89 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEDOVE>CUSTER TROJAN OFF			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMAER- ELECTHTS 115	306A	(587A)	RAVER-PAUL 500	132	140	141	142
ELECTHTS- WR KC TP 115	306A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	108 99	113 105	114 105	114 104
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	62 125	67 132	67 132	66 133
OBRIEN- TALBOT H 230	552A	(1015A)	NO OUTAGE RAVER-SNOQ 500 TACOMA 500/230 CHRIS-COVINGTON 230 CHRIS-OBRIEN 230	87 101 124 113 112	107 132 142 129 115	105 142 141 129 117	103 145 140 127 117
MAPLE VL- TALBOT H 230	1767A	(3304A)	MAPLE VL-TALBOT H 230	90	105	105	105
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	145	151	155	156
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	131	136	140	142
COVINGTON- WHITE RV 230	730A		COVINGTON-WHITE RV 230	93	97	99	100
HOTHELL- 1,2,3 SNOHOMSH 230			MONROE-SNOK TP 500	N/A	147	N/A	N/A
HELL- ING 230	1048A		MONROE-SNOK TP 500	108	127	N/A	N/A
AKESIDE- SNOKING 230	980A		SNOK TP-SNOQ 500	N/A	116	N/A	N/A

SPG94CY09 STUDIES

LOAD	RATING	100DEG RATING	OUTAGE	% LINE LOADING 1800MW CUSTER-INGLEDOW					PF #
				NO	MONROE	MON-SNOQ	SNOQ		
				PLAN	PLAN	PLAN	PLAN	FO PF	
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230 DOUGLS-SICKLR 500/230	170% 159%	182% 185%	185% 188%	185% 186%		
OKANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230 DOUGLS-SICKLR 500/230	156% 147%	168% 170%	171% 173%	171% 172%		
HOLCOMB- NASELLE 115	420A		LONGVW-LONGVW T 230	105%	111%	111%	111%		
BELINGHAM- SEDRO 230	660A		MONROE-SNOK TP 500 SNOK TP 500				113 106		SPG94114
BELINGHAM P- SEDRO 1 115	387A		BELINGHAM-SEDRO 230	109%	105%	106%	115%		
REV PK- GOLDBART 115	276A		SNOK TAP-SNOQUALM 500 SNOK TP 500				103 106		SPG94114

212
SPG94CY09 STUDIES

CIRCUIT LOAD	RATING	100 DEG RATING	OUTAGE	% LINE LOADING 2000MW INGLEWOOD-CLUSTER			
				NO PLAN	MONROE PLAN	MON-SNOQ PLAN	SNOQ PLAN
BLUMBER- ELECTHTS 115	387A	(587A)	RAVER-PAUL 500	136%	142%	144%	144%
ELECTHTS- WR KC TP 115	387A	(447A)	RAVER-PAUL 500 ELECTHTS-WHITE RV 115	104% 91%	108% 95%	109% 96%	109% 96%
ST CLAIR- WHITE RV 115	552A	(1015A)	NO OUTAGE RAVER-PAUL 500	157%	162%	164%	164%
OBRIEN- TALBOT H 230	723A	(1015A)	NO OUTAGE	N/A	88%	90%	N/A
			RAVER-SNOQ 500	91%	116%	125%	129%
			TACOMA 500/230	108%	117%	119%	119%
			CHRIS-COVINGTON 230 CHRIS-OBRIEN 230	100% 100%	108% 101%	110% 103%	110% 104%
MAPLE VL- SHORING 230	890A	(1015A)	MONROE-SNOQ 500 MAPLE VL 500/230		102%		
BREWSTER- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	156%	163%	167%	169%
ORANOGAN- OPHIR T 115	180A	(353A)	DOUGLAS-WELLS 230	143%	149%	154%	155%
BOTHELL- SNOQH 3 230			MONROE-SNOQUALM 500		121%		
BOTHELL- SAMMASH 230	1015A		MONROE-SNOQUALM 500	74%	101%	91%	
WELL- ING 230	1048A		MONROE-SHOK TP 230 MONROE-SNOQUALM 500	103% 126%	133%		
SAMMASH 115/230			SAMMASH 115/230 1	96%	107%	106%	103%
CHEHALIS- TACOMA A 230	1070A		PAUL-RAVER 500	97%	101%	102%	103%

TABLE 302

TECHNICALLY FEASIBLE TRANSMISSION ALTERNATIVES REJECTED FOR ECONOMIC REASONS

1. CHIEF JOE-SNOQUALMIE 765-KV LINE

Assumptions used for 765-kV study:

- a. 765/500-kV transformers will be 500 MVA/phase, 10.5% impedance.
- b. Phase shifting transformers will be on 500-kV sending end and have same size and impedance as step-up transformers.
- c. 765-kV transmission line will be 6-SeaHawk, 2 PU, double circuit design.
- d. Plan 2, the Chief Joe and Snoqualmie terminations, will be tested to determine the feasibility of this voltage class.
- e. If a 765-kV line is built, it will initially operate at 500-kV until 2004 and then converted to its design voltage.
- f. The 765-kV plan will have same SVC's added as the 500-kV Plan 2: at Maple Valley and Keeler.

Results of 765-kV study

- a. Operating a 765-kV line at 500-kV provides about 50 MVARs additional reactive over a 500-kV line for the three critical outages (compare J04198QV and J04200QV in QV-160, J04EH73QV and J04EH76QV in QV-161, and J04EH82QV and J04EH84QV in QV-162). Upgrading this line to 765-kV operation does not provide an appreciable improvement due to the additional impedance of the transformation at each end (compare J96EH26QV and J96EH139QV in QV-164 and J9610QV and J96103QV in QV-164). Also voltage control for all operating conditions is much more difficult than 500-kV lines. Several switched and fixed shunt reactors will be required.
- b. To make the first 765-kV line attractive (without a 765-kV grid), the line must be force-loaded. Adding phase shifters to the sending end would enable the line to be loaded to a predetermined level. Loss savings favor about 2000 MW loading on each line (Table 350). Surge Impedance Loading (SIL), with terminating transformer impedance added, is also about 2000 MW.
- c. The voltage stability performance of several line loadings were studied. For the worst double line outage, the performance was better for lower initial loadings as shown in QV-166 (probably due to problems at Chief Joe). For the single Coulee-Raver line outage, performance was better for higher pre-outage flows as shown in QV-167. The single Chief Joe-Snoqualmie 765-kV line outage also is better for higher pre-outage loadings, but the differences are not as great as shown in QV-168. This makes sense since one of the phase shifted lines is removed in this case.
- d. 2000 MW pre-loading of the new 765-kV line appears to be optimal.
- e. Adjusting the phase shift of the new line after an outage occurs was investigated. QV-169 shows the effect of increasing and decreasing the phase shift angle after the worst single line outage occurs. From these studies it appears to be beneficial to decrease the angle after a single line outage

occurs and detrimental to increase the angle. Adjusting the phase shift after double line outages was not investigated at this time since a phase shift adjustment will not help for a double 765-kV line outage.

f. The remaining studies assume that each new line is loaded to 2000 MW prior to any outage and the pre-outage phase shift angle is held after the outages occurs.

g. The phase shifter impedance does not have an appreciable difference in the performance (compare J04EH78QV and J04EH88QV in QV-161.).

h. Performance of the 765-kV line plan with 2000 MW loading (as compared to the 500-kV line) appears to be better at the start of the QV curves for the three critical outages. But as the voltage drops through the QV curve, the performance drops off sharply apparently due to voltage collapse at Chief Joe. This is especially true for the double Coulee-Raver line outage where most of the power must go through Chief Joe. QV-160 compares the double line outages, QV-161 the single line outages and QV-162 the Trojan scram.

i. From the performance of the above, at least one of the 765-kV lines will need to be extended to Coulee.

j. The performance of a Chief Joe/Coulee-Snoqualmie 765-kV double circuit line is shown in J04EH102QV, J04EH103QV and J04EH105QV in QV-165. J04203QV in QV-160 gives a good indication of how this plan would operate during the loss of the new double circuit line. This plan has 500 MVAR SVC's at Keeler and Maple Valley like the 500-kV plans and is not necessarily optimized. Comparing these curves with those in QV-121 (the same plan at 500-kV), it is estimated that this line addition would last only about 2 years longer than a 500-kV double circuit line.

k. The loss savings of this plan are as follows (with Snoking Reinforcement): These also included in Table 100.

	1996*	2004+
Chief Joe-Snoqualmie 500-kV SDC	66.9	65.1
Chief Joe-Snoqualmie 765-kV SDC operated at 500-kV	77.7	76.9
Chief Joe/Coulee-Snoqualmie 765-kV SDC phase shifted to 2000 MW		141.5

* 1996 losses compared to base system

+ 2004 losses compare to reactive plan

l. There is a benefit of a 765-kV line as part of a future 765-kV grid that is hard to evaluate at this time.

Conclusion

The additional expense of constructing the new line to 765-kV does not appear to but justified by the QV performance. There is a significant loss savings though.

TABLE 302 Continued

TECHNICALLY FEASIBLE TRANSMISSION ALTERNATIVES REJECTED FOR ECONOMIC REASONS

2. COULEE-SNOQUALMIE DIRECT CURRENT LINE

A Coulee-Snoqualmie DC line was modeled for abnormal cold 2004 system conditions. A 1500MW power schedule is needed with all lines in service (JO4EH60QV, JO4EH61QV). The base case with one Centralia unit down needs one SVC at Maple Valley for the reactive margin (JO4EH61QV). Normal winter conditions were not modeled.

The post transient outage of the Chief Jo-Monroe 500kv line needs DC fast ramping to 3000MW. One SVC at Maple Valley is needed to provide reactive margin (JO4EH62QV).

The post transient Trojan outage with one Centralia unit down and an SVC at Keeler is slightly less severe than the Chief Jo-Monroe outage (JO4EH63QV). This also needs DC fast ramping to 3000MW.

The estimated cost of this plan is 3 times the cost of the comparable AC plan.

A Celilo-Snoqualmie DC line was not studied because the area interchange assumptions for normal winter do not allow full use of the existing Celilo DC terminal for scheduling power to Snoqualmie. Another Celilo terminal is needed in addition to longer line length (290 miles vs. 190 miles). This provides no apparent benefit for the increased cost.

3. HIGH-PHASE-ORDER TRANSMISSION LINE (SIX-PHASE, 500-kV+)

Similar problems to 765-kV analysis listed above. Reliability is reduced from standard double-circuit lines: would need to plan for loss of entire circuit during abnormally cold weather (presently just plan for one circuit on double-circuit towers). These requirements would make this alternative even more expensive than a similar 765-kV AC three-phase alternative. And like the 765-kV plan, there does not appear to be any justification for additional cost.

TABLE 303

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

Alternative	Comments
1. Chief Joe-Raver 500-kV double circuit line.	Voltage Stability performance was inferior to northern termination plans, 4 of 5 existing 500-kV CM lines already terminated at Raver.
2. Chief Joe-Raver 500-kV double circuit and Raver-Snoqualmie 500-kV #2 lines.	Performance is similar to preferred plans, however, 4 of 5 existing 500-kV CM lines already terminated at Raver.
3. Coulee-Raver 500-kV double circuit line.	Coulee termination does not improve performance of the critical single line outage, 4 of 5 existing 500-kV lines already terminated at Raver
4. Ashe-Snoqualmie 500-kV double circuit line.	Performance is OK, but not any better than a Hanford termination.
5. Chief Joe-Monroe/Snoqualmie 500-kV double circuit, add Raver-Snoqualmie #2 and use with one existing Coulee-Raver line to form Coulee-Snoqualmie 500-kV line.	Tying existing line into Snoqualmie degrades performance.
6. Chief Joe-Coulee 500-kV single circuit line.	Slight improvement in performance, not enough to justify 30 miles of line construction and terminations.
7. Monroe-Raver-Paul 500-kV single circuit line.	Improvement is small, comparable to a 500-kV shunt capacitor group, not economic.
8. Monroe-Raver-Olympia 500-kV single circuit line.	Not quite as good as Monroe-Raver-Paul (#7).
9. Naneum Switchyard (tie Coulee-Raver lines, Vantage-Raver and Sickler-Raver lines together near Ellensburg).	Little effect on performance for abnormally cold weather conditions.
10. Naneum Switchyard and Grand Coulee-Naneum 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
11. Naneum Switchyard with shunt capacitors.	Cap group is effective addition.
12. Naneum Switchyard with series capacitors within station.	Shunt caps more effective per MVAR.

TABLE 303 Continued

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

13. Naneum Switchyard, Naneum-Snoqualmie 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
14. Naneum Switchyard, Naneum-Monroe 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
15. Naneum Switchyard, 500-kV single-circuit tap line to Hanford-Grand Coulee.	Little improvement in system performance when compared to existing system.
16. Naneum Switchyard, Naneum-Hanford 500-kV single circuit line.	Little improvement in system performance when compared to existing system.
17. 500-kV single circuit tap line from Sickler to existing Grand Coulee-Hanford 500-kV line.	Little improvement in system performance when compared to existing system.
18. Sickler-Monroe 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
19. Sickler-Monroe 500-kV double circuit line, 500-kV single circuit tap line from Sickler to existing Grand Coulee-Hanford 500-kV line.	Not enough improvement for Coulee-Raver outage.
20. Sickler-Snoqualmie 500-kV double circuit line.	Performance improves somewhat over existing system, but other alternatives perform much better.
21. John Day-Paul 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
22. John Day-Allston 500-kV double circuit line.	Little improvement in system performance when compared to existing system.
23. John Day-Allston 500-kV Raver-Olympia 500-kV single circuit line.	Better than #22 but still mediocre.
24. Lower Monumental-Hanford 70% Series Compensation - 136 MVAR.	These additions are ineffective in correcting the problem.

TABLE 303 Continued

TRANSMISSION ALTERNATIVES REJECTED DUE TO POOR TECHNICAL PERFORMANCE

25. Raver-Snoqualmie 500-kV single circuit line, Snoqualmie switchyard.	Surprisingly effective, but not nearly enough to correct problem. This will be investigated in conjunction with CM alternatives.
26. Raver-Snoqualmie 500-kV single circuit line, Raver-Covington 500-kV single circuit line.	Similar to #25.
27. Raver-Snoqualmie, Raver-Covington and Raver-Tacoma 500-kV single circuit lines.	Similar to #25.
28. Covington-Maple Valley 500-kV single circuit line, Covington and Maple Valley switchyards.	Most effective of westside line construction, but still not enough to correct problem. This will be investigated in conjunction with CM alternatives.

TABLE 310

INVESTIGATIONS OF QV PERFORMANCE FOR TRANSMISSION LINE ALTERNATIVES

The general development of the transmission line options is detailed in this table. Most of this development was done on Plans 2 and 3. This discussion covers many of the options and refinements that were investigated in this study.

1996 QV PERFORMANCE

With a new Chief Joe-Snoqualmie/Monroe or Chief Joe-Snoqualmie line added, the three critical outages for the Puget Sound area are 1) loss of one Coulee-Raver 500-kV line during abnormally cold weather, 2) loss of Trojan with one Centralia unit previously out-of-service, also during abnormally cold weather and 3) loss of both Coulee-Raver 500-kV lines during normal winter peak loads.

The new line with the LDC's proposed in the assumptions and the Snoking Reinforcement project do not provide the necessary reactive margins in either the Puget Sound or Portland areas without SVC's. A 300 MVAR SVC is required on the Keeler 230-kV bus to provide the necessary reactive margins in the Portland area for the Trojan scram. The QV performance of these additions are shown in the attached QV-131. The required 500 MVAR on-line margin cannot be obtained without switching the existing shunt capacitors at Raver or adding additional high-speed reactive. A 300 MVAR SVC is therefore required on the Maple Valley 230-kV bus to provide this margin. The performance of these additions is shown in QV-132, which has the required margins without switching capacitors after the outage.

Additions of series compensation were studied in 1996 as an alternative to SVC additions. As shown in QV135 (Normal winter outages) and QV-136 (abnormal cold weather outages), the addition of SVC's is much more effective at this time. However, once these SVC's are added, the addition of series comp becomes much more effective (QV-137). Series capacitor additions may be more appropriate rather than the increases in SVC size due to performance and loss savings. This will be discussed later.

2000 QV PERFORMANCE - SOLVING PROBLEMS IN THE PORTLAND AREA

With Plan 3, the QV-outages for 2000 (QV-220) were compared with 1996 (QV-132). The line outages are marginal in 2000, but since additional cap groups are available at Raver during these outages, that group can be switched automatically (MSC) after the outage in conjunction with the Maple Valley SVC. The Trojan Scram outage, however, has just a 500 MVAR margin in 2000, and the base system already has all three caps groups energized. Therefore, system reinforcement will be needed by 10-2000 in the Portland area. Increasing the SVC at Keeler to 500 MVAR will provide enough support for this outage through 2004, as shown in study QV-221 and will be assumed as the long range support for this initial planning process. Other options exist, which include:

1. 300 MVAR SVC at Ostrander

This is about equally effective per MVAR as Keeler (QV-222) and would provide additional reliability due to the different location. Also MSC switching a 300 MVAR capacitor group at Ostrander was nearly as effective as the SVC (QV-240).

2. Series compensation on Ashe-Marion and Big Eddy-Ostrander lines

Ashe-Marion compensation didn't seem to help much (compare QV-215 with QV-223) but the Big Eddy-Ostrander line, which is heavily loaded during these conditions, seems to help as much as a 300 MVAR SVC at Ostrander (QV-216). Because this is an old line with small conductor, continuous series compensation is probably not desirable, however, switching the comp after outages is actually better (QV-241).

3. Tap lines from Big Eddy to the Hanford-Ostrander and the Ashe-Marion

These tap lines were studied to relieve the bottleneck between Big Eddy and Ostrander. These were not very effective as shown in QV-218.

2004 QV PERFORMANCE - SOLVING PROBLEMS IN PUGET SOUND AREA

After the Portland reactive problems are solved (by increasing the SVC at Keeler to 500 MVAR), the Puget Sound area again experiences problems. QV-223 shows the 2004 system with only a 300 MVAR SVC at Maple Valley. The double Coulee-Raver line outage does not have sufficient margin in these cases. To meet the reactive margins for this critical double line outage, the operating voltage at Raver must be nearly 550-kV or the existing 500-kV shunt capacitors at Raver must be automatically switched with the outage. As discussed below, to maintain reactive margins at Monroe and prevent overvoltages at Raver, MSC at Raver is favored.

Comparing QV-223 with QV-220, the critical single line outage will not have the required 500 MVAR margin (even with MSC at Raver) in 2003. Support will be needed by 10-2002. Increasing the SVC at Maple Valley will correct the system through 2004 as shown in QV-221 and will be the assumed long range plan. Again other options exist:

1. An additional 300MVAR SVC at Snohomish

An additional SVC in the North Puget Sound area (as opposed to increasing the size of the Maple Valley SVC) would provide some additional reliability by separating the facilities. This also more effective for the CM plans that have lines terminated south of Monroe.

2. Series compensation of the new line

Compensation of the new lines was investigated as a second phase reinforcement (as an alternative to the SVC increases at Maple Valley). Previous loss savings studies indicated that the optimal compensation level for the future system with a new 4-bunting conductor line into the Snoqualmie/Monroe area would be 35% on the new line and 40% total on the Coulee-Raver lines. Since these J96 studies showed only about a 2 MW loss savings for all this compensation and due to the need for some variable reactive supply in the load area, SVC's were selected as the best reinforcement initially. However, once SVC's are installed in the load area, series comp becomes more attractive.

As noted earlier, the J04 cases contain an error in the Coulee-Raver series compensation. 45% comp was inadvertently used instead of the planned 22.5%. This error results in slightly over-optimistic QV curves. As shown in QV-230, the EH winter QV curves for Plan 3 with the corrected impedances have about 150 MVARs less margin. With the lower compensation levels, more shunt reactive can be on in the base. The double line outage shows the largest difference,

obviously since a larger amount of series reactive is lost with these outages. All three curves for Plan 3 (with the correct compensation level) still have the required 500 MVAR margin.

If 35% compensation is added on the new circuits, the critical outages change. The worst single line outage becomes the new Chief Joe-Monroe circuit and the worst double line outage becomes loss of the new double circuit line (QV-231 and QV-232).

If the compensation is added in lieu of the 200 MVAR additions to the SVC's at Maple Valley and Keeler, performance is improved for the line outages as shown in QV-233. For the single and double line outages, the knees of the QV curves move to the left by about 125 to 250 MVARs. The Trojan scam, however, appears to get worse if the series comp is added (compare J04EH196QV and J04EH161QV). In fact the curve for the series comp case (J04EH196) will not solve below 1.05 pu voltage. The reason for this appears to be that the Keeler SVC is hitting the ceiling and the system collapses in the Portland area (note that the J04EH196 curve starts to solve better than 161 at Raver but drops off sharply below 1.08 pu voltage). Although series comp improves the Puget Sound area line outages, separate reinforcement, such as the Keeler SVC increase or others mentioned above, will also be needed in the Portland area. Otherwise this option looks attractive, especially since the series comp should "grow" with the load, that is, it will provide increasing MVARs to the system as the line loadings increase. Series compensation, as a second phase reinforcement to the transmission line options, should be studied further.

3. Mechanically Switched Capacitors at Grand Coulee

A general observation from the QV curves of the transmission line options is that the knees tend to coincide with the Coulee generators reaching Q_{max} . Curves were run with an infinite VAR source at Coulee as a comparison (QV-234). These cases were run on Plan 3 with 35% compensation. Included on this curve is the unscheduled reactive required at Coulee to hold the pre-fault voltage. These numbers show that initially it doesn't take much reactive to make a significant difference at Raver. However, larger reactive additions at the source have a diminishing effect at the receiving end. Limited reactive additions may be beneficial. Due to the large number of machines at Coulee to provide VAR regulation, shunt capacitor additions at Coulee are all that is needed to provide this benefit.

Curves QV-235 and QV-236 show the addition of a 300 MVAR MSC at Coulee for the double and single line outages respectively. These curves show that a 300 MVAR shunt capacitor addition at Coulee provides about 200 MVARs at Raver. In other words, a 300 MVAR MSC at Coulee is equivalent to a 200 MVAR SVC in Puget Sound. These capacitors can either be energized prior to outage or mechanically switched after outages occur.

Similar studies were run in J96 without any system reinforcement beyond LDC's at Paul, Coulee, John Day, Dalles and Bonneville and the 300 MVAR SVC's at Maple Valley and Keeler (QV-237). This addition is not quite as effective at moving the curves to the left but it does drop the knees considerably. Apparently with the reduced system impedance from the line additions, supporting the sending end of the transmission lines becomes more effective.

MSC's at Coulee (and other generating plants such as Chief Joe) should be investigated in more detail.

DOUBLE LINE OUTAGE

To obtain adequate reactive margins at Raver for the double Coulee-Raver line outage, all three capacitor groups are required on line or MSC switched after the outage. If the capacitors are on line prior to the outage, overvoltages may exist on the system (J04440) and adequate margins might not exist at Monroe, since having all 3 cap groups on at Raver do not allow any capacitors on at Monroe. As an example, refer to QV-225 which shows no margin at Monroe for the double Coulee-Raver line outage. QV-226 shows the performance at Raver for the double Coulee-Raver line outage with one, two and three cap groups on at Raver prior to the outage.

Another option to improve the double line outage performance would be to develop the Naneum switchyard, as in Plan 5. The switchyard development may also have some loss savings benefits. Series comp on the new lines would also improve the double line outage.

LDC AT CHIEF JOE

With new circuits terminated at Chief Joe, the additional charging current reduces the reactive output of the generators at that dam. The addition of an LDC at Chief Joe to control the 500-kV bus, however, does not help much in addition to the other LDC's previously proposed. Refer to QV-130. The addition of shunt capacitors at Chief Joe could make an LDC there beneficial.

LINE DESIGN

As mentioned in the assumptions, a 2.0 p.u. line design was used in these studies due to poor experience on lines of the 1.7 design. Recent information indicates that the poor experience is due to 60hz withstand and that a 1.7 p.u. design would perform more favorably if additional bells were added in place of spacers on the existing tower designs. QV-250 compares the outage performance of the two designs for the single and double Coulee-Raver line outages. As can be seen, the 1.7 p.u. design is about 25-50 MVARs better than the 2.0 design. If a 1.7 p.u. line design is used, the system performance would be slightly better than shown in this study.

SHUNT REACTIVE ADDITIONS

To maintain adequate voltages on the system throughout the study period, it is assumed that shunt capacitors will be added on the 500-kV system. In reality, some capacitors will be needed on the lower voltage systems to maintain voltages for outages on these systems. However, the assumption of 500-kV capacitor additions will provide an approximation of the total shunt compensation required.

By the year 2000, additional shunt capacitor groups will be needed at Keeler and Ostrander (refer to case J00EH17). Going out to 2004, a second capacitor group is needed at Pearl and a third is needed at Ostrander (refer to case J04EH160). Because of the transmission line addition into the Puget Sound area, additional capacitors will not be required until 2002. One capacitor group is needed at Snoqualmie by 2002 and a second capacitor group at Monroe is needed by 2004. The following shunt compensation plan is assumed as a starting point for the Transmission line options:

1998 Add 500-kV shunt capacitor bank at Keeler.

2000 Add second 500-kV shunt capacitor bank at Ostrander.

2002 Add 500-kV shunt capacitor bank at Snoqualmie;
 Add second 500-kV shunt capacitor bank at Pearl;

2004 Add second 500-kV shunt capacitor bank at Monroe;
 Add third 500-kV shunt capacitor bank at Ostrander.

TABLE 350
 LOSS SAVINGS OF VARIOUS
 765-KV LINE LOADINGS.

PF CASES

Powerflow Cases for North Seattle Studies

BASES	PLAN 1	PLAN 2	PLAN 3	REACTIVE PLAN	PLAN 7 & 8
J96122	J96171	J96172	J96144	A93160	J96287
J96152	J96235	J96234	J96241	A93194	J96288
J96243	J96248	J96236	J96250	SPG94116	J96EH582
J96254	J96261	J96239	J96251	A96170	J00EH17
J0008	J96262	J96249	J96255	A96174	
J00EH11	J96EH502	J96253	J96260	A96175	J04497
J96244	J96EH554	J96257	J96EH206	J96273	J04498
	J96EH555	J96259	J96EH251	J96279	J04EH160
	J96EH565	J96EH503	J96EH252	J96280	J04EH162
	J96EH566	J96EH553	J96EH315	J0049	J04EH163
	J96EH568	J96M216	J96EH328	J04EH22	J04EH165
	J96M215	J96M219	J96M146	J04EH25	J04EH166
	J96M217	J96M220	J96M147	J04EH34	J04EH167
	J96M218	J0017	J96M148		J04EH168
	J96M221	J0018	J0023		J04EH183
	J96M226	J0021	J0024		
	J96M227	J0022	J0027		
	J0035	J0025	J0028		
	J0036	J0030	J00EH34		
	J0037	J00EH25	J00EH35		
	J0038	J00EH26	J00EH39		
	J00EH28	J00EH27	J04165		
	J00EH29	J04197	J04207		
	J00EH30	J04216	J04EH26		
	J00EH31	J04EH94	J04EH42		
	J00EH32	J04EH97	J04EH110		
	J00EH112		J04440		
	J00EH113				
	J04196				
	J04232				

PF - BASES

PF - PLAN 1

LOSSES
 BPA= 687.82
 FMH= 1067.16
 SYSTEM= 3654.14

PAGE 1 SOUND 230 EV
 PAGES 5 5/15/90 14 4.020
 CYBER HIL
 BASED ON 1964P.02
 SPOKING 500 230 1000

S:FO R- PLOTTED 13-APR-90 AT 08:40:39 HOURS

for Skagit Gen

LOSSES BPA= 602.80
PNW= 940.57
SYSTEM= 3536.73

J96M217 4/13/90 PF 4.020
CY89 MJL-ALH
BASED ON J96M215
SNOKING TP 230KV BUS OUT

J96M21 4/13/90 11 4.020
CY89 MJL
BASED ON J96M121
NORMAL SKAGIT GENERATION
PLAN 1 - C-J-M ADDED
COVINGTON BERRYDALE 230 ADDED
NO SNOOKING TX

LOSSES BPA= 598.79
PNW= 929.93
SYSTEM= 3514.86

J96M227 4/13/90 PF 4.020
CY89 MJL-ALH
BASED ON J96M221
MONROE TAP 230KV BUS OUT
SEDRO TAP 230KV BUS OUT
N-SEATTLE AREA

LOSSES
 BPA= 655.37
 PNW= 1001.64
 SYSTEM= 3575.86

10035 545290 FT 4.020
 10035 HJL
 BASED ON 10008
 PLAN 1 - 111111
 SNOHOMISH AND SNOOKING 1X ADDED
 NORMAL SNOOKING GEN

J04232 6/ 1/90 PF 4.020
 CY89 MJL-ALH
 BASED ON J04196
 CJ-M PLAN 1 ADDED
 SNOHOMISH AND SNOOKING 500/230 TX ADDED
 CB FAILURE AT RAVEN: REMOVES RAVEN-
 SNOQUALMIE AND RAVEN-TACOMA

PF - PLAN 2

S:PO R- PLOTTED 14-MAY-90 AT 09:29:11 HOURS

LOSSES
 BPA= 681.18
 PNW= 1061.94
 SYSTEM= 3650.24

239 -53
 OLYMPIA
 543 -50

J96EH503 4/12/90 PF 4.020
 CY89 MJL
 BASED ON J96EH158
 PLAN 2 - CJ-S ADDED
 COVINGTON-BERRYDALE 230 ADDED
 NO SNOOKING TX

LOSSES BPA= 591.68
 PNW= 927.46
 SYSTEM= 3524.38

J96M216 4/12/90 PF 4.020
 CY89 MJL
 BASED ON J96M121
 PLAN 2 - CJ-S ADDED
 COVINGTON-BERRYDALE 230 ADDED
 NO SNOOKING TX

LOSSES BPA= 596.69
PNW= 938.04
SYSTEM= 3535.40

J04EH97 4/27/90 PF 4.020
 CY89 MJL
 BASED ON J04EH94
 SNOKING 500/230 TX AND LINE OUT

PF - PLAN 3

LOSSES BPA= 662.51
PNW= 1031.17
SYSTEM= 3618.18

LOSSES BPA= 589.71
PNW= 922.00
SYSTEM= 3518.80

J96M146 2/ 6/90 PF 4.020
CY89 ALH-MJL
BASED ON J96M121
ADD CHIEF JOE-SNOQUALMIE/MONROE
ADD COVINGTON-BERRYDALE

LOSSES
BPA= 681.53
FNW= 1012.36
SYSTEM= 3588.91

J0023 5/ 8/90 PF 4.020
CY89 MJL
Entered 10 09
Page 1 of 1

INTERTIE SCHEDULE

AC= 400. AC= 76.
DC= 400. DC= 400.

LOSSES

BPA= 652.46
PNW= 1000.63
SYSTEM= 3599.22

CANADA TO PNW
(BCH & WKOOT)
SI= 850.
AI= 850.

MONT TO PNW
SI= 1250.
AI= 968.

IDAHO TO PNW
SI= 700.
AI= 658.

500BUSNORTHWEST

J04440 7/26/90 PF 4.020
CY89 MJL
BASED ON J0475
PLAN 3 CJ-S/M
C-R COMP CORRECTED

PF - REACTIVE PLAN

AB3160 5/24/90 PF 5.001*
CY88 BLC
BASED ON AB3159
OUTAGE OF ALLSTON-KEELER 500 LINE

LOSSES
BPA= 1001.33
PNA= 1302.68
SYSTEM= 4306.65

A93194 6/25/90 PF 4.020
CY89 GLC
BASED ON A93CY89
GEN PATTERN SIMILAR TO A93195
ALLSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

LOSSES
BPA= 1046.80
PNA= 1360.07
SYSTEM= 4376.01

LOGSBS
 BPA= 1015.02
 PMN= 1200.00
 BYTEM= 3707.30

BP004118 0/25/00 PF 4.070
 CY00 OLC
 BASED ON BP004103
 CHIEF JO 500/230 OUTAGE

BPA= 1006.01
PIW= 1370.77
SYSTEM= 4389.13

A96170 6/ 6/90 PF 4.020
CY80GLC-ALH
BASED ON A9885 MONROE PLAN
DOUGLAS-WELLS 230KV LINE OUT

ASBL74 6/25/80 RF 4.320
CYBS 6.1
BASED ON ASBL7
NO XRTN PLAN
ALSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

LOSSES
SPAC 1008.41
PMW 1407.35
SYSTEM 4427.75

ABSEITE 6/25/90 RF 4.020
CYBS ELC
BASED ON 1988S
MONIE DITN P.14
ALLSTON-KEELER OUTAGE WITH
100% NORMAL SUMMER PEAK LOAD

LOSSES
SMA= 992.13
PMA= 1396.06
SYSTEM= 4412.40

LOSSES BPA= 674.58
PNW= 1009.75
SYSTEM= 3637.39

J96280 6/19/90 PF 4.020
CY69 SEATTLECAPS GLC
LOSS COMPARISON
COULEE-RAVER SERIES COMP 52.5%

PF - PLANS 7 + 8

500BUSNORTHWEST

INTERTIE SCHEDULE

AC= -870.
DC= -1200.

ACTUAL

AC= -1137.
DC= -1200.

LOSSES

BPA= 829.94
PNW= 1227.15
SYSTEM= 3865.93

CANADA TO PNW
(BCH & WKOOT)
SI= 850.
AI= 850.

MONT TO PNW
SI= 1310.
AI= 1042.

IDAHO TO PNW
SI= 630.
AI= 631.

J00EH17 8/ 7/90 PF 4.020
CY89 MJL
BASED ON J00EH11
PLAN 3 CJ-S/M
CENTRALIA UNIT DOWN

SIPU R- PLOTTED 6-AUG-90 AT 15:36:41 HOURS

J04497 8/ 6/90 PF 4.020
CY89 MJL
BASED ON J04438
TACOMA 500/230 TX OUT
RAVER-SNOQUALMIE 500 OUT
SIMULATING LB FAILURE AT RAVER
PLAN 7

SIPQ R- , PLOTTED 27-JUL-90 AT 15:37:42 HOURS

5190 F- , PLOTTED 27-JUL-90 AT 15:45:55 HOURS

J04EH166 7/27/90 PF 4.020
 CY89 MJL-ALH
 BASED ON J04EH154
 PLAN 7
 SNOOPING 500/2301V TXF OUT

5100 F-1, PLOTTED 27-JUL-90 AT 15:50:00 HOURS

Attachment 2

U.S. DEPARTMENT OF ENERGY - BONNEVILLE POWER ADMINISTRATION

DATE : OCT 12 1990

Memorandum

FROM : Marv Landauer, Electrical Engineer
Project Studies Section - EOFB

Marv Landauer

SUBJECT: New Cross Mountain Transmission Line Alternative

TO : Dennis Porter, Assistant Director
Division of System Planning - EO

ATTACHMENT 2

I have recently been studying a new cross mountain transmission line alternative for the Puget Sound Area Electric Reliability Project that shows some promise. This alternative consists of rebuilding the double-circuit Chief Joe-Snohomish 345-kV Line to single-circuit 500-kV, using as much of the existing tower structures and conductor as possible. The new line would be looped into Monroe and terminated at Snohomish with a new 500/230-kV autotransformer. New 500-kV switching stations would be added at Columbia and Mad River (my name for a new station along the Stevens Pass corridor), with a new single circuit 500-kV line connecting these new stations to the existing Sickler switchyard. Refer to Attachment A.

Only 2004 studies of this plan have been run and these are not complete. A step plan between 1996 and 2004 has not been developed. There are also many potential variations to this plan that have not yet been explored.

It is assumed that the addition of the Snohomish 500/230-kV transformer (to replace the existing 345/230-kV transformers) and a Snoking 500/230-kV transformer will provide adequate support to the North Seattle area through 2004. A second Chief Joe 500/230-kV transformer will be needed because of the removal of the 345-230-kV transformers there. 500 MVAR SVCs are assumed at Maple Valley and Keeler in the 2004 studies, as in the other plans.

The addition of the new east side crosstie reduces the severity of the outages that can occur by providing a more integrated transmission system. The post-transient performance of the three worst outages for this alternative is shown in the Q-V curves in Attachment B. These curves can be compared to the three worst outages for the Chief Joe-Snoqualmie/Monroe plan we submitted as the budget plan (Plan 3 shown in Attachment C). This new plan will require additional reinforcement for the single line outage in 2004 to provide the necessary 500 MVAR margin, whereas the budget plan does not require additional reinforcement until 2005. It should be noted that this new plan, like the Reactive Alternative, does not have the same ultimate capacity that the new 500-kV double-circuit Line plans do. The crosstie plan and the Reactive Alternative make better use of existing system capacity, especially during outages.

The loss savings for this plan is lower than the new double circuit line plans in the most recent engineering report. As compared to the Reactive Alternative (since the base system will not solve without reinforcement in later years), this new alternative will save about 57 MW in losses in 2004. For comparison, the Chief Joe-Snoqualmie 500-kV double circuit line alternative saves about 65 MW and the Chief Joe-Snoqualmie/Monroe 500-kV double circuit Line plan saves about 77 MW.

Even though the post-transient performance and loss savings are inferior to the better double-circuit plans, this new plan should be considerably cheaper. The rebuild of the 345-kV line will be less expensive than a new single-circuit line since the conductor and much of the existing towers, can be reused. This savings should more than offset the additional cost of the extra losses, east side line construction and switchyard development at Columbia and Mad River.

This crosstie concept could also be applied to many of the other plans documented in the engineering report. It would also allow for a staged development of these alternatives that could reduce the overall cost.

5 Attachments

MLandauer:zb:3887 (VS16-EOFB-6844L)

cc:

A. Courts - E

M. Raschio - EOF

A. Rodrigues - EOFA

M. Bond - EOFB

G. Comegys - EOFC

Official File - EOF (FY 91 BI 14)

Viles

Taylor

Attachment A: Cross tie Plan

Attachment B

PLAN 10: CROSS TIE COLUMBIA-SICKLER-MADRIVER
 CHIEF JO-SNOHOMISH 345 REBUILD TO 500
 O J04541 BOTH COLUMBIA-RAVER 500 OUT (J04534)
 Δ J04EH244 MADRIVER-MONROE #2 500 OUT (J04EH238)
 + J04EH240 TROJAN SCRAM (J04EH239)

O J04541QV
 Δ J04EH244QV
 + J04EH240QV

Attachment C

PLAN 3 CHIEF JOE-SNOQ/MON correct C-R
 O J04EH159: COULEE-RAVER OUT (J04EH158) Series comp
 Δ J04441: BOTH COULEE-RAVER LINES OUT (J04440)
 + J04EH161: TROJAN SCRAM (J04EH160)

500BUSNORTHWEST

INTERIE SCHEDULE	ACTUAL	LOSSES
AC = -730.	AC = -909.	BPA = 876.75
DC = -1700.	DC = -1261.	PMH = 1291.90
		SYSTEM = 3938.84

CANADA TO FRW	MONT TO FRW	INDIA TO FRW
(BOB & BROUT)	51: 1300.	51: 480.
51: 850.	81: 1012.	81: 528.
81: 850.		

J04EH158 7/26/90 PF 4.020
CY89 MJL
BASED ON J04EH69
PLAN 3 CJ-S/H
C-F COMP CORRECTED

Attachment 3

ATTACHMENT 3: THE REACTIVE PLAN

by Marv Landauer - BPA

3-9-92

The preferred reactive plan is the addition of a new switchyard in the Naneum area that includes series compensation on the Raver side. Initially banks of 19 ohms and 3150 amps will be added to the double circuit lines, followed later by two new banks, one on the Sickler-Raver line (20 ohms and 2200 amps) and one on the Vantage-Raver line (23 ohms and 2000 amps). This plan evolved from the original reactive plan that was described in the Puget Sound Transmission Alternatives Report. This report documents the study work that was done since that time to develop this preferred reactive plan.

Section 1: Assumptions

Plans were designed to provide at least 500 MVAR reactive margin. The studies in this report assume that the following facilities are installed:

To provide reactive support in the Puget Sound Basin through 1996:

- 230-kV, 300 MVAR SVC's at Maple Valley and Keeler,
- 500-Kv Snoqualmie switchyard,
- LDC's added at Coulee, Centralia, John Day, The Dalles, Bonneville.
- additional 500-kV shunt caps at Snoqualmie (625 MVAR) and Monroe (312 MVAR),
- additional 230-kV shunt caps at Snoking, Tacoma and Olympia (153 MVAR each),

These additional shunt capacitors can be used as MSC's.

To provide local reinforcement to the Puget Sound area:

- Raver-Snoqualmie 500-kV line #2
- Maple Valley 500/230-kV transformer #2 and Monroe-Snohomish 230-kV #3 OR Snoking 500/230-kV transformer

These local reinforcement assumptions will be reviewed later in this report.

Some support appears to be needed in the Portland area about 2004, regardless of the reinforcement added in the Puget Sound area. An SVC at Ostrander was proposed in the original reactive plan and would provide this support. However an MSC at Marion is probably sufficient, especially since these studies already include 3 capacitor groups at Ostrander.

Section 2: Evolution of reactive plan

Several reactive options were developed and studied. The more important options are listed below. Other options that were studied and eliminated are included in Table 9 at the end of this report.

System losses and the performance of all option are summarized in Table 1. A diagram of the major cross mountain transmission lines is included in Table 2. QV curves for each option, by plan number, are also attached.

REACTIVE PLAN 3

The Original Reactive Plan consisted of the following additions:

- A. 300 MVAR SVC's at Covington, Snohomish and Ostrander,
- B. Chief Jo-Monroe series caps, 25% fixed and 25% switched,

- C. Naneum-Raver #1 and #2 series caps, 35% fixed and 35% switched,
- D. Coulee-Raver #1 and #2 series caps, 20% fixed,
- E. Raver-Snoqualmie 500 #2 line, and
- F. Maple Valley 500/230 Tx #2 and Monroe-Snohomish 230 #3 line.

This reactive plan appears to have plenty of margin as shown in QV-Curve 3. This is largely due to the MSC's that have been proposed for the Puget Sound Basin since the original engineering report. Overvoltages would occur with the 50% comp on Chief Joe-Monroe line. This would require that the comp be split into two banks, separated by several miles of line impedance.

REACTIVE PLAN 3C

Since the original plan had so much margin, some of the components of that plan could be eliminated. The SVC's are very expensive and the reliability of the switched series is questionable. Therefore this plan was developed with only fixed series caps:

- A. 35% series comp on Chief Jo-Monroe line,
- B. 60% series comp on Naneum-Raver #1 and #2 line,
- C. additional 27.5% series comp on Coulee-Raver #1 and #2 lines,
- D. Raver-Snoqualmie 500 #2 line, and
- E. Maple Valley 500/230 Tx #2 and Monroe-Snohomish 230 #3 line.

Series comp levels for this plan were selected for optimum loss savings. The Coulee-Raver level was optimized first, Chief Joe-Monroe next, then Naneum-Raver lines (together). Then the sensitivity of these levels were tested against each other and adjusted. The comp levels obtained from this method make the X/R ratios of the five 500-kV lines nearly equal. The loss saving of this plan is slightly better than the original plan as shown in Table 1.

With this plan, there are no series cap terminal overvoltages at operating points. The Chief Joe-Monroe compensation could be added at one site. This plan works through 2003 as shown in QV-Curve 3C.

NANEUM DEVELOPMENT

Large amounts of series compensation are needed in these plans to support the system for the loss of the double circuit Coulee-Raver line. However adding series compensation on the other cross mountain lines is not the most efficient; it is better to load the double circuit lines. One way to improve the system performance without adding excessive amounts of compensations is to develop a switchyard to tie the system together. This would reduce the severity of the double line outage significantly. The switchyard must be developed somewhere along the Coulee-Raver lines, preferably around the midpoint. There are 2 existing stations in this area at Naneum and Columbia. Naneum development would require tying both Coulee-Raver lines, the Vantage-Raver line and the Sickler-Raver line together. Columbia development would require tying both Coulee-Raver lines together near the existing Columbia site and adding a new tie line to Sickler (Rocky Ford on the Coulee-Hanford line is another possibility). This tie line addition would be about 20-25 miles long.

A comparison of the double line outages for these two plans in J97 is shown in QV-Curve 4. If a Naneum Switchyard is developed, the double Coulee-Naneum and double Naneum-Raver line outages are of similar severity and are much better

than the existing system without the switchyard. If a Columbia switchyard is developed along with a Sickler-Columbia 500-kV line addition, the double Coulee-Columbia outage is also much better, but the double Columbia-Raver line outage is significantly worse than the Naneum-Raver outage if the Naneum switchyard is developed. However, both of these outages are better than the existing system. The Naneum switchyard performance is better than Columbia.

The loss saving of these two plans and the existing system are very similar. Naneum development should be less expensive to construct since there is no significant line construction. A Naneum Switchyard could also help the line crossing problems in that area.

Either Naneum or Columbia development should fit into the long range planning for the area since they could be the start of a crosstie, which would definitely provide a stronger system, especially if a new line is built in the Stevens Pass (northern) corridor. Also, with a new line addition and no switchyard development, the worst double line outage is still the loss of both Coulee-Raver circuits since they are series compensated. Adding a switchyard along these lines reduces the severity of this worst double line outage and would make the new line options perform much better.

Naneum appears to be the best plan to reduce the severity of the double line outage. If this switchyard is developed, the next problem to solve is the Chief Joe-Monroe outage during abnormal winter since Naneum does little to help that problem. If the problems associated with this line outage is solved, the system should also be acceptable for the Trojan scram. Adding series comp to the new Naneum-Raver line sections (the old Coulee-Raver circuits) would help for both of these outages.

Once a switchyard is added at Naneum, percent compensation levels become confusing. Percent compensation is defined as the terminal-to-terminal impedance of the line in question. For example, an additional 20% compensation on the Coulee-Raver lines is 19 ohms. If Naneum is developed and this same compensation is added on the new Naneum-Raver lines, the percent compensation is 44%. In an attempt for clarity, whenever percent compensation amounts could be confusing, the actual ohms of the bank will also be noted. The impedance of all 500-kV cross mountain lines is summarized in Table 2.

REACTIVE PLAN 3F

This plan consists of the Naneum Switchyard to solve the double line outage and series comp on the new Naneum-Raver lines (26 ohms, 60%) to solve the Chief Joe-Monroe outage and Trojan scram. QV-Curve 3F shows that this plan would perform acceptably through 2004. There is some loss savings due to this plan, however these series comp levels also have not been optimized.

REACTIVE PLAN 3G

The capacitor banks in Plan 3F would need to be extremely large (about 4600 amps to meet the 2004 load). The existing switchgear at Raver is limited to about 4200 amps in winter. Also losses are not optimal for 26 ohm banks.

With the addition of a Naneum switchyard to the existing system, the optimum compensation level for the new Naneum-Raver lines is an additional 20-25% of entire line length (44 to 56% of the Naneum-Raver section). Refer to Graph 5.

With a new cross mountain line added (Chief Joe-Snohomish 345 rebuild to 500-kV double circuit was assumed in this analysis) in addition to the Naneum switchyard, the optimal comp level for loss savings decreases to 15-20% of the entire line length (33 to 44% of the Naneum-Raver section). Refer to Graph 6. An additional 20% (44% of the new Naneum-Raver line section or 19 ohms) is assumed to be optimal for both the existing system and the future system with a new line added.

With 19 ohms compensation added in the double circuit line and a Naneum switchyard in place, the system performance is adequate beyond the year 2000 (refer to QV Curve 3Ga), and even further if a third shunt capacitor is added at Raver or one is added at Naneum. When additional reinforcement is needed, the size of these banks can be increased to 26 ohms (like Plan 3F) or additional comp can be added on the remaining two Naneum-Raver 500-kV lines.

These lines are limited thermally due to sections of 2 1/2 inch conductor. Compensating them too heavily is not efficient. It could also overload these lines and/or cause capacitor terminal overvoltages (this is discussed more later). A workable compensation plan would be to add 19 ohms series capacitors initially on the double circuit Naneum-Raver lines, followed by a 20 ohm (40%) bank on the Sickler-Raver line section and a 23 ohm (40%) bank on the Vantage-Raver line section. This would provide adequate reactive support through 2004 as shown in QV Curve-3G without overvoltages.

Staging the series capacitors has a few advantages. It delays the cost of some of the compensation. It also provides banks with an optimum compensation level that can minimize transmission losses. Depending on the load level, the losses may be lower on the system with the Sickler-Raver and Vantage-Raver capacitors bypassed. These banks could be reserved only for emergency situations by bypassing them during lower load level periods.

REACTIVE PLAN 3J

Because of the heavy loading the caps experience during certain outages and the potential overload problems, it would be beneficial to have adjustable series capacitor banks (Thyristor Controlled Series Capacitors - TCSC) to reduce the effective compensation of the new banks when necessary. This technology is unfortunately in the early stages of development and has not been proven in the field. However, discretely switched capacitor banks could be used to accomplish this objective. This plan was developed with 2-stage caps on the double circuit Naneum-Raver lines.

This plan would add 15 ohm capacitor banks initially in the Coulee-Raver lines at the new Naneum switchyard. In about 2000, an additional 11 ohm capacitor bank would be added in series with the other bank for a total of 26 ohms (60% in 2 switching steps). After Phase II, both banks would be used during EH winter. The comp level could be reduced in lower load periods if the system loss savings would be better. Some or all the capacitors could be bypassed during outages to reduce the loading of the banks as discussed later. The performance of this plan is shown in QV Curve 3Ja (Phase I) and QV Curve 3J (Phase II). QV Curve 3Jb shows the performance of the Phase II system with some caps bypassed.

Section 3: Analysis of favorable options

Of all the reactive plans listed above and in Table 9, only Plans 3F, 3G and 3J

will be considered further. Plan 3 would be expensive and complicated. Plan 3C is attractive due to its loss savings and cost, however it requires at least two new stations. The addition of the Naneum switchyard fits better into the long range plans of the addition of a new cross mountain line since it reduces the severity of the loss of both Coulee-Raver lines (which is still the critical outage even after the addition of a new line).

The reactive options will be planned to meet the 2004 load level. Higher load levels would be difficult for the following reasons:

1. The Vantage-Naneum line is near its thermal capacity in 2004. Refer to case J04908 which shows this line, which will be rated at 3000 amps when upgrades are complete, loaded to 2903 amps. This line is limited by the existing 2 1/2 inch conductor (33 miles).
2. This plan is beginning to require excessive amounts of shunt reactive in the load area. The QV curves get much flatter as shunt capacitors are added. All three major 500-kV busses serving the Puget Sound area (Raver, Snoqualmie and Monroe) are all approaching minimum reactive margin.
3. Adding series comp to the Chief Joe-Monroe line will not help the voltage stability performance of the system since the loss of this line is a critical outage for the system.
4. The old Vantage-Raver and Sickler-Raver lines could be reconductored, however this is expected to be expensive as compared to the construction of a new line. These rebuilds would save losses but would only provide reactive support for a couple of years until further reinforcement is needed.
5. SVC additions in the Puget Sound Basin could provide adequate reactive support to the system for a few more years, but they would be expensive both in terms of equipment costs and the higher transmission system losses that would result. The line overloads mentioned in (1) above would also have to be corrected.
6. The ampacity of the series capacitor banks needed for these plans are quite high to meet the 2004 load level. Extending this plan beyond 2004 would significantly increase the MVARs that are required (the MVARs are proportional to current squared).

Therefore the series capacitor additions will be sized for 2004 only. Plans 3F, 3G and 3J will be studied further to determine the ampacities required for the series capacitors. Some of the outages required by the Reliability Criteria cause very high capacitor loading.

All the series capacitors in these plans are needed for the voltage stability of the Chief Joe-Monroe and Trojan outages in EH winter. The Naneum switchyard is needed for the voltage stability of the double line outages in normal winter. However, the heaviest series capacitor loading does not occur for the critical outages for voltage stability, but it occurs during the less probable double line outages in normal winter (same corridor, bus or CB). The series caps are not necessarily needed for the voltage stability of these outages.

Two options exist to reduce the series capacitor loadings during double line outages. One is to run the CT's in the load area and the other is to bypass the overloaded series capacitors as long as the system is still voltage stable without the capacitors.

Regardless of capacitor loadings, the CT's in the load area would probably be started during winter peakload conditions if any permanent Cross Mountain line outage occurred (they are only assumed on in EH winter basecases). This could reduce the size of the new series capacitor banks. The capacitor banks have a 30 minute overload capability of 135% that can be used while the CT's are started. These studies assume that the same CT's are used as is assumed in the EH winter cases. But as it turns out, the CT's only decrease the capacitor bank loadings by about 5% as shown in the cases discussed later.

Since the new series capacitors are not necessarily needed for the voltage stability for the low probability double line outages that cause high capacitor loading, they can be bypassed after these outages occur. This would reduce the maximum loading of the capacitor banks significantly.

The reason that these caps are not needed for the voltage stability of the system for these outages is as follows. The Plan 3F system is voltage stable for the outage of the two high-capacity Naneum-Raver #3 and #4 lines which removes both capacitor banks and leaves only the two old Naneum-Raver lines in service. The performance of the system will be better for the outage of the #1 and #3 lines (a critical outage for the sizing of the capacitors) even if the remaining capacitors are bypassed since this leaves one old Naneum-Raver line and one of the circuits from the stronger double-circuit lines. The same reasoning applies to outages of the Coulee-Naneum lines.

The ampacity of the capacitors required in each of these three plans is discussed below. As it turns out, bypassing capacitors is the only measure to significantly reduce the size of the series cap banks.

PLAN 3F

Naneum switchyard and 60% comp on double circuit Naneum-Raver lines

With only two large capacitor groups added, the current rating would need to be very high; 4620 amps at Naneum and 3286 at Columbia as shown in Table 15. This Naneum cap rating would cause switchgear overloads at Raver (the 3000 amp switchgear is capable of only about 4200 amps in cold weather). The Columbia caps are only designed for uprates to 3000 amps. Use of CT's alone will not reduce these loadings below these limits (4375 amps and 3110 amps respectively). Bypassing the caps whenever they overload (for two line, voltage stable outages) will reduce the loading to below the amperage needed for single line outage during EH winter. The worst single line outage will require ratings of 4120 amps for Naneum and upgrade of the Columbia caps to 2620 amps. The 2 line outage loadings would be within the 135%, 30 minute ratings of the series capacitors to allow time for manually bypassing the caps.

PLAN 3G

Naneum switchyard, 44% comp on double circuit Naneum-Raver lines, 40% comp on Sickler-Raver line and 40% on the Vantage-Raver lines.

This plan includes the addition of 19 ohm cap banks on the double-circuit Naneum Raver lines initially with the addition of the switchyard (Phase I). In about 2001, additional banks will be needed on the Sickler-Raver and the Vantage-Raver lines, also at the Naneum Switchyard (Phase II). Since the 19 ohm banks are adequate to meet the voltage stability requirements of the system through 2001, these banks need only to be sized for the worst outage in this timeframe. The addition of the cap banks on the other two Naneum-Raver lines decreases the

maximum loading that the double-circuit banks experience. A complete table of all outages run for this analysis is included in Table 16.

With this capacitor plan, the Phase I capacitor banks need to be about 3700 amps and the Columbia banks upgraded to 3060 amps (slightly above the 3000 amp design limit). Running CT's after these outages occur will only reduce these ratings to 3500 and 2900 amps respectively. Bypassing overloaded series capacitors for voltage stable, low probability two-line outages will reduce these ratings to 3120 and 2700 amps respectively. The Phase II capacitor additions would need to be 3000 amps for the Sickler-Raver line and 2600 amps for the Vantage-Raver line for the parallel double-circuit line outage. With the Phase II additions, the Phase I Naneum bank loadings will still be within its 3120 amps limit (only 2700 amps is needed in 2004).

It would also be noted that the Phase II caps are also not needed for the loss of the parallel double circuit lines (Plan 3F is voltage stable for this outage without them). These capacitor bank sizes could be reduced to 2200 and 2000 amps respectively for the Sickler-Raver and Vantage-Raver banks by bypassing them for this outage. These ratings are determined by the loss of one of the double circuit Naneum-Raver lines during EH winter.

PLAN 3J

Naneum switchyard and 60% comp on double circuit Naneum-Raver lines in two steps, 35% and 25%.

Plan 3J utilizes two-step series capacitors that can be bypassed partially or completely during non-critical double line outages and during light load periods. A complete table of all outages run for this analysis is included in Table 17.

Phase I of this capacitor plan includes 15 ohm capacitors in the double circuit Naneum-Raver lines. These caps would be adequate until 2000 as shown in QV Curve 3Ja. Bypassing overloaded Naneum series capacitors for voltage stable, low probability two-line outages will require ratings of less than the 3120 amps needed for Plan 3G (15 ohms is used here instead of 19 ohms). For Phase II, an additional 11 ohms series comp is needed on the same Naneum-Raver lines, for a total of 26 ohms. This 11 ohm bank will need to be bypassed to keep the bank from loading beyond 3100 amp during the EH outage of a single Naneum-Raver line. At least 15 ohms is needed for voltage stability of this outage as shown in QV Curve 3Jb. The Columbia series capacitors in Phase II need to be rated for 2700 amps, which also assumes that these capacitors will be bypassed for the low probability, two-line outages in normal winter.

COMPARISON OF 3 OPTIONS

Very rough cost estimates of each of these plans were included in Table 18. These estimates assume that all facilities are installed at the same time. Plan 3J is the least expensive, followed closely by Plan 3G. The capacitors for Plan 3F would be 1324 MVARs each. Capacitors of this size, besides being expensive, have never been built. Smaller banks sizes would be much easier to design and construct.

Plan 3G requires that capacitors be bypassed for double line outages during normal winter. Plan 3J is further complicated by the factor that the caps may need to be bypassed for some outages during EH winter load conditions. This could be very confusing to the operators.

Plan 3J requires the Phase II capacitor additions one year earlier than Plan 3G. Plan 3G could be modified into a plan similar to 3J in the future by adding parallel capacitor cans to upgrade the Phase I capacitors to about 3300 amps and 18 ohms and adding an 8 ohm bank in series. Plan 3G also has a benefit to reliability of spreading the compensation among more lines.

Plans 3G is the favored Reactive Option. It fits in well with the long range plans for the area. The compensation is optimally sized for the existing system and the system with the addition of a new cross mountain transmission line. The additions are confined to one new substation. It provides the most flexibility for the Phase II capacitor additions.

Provisions should be added to upgrade all these capacitors to 4200 amps (CB limitations) to allow for possible upgrading if lines are reconductored. Before the comp levels for Phase II of these plans are finalized, reconductoring options on the Sickler-Raver and Vantage-Raver lines should be explored. This should not affect the comp level on the Coulee-Raver lines significantly. Also, as discussed later, FACTS technology should be considered for the Phase II banks.

Section 4: Local Reinforcement

LOCAL REINFORCEMENT NEEDS FOR THE REACTIVE OPTION

All reactive plans would have similar local reinforcement requirements. Plan 3F was used for study purposes in this section.

MAIN GRID TRANSFORMER NEEDS OF PUGET SOUND BASIN

Case J00EH55 shows the Monroe transformer just below the emergency rating for a Maple Valley 500/230-kV transformer outage (1506 MVA, 1512 mva limit). The Covington and Tacoma banks are also heavily loaded for this outage. Case J04EH508 shows Monroe transformer loaded 8% above emergency rating for this same outage. Additional transformation will be needed by October, 2000. The Covington-Creston 230-kV line is close to overload in these cases also. Previous studies showed another load area problem where the Monroe-Snohomish 230 kV lines overloaded for the double loss of the Chief Joe-Snohomish 345-kV lines. Therefore a new 500/230-kV transformer at Snoking is proposed to take care of these problems. This transformer addition would be accomplished by converting the existing Snoking Tap-Snoking line to 500-kV operation, tapping the existing Monroe-Snoqualmie 500-kV line. A second Maple Valley 500/230 transformer and Monroe-Snohomish 230 line #3 would also solve these problems.

THERMAL PROBLEMS BETWEEN RAVER AND SNOQUALMIE

Case J04EH515 shows the loss of the Raver-Snoqualmie line during abnormal winter. The Covington-Creston 230-KV line overloads (107%) along with the Covington (100% and 102%) and Tacoma (101%) 500/230-kV transformers. This same outage in J00EH71 shows the loading on the Covington-Creston line at 97% of its thermal rating. This line would overload in about 2002. As mentioned in the next section, there are reactive problems for this outage also.

The overloads shown in case J04EH515 are caused by the amount of power flowing into Raver. This could be decreased by bypassing the series capacitors at the

new Naneum switching station whenever this outage occurs. Case J04EH774 shows that the overloads can be deferred until 2004 if this is done. Although bypassing the caps will defer the overloads, it would also jeopardize the cross mountain transmission into the Puget Sound Basin while the caps are bypassed.

Adding series compensation in the Chief Joe-Monroe line would also help the thermal overload problems, reduce system losses and not weaken the cross mountain transmission system (as bypassing the capacitors would).

If a second Raver-Snoqualmie line is added to correct this problem, the Reliability Criteria then requires that the system withstand the loss of both Raver-Snoqualmie circuits during normal winter peak conditions. J04760 shows the outage of both Raver-Snoqualmie 500kV lines. The Covington-Creston 230-kV line overloads (103%) for this outage. The Covington-Duwamish 230-kV line and the Tacoma and Covington transformers are heavily loaded for this outage also. An additional line will need to be added about 2003, just one year later. This Reliability Criteria requirement should be reviewed for this case since these lines are so short and the probability of this outage is low. The series capacitors at Naneum could be bypassed whenever this double line outage occurred. Also, if a new cross mountain line is terminated at Snoqualmie or Monroe, the need for additional transmission between Raver and Snoqualmie for winter conditions would be reduced.

REACTIVE ANALYSIS OF THE PUGET SOUND BASIN

Comparing QV Curves 3F and 11, the Raver-Snoqualmie #2 and Maple Valley transformer #2 provide about 300 MVARs reactive support for the Chief Joe-Monroe outage. This is probably equivalent to about one year load growth.

Both Monroe and Snoqualmie have adequate reactive margin for loss of Raver-Snoqualmie in normal winter. QV Curve 12 shows 600-700 MVAR margin for both busses for this outage.

However, QV Curve-13 shows that there is a slight reactive deficit in 2004 for the loss of this line in addition to the overloads shown above. Reinforcement is also needed in this area by about 2002 to provide sufficient reactive margin for this outage. A second Raver-Snoqualmie line would obviously help this problem, but, as mentioned above, a third line between these stations would be needed soon after that to meet the Reliability Criteria for the double line outage during normal winter peak load periods.

Other options could also correct the system problems for the Raver-Snoqualmie outage. Series comp in the Chief Joe-Monroe line would correct both the thermal and the reactive problems caused by this outage by increasing the flow in the northern corridor. Additional MSC's in the Monroe/Snoqualmie area would help the reactive deficit, but not the thermal problems. Any conservation and/or local generation added north of Snoqualmie would help both the reactive and thermal problems caused by the Raver-Snoqualmie outage.

Some reinforcement is needed in 2002 to correct both the thermal problems and provide reactive margins for the Raver-Snoqualmie outage. A Raver-Snoqualmie 500-kV line #2 is proposed here but this problem will require further study at a later date.

The FY92 reactive study assumed that the PCB capacitor group at Raver would be retired when the second Monroe capacitor bank was added in 1994. QV Curve 3Ga and QV Curve 3G show that a third Raver shunt cap group is again needed between

2001 and 2004. The actual date of the cap bank is tied to the addition of Phase II caps and will need to be studied further. Naneum and Snoqualmie are also possible sites for this MSC.

Section 5: Other Items of Interest

QV PERFORMANCE OF PORTLAND BUSES FOR TROJAN SCRAM

The QV performance of the critical buses in the Portland area for the Trojan scram is shown in QV Curve 10 for reactive Plan 3F. A 312 MVAR MSC was added at Marion for these outages. The three buses tested all have at least 500 MVAR margin.

NANEUM SPLIT BUS

Development at Naneum could either be a full bus tying the 4 lines together or a split bus where one Coulee-Raver line is tied to the Sickler-Raver line and the other tied to the Vantage-Raver line. Earlier loss saving studies show that the losses of both plans are nearly identical. Case J93787 which had a split Naneum bus had essentially the same losses as J93799 which had the full Naneum bus. The QV performance is also very similar as shown in a comparison on QV-Curve 3F-Split and QV-Curve 3F (full bus). The split bus would be cheaper and it was originally thought that this arrangement would be better for conditions of summer export to California. However as shown in the analysis of this problem (below), the split bus makes some outages better, but others get worse. The summer problems with either switchyard development plan were not as bad as originally thought also. Therefore it was decided not to pursue the split bus further since the full bus provided much additional operational flexibility.

The earlier Naneum studies that assumed only the split bus should still be adequate for comparison purposes.

SUMMER STUDIES WITH NANEUM SWITCHYARD

The effect of the new Naneum Switchyard (both full and split bus) on high-export summer conditions on problems in the Vantage-Richland area was investigated. These results are summarized in Table 14. The addition of the new switchyard does not affect this area significantly.

STATION LOCATION

Although all the studies in this report assume that the location of the new switchyard in the reactive plans is at Naneum, that site is not adequate for much development due to its slope. The voltage stability performance of other sites west of the existing site were investigated. As the site moves west, the loss of both Coulee-Naneum lines becomes worse (the lines become longer) while the double Naneum-Raver outage becomes better. However, the double Naneum-Raver outage is most critical if the switchyard is at Naneum. The Coulee-Naneum line outage would not become the critical case unless the site were located more than 10 miles west of the existing Naneum site. This is shown in QV Curve 7. However, due to the terrain, no sites more than 10 miles west of Naneum were investigated.

The losses also increase as the site moves west. This is because it is beneficial to shift the power off the old Vantage-Raver and Sickler-Raver lines and onto the Coulee-Raver lines as soon as possible. Graph 8 shows the loss changes at several locations west of Naneum. The 2 best locations from a siting standpoint are 2 miles and 8 miles west. The difference in losses between these two points is about 2 MW. These studies assumed new 26 ohm cap banks on the Coulee-Raver lines. They also included a new large generator at Ashe (1200 MW) which would tend to inflate these loss savings somewhat.

OVERVOLTAGES ON CAPS ON OLD NANEUM-RAVER LINES

When adding series compensation on the old Naneum-Raver lines an interesting phenomenon was noted. If the comp level was above 40%, the voltages on the west capacitor terminal would rise during the parallel double circuit outage, even as the system voltage dropped while the QV-curve was defined. The higher the comp level, the higher the overvoltages (in the 560-kV range). The voltage at these terminals would not start to drop until the reactive limits were reached at Coulee, which usually signifies the total collapse of the transmission system. This phenomenon is probably due to the low impedance of this point with respect to its source and the phase angle of the power that is going through the series capacitors. The final comp level on these lines is slightly lower than these problem levels so it is not anticipated that this phenomenon will cause any problems.

MOVING SERIES CAPS TO RAVER

Case J04787QV was run to show the affect of moving the new series caps on the old Naneum-Raver lines to the Raver end of those lines. Very high overvoltages resulted on the capacitor terminals at Raver (around 600-kV) for the double circuit Naneum-Raver line outage. The cause of these high voltages is apparently the reactive current from the shunt capacitors at Raver flowing into the remaining Naneum-Raver lines through the series compensation. Raver is not a viable location for the series capacitors because of the shunt compensation there.

FACTS TECHNOLOGY

Phase II series capacitor additions would probably be good candidates for FACTS (Flexible AC Transmission System) technology. Since these are lossy lines, it would be desirable to bypass all or most of these capacitors normally for loss savings. The optimum amount of compensation would increase as loads grow. Although some compensation is needed for various outages, overvoltages and high currents somewhat limit the total ohms that can be put into service. By the time these banks are needed (around 2000), FACTS technology may be mature enough for possible implementation.

Section 6: Recommended Plan

Plan 3G is the preferred reactive option. It has favorable loss savings, cost and flexibility. The plan consists of:

PHASE I

- 1) Naneum switchyard
- 2) 19 ohm, 3150 amp series cap banks on both Coulee-Raver lines west of Naneum

PHASE II (around 2001)

- 3) 20 ohm, 2200 amp series cap bank on Sickler-Raver line west of Naneum
- 4) 23 ohm, 2000 amp series cap bank on Vantage-Raver line west of Naneum
- 5) upgrade Columbia series caps to 2700 amps (reduces ohms from 21 to 19)
- 6) third 500-kV shunt capacitor group in the vicinity of Raver

Local Reinforcement requirements

- 7) Snoking 500/230-kV transformer (2001)
- 8) Raver-Snoqualmie 500-kV #2 line or Chief Joe-Monroe series comp (2002)

XX
 TABLE 1: LOSS SAVINGS AND PERFORMANCE OF REACTIVE OPTIONS
 XX

	DESCRIPTION	BPA LOSSES	PNW LOSSES	CASE #	REACTIVE MARGINS 2-L/1-L/TROJAN INCL UNUSED MSC
	BASE	755	1148	J04706	
	RAVER-SNOQ #2, MV TX #2	745	1135	J04705	
PLAN 1	CJ-MON/SNOQ - STEVENS PASS	669	1040	J04662	1100/900/900
PLAN 3	REACTIVE - FIXED PLUS SWITCHED SERIES CAPS AND SVC'S 25+25%(CJ-M), 35+35%(N-R), 20%(C-R)	736	1117	J04660	900/1100/1400
PLAN 3A	REACTIVE - FIXED PLUS SWITCHED SERIES CAPS 25+25%(CJ-M), 35+35%(N-R), 20%(C-R)	736	1117	J04660	500/500/700
PLAN 3B	SERIES CAPS PLUS SVC	736	1117	J04660	700/900/1100
PLAN 3C	SERIES CAPS 35%(CJ-M), 60%(N-R), 20%(C-R)	734	1112	J04714	300/600/700
PLAN 3D	NANEUM SERIES PLUS CAPS 35%(CJ-M), 60%(C-R)	737	1117	J04723	700/400/700
PLAN 3E	NANEUM SERIES PLUS CAPS 35%(CJ-M), 60%(C-R), NANEUM MSC	737	1117	J04723	700+/700/900
PLAN 3F	NANEUM PLUS SERIES CAPS 60%(C-R)	741	1124	J04767	500/450/500
PLANS 3C&1	REACTIVE AND CJ-MON/SNOQ	666	1031		
PLAN 3G	NANEUM PLUS SERIES CAPS 44%(C-R), 40%(S-R), 40%(V-R)	737	1121	J04905	700/400/550
PLAN 3Ga	NANEUM PLUS SERIES CAPS 44%(C-R) - Phase 1 only	739	1125	J04910	
PLAN 3H	NANEUM PLUS SERIES CAPS 44%(C-R), 30%(S-R), 39%(V-R)	739	1123	J04829	650/350/450
PLAN 3J	NANEUM PLUS SERIES CAPS 35+25%(C-R)	741	1128	J04960	500+/400/500+ (15 ohms)
PLAN 3K	NANEUM PLUS SERIES CAPS 44+16%(C-R)	739	1125	J04910	500+/450/500+ (19 ohms)

NOTE:

The addition of the Raver-Snoqualmie #2 and the Maple Valley transformer #2 account for about half the loss savings of the reactive plans.

XX
 TABLE 2: IMPEDANCES OF 500-KV CROSS MOUNTAIN TRANSMISSION
 XX

Line	ohms impedance		
Coulee-Naneum-Raver	$51.64 + 43.04 = 94.68$ ohms		
Columbia series caps	originally	30%	28.4 ohms
	with upgrade	22.5%	21 ohms
Sickler-Naneum-Raver*	$21.93 + 51.38 = 73.31$ ohms		
Vantage-Naneum-Raver*	$24.39 + 59.55 = 83.94$ ohms		
Chief Joe-Monroe	72.14 ohms		

* If these lines are compensated in any of the plans, the percentage comp is based on the Naneum-Raver sections only

PRE-PSAERP SYSTEM
 (EXISTING SYSTEM
 PLUS ECHO LAKE SUB.)

500-KV —————
 345-KV - - - - -

QV-Curve - 3

SVC's @ K, MV, Snoh, Cov, Ostr.
Switched series caps

PLAN 3

J04661:DOUBLE COULEE-RAVER 500 OUT (J04660)

MSC AT SNOQ (1)

J04EH420:CHIEF JO-MONROE 500 OUT (J04EH418)

NO MSC ADDED

J04EH421:TROJAN SCRAM(J04EH419) NO MSC ADDED

MSC avail.

Raw (1), Mon(1), day(1)

oly (1)

oly (1)

○ J04661
+ J04EH421

△ J04EH420

29-MAR-1991

J04661QV.SETUP

QU Curve-3A

SVC's @ Keeber & MV
switched series caps

MSC avail

PLAN 3A

o J04666: DOUBLE COULEE-RAVER 500 OUT (J04660)

MSC AT SNOO (1), MSC AT MON (1)

Δ J04EH436: CHIEF JO-MONROE 500 OUT (J04EH418)

MSC AT OLYMPIA (1)

+ J04EH437: TROJAN SCRAM (J04EH419) MSC AT MARION (1)

Rav(1), oly(1)
none.

oly(1)

o J04666
+ J04EH437

Δ J04EH436

QV Curve - 3C

ALL SERIES REACTIVE PLAN - FIXED
50% C-R COMP, 35% CJ-M COMP, 60% N-R COMP
O J04715: DOUBLE COULEE-RAVER OUTAGE, MSC
AT SNOQ(1), MON(1), OLY: (J04714)
Δ J04EH442: CJ-MONROE OUT (J04EH440) NO MSC
+ J04EH444: TROJAN SCRAM (J04EH441) NO MSC

Plan 3C

O J04715QV
+ J04EH444QV

Δ J04EH442QV

25-APR-1991
PLAN3SER.SETUP

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD

50% C-R COMP, 35% CJ-M COMP, SPLIT NANEUM BUSSES
 J04724: 2 COUL-NAN OUT, MSC @SNOQ,MON,OLY(J04723)
 J04725: 2 NAN-RAV OUT, MSC @SNOQ,MON,OLY(J04723)
 J04EH451: CJ-MONROE OUT (J04EH449) MSC @ OLY
 J04EH452: TROJAN SCRAM (J04EH450) MSC @ OLY

○ J04724QV
 × J04EH452QV

△ J04725QV

+ J04EH451QV

QU Curve - 3E

PLAN 3E

FIXED SERIES REACTIVE PLAN WITH NANEUM SWYD & CAPS
50% C-R COMP, 35% CJ-M COMP, SPLIT NANEUM BUSSES
200 MVAR ON EACH NANEUM BUS
○ J04EH457: CJ-MONROE OUT (J04EH447) MSC @ OLY
△ J04EH458: TROJAN SCRAM (J04EH448) MSC @ OLY

2-MAY-1991
PLAN3NANEUMCAPS.SETUP

AV Curve 3F

PLAN 3F VOLTAGE SUPPORT 2
 ADDITIONAL 27.5% SERIES COMP ON COULEE-RAVER
 LINES AT NEW NANEUM SWITCHYARD - ALL MSC USED
 J04768:NAN-RAV OUT, MSC @ SNQ, MON, OLY, RAV (J04767)
 J04EH526:CJ-MONROE OUT, MSC @ OLY, RAV (J04EH524)
 J04EH527:TROJAN SCRAM, MSC @ OLY, MARION (J04EH525)

○ J04768QV
 + J04EH527QV

△ J04EH526QV

23-JUL-1991
 PLAN3M.SETUP

QU Curve - 3F - Split

PLAN 3F - Split

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD

50% C-R COMP, SPLIT NANEUM BUSSES

J04732: 2 NAM-RAV OUT, MSC @ SNOQ, MON, OLY (J04731) MSC RAV

J04EH464: CJ-MONROE OUT, MSC @ OLY (J04EH462) MSC RAV

J04EH468: TROJAN SCRAM MSC @ OLY & MARION (J04EH463)

○ J04732QV
+ J04EH468QV

△ J04EH464QV

8-MAY-1991
PLAN3NANEUM.SETUP

QV Curve 3Ga

REACTIVE PLAN 3.2:NANEUM SWYD.42% COMP ON COUL-RAV

○ J00145:NAN-RAV 3&4 OUT, MSC @SNOQ, MON(J00144) } OLY Avail.
 ▲ J00146:GC-NAN 1&2 OUT, MSC @SNOQ, MON(J00144) }

+ J00EH69:CJ-MON, MSC @MON, OLY(J00EH67)
 J00EH70:TROJAN SCRAM, MSC @ OLY (J00EH68)

○ J00145QV
 x J00EH70QV

▲ J00146QV

+ J00EH69QV

26-AUG-1991
 J00145QV.SETUP

QV Curve 3G

PLAN 3: NANEUM SWYD, SERIES COMP ALL NAN-RAV LINES

42% ON COULEE-RAVER, 40% ON OLD NANEUM-RAVER LINES

○ J04906: NAN-RAV 3&4 OUT, MSC 00L, SNQ, MON, RAV(J04905)

△ J04907: GC-NAN 1&2 OUT, MSC 00L, SNQ, MON, RAV(J04905)

+ J04EH637: CJ-MON, MSC 0 OLY (J04EH635)

x J04EH638: TROJAN SCRAM, MSC 0 OLY, MARION (J04EH636)

ALL
MSC'S
USED

○ J04906QV

△ J04907QV

+ J04EH637QV

x J04EH638QV

26-SEP-1991

J04PLAN3-3.SETUP

QV Curve 3H

ALL MSC'S
USED

PLAN 3H:NANEUM SWYD

20% ON COULE-RAV, 30% ON SICK-RAV, 39% ON VANT-RAV
 O J04826:NAN-RAV 3&4 OUT, MSC 00L, SNQ, MON, RAV(J04825)
 Δ J04827:GC-NAN 1&2 OUT, MSC 00L, SNQ, MON, RAV(J04825)
 + J04EH579:CJ-MON, MSC 0 OLY (J04EH577) MSC RAV
 x J04EH580:TROJAN SCRAM, MSC 0 OLY, MARION (J04EH578) MSC RAV

22-AUG-1991

J04PLAN3-4.SETUP

QV Curve 3J

PLAN 3J: NANEUM SWYD, 11+15 OHM COMP ON COUL-RAV

ALL MSC'S USED

○ J04961:GC-NAN 1&2 OUT, 15 OHMS IN NAN-RAV (J04960)

△ J04967:GC-NAN 1&2 OUT, 11 OHMS IN NAN-RAV (J04960)

+ J04968:NAN-RAV 1&3 OUT, 0 OHMS IN NAN-RAV (J04960)

x J04EH526:CJ-MON, 26 OHMS IN NAN-RAV (J04EH624)

○ J04961QV

△ J04967QV

+ J04968QV

x J04EH526QV

3-OCT-1991

J04PLAN3J.SETUP

QV Curve 3Ja

REACTIVE PLAN 3J:NANEUM SWYD & 15 OHMS ON COUL-RAV

○ J00145:NAN-RAV 3&4 OUT, MSC @SNOQ, MON(J00144)

△ J00EH72:CJ-MON, MSC @MON, OLY (J00EH67)

+ J00EH73:TROJAN SCRAM, MSC @ OLY (J00EH68)

○ J00145QV
+ J00EH73QV

△ J00EH72QV

4-OCT-1991
j00plan3J.SETUP

QV Curve 3Jb

PLAN 3J: NANEUM SWYD, SWITCHABLE COMP ON COUL-RAV

BASED ON J04EH524, ALL MSC'S USED

J04EH526:CHIEF JO-MONROE OUT, 26 OHMS IN NAN-RAV

J04EH682:NANEUM-RAVER OUT, 7 OHMS IN NAN-RAV

J04EH683:NANEUM-RAVER OUT, 0 OHMS IN NAN-RAV

J04EH639:NANEUM-RAVER OUT, 15 OHMS IN NAN-RAV

○ J04EH682QV

△ J04EH683QV

+ J04EH526QV

x J04EH639QV

18-OCT-1991

J04PLAN3JSH.SETUP

QV Curve 4

WORST DOUBLE LINE OUTAGE - ALL MSC'S USED

○ J97133QV NO ADDITIONS, 2COUL-RAV OUT (J9782)
△ J97131: SICKLER-COL, 2COUL-COL OUT (J97130)
+ J97132: SICKLER-COL, 2RAVER-COL OUT (J97130)
× J97135: NANEUM SY, 2COUL-NANEUM OUT (J97134)
◇ J97161: NANEUM SY, 2NANEUM-RAVER OUT (J97134)

26-APR-1991

J97TRANS.SETUP

Graph 5
Loss Savings vs. Coulee-Raver comp level
with Naneum Switchyard

Graph 6
Loss Savings vs. Coulee-Raver comp level
with Naneum SWYD and CJ-Snoh 345 rebuild

QV Curve-7

EFFECT OF MOVING NEW STATION WEST OF NANEUM

J04767: NEW STATION AT NANEUM

J04791: NEW STATION AT KITTITAS, 10 MILES WEST

○ J04792QV: GC-KITT 1&2 OUT, MSC @ SNQ, MON, OLY (J04791)

△ J04793QV: GC-NAN 1&2 OUT, MSC @ SNQ, MON, OLY (J04767)

+ J04768QV: NAN-RAV OUT, MSC @ SNQ, MON, OLY, RAV (J04767)

○ J04792QV
+ J04768QV

△ J04793QV

15-AUG-1991
KITTMOVE.SETUP

GRAPH-8

22 141 50 SHEETS
22 142 100 SHEETS
22 143 100 SHEETS

BPA Losses (MW)

CHANGE IN SYSTEM
LOSSES AS NEW
STATION IS MOVED
WEST OF NINE IN

Miles to west

Miles to west

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
TABLE 9: OTHER REACTIVE PLANS STUDIED
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

These reactive plans were also studied but for various reasons were eliminated from further study. QV Curves are attached for each. Performance and losses are also summarized in Table 1.

REACTIVE PLAN 3A

This plan is the same as Plan 3 except that the SVC's at Covington and Snohomish are eliminated. Even without these 2 SVC's, the system performance is still acceptable through 2004. Refer to QV-Curve 3A. There are also overvoltage problems with 50% comp on Chief Joe-Monroe line; therefore the two 25% comp groups would need to be separated.

REACTIVE PLAN 3B

This plan is the same as Plan 3 except that the switched series caps are eliminated. This plan would probably work through 2005 as shown in QV-Curve 3B. It has slightly better margins than Plan 3A. There are no overvoltage problems on the Chief Joe-Monroe line since there are no switched capacitors.

REACTIVE PLAN 3D

This plan consists of:

- A. Naneum switchyard (2-4 CB rings or full development of 12 CB's),
- B. 35% comp on Chief Jo-Monroe and
- C. 60% comp (26 ohms) on Naneum-Raver #3 and #4 (double circuit line)

With the addition of a Naneum Switchyard, the Chief Jo-Monroe outage becomes the critical outage. This plan will meet the 500 MVAR margin through 2003 as shown in QV-Curve 3D.

The transmission losses for this plan are slightly higher than the above plans (see Table 1), however the series comp levels have not yet been optimized with a Naneum switchyard in place. The same comp levels as Plan 3C were assumed. As will be shown later, the series capacitors at Naneum load very heavily during outages. An advantage to this plan is that the Chief Joe-Monroe comp would help reduce the loading of the series capacitors at Naneum during multiple outages. Cases J04916 (25% comp) and J04917 (35%) were run to test this concept against case J04910 (no comp) which depicts one of the worst outages for capacitor loading. The 25% comp addition reduces the loading on the Naneum capacitors by only 5%, while the 35% comp reduced it 8%. This 35% comp station would need to be at least 2600 amps. This ampacity reduction benefit is not significant enough to warrant the addition of a new capacitor bank on the Chief Joe-Monroe line. Compensation levels above 35% would need to be added in this line to be effective and line overvoltages would surely result.

XXX
TABLE 9: OTHER REACTIVE PLANS STUDIED CONT.
XXX

REACTIVE PLAN 3E

This plan is the same as Plan 3D except that two 200 MVAR shunt capacitor banks were added at Naneum (split bus) for additional voltage support. Larger banks caused overvoltages.

This plan would have the required margins through 2004 as shown in QV-Curve 3E. The loss saving of this plan is also slightly less than the above plans (Table 1), however the series comp levels have not been optimized with a Naneum switchyard in place.

REACTIVE PLAN 3H

This plan is similar to Plan 3G. With 40% comp added on each of the Sickler-Raver and Vantage-Raver lines, the loading for the double Naneum-Raver outage is not equal as shown in J04824 for the outage of the double circuit Naneum-Raver lines. In fact the Sickler-Raver line is at its thermal capacity while the Vantage-Raver line is well below. This contingency appears to be the limiting outage for Plan 3G. These two lines can be more equally loaded by reducing the Sickler-Raver comp to 30% (15.4 ohms). The corresponding outage for this condition is shown in J04828. The outage performance of this plan is slightly degraded by this lower comp level.

REACTIVE PLAN 3K

This plan is very similar to Plan 3J except that the capacitor bank step sizes would be 19 and 7 ohms. The 19 ohm bank size is slightly better than 15 ohms for loss savings. The 19 and 7 ohm sizes gives a wider range of cap bank sizes than the 15 and 11 ohm plan. The 19 ohm step size also provides better reactive margins for the loss of the parallel circuit in the EH winter. But it will also require larger cap bank sizes as was shown in the analysis for Plan 3J.

QV-10
Plan 3F

Portland Reactive
Requirements

TROJAN SCRAM
BASED ON J04EH493
○ J04EH516: MSC POLY & MARION, HOLD ALLSTON
△ J04EH517: MSC POLY & MARION, HOLD OSTRANDER
+ J04EH518: MSC POLY, HOLD MARION

1-JUL-1991
J04EH516QV.SETUP

QV Curve 11

w/o Raver-Snoy #2
and MV Tx #2

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD

○ J04753: NAN-RAV OUT, MSC @ SNQ, MON, OLY (J04752)
△ J04EH506: CJ-MONROE OUT, MSC @ OLY (J04EH504)
+ J04EH507: TROJAN SCRAM, MSC @ OLY, MARION (J04EH505)

○ J04753QV
+ J04EH507QV

△ J04EH506QV

26-JUN-1991

plan3naneum.SETUP

QV-Curve 12

PLAN 3 - LOSS OF RAVER-SNOQUALMIE LINE
RAVER-SNOQUALMIE OUT - BASE J04741

○ J04750: MONROE BUS, MSC @SNOQ, MON, OLY, RAV
△ J04751: SNOQUALMIE BUS, MSC @SNOQ, MON, OLY, RAV

20-AUG-1991

PLAN3RAVSNOQ.SETUP

QV Curve 13

FIXED SERIES REACTIVE PLAN WITH NANEUM SWITCHYARD
 LOSS OF RAVER-SNOQUALMIE 500: BASED ON J04EH491
 MSC AT OLYMPIA AND RAVER
 J04EH511:SNOQUALMIE CHARACTERISTICS
 J04EH512:MONROE CHARACTERISTICS

22-OCT-1991

plan3snoqnon.SETUP

XX
 TABLE 14: NANEUM SUMMER STUDIES OF RICHLAND/VANTAGE PROBLEMS
 XXX

The effect of adding a new Naneum switchyard (both full bus and split) was investigated for summer problems with heavy export to SW. The following is a summary of these studies. The base case used for these studies contained some very pessimistic assumptions which resulted in loadings that would be heavier than should actually occur. However, the data can be used as a comparison to show the differences between the system configurations. None of the changes in loading were felt to be significant. The Vantage-Hanford overload for the Coulee-Hanford outage is probably the most significant with a 3.6% increase with the addition of a full bus.

NANEUM SUMMER STUDY ASSUMPTIONS

1. Coulee gen increased from 5400 to 6000
2. Chief Jo gen increased from 2100 to 2380
3. Lower Snake decreased from 650 to 500 each
4. BCH intertie increased from 1200 to 2200
5. Wanapum left at 840
6. Rocky Reach gen increased from 1100 to 1250
7. Boardman and Ashe gen removed
8. PNW/PSW interties left at 4900 scheduled/3900 actual and 2734 DC
9. Trojan and Centralia on
10. WWP/BCH intertie removed
11. Run from Budget basecases

OUTAGE	HEAVILY LOADED LINES	RATING*	CASE # AND LOADING		
			EXISTING	SPLIT BUS	FULL BUS
Base: No outage			A96179	A96180	A96181
	Rocky Rh-Columbia	1200	748	815	752
	Coulee-Potholes	900	559	553	536
Coulee-Hanford			A96182	A96186	A96190
	Coulee-Potholes	900	752	714	685
	Naneum-Vantage	2590	1827	1892	2129
	Vantage-Hanford	2900 (80)	3130	3154	3243 XX
	Columbia-Vantage	950	884	907	808
	Douglas-Rocky Rh	2120	452	1116	545
Vantage-Hanford	Rocky RH-Columbia	1200	874	972	883
			A96183	A96187	A96191
	Coulee-Potholes	900	466	484	476
	Coulee-Hanford	3420	2890	2884	2878
2 Coulee-Raver or 2 Coulee-Naneum	Midway-Grandview T	1200	1146	1125	1133
			A96185	A96189	A96193
	Coulee-Hanford	3420	2895	2998	2899
	Sickler-Naneum	2900	2242	2292	2587
	Coulee-Potholes	900	727	753	729
	Naneum-Vantage	2590	520		

* Includes planned uprates

XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
TABLE 14: NANEUM SUMMER STUDIES CONT
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

OUTAGE	HEAVILY LOADED LINES	RATING*	CASE # AND LOADING		
			EXISTING	SPLIT BUS	FULL BUS
2 Naneum-Raver			A96185	A96194	A96195
	Naneum-Vantage	2590	520	1111	1452
Stevens-Thayer			A96184	A96188	A96192
	Horn R-HRT	330	440	440	440
Naneum-Sickler			A96196	A96200	A96204
	Rocky RH-Mckenzie	1190	1251	1186	1179
	Rocky RH-Columbia	1200(80)	1105	1040	1033
	Coulee-Potholes	900	612	555	551
	Columbia-Vantage	950	890	780	767
	Hanna-Eastmt	260	260	255	253
Midway-Wanapum			A96197	A96201	A96205
	Coulee-Potholes	900	586	580	564
Mckenzie-Rocky R			A96198	A96202	A96206
	Rocky RH-Columbia	1200	1126	1226	1139 XX
	Hanna-Eastmt	260	258	286	262
Douglas-Rocky Rh			A96199	A96203	A96207
	Hanna-Eastmt	260	223	300	235 XX

Vantage-Midway-Outlook loadings decrease with Naneum development (base)

Slatt-John Day loading increases only slightly with Naneum development (base)

XXX
 TABLE 15: SUMMARY OF OUTAGES RUN FOR PLAN 3F
 XXX

WORST SINGLE LINE OUTAGE IN EH WINTER:

Outage	Case #	Naneum cap loading	Columbia cap loading
Parallel 500 line	J04EH510 J04EH509	4121 amps	2616 amps

WORST DOUBLE LINE OUTAGE DURING NORMAL WINTER

Outage	Case #	Naneum cap loading	Naneum cap loadg w CT	Columbia cap loading	Columb cap loadg w CT
Vantage-Naneum and Coulee-Naneum #1 or #2	J04757			3286 amps*	3110 A est.*
Naneum-Raver #1 and Naneum-Raver #3 or #4	J04755	4620 amps**	4375 A est**		

* Exceeds maximum upgrade capability of existing Columbia series capacitor banks (3000 amps).

** Exceeds Switchgear limitations of existing equipment at Raver.

Load reductions due to the CT's is estimated from actual cases run in Table 16 and 17. Loading is reduced by about 5% when CT's were run. The same CT's were run here as in the EH winter cases.

XX
 TABLE 16: SUMMARY OF OUTAGES RUN FOR PLAN 3G
 XX

WORST SINGLE LINE OUTAGE IN EH WINTER, PHASE I:

Parallel 500 line	J00EH65	3073 amps	
	J00EH66		2495 amps
	J04EH560	3233 amps	
	J04EH561		2594 amps
Estimated J01 loading		3113 amps	2520 amps

WORST DOUBLE LINE OUTAGE DURING NORMAL WINTER, PHASE I:

Outage	Case #	Naneum loading	Naneum loading with CT	Columbia loading	Columbia loading with CT
Vantage-Naneum and	J00149			2995 amps	
Coulee-Naneum #1 or #2	J04913			3242 amps	
	J04919				3076 amps
Estimated J01 loading				3057 amps	2900 amps
Naneum-Raver #1 and	J00150	3611 amps			
Naneum-Raver #3 or #4	J00152		3418 amps		
	J04914	3942 amps			
	J04918		3735 amps		
Estimated J01 loading		3694 amps	3497 amps		
Naneum-Raver #1 and #2	J00147	2770 amps			
	J04911	3023 amps			
Sickler-Naneum and	J00148			3041 amps	
Coulee-Naneum #1 or #2	J04912			3197 amps	
Naneum-Raver #2 and	J00151	3492 amps			
Naneum-Raver #3 or #4	J04915	3812 amps			
Phase II caps: 20 ohms on Sickler-Raver line					
23 ohms on Vantage-Raver line					

WORST SINGLE LINE OUTAGE IN EH WINTER, PHASE II:

Outage	Case #	Naneum cap loading	Columbia cap loading	S-R caps	V-R caps
Parallel 500 line	J04EH563	2706 amps		2110 amps	1816 amps
	J04EH562		2704 amps		

xxx
 TABLE 16: SUMMARY OF OUTAGES RUN FOR PLAN 3G cont.
 xxx

DOUBLE CIRCUIT LINE OUTAGES DURING NORMAL WINTER, PHASE II:

Outage	Case #	Sickler-Raver cap loading	Vantage-Raver cap loading
Naneum-Raver #3 and #4 double circuit	J04824	2999 amps	2581 amps

Outage	Case #	Naneum cap loading	Columbia cap loading	S-R caps loading	V-R caps loading
Vantage-Naneum and Coulee-Naneum #1 or #2	J04814 J04919 w CT		3294 amps 3076 amps		
Naneum-Raver #1 and Naneum-Raver #3 or #4	J04815	3457 amps			2322 amps
Naneum-Raver #1 and #2	J04909	3023 amps			
Sickler-Naneum and Coulee-Naneum #1 or #2	J04813		3283 amps		
Naneum-Raver #2 and Naneum-Raver #3 or #4	J04816	3295 amps		2574 amps	

Series caps are not needed for voltage stability of the double line outages on this page.

XXX
 TABLE 17: SUMMARY OF OUTAGES RUN FOR PLAN 3J
 XXX

Phase I: 15 ohms in Naneum-Raver double circuit
 Phase II: 15 + 11 ohms in Naneum-Raver double circuit

SINGLE LINE OUTAGE IN EH WINTER: PHASE I CAPS

These outages are similar to Plan 3G in Table 16.
 Caps will need to be bypassed for most 2 line outages

DOUBLE LINE OUTAGE DURING NORMAL WINTER: PHASE I CAPS

These outages are similar to Plan 3G in Table 16.
 Caps will need to be bypassed for most 2 line outages

SINGLE LINE OUTAGE IN EH WINTER: PHASE II CAPS

Outage	Case #	Comp Level	Naneum cap loading	Columbia cap loading
Parallel 500 line	J04EH640	26 ohms	4039 amps	
	J04EH641	26 ohms		2700 amps
	J04EH639	15 ohms	3071 amps*	
		19 ohms	3425 amps est.	
Chief Joe-Monroe	J04EH526	26 ohms	3041 amps	

DOUBLE LINE OUTAGE DURING NORMAL WINTER: PHASE II CAPS

Outage	Case #	Comp Level	Naneum cap loading	Columbia cap loading
Vantage-Naneum and Coulee-Naneum #1 or #2	J04963	15 ohms		3207 amps
	J04965	11 ohms		3175 amps
	J04969	15 ohms + CT		3043 amps
Naneum-Raver #1 and Naneum-Raver #3 or #4	J04962	15 ohms	3661 amps	
	J04964	11 ohms	3410 amps	
	J04966	11 ohms + CT	3228 amps	

* A minimum of 15 ohms is needed to meet voltage stability margins for the outage of one Naneum-Raver compensated line during EH winter.

INTERTIE SCHEDULE

AC= -04. AC= -435.
DC= -1710. DC= -1710.

LOSSES

BPA= 944.13
PNW= 1361.51
SYSTEM= 4043.71

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1310.
AI= 1012.

IDAHO TO PNW
SI= 630.
AI= 577.

500BUSNORTHWEST

J00EH66 8/14/91 PF V6012
CY89 ALH MJL
BASED ON J00EH004
COULEE-NANEUM #1 OUT

INTERTIE SCHEDULE

AC= 0.
DC= 832.

ACTUAL

AC= -284.
DC= 832.

LOSSES

BPA= 734.50
PNW= 1095.82
SYSTEM= 3644.71

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 982.

IDAHO TO PNW
SI= 700.
AI= 684.

500BUSNORTHWEST

J00147 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J00144
NANEUM - RAVER 1&2 500KV LINES OUT

500BUSNORTHWEST

INTERVIEW SCHEDULE

AC= 0. AC= -284.
DC= 832. DC= 832.

LOSSES

```

BPA= 762.59
PNW= 1130.77
SYSTEM= 3684.51

```

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MON7 TO PNW
SI= 1250.
AI= 995.

IDAHO TO PNW
SI= 700.
AI- 681.

J00149 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J00144
VANTAGE - NANEUM 500KV LINE OUT
COULEE - NANEUM 1 500KV LINE OUT

INTERTIE SCHEDULE

AC= -730.
DC= -1710.

ACTUAL

AC= -952.
DC= -1710.

LOSSES

BPA= 1041.99
PNW= 1504.42
SYSTEM= 4345.77

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1023.

IDAHO TO PNW
SI= 480.
AI= 535.

500BUSNORTHWEST

J04EH526 10/ 3/91 PF V6012
CY89 MJL
BASED ON J04EH524
CHIEF JOE MONROE OUT

26 n on Nam... 3 -

INTERIE SCHEDULE

AC= -730.
DC= -1710.

ACTUAL

AC= -950.
DC= -1710.

LOSSES

BPA= 1028.14
PNW= 1484.83
SYSTEM= 4324.99

CANADA TO PNW

(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW

SI= 1300.
AI= 1014.

IDAHO TO PNW

SI= 480.
AI= 540.

500BUSNORTHWEST

J04EH563 10/ 1791 PF V6010
CY89 ALH-MJL
BASED ON J04EH542
NANEUM - RAVER 3 500KV LINE OUT

500BUSNORTHWEST

INTERIE SCHEDULE	ACTUAL	LOSSES
AC= -730.	AC= -953.	BPA= 1024.49
DC= -1710.	DC= -1710.	PNW= 1485.30
		SYSTEM= 4324.90

CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WKOOT)	SI= 1300.	SI= 480.
SI= 450.	AI= 1022.	AI= 535.
AI= 450.		

J04EH039 10/ 3/91 PF V6012
 CY80 MJL
 BASED ON J04EH524
 NANEUM-RAVEN #3 OUT
 15 OIMS COMP IN OTHER NANEUM-RAVEN LINE

WFO R , PLOTTED 3 OCT 91 AT 11:18:48 HOUR

PEPLOT PEP334 REVISED 10/11/90

500BUSNORTHWEST

INTERTIE SCHEDULE

AC= -730.
DC= -1710.

ACTUAL

AC= -951.
DC= -1710.

LOSSES

BPA= 1026.00
PNW= 1480.20
SYSTEM= 4317.75

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1300.
AI= 1027.

IDAHO TO PNW
SI= 480.
AI= 533.

J04EH640 10/ 3/91 PF V6012
CY89 MJL
BASED ON J04EH524
NANEUM-RAVER #3 OUT
26 OHMS COMP IN OTHER NANEUM-RAVER LINE

INTERTIE SCHEDULE		ACTUAL		LOSSES	
AC= -730.		AC= -952.		BPA= 1012.15	
DC= -1710.		DC= -1710.		PNW= 1465.17	
				SYSTEM= 4302.49	
CANADA TO PNW		MONT TO PNW		IDAHO TO PNW	
(BCH & WKOOT)		SI= 1300.		SI= 480.	
SI= 450.		AI= 1021.		AI= 536.	
AI= 450.					

J04EH641 10/ 3/91 PF V6012
 CY89 MJL
 BASED ON J04EH524
 COULEE-NANEUM #1 OUT
 26 OHMS COMP IN NANEUM-RAVER LINES

INTERTIE SCHEDULE

AC= 0. AC= -285.
DC= 557. DC= 557.

LOSSES

BPA= 803.12
PNW= 1203.79
SYSTEM= 3938.20

CANADA TO PNW

(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW

SI= 1250.
AI= 980.

IDAHO TO PNW

SI= 700.
AI= 684.

500BUSNORTHWEST

J04757 6/27/91 PF V6012
CY89 ALH-MJL
BASED ON J04741
SICKLER-NANEUM AND COULEE-NANEUM OUT

Full Bus

INTERVIEW SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -295.	BPA= 810.49
DC= 557.	DC= 557.	PNW= 1216.94
		SYSTEM= 3957.48

CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WK001)	SI= 1250.	SI= 700.
SI= 450.	AI= 958.	AI= 696.
AI= 450.		

500BUSNORTHWEST

J04813 10/ 2/91 PF V6012
 CY89 ALH-MJL
 BASED ON J04788
 SICKLER-NANEUM OUT
 COULEE-NANEUM #1 OUT

INTERIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -292.	BPA= 811.06
DC= 557.	DC= 557.	PNW= 1208.79
		SYSTEM= 3948.87

CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WKO01)	SI= 1250.	SI= 700.
SI= 450.	AI= 966.	AI= 692.
AI= 450.		

500BUSNORTHWEST
 J04016 10/ 2/91 PF V6012
 CY89 ALH-MJL
 BASED ON J04788
 NANEUM-RAVER #2 AND #3 OUT

S:PD R , PLOTTED 2 OCT 01 AT 14:12:40 HOURS

PFLOT PFP334 I REVISED 10/11/80

INTERTIE SCHEDULE

AC= 0.
DC= 557.

ACTUAL

AC= -294.
DC= 557.

LOSSES

BPA= 854.31
PNW= 1250.02
SYSTEM= 3997.45

CANADA TO PNW
(DCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 964.

IDAHO TO PNW
SI= 700.
AI= 692.

500BUSNORTHWEST

J04824 10/ 1/91 PF V6010
CY89 MJL
BASED ON J04780
NANEUM - RAVEN 3&4 500KV LINES OUT

INTERIM SCHEDULE	ACTUAL	LOSSES
AC 0.	AC 295.	BPA 867.41
DC 557.	DC 557.	PNW 1273.53
		SYSTEM 4019.89

CANADA TO PNW	MONI TO PNW	IDAHO TO PNW
(BCH & BK001)	SI 1250.	SI 700.
SI 450.	AI 962.	AI 692.
AI 450.		

GEORGE NORTHWEST
 1000.0 0.0000 11 06.010
 129 ALH HLI
 BASED ON J04825
 NANEUM - RAVEN 364 OUT

5:50 P M, PLOTTED 26 AUG 61 AT 15:10:30 HOURS

PIELOT PFP334 : REVISED 10/11/60

INTERFIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -292.	BPA= 859.25
DC= 557.	DC= 557.	PNW= 1264.47
		SYSTEM= 4009.09

CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WK001)	SI= 1250.	SI= 700.
ST= 450.	AI= 969.	AI= 689.
AL= 450.		

500BUSNORTHWEST
 J04908 8/26/91 PF V6010
 CY89 ALH-MJL
 BASED ON J04805
 BOTH COULEE-NANEUM LINES OUT

5160 R PLOTTED 26-SEP-91 AT 13:27:12 HOURS

PEPLOT PEP334 4 REVISED 10/11/88

INTERIE SCHEDULE
AC= 0.
DC= 557.

ACTUAL
AC= -279.
DC= 557.

LOSSES
BPA= 738.93
PNW= 1125.39
SYSTEM= 3854.95

CANADA TO PNW
(RCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 991.

IDAHO TO PNW
SI= 700.
AI= 680.

J04910 10/ 4/91 PF V6012
CY89 ALH-MJL
BASED ON J04632
NANEUM SHYD AND 19 OHMS ADDED

PFPL0T PFP334 : REVISED 10/11/90

S:PO R- , PLOTTED 4-OCT-91 AT 13:43:06 HOURS

500BUSNORTHWEST

INTERIE SCHEDULE

AC=	0.	AC=	-282.
DC=	557.	DC=	557.

LOSSES

```

BPA= 778.85
PNW= 1168.35
SYSTEM= 3901.32

```

J04911 10/ 1/91 PF V6010
CY89 ALH-MJL
BASED ON J04910
NANEUN - RAVEN 1&2 500KV LINES OUT

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
A - 988.

IDAHO TO PNW
SI= 700.
AI= 680.

INTERTIE SCHEDULE

AC= 0. AC= -282.
DC= 557. DC= 557.

LOSSES

BPA= 821.19
PNW= 1221.78
SYSTEM= 3960.36

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 993.

IDAHO TO PNW
SI= 700.
AI= 675.

500BUSNORTHWEST

J04913 10/ 1/91 PF V6010
CY89 ALII MJL
BASED ON J04910
VANTAGE - NANEUM 500KV LINE OUT
COULEE - NANEUM 1 500KV LINE OUT

INTERIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -284.	BPA= 812.84
DC= 557.	DC= 557.	PNW= 1208.89
		SYSTEM= 3945.41

CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WKOOT)	SI= 1250.	SI= 700.
SI= 450.	AI= 985.	AI= 681.
AI= 450.		

5:PO R- , PLOTTED 1-OCT-81 AT 15:32:42 HOURS

500BUSNORTHWEST

J04914 10/ 1/91 PI V6010
 CY89 ALH-MJL
 BASED ON J04910
 NANEUM - RAVEN 1&3 500KV LINES OUT

PFPL0T PFP334 : REVISED 10/11/80

INTERTIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= -284.	BPA= 806.74
DC= 557.	DC= 557.	PNW= 1201.89
		SYSTEM= 3938.61

CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WKOOT)	SI= 1250.	SI= 700.
SI= 450.	AI= 985.	AI= 681.
AI= 450.		

500BUSNORTHWEST

J04915 10/ 1/91 PF V6010
 CY89 ALH-MJL
 BASED ON J04910
 NANEUM - RAVEN 2&3 500KV LINES OUT

INTERIM SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= 283.	BPA= 813.38
DC= 557.	DC= 557.	PNW= 1203.05
		SYSTEM= 3936.11
CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WK001)	SI= 1250.	SI= 700.
SI= 450.	AI= 987.	AI= 680.
AI= 450.		

J04917 9/30/91 PI V6012
 CY89 ALH MJL
 based on J04910
 nanum raver #1 and #3 out
 35% comp added to chief Joe monroe

5:PO R , PLOTTED 1 OCT 81 AT 07:50:58 HOURS

PEPLOT PEP334 : REVISED 10/11/90

INTERIE SCHEDULE

AC= 0.
DC= 557.

ACTUAL

AC= 278.
DC= 557.

LOSSES

BPA= 761.88
PNW= 1152.72
SYSTEM= 3884.34

CANAL TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 997.

IDAHO TO PNW
SI= 700.
AI= 675.

500RUSNORTHWEST

J04019 10/ 1/91 PI V6012
CY89 ALH MJL
BASED ON J04010
COULEE NANEUM #1 AND VANTAGE NANEUM OUT
604 MW CT'S ADDED IN PUGET SOUND

INTERIE SCHEDULE			LOSSES		
AC=	0.	AC= 283.	BPA=	823.35	
DC=	557.	DC= 557.	PNW=	1225.15	
			SYSTEM=	3964.50	
CANADA TO PNW			IDAHO TO PNW		
(BCH & WK001)			SI= 700.		
SI= 450.			AI= 676.		
AI= 450.					
MONT TO PNW					
SI= 1250.					
AI= 992.					

500BUSNORTHWEST

J04963 10/ 3/91 PF V6012

CY89 ALH MJL

BASED ON J04060

VANTAGE-NANEUM OUT

COULEE-NANEUM #1 OUT

15 N-R

PPLOT PFP334 1 REVISED 10/11/00

INTERIEU SCHEDULE

AC :=
DC := 5

ACTUAL

AC = 280.
DC = 557.

LOSSES

```

BPA= 819.06
PNW= 1220.20
STEM= 3959.69

```

CANADA TO PNW
(BCH & WKOO)

$$\begin{aligned}SI &= 450, \\AI &= 450,\end{aligned}$$

MONT TO PNW

SI = 1250.
AI = 983.

IDAHO TO PNW

SI= 700.
AI= 681.

J04964 10/ 3/91 PF V6012

CY89 ALH-MJI

10/ 3/91 PF V6012

BASED ON J04960

NANEUM-RAVER #1 AND #3 OUT

11 OHM COMP IN OTHER NAN-RAV LINE

9:00 R- , PLOTTED 3-OCT-01 AT 14:01:35 HOURS

PEPL01 PEP334 : REVISED 10/11/90

INTERTIE SCHEDULE

AC= 0.
DC= 557.

ACTUAL

AC= -283.
DC= 557.

LOSSES

BPA= 824.55
PMW= 1227.22
SYSTEM= 3967.26

CANADA TO PNW
(BCH & WKOOT)
SI= 450.
AI= 450.

MONT TO PNW
SI= 1250.
AI= 991.

IDAHO TO PNW
SI= 700.
AI= 676.

500BUSNORTHWEST

J04965 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
VANTAGE-NANEUM AND
COULEE-NANEUM #1 OUT
11 OHM COMP IN NANEUM-RAVER LINES

INTERTIE SCHEDULE

AC= 0. AC= -281.
DC= 557. DC= 557.

LOSSES

BPA= 763.04
PNW= 1154.90
SYSTEM= 3886.71

CANADA TO PNW

(BCH & WK001)
SI= 450.
AI= 450.

MONT TO PNW

SI= 1250.
AI= 989.

IDAHO TO PNW

SI= 700.
AI= 680.

500BUSNORTHWEST

J04966 10/ 3/91 PF V6012
CY89 ALH-MJL
BASED ON J04960
NANEUM-RAVER #1 AND #3 OUI
11 OHM COMP IN OTHER NAN-RAV LINE
604 MW CT'S ADDED IN PUGET SOUND

500BUSNORTHWEST

INTERIE SCHEDULE	ACTUAL	LOSSES
AC= 0.	AC= 278.	BPA= 763.02
DC= 557.	DC= 557.	PNW= 1155.16
		SYSTEM= 3886.35
CANADA TO PNW	MONT TO PNW	IDAHO TO PNW
(BCH & WKOOT)	SI= 1250.	SI= 700.
SI= 450.	AI= 997.	AI= 675.
AI= 450.		

J04969 10/ 3/91 PI VG012
 CY89 ALIF MJL
 BASED ON J04960
 VANTAGE NANEUM OUT
 COULEE NANEUM #1
 15 OHMS IN NAN RAV #3 AND #4
 604 MW CTS ADDED IN PUGET SOUND

5:PO R , PLOTTED 3 OCT-61 AT 16:15:56 HOURS

PEPLOT PEP334 : REVISED 10/11/90

Attachment 4

PLAN 6 DEVELOPMENT - REPLACEMENT OF ROCKY REACH-MAPLE VALLEY 345 LINE
by Marv Landauer - BPA

One of the obvious rebuild options for Cross Mountain lines is the Rocky Reach-Maple Valley 345-kV line. However, as is shown below, Sickler is not a very strong source for a new double-circuit line. Sickler must also be reinforced. There are several options to do this:

Plan 6: Replacement of Rocky Reach-Maple Valley 345-kV with Sickler-Snoqualmie 500-kV double circuit line. The second Maple Valley 500/230-kV transformer was added to replace the 345/230-kV transformer that was removed and provide needed additional transformation in the Puget Sound Basin.

Plan 6A: same as Plan 6 plus Chief Joe-Sickler 500-kV single circuit added.

Plan 6B: same as Plan 6 plus Naneum Switchyard added (NO Coulee-Raver comp). This plan was investigated to see if Naneum development could reinforce the Sickler area enough.

Plan 6C: same as Plan 6 plus double circuit 500-kV tie added to new Columbia switchyard from closest point on the 345-kV right-of-way.

Plan 6D: same as Plan 6C plus 500-kV single circuit tie added from Columbia to Rocky Ford.

Plan 6E: same as Plan 6 plus Chief Joe-Sickler 500-kV double circuit line added creating Chief Joe-Snoqualmie and Chief Joe-Sickler-Snoqualmie 500-kV circuits.

Plan 6F: same as Plan 6 plus Chief Joe-Sickler 500-kV double circuit line added without the tie into Sickler, ie, a new Chief Joe-Snoqualmie double circuit.

Plans 6, 6A and 6B have unacceptably low voltages at Tacoma 500 in the base case with a Centralia unit out of service. Additional shunt capacitors would be needed in this area for these plans.

Local Reinforcement

With the removal of the 345/230-kV transformer at Maple Valley, there will be an increased need for transformation in the Puget Sound area. A second Maple Valley 500/230-kV transformer was added in these cases, however the Snoking transformer may also be needed in this study period.

The transformation in the Sickler-Rocky Reach area needs to be studied since a 345/230-kV transformer is removed at Rocky Reach with these Plans.

Performance Comparison

A comparison of system performance for the critical outages is included in Table 1. A Sickler-Snoqualmie line by itself is not enough to meet the J04 load. The addition of a Chief Joe-Sickler SDC line (Plan 6E and 6F) is still not as strong as Plan 2 (in main report) since this plan involves the removal of the 345-kV

circuit which provides some support to the Puget Sound Basin, especially during the abnormally cold weather. With the addition of the loop to Columbia and tie to Rocky Ford (plan 6D), it has similar performance to Plan 2.

Loss Savings Comparison

A comparison of loss saving for the various options is included in Table 1. A Rocky Ford tie added with the Columbia loop-in helps losses two ways by adding additional transmission in parallel with the Coulee-Columbia lines and the Hanford-Vantage-Naneum line. However, some of this loss reduction is due to the assumption of the second unit at Ashe (this increases the Hanford-Vantage-Naneum flow).

If a Chief Joe-Snoqualmie line is built, it appears to be beneficial from loss savings (and outage performance) to tie at least one line into Sickler. A double circuit line between Chief Joe and Sickler does not reduce losses any more than a single circuit line however it does improve post-transient performance.

Staged Development

All of these options start with the replacement of the Rocky Reach-Maple Valley 345-kV line which will work for a while (the study results below are for the year 2004). Any of these plans could be staged as development is needed.

Recommended Plan

Due to system performance and especially loss savings, Plan 6D is favored and included in the favored options.

TABLE 1: COMPARISON OF PLAN 6 OPTIONS FOR PSAERP

<u>OPTION</u>	<u>DESCRIPTION</u>	<u>PEAK SYSTEM LOSS SAVINGS</u>			<u>REACTIVE MARGIN</u>
		Case #	MW - 2004 BPA PNW		MVARs - 2004 2-line/1-line/Trojan Margins include unused MSC, QV curves follow
Plan 6	Sick-Snoq SDC	J04840	693	1077	150/300/300
Plan 6A	Sick-Snoq SDC CJ-Sick SSC	J04843	685	1069	400/450/450
Plan 6B	Sick-Snoq SDC Naneum SWYD (no Comp)	J04866	693	1076	900/250/300
Plan 6C	Sick-Snoq SDC SDC loop to Columbia	J04869	691	1075	800/400/500
Plan 6D	Sick-Snoq SDC SDC loop to Columbia SSC tie to Rocky Ford	J04902	677	1058	1100/700/600
Plan 6E	Sick-Snoq SDC CJ-Sick SDC	J04903	685	1070	1200/700/500
Plan 6F	CJ-Snoq SDC no Sickler tie	J04901	693	1082	600/600/450

PLAN 6

Sick-Snoq 500 SDC added.

○ J04841:COUL-RAV 1&2(J04840)MSC OLY,SNQ(1),MON(1)
 △ J04842:SICKL-SNOQ 1&2(J04840)MSC OLY,SNQ(1),MON(1)
 + J04EH479:CHIEF J-MON OUT(J04EH471)MSC OLY(1)
 J04EH483:TROJAN SCRAM(J04EH475)MSC OLY(1)
 ◇ J04EH497:TROJAN SCRAM(J04EH475)MSC OLY(1),MARION(1)

All MSC's
used.

○ J04841QV
 x J04EH483QV

△ J04842QV
 ◇ J04EH497QV

+ J04EH479QV

12-SEP-1991
 J04841QV.SETUP

Sickler-Snoq SOC and
CJ-Sickler SSC added.

PLAN 6A

○ J04864: COUL-RAV 1&2 (J04843) MSC OLY, SNQ(1), MON(1)
 △ J04865: SICKL-SNOQ 1&2 (J04843) MSC OLY, SNQ(1), MON(1)
 + J04EH480: CHIEF J-MON OUT (J04EH472) MSC OLY(1)
 x J04EH484: TROJAN SCRAM (J04EH476) MSC OLY(1)
 ◇ J04EH496: TROJAN SCRAM (J04EH476) MSC OLY(1), MARION(1)

All MSC's
used.

○ J04864QV
x J04EH484QV

△ J04865QV
◇ J04EH496QV

+ J04EH480QV

13-SEP-1991

J04864QV.SETUP

Sickler-Snoq SDC added
Nancum SW40 (no comp) added.

PLAN 6B

○ J04868:SICKL-SNOQ 1&2(J04866)MSC OLY,SNQ(1),MON(1)
△ J04EH481:CHIEF J-MON OUT(J04EH473)MSC OLY(1)
+ J04EH485:TROJAN SCRAM (J04EH477)MSC OLY(1)
× J04EH498:TROJAN SCRAM (J04EH477)
MSC AT OLY(1), MARION(1)

} ALL MSCs
USED

○ J04868QV
× J04EH498QV

△ J04EH481QV

+ J04EH485QV

13-SEP-1991

J04868QV.SETUP

Sick-Snog with DC
loop to Columbia.

PLAN 6C

○ J04870: COUL-COLMBIA 1&2(869)MSC OLY, SNQ(1), MON(1)
△ J04879: COL-SNQ/SICKL-SNQ(879)MSC OLY, SNQ(1), MON(1)
+ J04EH482: CHIEF J-MON OUT(J04EH474)MSC OLY(1)
J04EH486: TROJAN SCRAM (J04EH478)MSC OLY(1)
◇ J04EH499: TROJAN SCRAM(J04EH478)MSC OLY(1), MARION(1)

} All
MSC's
used

○ J04870QV
x J04EH486QV

△ J04879QV
◇ J04EH499QV

+ J04EH482QV

RAVER SHUNT REACTIVE

16-SEP-1991
J04870QV.SETUP

Sick-Snoq DC added
with DC loop to Columbia.
Columbia - Rocky Fl SC tie added.

PLAN 6D

○ J04657:COULEE-COLUMBIA 1&2 OUT (J04655)NO MSC
 △ J04658:COL-SNOQ/SICKL-SNOQ(655)MSC SNQ(1),RAV(1)
 +J04871:RAVER-COLUMBIA 1&2(J04655)NO MSC
 × J04EH410:CHIEF J-MONROE(J04EH404)MSC OLY(1),MON(1)
 ♠ J04EH495/◇411:TROJAN SCRAM(405)MSC OLY1/OLY1,MARN1

Mon, Snoq, Oly avail.
 Mon, Oly avail.
 Mon, Snoq, Oly avail.
 ALL MSC use.

○ J04657QV
 × J04EH410QV

△ J04658QV
 ◇ J04EH411QV

+ J04871QV
 ♠ J04EH495QV

13-SEP-1991
 J04657QV.SETUP

Sick-Snoq DC added
CT-Sickler DC added
one circuit tied to Sickler

PLAN 6E

○ J04777: COULE-RAVE 1&2 OUT, MSC 00LY, SNOQ, MON(J04776) } Snoq avail
 △ J04778: CJ-SNQ & SICK-SNOQ OUT MSC 00LY, SNQ(J04776) } Snoq, Mon avail
 + J04EH532: CJ-MON, EH533: COUL-RVE, EH534: CJ-SNOQ, } All MSC
 MSC 00LY, MONROE (J04EH530) } used.
 † J04EH535: TROJAN SCRAM, MSC 00LY, MARION(J04EH531) }

Q J04777QV
X J04EH533QV

Δ J04778QV
 ◇ J04EH534QV

+ J04EH532QV
▲ J04EH535QV

10-SEP-1991
J04777QV.SETUP

CJ-Snoq SDC added
no tie into Sickler

PLAN 6F

o J04900:CHIEF J-SNOQ 1&2 OUT(J04899)MSC OLY,SNQ(2) } MON AVAIL.
 Δ J04904:COULEE-RAVER 1&2 OUT(J04899)MSC OLY,SNQ(2) }
 + J04EH633:COUL-RAVER OUT (J04EH631)MSC OLY,MON(1) } ALL MSC's
 x J04EH634:TROJAN SCRAM(J04EH632)MSC OLY,MARION(1) } used

o J04900QV
x J04EH634QV

Δ J04904QV

+ J04EH633QV

20-SEP-1991

J04900QV.SETUP

Attachment 5

ATTACHMENT 5

VOLTAGE COLLAPSE STUDIES FOR THE PUGET SOUND AREA

Submitted to the Puget Sound Area Electric Reliability Plan
Transmission Studies Team

By Gordon Comegys
Bonneville Power Administration

Background

The Puget Sound Area Electric Reliability Plan (PSAERP) Transmission Studies Team directed BPA to investigate the scenario of voltage collapse for their area. The team members are BPA, Snohomish Co. PUD (SPUD), Puget Sound Power and Light (PSPL), Seattle City Light (SCL), and Tacoma City Light (TCL). This report applies the powerflow program to calculate system conditions as snapshots in time.

Steady state powerflow studies assume constant power load models (load demand insensitive to voltage). The winter Puget Sound area powerflow cases need large reactive additions and a high operating voltage near the maximum allowable level to successfully solve. Without these large reactive additions, the powerflow network does not have a mathematical solution. The failed solution indicates that the modeled condition of the existing transmission system and high projected loads cannot exist.

Despite the lack of a mathematical solution for the steady state system, transient stability studies with generator exciters limited show fully satisfactory performance. The key difference is the assumed load model for the transient stability studies. These studies assume voltage sensitive load models and no voltage regulation by distribution voltage regulating transformers. Steady state studies assume load models insensitive to voltage, representing the assumption that the constant energy demand will restore the power demand to pre-outage levels.

The purpose of this study is to explore the general system response during the attempted transition from transient to steady state. The PSAERP "superbase" powerflows are used. The development of the "superbases" is described in Appendix A. The loads are modeled with constant power, constant current, and constant impedance components. Distribution voltage regulating transformers are represented with approximate equivalents. The modeled system is intentionally put into the voltage instability state. The model includes the effects of varying amounts of shunt reactive, transformer tap changing, and added resistive heating load through thermostat action. The powerflow calculations show snapshots in time. At the time of this study, a time domain midterm dynamics program was not available to BPA. Any references to time such as 30 seconds, 2 minutes, or 20 minutes are estimates of regulator time delay, full tap range changing time, or thermostat response time, respectively.

Summary of Key Findings

Studies with voltage sensitive load models confirm that the minimum stable voltage in Puget Sound is the critical voltage calculated with constant power

load models. The PSAERP "superbase" studies suggest that uncontrolled, continuously declining voltage and power delivery are the consequences of insufficient reactive. This assumes that a large amount of unconnected thermostatically controlled resistive heating load is available to connect to the system.

Switching shunt capacitors, if available, will successfully bring the voltage from a low unstable level back to the high stable voltage. A voltage level is classified as unstable if voltage and power delivery simultaneously decrease over several minutes (caused by thermostat response or other attempted load pickup). Conversely, a voltage level is classified as stable if power delivery increases as load is added. In actual operation, capacitors will be planned to switch on before the voltage declines to a low, unstable voltage if this can be coordinated. However, switching capacitor banks will be difficult to coordinate before distribution voltage regulators change taps. This is due to the small voltage drop (2%-5%) prior to the regulator response, which is about the same as the voltage drop that occurs for a voltage stable system.

Switching the final capacitor bank to restore and maintain a high stable voltage causes a large voltage change. The large change will not occur immediately, but over a period of 1-2 minutes following the switched capacitor bank. A "chain reaction" occurs. The scenario appears to be this: switching the final capacitor bank causes the voltage on one load bus to become slightly high. The voltage regulator changes taps to reduce the voltage. This slightly decreases the system loading, causing the main system voltage to rise. The system voltage rise causes another load bus voltage to become high, causing the voltage regulator taps to change which causes the system loading to decrease and the system voltage rises again. The changing voltage is caused by the rapidly changing power demand as load voltage regulators change load voltages which subsequently changes load. The scenario continues until the voltage regulators are tapped out or equilibrium is reached. This scenario only occurs when voltages are within the voltage control range of the load voltage regulating transformers, about +10% or -10% of the stable main system voltage. If the Puget Sound customers had no load voltage regulating transformers, the voltage changes from capacitor switching would be much slower, perhaps 20 minutes or more.

Voltage control with large switched capacitor banks will be difficult once the minimum amount of shunt reactive is connected. A small increase in load demand will cause a relatively large decrease in voltage. Conversely, a small load decrease could cause a relatively large increase in voltage. These are the consequences of operating near the critical voltage. In the case of Maple Valley, the critical voltage is near the maximum criteria voltage. Exceeding the maximum criteria voltage could occur with voltage control from large shunt capacitor banks.

Key Assumptions

1. The 1993 winter "superbases" with enhanced load models and distribution voltage control models are accurate. These powerflow bases were approved by PSAERP transmission studies team.
2. Motor and generator dynamics will not be a factor in the post transient state for load voltages above 0.85 per unit.

Conditions Studied

Four system conditions were studied: (1) double Coulee-Raver line outage during 1993 normal winter loads, (2) double Coulee-Raver line outage during 1991 operations Level 1 conditions (about 93% of 1991 normal winter peak), (3) single Chief Jo- Monroe line outage during 1993 abnormal cold, and (4) Trojan outage with one Centralia unit down during 1993 abnormal cold. Condition (1) was found to be most severe. Most of the investigation focused on the most severe condition.

Double Coulee-Raver Line Outage

The constant power V-Q calculation shows that over 1000MVARs of additional shunt reactive is needed for a successful powerflow solution (J93910QV, attachment 1). The constant power critical voltage is 550kV. This severely stressed system is studied further using the newly developed voltage sensitive load models.

Applying voltage sensitive load models show the likely scenario. The system voltage does not initially collapse (powerflow case J93764). Raver voltage drops from the 542kV precontingency voltage to 513kV prior to load voltage regulator response (estimated duration is 30 seconds). The Puget Sound load drops from 11,147MW to 10,448MW.

The effects of load regulator tap changing was modeled (J93765). Raver voltage is down to 475kV at the end of the regulator action, (estimated duration is 2 minutes). This assumes load regulator tap range with 8% remaining boost. The Puget Sound load drops further to 10,159MW. Nearly a 1000MW load reduction occurs. Realistically, some loads will be lost. Some load models will be invalid with voltages below 90% of nominal. For study purposes, the models are assumed to remain valid and all loads are assumed to remain connected.

Much of the 1000MW load reduction occurs from thermostatically controlled resistive heating. A 1% increase in connected resistance load was modeled (J93766). This models the effect of more electric heaters turning on in the next few minutes. The load served drops further. Total thermal output of the heaters is reduced even though more electric heaters have turned on. The system is operating in a voltage instability state.

Changing EHV transformer taps through LTC control further depresses the 500kV voltage. This case does not solve with EHV LTC's active because of voltage collapse on the BC-Hydro system. BCH loads are modeled as constant power. Changing one tap position on the Maple Valley transformer is modeled to check for any benefits in load restoration. The result is negative (J93928). The load drops further.

The constant power V-Q calculation shows EHV LTC's provide benefit (J93927QV, attachment 2). The required amount of shunt capacitors predicted by the constant power load model calculation must be connected before benefits occur with the voltage sensitive loads. Over 200MVARs of reactive benefit occurs with active EHV LTC's at Custer, Monroe, Maple Valley, Tacoma, Olympia, and Satsop (J93929). If the EHV LTC'S operate before the required shunt reactive is switched on, then the LTC's are a detriment to the system (J93928).

The system appears to be in a severe voltage instability state after load regulator and thermostat action. Power delivery decreases as more load is connected. Conversely, power delivery increases as load is disconnected.

The transient stability program is used to model the LOADSYN dynamic load model. The result shows no transient stability problem (swing J93S01).

Switching shunt capacitors was modeled to see how the system could recover from the voltage instability state. Switching shunt capacitors is successful (J93923, J93924). Initially, as shunt reactive is connected, the voltage increase is small. As more shunt capacitors are switched in, the voltage eventually increases enough to cause some load regulators to begin returning to the original tap. Load is slightly reduced from regulator action at these locations. Main system loading slightly decreases and 500kV voltage subsequently increases. More load regulators begin to change taps as voltages increase. After load regulator action the main system voltage begins to dramatically increase for smaller shunt reactive increments. The system voltage is more sensitive to load changes caused by regulator action than shunt reactive changes at any instant in time. Also, the resistive load is decreased to the original state because thermostats restore the diversity of electric heaters as thermal output increases. The system eventually reaches a stable state.

This case shows the amount of shunt capacitors needed to restore full load is the same for voltage sensitive or constant power load models. Switching capacitors does not dramatically change voltage at that instant. However, the voltage significantly changes once the voltage is in the range of load regulator control. This case needed 1000MVARs to restore load. The main system voltage did not significantly change until the last 300MVARs was inserted. The Raver voltage then increased 9% following load regulator action.

Inserting too much shunt reactive causes main system overvoltages after several minutes of load regulator action. Initially, load voltages and system voltages are only slightly high. The voltage sensitive loads increase. The subsequent increase in main system loading damps the initial overvoltage. However, the load regulators begin to change taps to reduce load voltages. The main system loading decreases and the voltage increases. The eventual magnitude of the overvoltage corresponds with constant power load model calculations.

Trojan Outage (One Centralia Unit Off)

This condition is slightly less severe than the double Coulee-Raver outage during normal weather, but more severe than the Chief Jo-Monroe outage. The critical voltage calculated with constant power load models is 535kV (J93EH1058QV, attachment 3). Only a 1% increase in load level raises the critical voltage to nearly 545kV and requires another 300MVARs for a mathematical solution.

Raver voltage drops from the 531kV precontingency voltage to 522kV immediately following the Trojan outage (J93EH1056). Voltage sensitive loads in Western Washington and Oregon drop from 23974MW to 23354MW. Raver voltage drops further to 491KV after load regulator action (J93EH1057). Loads reduce further to 22895MW.

An interesting correlation exists in this case between the constant power

critical voltage and positive load restoration by load regulator action (attachment 4). Load appears to partially restore until the main system voltage drops to the constant power critical voltage. The load actually drops as the main system voltage continues to decline below the critical voltage. The double Coulee-Raver outage has a critical voltage too high to see this correlation.

Chief Jo-Monroe Outage

This condition is slightly less severe than either of the above two conditions. The critical Raver voltage using the constant power load model is 540kV following the Chief Jo-Monroe outage (J93EH1045QV, attachment 5). Only a 1% increase in load level raises the critical voltage to 545kV and requires another 250MVARs for a mathematical solution.

The Raver voltage falls from 535kV before the outage to 517kV after the outage (J93EH1038). The voltage sensitive loads drop from 12229MW to 11746MW. Voltage drops further to 496kV following load regulator action (J93EH1039). The load also drops to 11653MW. Increasing constant resistance load to simulate thermostat action decreases load further (J93EH1040). This confirms the system is in the voltage instability state.

The same correlation seems to exist between positive load restoration by load regulator action and the constant power critical voltage (attachment 6).

1991 Level 1 Winter Load Modeling Test (Proposed)

These studies examine voltage stability with a less stressed system. Level 1 for the 1990-91 operating winter is defined by System Operations as the maximum loading level where all load can still be served with no combustion turbine operation following a double Coulee-Raver line outage. The powerflow case under study represents the 1991 system with Puget Sound area load at 89% of the 1993 study. The level 1 condition is analyzed to compare results of a less stressed system with the highly stressed 1993 system above.

Raver voltage is 535kV with all Raver shunt capacitor banks off line and all lines in service. Puget Sound load level is 9956MW. The critical voltage for the post transient double Coulee-Raver outage using constant power load model is 520kV (J9150QV, attachment 7).

Raver voltage drops to 512kV initially after opening the two Coulee-Raver lines (J9145). The voltage sensitive loads drop to 9528MW. Following load regulator tap changes, the Raver voltage drops further to 487kV (J9146). However, a small part of the load partially restores to 9610MW. The system does not appear to be in the voltage instability state because of some load restoration by load regulators. Also, adding a small amount of constant resistance load results in more load served (J9189). Switching the 952MVARs of available Raver shunt capacitors fully restores the load as predicted by the constant power calculation (J9161, J9163).

The previous correlation between load restoration by load regulator action and the constant power critical voltage does not appear with this less stressed system. Also, correlation is not precise between the critical voltage of a P-V curve using voltage sensitive loads and the critical voltage of the constant power V-Q curve (attachment 8).

Conclusions

Constant power studies accurately determine the amount and location of required voltage support to serve full load. This includes benefits from shunt capacitors, EHV LTC adjustment, and line drop compensators at generator terminals. Shunt reactive must be inserted before benefits occur from EHV LTC changes.

The studies show the following:

- * the key planning indicator of voltage stability is the critical voltage as calculated from the constant power V-Q curve.
- * a system with voltage sensitive loads similar to the Puget Sound area cannot operate below the critical voltage. This conclusion assumes a large amount of resistive heating load can be connected through thermostat response. Shunt reactive additions are no longer an alternative when the critical voltage reaches the maximum system voltage.
- * the state of voltage instability is characterized by an actual reduction in load served as more resistive heating load is connected through thermostat response. Sudden voltage collapse does not occur with these PSAERP load models.
- * the voltage level that voltage instability occurs from a P-V calculation approximately corresponds with the critical voltage of a constant power V-Q calculation.
- * switching capacitors causes large voltage excursions over a several minute period when full load restoration is approached. This assumes the switching of capacitors cannot be coordinated prior to load voltage regulator response (the initial voltage change is small, only 2%-5%).
- * restoring lines to service after mechanically switched capacitor (MSC) action has occurred does not cause severe overvoltages for 30 seconds. Following load voltage regulator action, the overvoltage is accurately predicted by constant power calculations.

Further Studies

The above information is based on powerflow studies with static load models. This assumes the motor and generator dynamics will not be significant with a load area dominated by constant impedance or resistive heating load. To confirm this assumption, a study using one of the mid-term dynamics programs under development, such as the EPRI ETMSP or the PTI program, is recommended.

GLC 2/11/91 last revision 2/3/92
bpa65::disk15:[eofcglc]voltagestability.report

ATTACHMENT 1 DOUBLE COULEE-RAVER LINE OUTAGE
NORMAL WINTER PEAK LOADS
CONSTANT POWER LOAD MODEL

ATTACHMENT 2 DOUBLE COULEE-RAVER LINE OUTAGE NORMAL WINTER PEAK LOADS CONSTANT POWER LOAD MODEL EFFECT OF EHV LTC ACTION

ATTACH. 3 TROJAN OUT WITH ONE CENTRALIA UNIT OFF
 ABNORMAL COLD WINTER PEAK LOADS
 CONSTANT POWER LOAD MODEL

2-FEB-1992
 J93EH1058QV.SETUP

J93 Post Transient Trojan Outage
MSC 300 MVARS AT KEELER

Attachment 4

Raver V vs Raver Q

constant power load
compared to
voltage sensitive
load models

- Ⓐ CAP BANK A
- Ⓑ CAP BANK B
- Ⓒ CAP BANK C

J93 Post Transient Trojan Outage
MSC 300 MVARS AT KEELER

Load unserved vs. Raver Voltage

Ⓐ Ⓑ Ⓒ
refers to
operating points
on VQ curve above

ATTACHMENT 5 CHIEF JO-MONROE 500KV LINE OUTAGE 1992-1993 COLD WINTER LOADS CONSTANT POWER LOAD MODELS VOLTAGE VS SHUNT REACTIVE • RAVR

J93EH Post Transient CHIEF TO-MICHADE OUTAGE
 CONSTANT POWER LOAD MODEL COMPARED TO
 VOLTAGE SENSITIVE LOAD MODEL
 BEFORE AND AFTER DIST. VOLTAGE REG. CHANGES

Attachment 6

LOAD UNSEEN VS RAVER VOLTAGE

ATTACHMENT 7 1991 LEVEL 1 SYSTEM TEST
DOUBLE COULEE - RAVER OUTAGE

J91 Level 1 Load Response Test (proposed)

Raver V vs. Raver Q

Attachment 8

CONSTANT POWER
LOAD MODEL COMPARED
TO VOLTAGE SENSITIVE
MODEL BEFORE AND
AFTER DIST VOLTAGE
REGS CHANGE TRIPS

Load unserved vs Raver V

COULEE -R : 500KV DOUBLE LINE OUTAGE

J93501

J9143 BASE FOR SYSTEM TEST USING VOLTAGE SENSITIVE LOAD MODELS

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
059	1.090	1.079	1.070	1.086	1.051
OLYMPIA500	SATISOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.087	1.088	1.084	1.083	1.084	1.079
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.082	1.038	1.042	1.014	1.013	1.035
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
1.029	1.042	1.026	1.016	1.043	1.041
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
1.041	1.032	1.044	1.040	1.052	1.044
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
1.024	1.035	1.035	1.024	0.999	1.004
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
1.009	0.951	0.951	1.034	1.034	0.994
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.994	0.948	0.948	0.984	0.984	0.969
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLBOS115
0.969	0.979	0.979	0.973	0.973	0.964
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.964	1.040	1.040	1.040	1.012	1.012
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1
1.022	0.968	0.940	0.940	0.998	0.998
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.
0.950	0.950	0.940	0.940	1.000	1.000

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
176	12	8	182	22	166	-1
1.045	0.996	0.997	1.026	1.020	1.012	1.002
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
105	-1	10	3	5	88	67
1.011	1.002	1.050	1.004	1.008	1.014	1.001
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	
105	44	-224	-130	-85	-63	
1.011	1.001	0.959	0.950	0.950	0.978	

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
178	839	2000	600	600	1180	5219

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1647	3403	501	1706	1284	1417	7081	3307	8419
Q	577	1099	239	437	359	501	1809	1002	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	9956	Q=	3211	P=	20344	Q=	6023		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1913	352	0	298	100	278	3038	700	9466
Q	66	27	0	-5	41	94	385	155	321
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	2941	Q=	223	P=	6679	Q=	540		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 7015 WEST ORE & WA=13665

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	206	67	1	19	7	14	159	109	575	314
Q	393	360	0	71	26	186	701	-367	-5625	-856
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	315	Q=	1035	P=	583	Q=	1369			

.....BUS SHUNT REACTIVE (MVAR).....

RAVER= 0 USED 0 UNSCHEDULED

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	2668	1007	103	610	0	125	2157	714	-2381	660
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	4513	QSHUNT= 7384								

J9145 BASED ON J9144, OPEN COULEE-RAVER #2 (BOTH LINES NOW OPEN)

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
033	1.047	1.035	1.024	1.066	1.008
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.066	1.067	1.068	1.069	1.070	1.065
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.069	1.012	1.014	0.983	0.978	0.997
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
0.994	1.003	0.989	0.978	1.000	0.999
TALBOTN230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
0.999	0.991	1.020	1.015	1.025	1.017
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHOMSH115	SNOKING115
0.999	1.020	1.025	0.996	0.963	0.969
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.970	0.923	0.923	0.979	0.979	0.954
EPFOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.953	0.920	0.920	0.947	0.947	0.934
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.934	0.944	0.944	0.937	0.937	0.925
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.925	1.013	1.013	1.013	0.985	0.985
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1
0.981	0.930	0.913	0.913	0.955	0.955
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.
0.912	0.912	0.914	0.914	0.957	0.957

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
338	187	134	408	181	240	21
1.045	0.996	0.997	1.025	1.020	1.012	1.002
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	21	20	8	19	221	96
1.000	1.002	1.050	1.004	1.008	1.029	1.001
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	
157	66	-187	-111	-72	33	
1.000	1.001	0.959	0.950	0.950	0.978	

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5 TOTAL PNW
193	546	1976	561	561	1087 4730

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1591	3230	496	1636	1219	1356	6979	3269	8419
Q	551	1026	236	410	336	474	1780	988	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	9528	Q=	3033	P=	19776	Q=	5801		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1913	352	0	298	100	278	3038	700	9481
Q	265	59	0	77	50	124	544	193	826
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	2941	Q=	575	P=	6679	Q=	737		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 6587 WEST ORE & WA=13097

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	225	74	1	19	7	14	167	111	590	356
Q	1482	412	1	84	28	175	862	-270	-5276	-21
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	340	Q=	2181	P=	619	Q=	2772			

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	2484	939	97	576	0	115	2111	703	-2634	37
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	4211	QSHUNT=	7025							

J9146, BASED ON J9145, SYSTEM AFTER DISTRIBUTION SYSTEM VOLTAGE REGULATOR ADJUST

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
997	0.998	0.982	0.973	1.037	0.955
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.034	1.034	1.043	1.046	1.048	1.044
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.049	0.971	0.965	0.930	0.923	0.943
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
0.942	0.951	0.936	0.922	0.945	0.943
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
0.943	0.934	0.980	0.966	0.968	0.958
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
0.945	0.995	1.007	0.942	0.906	0.912
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.979	0.851	0.920	0.925	1.000	0.884
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.956	0.847	0.916	0.887	0.959	0.874
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.945	0.885	0.957	0.878	0.949	0.866
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.937	0.953	1.030	1.036	0.920	0.994
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1
0.990	0.871	0.929	0.859	0.887	0.959
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.
0.845	0.913	0.859	0.929	0.902	0.975

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	346	249	408	415	371	52
1.045	0.996	0.997	0.999	1.020	1.012	1.002
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	52	41	15	26	429	143
0.972	1.002	1.050	0.974	0.969	1.051	1.001
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	
157	102	-137	-85	-55	156	
0.972	1.001	0.959	0.950	0.950	0.978	

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
214	729	1991	585	585	1145	5035

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1633	3304	499	1549	1247	1378	7082	3308	8419
Q	570	1056	238	373	346	483	1808	1002	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	9610	Q=	3067	P=	20000	Q=	5878		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1913	352	0	298	100	278	3038	700	9503
Q	561	102	0	195	50	138	819	267	1544
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	2941	Q=	1047	P=	6679	Q=	1087		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 6669 WEST ORE & WA=13321

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	254	84	2	21	8	16	180	118	611	373
Q	2135	530	2	139	38	213	1076	-107	-4716	440
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	385	Q=	3058	P=	683	Q=	4027			

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH	
	2234	829	87	534	0	102	2027	671	-2586	18	
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)											
QSHUNT=	3786	QSHUNT= 6484									

J9161 BASEDON J9145, SWITCH IN 3 RAVEN CAP BANKS 20 SECONDS INTO TEST

```
.....BUS VOLTAGES (PER UNIT).....
STER500 MONROE500 MAPLEVL500 RAVEN500 PAUL500 TACOMA500 COULEE500
050 1.076 1.084 1.087 1.089 1.066 1.080
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 OSTRNDER500
1.089 1.090 1.084 1.078 1.076 1.070
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
1.073 1.029 1.032 1.003 1.000 1.021
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
1.020 1.029 1.018 1.010 1.050 1.043
TALBOTS230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
1.043 1.041 1.043 1.039 1.051 1.044
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHOMSH115 SNOKING115
1.024 1.035 1.034 1.014 0.986 0.996
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
1.010 0.941 0.941 1.009 1.009 0.998
EPTOR R115 LANGLEY115 LANGLE R115 NBOTHEL115 NBOTH R115 CAMANO115
0.998 0.938 0.938 0.972 0.971 0.956
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
0.956 0.971 0.971 0.960 0.960 0.970
HYLE R115 PORTAN69 PORTARR69 PAPN1 R69 SAPPHO69 SAPPHO R69
0.970 1.040 1.040 1.040 1.012 1.012
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
1.028 0.974 0.930 0.930 1.002 1.002
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
0.953 0.953 0.931 0.931 0.978 0.978
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
300 147 105 362 -1 175 6
1.045 0.996 0.997 1.026 1.020 1.012 1.002
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
157 6 14 2 2 135 85
1.004 1.002 1.050 1.004 1.008 1.019 1.001
CHIEF JO BONNVIL2 DALLES 3 DALLES21 DALLES22 JOHN DAY
157 58 -196 -116 -75 11
1.004 1.001 0.959 0.950 0.950 0.978
.....SLACK BUS AND AGC BUSES (MW).....
RIDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
188 850 2001 601 601 1183 5236
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1641 3395 501 1717 1264 1427 7032 3281 8419
Q 574 1096 239 441 352 505 1796 993 3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 9944 Q= 3208 P=20258 Q= 5997
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1913 352 0 298 100 278 3038 700 9476
Q 42 35 0 19 50 83 440 181 529
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 2941 Q= 229 P= 6679 Q= 621
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 7003 WEST ORE & WA=13579
.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
P 238 76 1 19 7 14 169 112 585 363
Q 1566 417 0 66 27 181 872 -270 -5469 103
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 355 Q= 2258 P= 637 Q= 2860
.....BUS SHUNT REACTIVE (MVAR).....
RAVEN= 1125 USED 0 UNSCHEDULED
MONROE= 381 USED 0 UNSCHEDULED
.....ZONE SHUNT REACTIVE (MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
3768 1003 101 615 0 127 2136 707 -2652 45
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 5615 QSHUNT= 8457
```


J9163 BASEDON J9161, DIST VOLTAGE REGS ADJUST AFTER 3 RAVER CAP BANKS SWITCHED

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500	COULEE500
045	1.070	1.078	1.081	1.086	1.061	1.078
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500	
1.086	1.087	1.080	1.074	1.071	1.066	
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNHOMSH230	
1.069	1.023	1.024	0.995	0.992	1.013	
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230	
1.013	1.022	1.010	1.003	1.045	1.037	
TALBOT230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230	
1.037	1.035	1.039	1.035	1.046	1.038	
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNHOMSH115	SNOKING115	
1.019	1.033	1.032	1.005	0.978	0.988	
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115	
1.009	0.926	0.949	1.003	1.034	0.992	
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115	
0.992	0.922	0.945	0.962	0.986	0.946	
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115	
0.970	0.962	0.980	0.951	0.974	0.965	
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69	
0.965	1.034	1.040	1.040	1.006	1.012	
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1	
1.021	0.970	0.938	0.921	0.996	0.998	
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.	
0.948	0.948	0.921	0.939	0.970	1.000	

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
325	166	119	390	26	196	10
1.045	0.996	0.997	1.026	1.020	1.012	1.002
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BUHRARD	BONN PH2
157	10	17	2	4	161	96
1.000	1.002	1.050	1.004	1.008	1.022	1.001
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	
157	66	-186	-111	-72	37	
1.000	1.001	0.959	0.950	0.950	0.978	

.....SLACK BUS AND AGC BUSES (MW).....

TRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PMW
190	910	2006	609	609	1199	5334

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	
P	1643	3400	501	1705	1286	1419	7082	3304	8419
Q	575	1098	239	437	360	502	1809	1001	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	9955	Q=	3210	P=	20340	Q=	6020		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	
P	1913	352	0	298	100	278	3038	700	9478
Q	76	43	0	35	50	91	491	202	623
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	2941	Q=	295	P=	6679	Q=	693		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 7014 WEST ORE & WA=13661

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	243	77	1	19	8	14	172	114	587	367
Q	1656	431	0	70	29	181	924	-221	-5402	191
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	362	Q=	2368	P=	648	Q=	3071			

.....BUS SHUNT REACTIVE (MVAR).....

RAVER=	1113	USED	0	UNSCHEDULED
MONROE=	376	USED	0	UNSCHEDULED

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	3725	990	100	610	0	126	2118	697	-2646	43
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	5550	QSHUNT=	8365							

J9189 BASEDON J9146, 1% CONSTANT R INCREASE

```

.....BUS VOLTAGES (PER UNIT).....
STER500 MONROE500 MAPLEVL500 RAVER500 PAUL500 TACOMA500 COULEE500
994 0.995 0.978 0.970 1.036 0.952 1.064
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 OSTRANDER500
1.032 1.032 1.041 1.045 1.047 1.043
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
1.048 0.968 0.962 0.927 0.919 0.939
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
0.939 0.947 0.932 0.918 0.941 0.939
TALBOTN230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
0.939 0.931 0.977 0.964 0.965 0.955
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHMSH115 SNOKING115
0.943 0.994 1.006 0.939 0.903 0.909
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
0.975 0.847 0.915 0.921 0.996 0.880
EPTOR R115 LANGLY115 LANGL R115 NBOTHEL115 NBOTH R115 CAMANO115
0.952 0.843 0.911 0.884 0.955 0.870
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
0.941 0.882 0.953 0.874 0.945 0.863
HYLE R115 PORTAN69 PORTARR69 PAPN1 R69 SAPPHO69 SAPPHO R69
0.933 0.950 1.027 1.033 0.917 0.991
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
0.986 0.867 0.925 0.856 0.883 0.955
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
0.841 0.909 0.856 0.925 0.898 0.971
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
403 358 257 408 429 379 54
1.045 0.996 0.997 0.997 1.020 1.012 1.002
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
157 54 42 15 26 445 145
0.970 1.002 1.050 0.970 0.966 1.052 1.001
CHIEF JO BONNVIL2 DALLS 3 DALLS21 DALLS22 JOHN DAY
157 103 -136 -85 -55 160
0.970 1.001 0.959 0.950 0.950 0.978
.....SLACK BUS AND AGC BUSES (MW).....
RIDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
?17 738 1992 587 587 1148 5051
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1642 3306 499 1550 1247 1378 7081 3307 8419
Q 570 1049 238 371 344 481 1809 1002 3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 9622 Q= 3052 P=20010 Q= 5863
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1913 352 0 298 100 278 3038 700 9505
Q 579 104 0 203 50 138 833 268 1606
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 2941 Q= 1074 P= 6679 Q= 1101
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 6681 WEST ORE & WA=13331
.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
P 256 85 2 21 8 16 180 118 614 375
Q 2185 538 2 146 39 215 1084 -102 -4660 465
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 389 Q= 3124 P= 687 Q= 4106
.....BUS SHUNT REACTIVE (MVAR).....
RAVER= 0 USED 0 UNSCHEDULED
MONROE= 326 USED 0 UNSCHEDULED
.....ZONE SHUNT REACTIVE (MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
2219 823 86 530 0 102 2024 670 -2582 17
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 3759 QSHUNT= 6453

```

J93764 OUTAGE BEFORE DIST VOLTAGE REGS CHANGE

```

.....BUS VOLTAGES (PER UNIT).....
CUSTER500 MONROE500 MAPLEVL500 RAVER500 PAUL500 TACOMA500
012 1.011 1.012 1.025 1.061 1.019
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 OSTRANDER500
1.059 1.060 1.061 1.058 1.058 1.051
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
1.065 1.001 0.993 0.953 0.938 0.962
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
0.961 0.980 0.958 0.947 0.988 0.982
TALBOTN230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
0.982 0.977 1.012 1.007 1.009 1.004
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHOMSH115 SNOKING115
0.990 1.014 1.021 0.987 0.945 0.944
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
0.951 0.922 0.922 0.950 0.950 0.929
EPTOR R115 LANGLEY115 LANGL R115 NBOTHEL115 NBOTH R115 CAMANO115
0.929 0.918 0.918 0.927 0.927 0.905
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
0.905 0.911 0.911 0.910 0.910 0.912
HYLE R115 PORTAN69 PORTARR69 PAPN1 R69 SAPPPO69 SAPPPO R69
0.912 1.005 1.005 1.005 0.971 0.970
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
0.966 0.918 0.901 0.901 0.938 0.938
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
0.893 0.893 0.901 0.901 0.930 0.930
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
403 312 223 408 218 271 41
1.045 0.998 0.999 1.006 1.019 1.013 1.007
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
157 41 24 10 23 279 104
0.978 1.007 1.050 1.004 1.008 1.035 1.002
CHIEF JO BONNVIL2 DALLES 3 DALLES21 DALLES22 JOHN DAY MSASVC
157 71 -112 -85 -59 142 7777777
0.978 1.002 0.969 0.956 0.954 0.983 7777777777
.....SLACK BUS AND AGC BUSES (MW).....
BRIDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
207 1022 2100 537 537 1029 5225
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1684 3622 528 1721 1451 1441 7194 3276 8419
Q 577 1142 248 425 400 501 1827 990 3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P=10448 Q= 3292 P=20918 Q= 6109
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1913 432 0 298 100 278 3038 700 9495
Q 319 89 0 172 50 130 616 204 1094
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 3021 Q= 760 P= 6759 Q= 820
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 7427 WEST ORE & WA=14159
.....ZONF REAL AND REACTIVE LOSSES (MW,MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
P 280 87 2 22 10 14 178 108 604 381
Q 2447 493 12 156 42 177 1152 -346 -5007 548
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 415 Q= 3328 P= 701 Q= 4134
.....ZONE SHUNT REACTIVE (MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
3189 915 95 548 0 400 2119 682 -2420 543
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 5146 QSHUNT= 7947

```

J93765 OUTAGE AFTER DIST VOLTAGE REGS ADJUST, LDC'S AT BCH BRIDGE R & MICA

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
958	0.941	0.935	0.950	1.015	0.941
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.010	1.009	1.020	1.020	1.022	1.017
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.031	0.940	0.923	0.877	0.859	0.884
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
0.884	0.904	0.880	0.865	0.907	0.900
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
0.900	0.895	0.953	0.940	0.930	0.921
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
0.915	0.975	0.988	0.910	0.862	0.864
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.930	0.827	0.895	0.869	0.940	0.833
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.900	0.824	0.890	0.840	0.909	0.818
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.884	0.825	0.892	0.823	0.890	0.829
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.896	0.919	0.994	0.999	0.879	0.951
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1
0.945	0.835	0.892	0.824	0.843	0.911
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.
0.800	0.865	0.825	0.892	0.848	0.917

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	526	377	408	560	400	85
1.045	0.998	0.999	0.972	1.016	0.998	1.003
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	85	50	15	26	537	178
0.942	1.003	1.037	0.938	0.933	1.052	1.002
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	MSASVC
157	128	-31	-43	-32	332	0
0.942	1.002	0.969	0.956	0.954	0.983	0

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
243	1013	2100	535	535	1027	5209

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

NA	AA	AB	SC	SP	TC	NB	NC	17
P 1700	3561	527	1536	1422	1414	7326	3324	8419
Q 584	1115	247	354	390	489	1865	1008	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)								
P=10159	Q= 3178			P=20810	Q= 6050			

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

NA	AA	AB	SC	SP	TC	NB	NC	17
P 1913	432	0	298	100	278	3038	700	9531
Q 756	132	0	338	50	138	984	278	2179
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)								
P= 3021	Q= 1413			P= 6759	Q= 1262			

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND=	WEST ORE & WA=
7138	14051

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P 307	97	2	25	11	16	197	117	640	402
Q 3155	620	16	210	55	218	1484	-90	-4123	1122
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P= 459	Q= 4274			P= 772	Q= 5668				

.....ZONE SHUNT REACTIVE (MVAR).....

NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
2725	763	80	463	0	332	1976	634	-2381	-81
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
QSHUNT= 4364			QSHUNT= 6973						

J93766 BASEDON 765, 1% INCREASE IN CONSTANT R LOAD

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500	COULEE500
.954	0.936	0.929	0.944	1.010	0.935	1.052
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500	
1.005	1.004	1.015	1.016	1.018	1.014	
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230	
1.027	0.936	0.918	0.871	0.853	0.878	
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230	
0.879	0.899	0.874	0.859	0.901	0.894	
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230	
0.894	0.889	0.947	0.934	0.923	0.914	
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115	
0.909	0.970	0.983	0.904	0.857	0.858	
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115	
0.923	0.821	0.888	0.864	0.934	0.827	
EPFOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115	
0.894	0.818	0.884	0.835	0.903	0.812	
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLBOS115	
0.878	0.820	0.886	0.817	0.884	0.823	
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69	
0.890	0.912	0.986	0.992	0.872	0.943	
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1	
0.939	0.829	0.886	0.819	0.836	0.904	
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.	
0.794	0.859	0.819	0.886	0.843	0.911	

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	541	387	408	560	400	85
1.045	0.998	0.999	0.970	1.011	0.994	0.999
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	85	50	15	26	553	186
0.940	0.999	1.032	0.933	0.927	1.052	1.002
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	
157	134	-25	-40	-30	346	
0.940	1.002	0.969	0.956	0.954	0.983	

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5 TOTAL PNW
247	997	2098	533	533	1022 5184

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	
P	1697	3547	526	1529	1417	1409	7329	3326	8419
Q	579	1100	247	348	385	484	1865	1008	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	10124	Q=	3143	P=	20779	Q=	6016		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	
P	1913	432	0	298	100	278	3038	700	9535
Q	760	132	0	344	50	138	1010	280	2262
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	3021	Q=	1424	P=	6759	Q=	1290		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 7103 WEST ORE & WA=14020

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	308	97	2	25	12	16	198	118	644	403
Q	3191	626	17	216	55	220	1512	-69	-4044	1151
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	460	Q=	4325	P=	777	Q=	5768			

.....BUS SHUNT REACTIVE (MVAR).....

RAVER=	571	USED	0	UNSCHEDULED
MONROE=	288	USED	0	UNSCHEDULED

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	2691	753	79	457	0	328	1960	629	-2376	-80
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	4308	QSHUNT=	6898							

J93037 BASE CASE FOR NORMAL SYSTEM PEAK, ONE RAVER CAP BANK IN RESERVE

```

.....BUS VOLTAGES (PER UNIT).....
CUSTER500 MONROE500 MAPLEVL500 RAVER500 PAUL500 TACOMA500 COULEE500
  047      1.069      1.069      1.083      1.086      1.075      1.090
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 OSTRANDER500
  1.087      1.067      1.082      1.077      1.076      1.069
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
  1.081      1.037      1.033      0.996      0.989      1.018
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
  1.014      1.037      1.012      1.001      1.044      1.039
TALBOTS230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
  1.039      1.029      1.043      1.039      1.044      1.039
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHMSH115 SNOKING115
  1.023      1.034      1.035      1.026      1.000      0.997
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
  1.004      0.960      0.960      1.021      1.021      0.982
EPTOR R115 LANGLY115 LANGL R115 NBOTHEL115 NBOTH R115 CAMANO115
  0.982      0.956      0.956      0.981      0.981      0.958
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
  0.958      0.965      0.965      0.962      0.962      0.962
HYLE R115 PORTAN69 PORTARR69 PAPN1 R69 SAPPHO69 SAPPHO R69
  0.962      1.040      1.040      1.040      1.006      1.006
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
  1.018      0.967      0.938      0.938      0.996      0.996
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
  0.943      0.943      0.938      0.938      0.992      0.992
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
  236      36      24      388      13      173      9
  1.045      0.998      0.999      1.047      1.019      1.013      1.007
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
  157      9      10      3      5      91      72
  1.019      1.007      1.050      1.004      1.008      1.014      1.002
CHIEF JO BONNVIL2 DALLES 3 DALLES21 DALLES22 JOHN DAY
  157      47      -160      -109      -76      21
  1.019      1.002      0.969      0.956      0.954      0.983
.....SLACK BUS AND AGC BUSES (MW).....
BRIDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
  186      1497      2140      600      600      1180      6017
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
  NA      AA      AB      SC      SP      TC      NB      NC      17
P 1764 3888 534 1866 1567 1527 7331 3328 8419
Q 613 1255 253 479 440 539 1866 1009 3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P=11147 Q= 3578 P=21805 Q= 6453
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
  NA      AA      AB      SC      SP      TC      NB      NC      17
P 1913 432 0 298 100 278 3038 700 9474
Q 64 36 0 48 42 98 417 152 396
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 3021 Q= 288 P= 6759 Q= 569
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 8126 WEST ORE & WA=15046
.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....
  NA      AA      AB      SC      SP      TC      NB      NC      17 ND+NE+NF+NG+NH
P 257 80 2 23 10 14 167 105 583 329
Q 1358 436 10 155 40 188 937 -469 -5506 -417
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 387 Q= 2187 P= 659 Q= 2654
.....BUS SHUNT REACTIVE (MVAR).....
RAVER= 751 USED 0 UNSCHEDULED
MONROE= 376 USED 0 UNSCHEDULED
.....ZONE SHUNT REACTIVE (MVAR).....
  NA      AA      AB      SC      SP      TC      NB      NC      17 ND+NE+NF+NG+NH
3523 1005 102 613 0 443 2179 697 -2176 578
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 5686 QSHUNT= 8562

```

J93923 BASEDON J93765, MSC 590MVAR @ MONROE AND 781MVAR @ RAVER TO GET
SYSTEM OUT OF VOLTAGE INSTABILITY STATE FOLLOWING DIST REG ACTION

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500	COULEE500
1.019	1.021	1.010	1.027	1.046	1.015	1.057
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500	
1.042	1.041	1.043	1.033	1.031	1.024	
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230	
1.037	1.000	0.982	0.930	0.911	0.936	
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230	
0.938	0.968	0.936	0.924	0.976	0.967	
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230	
0.967	0.962	0.985	0.973	0.965	0.957	
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115	
0.949	0.999	1.006	0.962	0.915	0.919	
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115	
0.998	0.879	0.950	0.911	0.985	0.897	
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115	
0.879	0.875	0.946	0.893	0.965	0.870	
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115	
0.940	0.877	0.948	0.875	0.946	0.893	
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69	
0.965	0.956	1.033	1.039	0.915	0.990	
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1	
1.018	0.899	0.945	0.874	0.913	0.986	
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.	
0.860	0.931	0.874	0.945	0.889	0.961	

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	466	334	408	335	392	56
1.045	0.998	0.999	0.981	1.019	1.013	1.007
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	56	33	15	26	205	163
0.947	1.007	1.050	0.999	0.995	1.027	1.002
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	
157	116	-45	-50	-36	308	
0.947	1.002	0.969	0.956	0.954	0.983	

.....SLACK BUS AND AGC BUSES (MW).....

IDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
201	1664	2154	622	622	1199	6261

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1818	3902	535	1695	1546	1539	7422	3345	8419
Q	638	1260	254	411	433	544	1894	1015	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	11035	Q=	3540	P=	21802	Q=	6449		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1913	432	0	298	100	278	3038	700	9489
Q	477	108	0	226	50	138	914	276	985
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	3021	Q=	999	P=	6759	Q=	1189		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 8014 WEST ORE & WA=15043

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	340	102	2	23	12	16	201	119	598	418
Q	3497	640	14	181	54	222	1522	-77	-5313	1466
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	496	Q=	4609	P=	815	Q=	6054			

.....BUS SHUNT REACTIVE (MVAR).....

RAVER=	1500	USED	0	UNSCHEDULED
MONROE=	959	USED	0	UNSCHEDULED

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	4543	864	91	532	0	184	2016	639	-2486	-65
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	6414	QSHUNT=	9069							

J93924 BASEDON J93923, DIST VOLTAGE REGULATORS ADJUST AFTER MONROE & RAVER MSC

.....BUS VOLTAGES (PER UNIT).....

MASTER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500	COULEE500
1.070	1.095	1.092	1.108	1.090	1.099	1.075
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500	
1.090	1.090	1.081	1.066	1.062	1.053	
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230	
1.065	1.058	1.050	1.005	0.992	1.018	
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230	
1.018	1.048	1.019	1.010	1.061	1.055	
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230	
1.055	1.048	1.044	1.040	1.045	1.039	
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115	
1.024	1.035	1.033	1.035	1.001	1.004	
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115	
1.007	0.971	0.959	0.992	1.023	1.001	
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115	
0.982	0.967	0.955	0.982	0.982	0.960	
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115	
0.960	0.966	0.966	0.964	0.964	0.979	
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69	
0.960	1.041	1.041	1.041	1.006	1.006	
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1	
1.018	0.984	0.936	0.948	1.014	0.996	
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.	
0.958	0.941	0.948	0.936	0.973	0.991	

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	234	167	408	-18	198	7
1.045	0.998	0.999	1.019	1.019	1.013	1.007
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	7	6	0	-2	-53	101
0.987	1.007	1.050	1.004	1.008	0.998	1.002
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	
157	69	-113	-85	-60	143	
0.987	1.002	0.969	0.956	0.954	0.983	

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
180	1628	2151	617	617	1188	6202

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1766	3890	534	1897	1570	1525	7325	3329	8419
Q	614	1255	253	492	441	538	1864	1009	3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+Nb+NC)									
P=	11181	Q=	3592	P=	21835	Q=	6465		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1913	432	0	298	100	278	3038	700	9468
Q	29	22	0	41	41	67	521	211	31
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+Nb+NC)									
P=	3021	Q=	201	P=	6759	Q=	732		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 8160 WEST ORE & WA=15076

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	310	89	2	22	10	14	184	112	577	399
Q	2704	491	10	135	40	174	1228	-283	-5941	899
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+Nb+NC)										
P=	447	Q=	3555	P=	743	Q=	4500			

.....BUS SHUNT REACTIVE (MVAR).....

RAVER=	1745	USED	0	UNSCHEDULED
MONROE=	1104	USED	0	UNSCHEDULED

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	5288	1028	106	627	0	458	2135	677	-2526	-36
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+Nb+NC)										
QSHUNT=	7507	QSHUNT=10319								

J93928 BASEDON 765, ADJUST MAPLE VL TX BY ONE TAP
FROM 534.38 TO 531.25

```

.....BUS VOLTAGES (PER UNIT).....
/STER500 MONROE500 MAPLEVL500 RAVER500 PAUL500 TACOMA500 COULEE500
0.958 0.940 0.932 0.949 1.014 0.939 1.052
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 OSTRNDER500
1.009 1.008 1.018 1.019 1.020 1.016
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
1.029 0.940 0.923 0.876 0.858 0.883
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
0.884 0.904 0.880 0.865 0.907 0.900
TALBOTS230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
0.900 0.894 0.951 0.938 0.928 0.919
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHMSH115 SNOKING115
0.914 0.974 0.986 0.909 0.862 0.864
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
0.930 0.827 0.894 0.868 0.939 0.833
EPTOR R115 LANGLEY115 LANGL R115 NBOTHEL115 NBOTH R115 CAMANO115
0.900 0.823 0.889 0.840 0.908 0.817
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
0.884 0.825 0.892 0.822 0.889 0.828
HYLE R115 PORTANG69 PORTARR69 PAPN1 R69 SAPPHO69 SAPPHO R69
0.896 0.918 0.992 0.998 0.878 0.949
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
0.945 0.834 0.891 0.824 0.842 0.910
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
0.800 0.865 0.824 0.891 0.847 0.916
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
403 531 381 408 560 400 85
1.045 0.998 0.999 0.971 1.015 0.996 1.003
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
157 85 50 15 26 539 181
0.941 1.003 1.037 0.938 0.932 1.052 1.002
CHIEF JO BONNVIL2 DALLES 3 DALLES21 DALLES22 JOHN DAY
157 130 -29 -42 -31 338
0.941 1.002 0.969 0.956 0.954 0.983
.....SLACK BUS AND AGC BUSES (MW).....
IDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
243 1015 2100 536 536 1027 5213
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1697 3558 526 1536 1421 1412 7330 3330 8419
Q 583 1113 247 354 389 488 1866 1010 3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P=10151 Q= 3174 P=20811 Q= 6050
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1913 432 0 298 100 278 3038 700 9531
Q 757 132 0 338 50 138 994 279 2187
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 3021 Q= 1415 P= 6759 Q= 1273
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 7130 WEST ORE & WA=14052
.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
P 308 97 2 25 11 16 198 118 640 403
Q 3165 621 16 210 55 218 1497 -75 -4123 1134
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 459 Q= 4285 P= 775 Q= 5707
.....BUS SHUNT REACTIVE (MVAR).....
RAVER= 576 USED 0 UNSCHEDULED
MONROE= 290 USED 0 UNSCHEDULED
.....ZONE SHUNT REACTIVE (MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
2719 763 80 463 0 331 1969 631 -2380 -78
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 4356 QSHUNT= 6957

```

J93929 BASEDON J93765, EHV LTC'S ACTIVE, MSC 590MVAR @ MONROE AND
@ RAVER

```

.....BUS VOLTAGES (PER UNIT).....
STER500 MONROE500 MAPLEVL500 RAVER500 PAUL500 TACOMA500 COULEE500
1.056 1.069 1.061 1.079 1.077 1.069 1.071
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 OSTRNDER500
1.076 1.076 1.071 1.059 1.056 1.048
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
1.060 1.044 1.036 0.993 0.981 1.008
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
1.007 1.040 1.007 0.997 1.041 1.039
TALBOTS230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
1.039 1.030 1.038 1.034 1.038 1.032
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHMSH115 SNOKING115
1.017 1.029 1.027 1.023 0.990 0.992
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
1.002 0.955 0.961 0.974 1.022 0.980
EPTOR R115 LANGLEY115 LANGL R115 NBOTHEL115 NBOTH R115 CAMANO115
0.980 0.952 0.957 0.970 0.982 0.947
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
0.959 0.954 0.966 0.952 0.964 0.962
HYLE R115 PORTAN69 PORTARR69 PAPN1 R69 SAPPHO69 SAPPHO R69
0.962 1.033 1.040 1.040 0.999 1.005
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
1.018 0.967 0.936 0.935 0.994 0.996
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
0.938 0.944 0.936 0.936 0.959 0.989
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
403 291 208 408 85 240 14
1.045 0.998 0.999 1.009 1.019 1.013 1.007
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
157 14 11 3 5 12 113
0.978 1.007 1.050 1.004 1.008 1.005 1.002
CHIEF JO BONNVIL2 DALLES 3 DALLES21 DALLES22 JOHN DAY
157 78 -101 -79 -55 174
0.978 1.002 0.969 0.956 0.954 0.983
.....SLACK BUS AND AGC BUSES (MW).....
IDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
184 1603 2149 614 614 1199 6179
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1764 3889 534 1861 1571 1526 7325 3329 8419
Q 613 1254 253 477 441 538 1864 1009 3340
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P=11144 Q= 3577 P=21799 Q= 6451
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1913 432 0 298 100 278 3038 700 9472
Q 148 41 0 67 50 98 601 230 292
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 3021 Q= 403 P= 6759 Q= 831
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 8123 WEST ORE & WA=15040
.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
P 314 92 2 22 11 14 186 113 581 401
Q 2860 516 11 141 42 181 1273 -249 -5804 985
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 455 Q= 3750 P= 754 Q= 4774
.....BUS SHUNT REACTIVE (MVAR).....
RAVER= 1466 USED 0 UNSCHEDULED
MONROE= 1052 USED 0 UNSCHEDULED
.....ZONE SHUNT REACTIVE (MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
4898 998 103 609 0 442 2112 671 -2520 -42
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 7051 QSHUNT= 9833

```

J93EH1021 COLD WEATHER BASE, BOTH CENTRALIA UNITS OPERATING

```

.....BUS VOLTAGES (PER UNIT).....
STER500 MONROE500 MAPLEVL500 RAVER500 PAUL500 TACOMA500
043 1.049 1.051 1.070 1.080 1.049
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 O3TRNDER500
1.081 1.078 1.075 1.065 1.066 1.061
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
1.082 1.035 1.033 1.002 0.986 1.019
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
1.013 1.048 1.009 0.995 1.036 1.031
TALBOTS230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
1.031 1.029 1.041 1.040 1.041 1.036
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHMSH115 SNOKING115
1.043 1.031 1.034 1.025 0.998 1.005
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
1.001 0.972 0.972 1.006 1.006 0.976
EPTOR R115 LANGLEY115 LANGL R115 NBOTHEL115 NBOTH R115 CAMANO115
0.976 0.968 0.967 0.976 0.976 0.953
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
0.953 0.958 0.958 0.959 0.959 0.961
HYLE R115 PORTAN69 PORTARR69 PAPN1 R69 SAPPHO69 SAPPHO R69
0.961 1.040 1.040 1.040 0.995 0.994
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
1.008 0.964 0.935 0.935 0.997 0.997
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
0.957 0.957 0.935 0.935 0.988 0.988
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
264 190 126 408 91 297 10
1.045 1.009 1.009 1.044 1.022 1.028 1.007
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
157 10 10 6 10 93 106
1.014 1.007 1.050 1.011 1.012 1.014 1.009
CHIEF JO BONNVIL2 DALLS 3 DALLS21 DALLS22 JOHN DAY MSASVC
157 69 94 64 44 193 7777777
1.014 1.008 1.006 1.006 1.006 0.995 7777777777
.....SLACK BUS AND AGC BUSES (MW).....
BRIDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
224 1503 2140 600 600 1180 6023
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1919 4217 534 2032 1777 1750 8149 3629 8556
Q 652 1361 253 522 500 615 2037 1096 3380
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P=12229 Q= 3904 P=24007 Q= 7037
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1913 1047 0 298 100 278 3038 700 9632
Q 162 176 0 52 44 113 646 154 521
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 3636 Q= 546 P= 7374 Q= 800
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 8593 WEST ORE & WA=16633
.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
P 285 89 1 27 13 18 214 130 604 340
Q 1893 544 11 232 53 259 1610 -65 -5240 -373
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 433 Q= 2992 P= 776 Q= 4537
.....ZONE SHUNT REACTIVE (MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
3989 1004 103 702 0 441 2543 1206 -1935 -672
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 6239 QSHUNT= 9988

```

J93EH1023 - BASE WITH ONE CENTRALIA UNIT DOWN

```

.....BUS VOLTAGES (PER UNIT).....
CUSTER500 MONROE500 MAPLEVL500 RAVER500 PAUL500 TACOMA500 COULEE500
040 1.044 1.042 1.062 1.080 1.036 1.090
OLYMPIA500 SATSOP500 ALLSTON500 KEELER500 PEARL500 OSTRANDER500
1.081 1.078 1.073 1.058 1.057 1.051
MARION500 CUSTER230 BELLNGM230 SEDRO230 MURRAY230 SNOHOMSH230
1.075 1.044 1.041 1.004 0.986 1.017
BOTHELL230 MONROE230 SNOKING230 SAMMAMSH230 COVINTN230 TALBOTN230
1.011 1.045 1.008 0.994 1.034 1.032
TALBOTN230 TACOMA230 OLYMPIA230 SHELTON230 FAIRMNT230 PORTANG 230
1.031 1.033 1.041 1.040 1.041 1.036
KITSAP230 CHEHALS230 LONGVW230 SEDRO115 SNOHOMSH115 SNOKING115
1.042 1.031 1.033 1.027 0.997 1.003
AMESL R115 BROOK H115 BRK H R115 CLE ELM115 CLE E R115 E PT ORC115
1.001 0.973 0.973 1.002 1.002 0.977
EPTOR R115 LANGLEY115 LANGLE R115 NBOTHEL115 NBOTH R115 CAMANO115
0.977 0.969 0.969 0.975 0.974 0.952
CAMNO R115 MEADWD115 MEADW R115 NSTAN115 NSTA R115 HYLEBOS115
0.952 0.956 0.956 0.957 0.957 0.963
HYLE R115 PORTAN69 PORTARR69 PAPN1 R69 SAPPHO69 SAPPHO R69
0.963 1.040 1.040 1.040 0.995 0.994
SUR LK12.5 SUR LK115 ANAC R57.5 ANACPUMP57 BOE AUB313.1 B AUB3 R13.1
1.012 0.967 0.936 0.936 0.998 0.998
CLAY C57.5 CLAYCK R57 FIR57.5 FIR R57.5 SKYKOMSH115 SKYKMH R115.
0.958 0.958 0.937 0.937 0.985 0.985
.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....
COULEE2 COULEE51 COULEE52 CHIEF J5 CENTRALA20 TROJAN22 ROSS42
277 288 192 408 112 308 11
1.045 1.016 1.015 1.042 1.038 1.029 1.008
CHIEF J2 ROSS44 UP BAKER CUSHMN1 CUSHMN2 BURRARD BONN PH2
157 11 9 5 8 93 108
1.011 1.008 1.050 1.009 1.011 1.014 1.010
CHIEF JO BONNVIL2 DALLES 3 DALLES21 DALLES22 JOHN DAY
157 70 -5 -3 -2 95
1.011 1.008 0.998 0.994 0.993 0.988
.....SLACK BUS AND AGC BUSES (MW).....
BRIDGE2 COULEE 2 JOHN DAY CHIEF J2 CHIEF JO CHIEF J5 TOTAL PNW
224 1497 2140 600 600 1180 6017
.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1890 4217 534 2032 1777 1750 8145 3628 8556
Q 628 1361 253 522 500 615 2036 1095 3380
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P=12200 Q= 3880 P=23974 Q= 7012
.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....
NA AA AB SC SP TC NB NC 17
P 1244 1047 0 298 100 278 3038 700 9632
Q 184 166 0 57 46 110 669 156 531
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 2967 Q= 564 P= 6705 Q= 825
.....NET MW LOAD (LOAD - GENERATION).....
PUGET SOUND= 9233 WEST ORE & WA=17269
.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
P 299 90 1 26 13 18 230 133 604 371
Q 2051 552 10 232 54 260 1825 9 -5230 48
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
P= 447 Q= 3158 P= 809 Q= 4993
.....BUS SHUNT REACTIVE (MVAR).....
RAVER= 1073 USED 0 UNSCHEDULED
MONROE= 358 USED 0 UNSCHEDULED
.....ZONE SHUNT REACTIVE (MVAR).....
NA AA AB SC SP TC NB NC 17 ND+NE+NF+NG+NH
3971 1005 103 702 0 444 2520 1204 -1889 774
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)
QSHUNT= 6225 QSHUNT= 9950

```

J93EH1038 POST TRANSIENT CJ-MONROE OUTAGE BEFORE DIST VOLTAGE REGS ADJUST

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
.027	1.025	1.015	1.033	1.065	1.012
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.065	1.062	1.064	1.057	1.058	1.054
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.077	1.019	1.017	0.983	0.959	0.987
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
0.982	1.018	0.978	0.963	0.999	0.993
TALBOTS230	TACOMA230	OLYMPIA230	SHELLTON230	FAIRMNT230	PORTANG 230
0.993	0.993	1.023	1.022	1.021	1.016
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
1.023	1.020	1.027	1.010	0.967	0.973
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.965	0.963	0.963	0.971	0.971	0.941
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.941	0.959	0.959	0.945	0.945	0.924
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.924	0.927	0.927	0.929	0.929	0.927
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.927	1.019	1.019	1.019	0.974	0.974
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE3 57.5	BOE3 R57.5
0.973	0.931	0.921	0.921	????????????????	????????????????
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	PACCAR57.5	PACCAR R57
0.924	0.924	0.921	0.921	????????????????	????????????????

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
347	327	226	408	213	350	28
1.045	1.009	1.009	1.041	1.022	1.028	1.007
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	28	15	11	22	180	119
1.002	1.007	1.050	1.011	1.012	1.024	1.009
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	COWLITZ
157	79	111	73	50	231	0
1.002	1.008	1.006	1.006	1.006	0.995	0.941

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
241	1188	2114	558	558	1080	5498

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1873	4040	530	1925	1698	1680	8082	3610	8556
Q	632	1287	250	483	473	584	2018	1089	3380
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	11746	Q=	3710	P=	23438	Q=	6817		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1913	1047	0	298	100	278	3038	700	9650
Q	314	234	0	123	50	130	742	179	888
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	3636	Q=	851	P=	7374	Q=	921		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 8110 WEST ORE & WA=16064

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	307	101	2	29	13	18	217	130	621	345
Q	2536	616	12	261	54	258	1676	-28	-4934	-247
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	468	Q=	3737	P=	815	Q=	5385			

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	3763	950	99	654	0	412	2511	1197	-2198	-679
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	5879	QSHUNT=	9587							

J93EH1039 POST TRANSIENT OUTAGE AFTER DIST VOLTAGE REGS ADJUST

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
0.001	0.986	0.971	0.993	1.038	0.969
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.036	1.032	1.039	1.033	1.035	1.033
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.056	0.990	0.984	0.948	0.916	0.942
BOITHEL1230	MONROE230	SNOKING230	SAMMAMSH230	COVININ230	TALBOTIN230
0.938	0.975	0.932	0.915	0.952	0.946
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
0.946	0.945	0.987	0.979	0.968	0.960
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
0.976	0.995	1.004	0.980	0.919	0.926
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.967	0.943	0.955	0.929	0.987	0.884
EPTOR R115	LANGLY115	LANGL R115	NBOITHEL115	NBOTH R115	CAMANO115
0.901	0.939	0.939	0.895	0.963	0.872
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.921	0.877	0.916	0.878	0.933	0.877
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.942	0.961	0.961	1.039	0.912	0.957
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE3 57.5	BOE3 R57.5
0.920	0.880	0.935	0.890	????????????????	????????
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	PACCAR57.5	PACCAR R57
0.870	0.924	0.891	0.907	????????????????	????????

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	502	351	408	430	400	55
1.045	1.009	1.009	1.023	1.022	1.013	1.007
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	55	27	15	26	332	168
0.983	1.007	1.050	0.976	0.971	1.041	1.009
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	COWLITZ
157	116	160	98	67	344	0
0.983	1.008	1.006	1.006	1.006	0.995	0.889

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
258	1220	2116	562	562	1090	5551

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1877	4056	530	1789	1713	1689	8147	3632	8556
Q	632	1291	250	434	477	589	2037	1097	3380
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	11653	Q=	3674	P=	23432	Q=	6808		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1913	1047	0	298	100	278	3038	700	9666
Q	594	298	0	224	50	138	949	258	1428
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	3636	Q=	1304	P=	7374	Q=	1207		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 8017 WEST ORE & WA=16058

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	328	109	2	29	14	20	229	136	638	353
Q	3071	709	13	278	64	298	1896	131	-4514	40
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	501	Q=	4433	P=	867	Q=	6460			

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	3451	862	92	594	0	369	2403	1145	-2176	-683
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	5368	QSHUNT=	8917							

J93EH1040 OUTAGE AFTER 5% CONSTANT R INCREASE, SIMULATING THERMOSTATS

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
0.987	0.968	0.950	0.973	1.025	0.948
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.021	1.017	1.026	1.021	1.023	1.021
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.044	0.976	0.967	0.929	0.896	0.921
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
0.917	0.954	0.911	0.894	0.930	0.923
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
0.923	0.923	0.970	0.960	0.947	0.938
KITGAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
0.955	0.983	0.992	0.962	0.897	0.904
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.942	0.925	0.936	0.907	0.964	0.861
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.877	0.921	0.921	0.873	0.939	0.850
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.898	0.856	0.893	0.856	0.909	0.855
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.919	0.938	0.938	1.020	0.888	0.932
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE3 57.5	BOE3 R57.5
0.896	0.859	0.927	0.872	????????????????	????????????
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	PACCAR57.5	PACCAR R57
0.847	0.900	0.873	0.889	????????????????	????????????

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	561	427	408	536	400	68
1.045	1.006	1.009	1.013	1.022	1.001	1.007
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	68	33	15	26	416	193
0.972	1.007	1.050	0.954	0.949	1.049	1.009
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	COWLITZ
157	136	186	112	76	404	0
0.972	1.008	1.006	1.006	1.006	0.995	0.868

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
268	1221	2117	562	562	1091	5554

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P 1887	4056	528	1771	1704	1678	8152	3626	8556	
Q 615	1242	249	411	458	567	2038	1094	3380	
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=11625	Q= 3541			P=23402	Q= 6674				

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P 1913	1047	0	298	100	278	3038	700	9676	
Q 730	313	0	272	50	138	1030	271	1717	
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P= 3636	Q= 1503			P= 7374	Q= 1301				

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 7989 WEST ORE & WA=16028

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P 339	113	2	31	15	20	236	139	648	358	
Q 3360	752	14	310	68	311	2005	203	-4271	207	
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P= 520	Q= 4816			P= 894	Q= 7024					

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
3309	824	88	564	0	351	2346	1117	-2163	-687	
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT= 5137	QSHUNT= 8600									

J93EH1056 TROJAN OUTAGE, POST TRANSIENT BEFORE DIST VOLTAGE REGS CHANGE

.....BUS VOLTAGES (PER UNIT).....

STER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
034	1.032	1.027	1.044	1.055	1.018
OLYMPIA500	SATSOP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
1.056	1.053	1.042	1.029	1.031	1.027
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.055	1.038	1.035	0.997	0.976	1.006
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
1.000	1.033	0.996	0.981	1.017	1.016
TALBOTN230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
1.016	1.015	1.016	1.015	1.014	1.009
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
1.016	1.009	0.996	1.021	0.986	0.991
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.986	0.970	0.970	0.986	0.986	0.962
EPYOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.961	0.965	0.965	0.964	0.964	0.942
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.941	0.946	0.946	0.947	0.947	0.947
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.947	1.012	1.012	1.012	0.967	0.967
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	B AUB3 R13.1
0.994	0.951	0.931	0.931	0.980	0.980
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.
0.943	0.943	0.931	0.931	0.973	0.973

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
360	383	260	408	216	0	18
1.045	1.016	1.015	1.033	1.038		01.008
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	18	12	7	14	127	167
1.003	1.008	1.050	1.009	1.011	1.018	1.010
CHIEF JO	BONNVIL2	DALLES 3	DALLES21	DALLES22	JOHN DAY	MSASVC
157	115	48	25	16	213	0
1.003	1.008	0.998	0.994	0.993	0.988	0

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5 TOTAL PNW
227	1479	2162	605	605	1190 6042

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1846	4122	531	1988	1749	1715	7848	3554	8556
Q	612	1322	251	506	490	600	1950	1068	3380
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	11952	Q=	3781	P=	23354	Q=	6799		

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1255	1055	0	303	100	278	1922	706	9695
Q	347	198	0	84	50	119	564	228	703
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
P=	2991	Q=	797	P=	5619	Q=	792		

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND= 8961 WEST ORE & WA=17735

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	308	90	1	26	13	18	253	136	613	383
Q	2324	562	10	230	54	258	2111	143	-5101	341
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
P=	456	Q=	3439	P=	845	Q=	5692			

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	3846	976	102	682	0	429	2389	1170	-2161	167
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
QSHUNT=	6035	QSHUNT=	9593							

J93EH1057 TROJAN OUTAGE AFTER DIST VOLTAGE REGS CHANGE TAPS

.....BUS VOLTAGES (PER UNIT).....

TER500	MONROE500	MAPLEVL500	RAVER500	PAUL500	TACOMA500
0.983	0.983	0.967	0.983	0.984	0.954
OLYMPIA500	SATROP500	ALLSTON500	KEELER500	PEARL500	OSTRNDER500
0.983	0.978	0.973	0.965	0.971	0.972
MARION500	CUSTER230	BELLNGM230	SEDRO230	MURRAY230	SNOHOMSH230
1.003	1.005	0.998	0.957	0.925	0.950
BOTHELL230	MONROE230	SNOKING230	SAMMAMSH230	COVINTN230	TALBOTN230
0.944	0.978	0.939	0.920	0.950	0.950
TALBOTS230	TACOMA230	OLYMPIA230	SHELTON230	FAIRMNT230	PORTANG 230
0.950	0.945	0.939	0.929	0.915	0.907
KITSAP230	CHEHALS230	LONGVW230	SEDRO115	SNOHMSH115	SNOKING115
0.925	0.944	0.926	0.988	0.928	0.932
AMESL R115	BROOK H115	BRK H R115	CLE ELM115	CLE E R115	E PT ORC115
0.971	0.949	0.960	0.927	0.985	0.886
EPTOR R115	LANGLY115	LANGL R115	NBOTH115	NBOTH R115	CAMANO115
0.902	0.945	0.945	0.904	0.972	0.881
CAMNO R115	MEADWD115	MEADW R115	NSTAN115	NSTA R115	HYLEBOS115
0.930	0.886	0.925	0.887	0.942	0.877
HYLE R115	PORTAN69	PORTARR69	PAPN1 R69	SAPPHO69	SAPPHO R69
0.943	0.907	0.963	0.986	0.858	0.901
SUR LK12.5	SUR LK115	ANAC R57.5	ANACPUMP57	BOE AUB313.1	R AUB3 R13.1
0.973	0.880	0.938	0.898	0.901	0.957
CLAY C57.5	CLAYCK R57	FIR57.5	FIR R57.5	SKYKOMSH115	SKYKMH R115.
0.867	0.921	0.898	0.915	0.916	0.956

.....GENERATOR REACTIVE (MVAR & PER UNIT VOLTAGE).....

COULEE2	COULEE51	COULEE52	CHIEF J5	CENTRALA20	TROJAN22	ROSS42
403	561	483	408	280	0	51
1.045	1.007	1.015	1.002	0.986		01.008
CHIEF J2	ROSS44	UP BAKER	CUSHMN1	CUSHMN2	BURRARD	BONN PH2
157	51	24	15	26	296	242
0.973	1.008	1.050	0.975	0.971	1.037	0.986
CHIEF JO	BONNVIL2	DALLS 3	DALLS21	DALLS22	JOHN DAY	MSASVC
157	191	167	86	57	465	0
0.973	0.989	0.998	0.994	0.993	0.988	0

.....SLACK BUS AND AGC BUSES (MW).....

BRIDGE2	COULEE 2	JOHN DAY	CHIEF J2	CHIEF JO	CHIEF J5	TOTAL PNW
186	1417	2162	605	605	1190	5979

.....ZONE REAL AND REACTIVE LOADS (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1787	4016	527	1803	1735	1681	7814	3531	8556
Q	589	1276	248	439	485	586	1938	1059	3380
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
	P=11550	Q=3624			P=22895	Q=6621			

.....ZONE REAL AND REACTIVE GENERATION (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17
P	1255	1055	0	303	100	278	1922	706	9654
Q	490	287	0	210	50	138	812	292	1285
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)									
	P=2991	Q=1175			P=5619	Q=1104			

.....NET MW LOAD (LOAD - GENERATION).....

PUGET SOUND=	8559	WEST ORE & WA=	17276
--------------	------	----------------	-------

.....ZONE REAL AND REACTIVE LOSSES (MW,MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
P	326	97	1	27	14	20	277	145	625	389
Q	2956	653	12	246	64	296	2553	432	-4698	752
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
	P=484	Q=4227			P=906	Q=7212				

.....ZONE SHUNT REACTIVE (MVAR).....

	NA	AA	AB	SC	SP	TC	NB	NC	17	ND+NE+NF+NG+NH
	3383	852	92	600	0	368	2099	1046	-2141	136
SUM PUGET SOUND (NA+AA+AB+SC+SP+TC) WEST ORE & WA (NA+AA+AB+SC+SP+TC+NB+NC)										
	QSHUNT=	5296			QSHUNT=	8441				

LOSSES

BPA= 847.55
 PMW= 975.57
 SYSTEM= 3398.46

SEATTLE AREA - ABOVE 230 KV

J9145 12/ 3/90 PF V6010
 PSRGLC

LOSSES

BPA= 681.15

PNW= 1015.43

SYSTEM= 3436.67

J9163
PSRGLC

12/27/90 PF V6011

LOSSES
 BPA= 799.99
 PNW= 1177.35
 SYSTEM= 3656.37

J93928 1/31/91 PF V6011
 PSRGLC

LOSSES

BPA= 802.14
 PMW= 1155.02
 SYSTEM= 3573.55

SEATTLE AREA - ABOVE 230 KV

J93929 2/ 8/91 PF V6011
 PSRGLC

.....
APPENDIX 1

Development of the PSAERP "Superbases"
with enhanced load and voltage regulating models
.....

The decision to develop the "superbases" was made in the Fall of 1989. Two key reasons were involved:

(1) Uncertainty from PSAERP Technical Studies Team members that a Puget Sound area voltage stability problem really existed. Some members believed that detailed modeling could potentially show a much less severe problem existed. The near term winter operating plans required uneconomical generation dispatch from combustion turbines. If no problem actually existed, the uneconomical CT operation would not be needed.

(2) recognition that a detailed model could potentially provide insight into the problem, improve the accuracy in reactive additions, learn more about the systems of other utilities, and establish credibility. We recognized that the detailed case might provide nothing new. Less detailed cases clearly showed that the problem was due to the cross mountain main grid lines and, to a lesser extent, the local 230kV system. However, we would never know unless we devoted the resources and went through the exercise.

The utilities committed resources to research and share their system data. BPA created a comprehensive questionnaire. The utilities responded with detailed information on load composition, distribution voltage regulating transformers, miscellaneous voltage controls, and generator data. The Puget Sound Area helped Transmission Planning in obtain similar information from other BPA customers. The BPA Power Forecasting Branch devoted very important resources to research load component information from conservation research (End-Use Load and Consumer Assessment Program or ELCAP). The total load magnitudes for each utility were developed by the PSAERP Load Forecasting Team.

The EPRI LOADSYN program was applied to obtain load models. The program used load composition and component data to model loads for powerflow and transient stability application (constant impedance, constant current, and constant power). Distribution voltage regulating transformer tap setting and tap range were modeled from survey results. Load and voltage regulation models were expected to provide important study results.

bpa65::disk15:[eofcglc]porter.memo

Data for 1993
CLASS MIX

Percent of Utility Load

	PUGET		SEATTLE		SNODHOMISH		TACOMA		NGN	
	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal
Residential	57.9	57.7	51.1	51.1	63.4	63.2	43.3	43.3	68.4	68.4
Commercial	29.8	28.6	37.9	36.5	26.2	25.2	27.3	27.3	13.6	13.6
Heavy Ind.	12.3	13.7	6.9	7.8	10.4	11.6	29.4	29.4	17.9	17.9
Steel Mill	0.0	0.0	4.2	4.7	0.0	0.0	0.0	0.0	0.0	0.0
Power Plant Aux.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ag. Pumping	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Primary Alum.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

RESIDENTIAL COMPOSITION

	PUGET		SEATTLE		SNODHOMISH		PIERCE		NGN	
	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal
Resistance Heat	58.4	48.4	54.5	44.3	61.4	52.0	58.6	48.9	48.9	48.9
Heat Pump	4.2	4.2	5.1	5.1	5.2	5.2	4.9	4.9	4.9	4.9
Furnace Fan	1.0	0.8	0.7	0.6	0.9	0.8	0.9	0.8	0.8	0.8
Air Conditioning	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL HEAT	63.6	53.4	60.3	50.0	67.5	58.1	64.4	54.6	54.6	54.6

	PUGET		SEATTLE		SNODHOMISH		PIERCE		NGN	
	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal
Water Heat	15.8	23.1	17.1	24.6	11.9	17.9	14.2	20.9	20.9	20.9
Range	4.7	5.4	1.1	1.2	2.9	3.3	2.9	3.4	3.4	3.4
Refrigeration	8.2	9.4	7.5	8.5	7.5	8.8	7.9	9.0	9.0	9.0
Dishwasher	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Clothes Washer	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dryer	1.2	1.3	1.1	1.2	1.1	1.3	1.1	1.2	1.2	1.2
Incandescent Lights	5.9	6.7	11.9	13.3	8.3	9.7	8.7	9.5	9.5	9.5
Fluorescent Lights	0.6	0.7	1.1	1.2	0.8	0.9	0.8	0.9	0.9	0.9
Television	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL MISCELLANEOUS	20.6	23.5	22.6	25.4	20.6	24.0	21.4	24.5	24.5	24.5

COMMERCIAL COMPOSITION

	PUGET		SEATTLE		OTHER	
	Extreme	Normal	Extreme	Normal	Extreme	Normal
Resistance Heat	44.7	42.7	39.8	37.7	42.1	40.1
Heat Pump	7.7	7.3	7.5	7.1	7.6	7.2
Fan/Ventilation	12.8	12.2	11.8	11.2	12.3	11.7
Air Conditioning	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL HVAC	65.1	62.2	59.1	56.0	62.0	59.0

	PUGET		SEATTLE		OTHER	
	Extreme	Normal	Extreme	Normal	Extreme	Normal
Incandescent Lights	4.0	4.2	4.8	5.0	4.4	4.6
Fluorescent Lights	20.1	21.0	22.8	23.6	21.6	22.4
TOTAL LIGHTS	24.1	25.2	27.7	28.6	26.0	27.0
Refrigeration	2.7	3.6	3.3	4.4	3.0	4.0
Water Heat	6.7	7.5	4.5	5.0	5.8	6.4
Range	1.3	1.5	0.9	1.0	1.2	1.3
Other	0.0	0.0	4.5	5.0	2.0	2.3
TOTAL MISCELLANEOUS	8.1	9.0	9.9	11.0	9.0	10.0

19 July 1990

Attachment 6

**A REVIEW OF
BONNEVILLE POWER ADMINISTRATION
VOLTAGE STABILITY ANALYSIS
AND SYSTEM UPGRADE PLANS
WITH COMMENTS AND RECOMMENDATIONS**

January 29, 1992

PTI Report # R7-92

Harrison K. Clark
Power Technologies, Inc.
Roseville, CA

**A REVIEW OF
BONNEVILLE POWER ADMINISTRATION
VOLTAGE STABILITY ANALYSIS
AND SYSTEM UPGRADE PLANS
WITH COMMENTS AND RECOMMENDATIONS**

Introduction

Planning and operating studies conducted in 1989 and 1990 at the Bonneville Power Administration have demonstrated that under winter peak load conditions, certain system disturbances can leave the Pacific Northwest system in a condition of voltage instability. The studies also show that the voltage stability problem will grow worse through time as the system load peak grows and is served largely from existing hydro generation to the east.

In 1990 BPA engineers examined potential solutions and developed an economical plan to reduce the risk of voltage instability. This report presents the results of my review of that plan.

Information on BPA studies and plans came from discussions with BPA engineers Marvin Landauer and Gordon Comegys and a review of three documents:

- Load and LTC data survey
- Voltage Collapse Report - Final Draft 11/18/91
- Attachment 3: The Reactive Plan

Reactive Plan Summary

The reactive plan is very well conceived. It consists of a new intermediate substation at Naneum, the addition of series compensation, and a combination of switched shunt capacitors and static var systems. Breaking the long lines down into shorter sections reduces the impact of line outages. Series compensation is very effective at improving voltage stability because it effectively shortens the lines. Shunt compensation is also very effective so long as it is not used to excess. The combination of series and shunt compensation is economical and avoids excessive use of shunt compensation.

Reactive Plans - Observations

The chief problem with heavy use of shunt compensation is that as the use increases, the reactive reserve that must be provided grows rapidly, and an increasing share of the total must be in the form of an SVS. The level of shunt compensation planned for the Puget Sound area is high, but is manageable.

The V-Q curve is being used extensively in BPA's analysis of the voltage problems in the 1993-2004 period. This is an appropriate and effective tool. There are, however, some concepts associated with its use that are not discussed in the reports. To ensure that final studies, and future studies (and there will be future studies -- voltage stability problems are a constant battle once they appear) are as effective as possible, I will cover those I feel are particularly important to the problems BPA is facing.

Critical Voltage

The critical voltage is often considered to be the 'bottom' of the V-Q curve. The critical point is at the lowest Q value only when the V-Q curve is tangent to the zero Mvar line at its lowest point as shown in Figure 1. When the V-Q curve is above the zero Mvar line, the critical voltage is the point at which a capacitor characteristic is just tangent to the V-Q curve, and occurs to the right of the

Figure 1

lowest point as shown in Figure 1. These are, in fact, the same point, and differ only in whether or not the critical amount of shunt compensation is included in the system model under test.

V-Q Curve Shape

The V-Q curve shape is heavily system dependent, and may vary from one operating condition to another in the same system. Post-contingency V-Q curve shape may also be different for different disturbances. A sharp V-Q curve like (a) in Figure 2 presents the problem keeping voltages in a narrow range to ensure stability. If voltage is allowed to drop, the reactive demand grows dramatically, making it difficult to restore voltages without load shedding. If the V-Q curve is quite flat in the desired operating

Figure 2

region as shown in (b) of Figure 2, that is, it is more-or-less parallel to the capacitor characteristic, normal load variations will require frequent trimming of the amount of shunt compensation that is on-line to keep voltages in the desired operating range. A flat V-Q curve will also require some banks to be constructed in relatively small sizes, about 100 Mvar for the planned Northwest 500 kV system. There must be sufficient shunt compensation to always provide a stable intersection of the capacitor and system characteristics or an intersection with the 0 Mvar line if the on-line capacitors are all included in the V-Q curve development.

The 'Critical' Voltage Can Be Above The Operating Voltage

The reactive planning and operating strategy outlined in the previous section is not sufficient when the lowest voltage at which a stable intersection can occur is above an acceptable system operating voltage as shown in Figure 3. When this is the case, the system can be operated at the desired voltage by operating to the left of the critical voltage on the V-Q

curve. Operation to the left of the critical voltage is feasible and practical and has been a planned operating condition in some systems. There is just one requirement for operation in this region, and that is that at least one generator, condenser, or SVS be actively regulating voltage. This means it must be operating below its maximum reactive limit.

Figure 3

Comparing the characteristics of generator and SVS regulators with the system steady state V-Q curve would seem to indicate that operation on the left side of the V-Q curve will not be stable. After all, conventional wisdom would seem to indicate that these devices are supposed to provide increased reactive power when voltage falls, while the V-Q curve seems to show that increasing reactive power would drive voltage lower. However, neither is true.

The left side of the steady state V-Q curve is no different from the combination of an induction motor and a shunt capacitor. Dropping the voltage on either will increase the reactive power needed to hold voltage. Generators and SVS can handle this kind of load. A review of the steady state relationships in a voltage regulator on either will show why this is the case. For instance, reducing the voltage setpoint on a generator will reduce field voltage and the terminal voltage, but the terminal voltage fed back to the regulator will tell it

that only a small change in field voltage is needed to cause a large change in voltage. Because flux in the generator is changed a small amount while the terminal voltage drops a large amount, the reactive power delivered is increased.

The stability of voltage controls on generators and SVS also seems questionable when they are faced with the left side of a V-Q curve. The answer here is that the V-Q curve we normally plot is a *steady state* curve, and generator and SVS regulators are dynamic controls that make corrective adjustments, effectively, dozens, or hundreds of times each second. They thus only interact with the system in a dynamic state. In the dynamic state the system V-Q curve is a positive slope as shown in Figure 4.

From the point of view of any one generator or SVS, the dynamic characteristic is a combination of the system short-circuit impedance and the load transient characteristics (i.e., resistance heat load is a resistance, and motors are a voltage behind a transient reactance). All systems have a positive slope transient characteristic as shown in Figure 4.

Figure 4

That operation with voltage regulation from an SVS is stable is most readily explained by recognizing that the SVS rapidly and continuously adjusts admittance in small steps. Assume that the system is operating at the stable operating point shown in Figure 4. The SVS admittance and the system transient characteristic are shown for that initial operating point in Figure 5. If system load increases, the transient curve will move to the left and voltage will fall toward the intersection of the SVS admittance and the new system transient V-Q curve. This voltage is below the setpoint of the SVS regulator, and will cause the SVS to increase its admittance. The intersection of the new system transient V-Q curve and the new SVS admittance will be at a higher voltage back on the SVS regulating characteristic. After this, the system,

Figure 5

through the slow dynamics of LTCs and loads, will adjust to the slightly lower voltage, causing voltages to drift even lower as the system approaches a new steady state operating point on a new steady state V-Q curve. Before, during, and following this process, the SVS continues to reset its admittance in response to the transient characteristic so that the voltage remains at some point on the SVS regulator droop curve. The SVS, in effect, never sees the steady state V-Q curve, but only the transient characteristic to which it responds in a stable manner. Though the SVS (or generator) may not recognize the steady state V-Q curve, when the system settles at a new operating point on the steady state V-Q curve, the SVS or generator average output will be on that curve, and, as noted earlier, its steady state equations will be satisfied.

Though it was stated above that automatic voltage control is required for stable operation to the left of the critical voltage, this is, strictly speaking, not true. It is, theoretically at least, possible for operators to regulate voltage on the left side of the V-Q curve with switched shunt capacitors. This is the case because, as noted above for generators and SVSs, the V-Q curve that we work with in power flow studies is the *steady state* system characteristic, and does not reflect how the system responds to changes in shunt compensation from second to second (see the transient characteristic in Figure 4). This is especially the case in the northwest when much of the load is resistance heating. As long as the effective "time constant" of operator response is shorter than the system time constant, operators can control voltage. The system time constant is dictated primarily by LTC response time at voltages above 92% and thermostats when voltages are below 92%. However, capacitor banks would have to be added or removed as frequently as once every few minutes, in steps as small as 50 Mvar (on the planned Northwest system). When the compensation is above the steady state V-Q curve, that is, the capacitor and system transient V-Q curves intersect above the steady state V-Q curve

curve, voltage will drift up until the operator removes a bank. If removing a bank places the system under the steady state V-Q curve, voltages will drift down until the operator switches a bank on. If removing a bank leaves the system above the steady state V-Q curve, voltages will continue drifting up and another bank will need to be switched off. This phenomena is shown in Figure 6. Figure 6a shows how voltage will behave for a system operating right on the V-Q

Figure 6

curve. Because this is not a stable operating point, voltage will drift away from this point and may drift up or down. A slight increase in load will put the operating point below the V-Q curve, and voltages will drift down and the system may collapse. A slight decrease in load will put the operating point above the V-Q curve, and voltages will drift up and ultimately reach a stable point on the right side of the V-Q curve.

Operators can control voltage if they continuously cycle banks on and off as shown in Figure 6b. When voltage is drifting down the Capacitor 1 curve and a bank is switched on, the voltage will jump up the transient V-Q curve to its intersection with the Capacitor 2 curve, then slowly rise further until the bank is switched off. When the bank is switched off, the voltage will jump down the new transient curve and then drift lower until it is switched back on to repeat the cycle. This burden on operators, and the capacitor switch duty are unacceptable for obvious reasons, and thus make *automatic* voltage control essential for operation below the critical voltage on the V-Q curve.

SVS Need

The SVSs planned for the Northwest will provide this automatic regulation if and when it is needed. Like the control suggested above for operators, the SVS could be designed to provide only step changes in shunt compensation. The step size would be limited primarily by the step change in voltage that customers can tolerate on a relatively frequent basis, probably on the order of 1 percent. A step size on the order of 50 Mvar in the 500 kV stations would probably be sufficiently close to the 'noise' to be acceptable. Thyristor switched capacitors, if used, would probably consist of, for instance, 50, 100, and 200 Mvar banks to provide 0 to 350 Mvar in 50 Mvar steps.

Unless there is a significant cost advantage, including losses, of thyristor switched capacitors, the smooth control of thyristor controlled reactors is preferable. Thyristor controlled reactors are more effective at providing system damping, and avoid any question of customer tolerance for step changes in voltage.

Providing for stable operation to the left of the V-Q curve critical voltage is essential in the Northwest. With the system that is planned, the 'critical voltage' point on the V-Q curve will be very close to the nominal operating voltage during contingencies. Hence a fairly minor second contingency, a higher than expected load level, an unexplored dispatch, an operator error, or any number of other events could place the system on the left side of the V-Q curve.

SVS Size

The size and type of SVS capacity required in the Northwest is largely a judgement call. That is, there are no specific voltage stability studies that can be run to pin down explicitly or precisely the necessary SVS capacity. For a problem such as first-swing stability, one can establish criteria such as fault type and location and transfer level, and then increase series compensation or SVS size in, say, 5% steps, until the system is first-swing stable. For the voltage stability problem no analogous set of cases can be defined (though some very useful guidance may be available from extended-term simulations as discussed later in this letter).

It is my opinion that the two SVSs that are planned for the Northwest (+/- 300 Mvar), combined with adequate controls for the mechanically switched capacitors, will provide adequate voltage control for the contingencies that have been identified as a threat to voltage stability, and for these contingencies combined with modest second contingencies or less than ideal system conditions. The adequacy of the planned SVSs cannot be proven by power flow cases, but I believe the SVSs are adequate and prudent because:

- The dynamic range from the normal operating point to ceiling, 300 Mvar for each unit, will quickly provide about one third of the reactive power required to stabilize voltage following one of the limiting disturbances.¹ This leaves it necessary for relays, controls, or operators to apply several 300 Mvar switched banks, or the equivalent, within about one minute to prevent continuing voltage decay. The planned SVS capacity, though it does not relieve the operators or undervoltage relays of the need to promptly switch on additional capacitor banks, does reduce the urgency somewhat, and will cover an error such as applying more banks than are needed. Also, operators will find the SVS reactive loading a more sensitive measure of system reactive need than system voltages. That is, they will find it easier to switch banks to keep the SVS in its regulating range than to switch banks to bring voltage into line.
- The 300 Mvar SVS capacitive range matches the largest mechanically switched banks, so that the combination of one SVS and mechanically switched banks at 300 Mvar and below provides, effectively, dynamic

¹ The total 600 Mvar of SVS capacitive range would provide more than one third of the total requirements, however, because one SVS is at Keeler, near Portland, and the other is at Maple Valley, near Seattle, most disturbances will only drive one SVS or the other to ceiling. For instance, the Keeler SVS will contribute only 100 to 150 Mvar when line outages occur in the Seattle area.

control over a much larger range (potentially 1200 to 1800 Mvar). The inductive range will also be used because operators will want to switch on mechanical banks before the SVS hits ceiling, and switching on 300 Mvar banks will thus push the SVS underexcited by 50 to 100 Mvar in practice.

In this respect, the size of the SVS is somewhat arbitrary. In the time frame of the slow dynamics of voltage instability, mechanically switched capacitors can be used as part of the dynamic var control without undue duty on the mechanical switches. The switched banks can be switched on to keep the SVS in its regulating range as the system responds to a line outage in the minutes following the line outage. If the largest mechanically switched banks were 200 Mvar, a 200 Mvar SVS (+200/-200) could be used, but mechanical switching would be more frequent. Economics, burden on operators, control complexity, system step voltages upon bank connection and disconnection, site availability, and communications requirements thus play a role in selecting the size of SVS and switched banks. 300 Mvar appears to be a reasonable trade-off among these requirements.

- The underexcited capability of the SVS is an even more difficult judgement call. As discussed elsewhere in this letter, the SVS will be critical to the limiting of equipment damage during system break-up. The two SVS can cover up to two capacitor banks, and this seems reasonable to me. As an aside, overvoltage withstand of the SVS is an important part of the SVS specification to ensure that it will remain on-line through system break-up overvoltages, or can bring potentially damaging overvoltages under control even when break-up does not occur.
- Though some equipment protection would be lost if the SVS were operated underexcited during peak load conditions to provide a larger capacitive response range, this option is available. For instance, if winter peak loads exceed expectations and it is found that the 0 to 300 Mvar range is not adequate, the SVS can be operated underexcited to provide a larger range.
- Another requirement that dictates SVS size is the shape of the V-Q curve in the vicinity of normal voltage under heavy system loading, and the normal area load variations. If normal system load variations would require excessively frequent switching of modest size banks (under 100 Mvar) to keep the SVS close to zero Mvar, then some SVS capacity must be allotted to cover normal minute to minute load variations. I expect that BPA will find it necessary to allow the SVS to 'wander' between about -50

to +50 Mvar, or maybe even -100 to +100 Mvar to limit the operations of mechanically switched banks. This means that only 200 to 250 Mvar of the SVS capacity can be relied upon to be available when a contingency occurs. This argument also suggests that the SVS controls need to have access to banks on the order of 100 to 200 Mvar in order to keep the SVS within the desired operating range (± 50 Mvar and ± 100 Mvar respectively).

- Finally, the system Mvar per MW characteristic during the worst-case line outage contingencies should have some impact on the size of the SVS. For instance, if the load tends to vary 50 MW within periods of 5 to 10 minutes, and changes reactive demand by 3 Mvar per MW, then the two ± 300 Mvar SVS should be capable of regulating voltage under such conditions without hitting ceiling or going underexcited. The switched capacitors would be selected to keep the SVS between 100 and 200 Mvar so that it can handle load variations with little attention from operators (operators will have plenty of other tasks to occupy their time during contingencies). If a control system will allow the SVS to switch mechanically switched banks on and off, and some of those banks are in the vicinity of 100 Mvar, then the 0 to 300 Mvar SVS size should be adequate to limit the frequency of mechanical switching to an acceptable level during severe contingencies.

In addition to the above, I believe that the limited experience with operation of voltage stability limited systems, and the significant change in the character of the system in the Northwest over the next 10 years calls for highly conservative planning in the early years (early to mid 90's). Though I expect the system could be reliable with SVS smaller than those planned, the risks of inadequate voltage control are too high to base plans on 'expectations.' A conservative approach is needed. The two planned SVS provide this conservative approach in my opinion. If experience shows that the two SVS provide more dynamic range than is essential, then later in the 90's additional SVS capacity will not be needed or can be deferred. On the other hand, experience or more in-depth studies in the early 90's may show that more SVS capacity is needed. Experience is unlikely to be very helpful because the kinds of contingencies that are being guarded against and which would provide a meaningful test may not occur. Further studies, including simulations, should be undertaken, and should provide reliable guidance for the late 90's.

SVS Operation and Overvoltages

The two 300 Mvar SVS can be operated 'underexcited' when load is heavy so that they will each be able to provide 400 or 500 Mvar quickly when a disturbance occurs. This will increase the security relative to voltage instability. However, in heavily compensated (shunt) systems, there is another risk. This risk is possible system breakup, for any reason, that would leave long lines lightly loaded and with large amounts of mechanically switched capacitors at or near their terminals. This kind of breakup can cause severe overvoltages, and equipment damage that would delay full restoration, perhaps for days. The levels of shunt compensation planned for the Northwest system make consideration of such events, no matter how unlikely, very important.

One possible scenario is voltage instability that triggers steady state angular instability. Angular instability is likely to cause line tripping in both the 500 kV and 230 kV systems. This kind of separation will leave many, if not all, of the 500 kV lines connected to the system and with capacitors at their receiving ends, possibly including some capacitors on nearby 230 kV buses. It simply is not possible to get mechanically switched shunt capacitors off the system quickly enough to prevent large Ferranti-effect overvoltages and even self-excitation of remote hydro plants. And, once the overvoltages occur, circuit breakers are likely to fail if opened. The overvoltages will cause arrester failures or flashovers which depress voltages, but then when circuit breakers open to clear the faults, voltages will rise again, repeatedly, causing additional equipment to fail. Cable potheads and transformer bushings are particularly susceptible to overvoltage failure, and can delay restoration even more than failed arresters and insulators.

It is essential that BPA, in planning and operating the Northeast system, take the possibility of the overvoltages described above into account. After looking at the potential for system breakup overvoltages, BPA will likely deem it unacceptable to operate the SVSs 'underexcited' when the system is heavily stressed. Not operating underexcited also implies fewer capacitor banks on-line as well as more SVS reactive range to control overvoltages. Fewer capacitor banks on-line also implies more reliance on operators or automatic controls to bring them on when necessary. It is possible to have the SVS controls extend to some of the capacitor banks, and this should be considered. The planned alarm system should be retained so operators can bring the banks on in the best sequence if automatic controls fail or they are able to perform the switching more quickly or in a pattern that is best for the present system condition (unless the SVS control over mechanical banks is quite sophisticated, it will not necessarily switch on banks where the voltage is lowest).

Load Characteristics - Summary of BPA Report

Load characteristics are extremely important in designing a system to avoid voltage instability. Load characteristics are needed to determine how much time operators have to deal within a disturbance, how much automation is needed, and whether or not load characteristics will help protect a system from collapse.

BPA load investigations have shown that LTCs in distribution substations have enough tap range to keep most customers at normal voltage with the bulk system as low as about 92%. They have also shown that it will take only about two minutes for LTCs to restore distribution voltage and drive bulk system voltages down to this level.

The investigations have also shown that much of the area load, especially the resistance heating load, will return to its pre-disturbance power levels within about 20 minutes after it experiences a drop in voltage. Hence in a disturbance in which LTCs reach limits and allow utility customer voltages to drop, there will be only a temporary drop in load. Some utility customers, such as many of those in the Seattle area are not on LTCs, and will not be even partially restored by LTCs in the first minutes after a disturbance, but will self-restore over 20 minutes. Self-restoration occurs through manual adjustment and thermostat action. Some loads will be restored in 5 minutes or less (e.g., aluminum reduction loads).

The conclusion from the above is that operators will have only a minute or two before substantial load restoration occurs, and drags voltage down substantially, possibly down close to 90% where area reactive demand will be very high. Also, if LTCs reach limits and leave some customer voltages below nominal, the remaining restoration will occur over the next 10 to 20 minutes dragging voltage down further.

In summary, without remedial action, bulk system voltages will drop several percent when the disturbance occurs, then drop to about 92% over several minutes as LTCs respond, then drop more slowly over the next 10 to 15 minutes as thermostats restore resistance heating load. The voltages are likely to reach levels that will cause angular instability or motor stalling and complete collapse within 10 to 15 minutes depending on the extent of the reactive shortage.

These changes can be visualized in terms of the V-Q curve. Figure 7 shows the V-Q curve at several points in time after a disturbance that leaves the system with insufficient reactive power to provide a stable operating point. In the first

minute or so the LTCs will remain at their initial settings, and the thermostats will restore only about 5% of the drop in resistance heating load power (curve 1). After two or three minutes, the LTCs will have run to limits, and pushed bulk system voltages down (curve 3). Then thermostats will continue to restore the resistance heating load to its initial power level over the next 17

Figure 7

minutes or so (curves 5, 10, 15 and 20). The system will reach curve 20 only if there is no load that remains voltage sensitive at the end of 20 minutes. Because, today, at least, most lighting load varies with voltage, the final V-Q characteristic of the Northwest system is probably somewhere between curves 10 and 15. Whether or not this load varies enough with voltage to provide an 'S' shaped V-Q curve with a stable operating point at a reasonable voltage (above 85%, preferably close to 90%) with the planned reactive compensation has not been determined. However, field tests conducted by BPA are not encouraging, and BPA plans to proceed on the basis that the system will collapse if a stable operating point above 90% isn't provided by compensation. Without convincing proof that load characteristics will provide a stable operating point, or some permanent load relief, this is a wise choice. Further, if a stable operating point were known to exist for a given load level and compensation level, depending on this operating point, even as backup to other solutions, may not be wise. This stable operating point, at best, would be very fragile so that even a modest additional contingency, or a slightly higher than expected load level could put the stable operating voltage so low that collapse through angular instability or motor stalling would occur. Any such operating point might become even more fragile or even cease to exist in the future as load characteristics move ever closer to constant power.

Load Characteristics - Observations

The first important conclusion from this knowledge is that operators have very little time to react to a disturbance that leaves the system short of reactive power. The second important conclusion is that the winter loads in the Northwest may not provide the system with a stable operating point down around 90% voltage as is typical today in some other portions of the country. The PJM system, for instance, has long had enough steady-state load relief as customer voltages drop (after LTCs have reached limits) to stabilize voltages at about 90%. In August 1988, the midwest experienced voltage instability on 6 days when loads reached new peaks, and in each case 345 and 138 kV voltages

stabilized between 88 and 92%. From the load information collected by BPA, it appears that this may not be the case in the Northwest.

The modeling done to date by BPA engineers takes into account that the Seattle City light system has few LTCs between the subtransmission system and customers. However, I understand the City is studying several options to improve voltage regulation, one of which is to add regulators to the system or replace transformers with LTC units. This would strengthen further the arguments used to justify use of constant kVA loads in BPA studies.

Another aspect of load characteristics justifies the use of the constant kVA characteristics. Load characteristics are changing and more and more load devices are exhibiting a constant kVA characteristic. Computers are an increasing share of the load and are a constant power load. New electronic ballasts and high efficiency fluorescent lamps are being used in new construction and being retrofit to existing buildings, and impose nearly a constant kVA load on the system. New solid state switching of resistance heat is reducing thermostat cycle times from the traditional 20 minutes to 6 seconds, thus leaving only the room thermal time constant (on the order of a minute or two) to control the time required for resistance heat load to return to constant power after a change in voltage. This trend to constant power loads, or rapid self-restoring loads appears likely to continue at a steady pace, thus making a conservative approach to voltage control essential.

Several utilities have observed this change in load characteristics. Consolidated Edison and utilities in the Northeast have long used voltage reduction to curtail demand when generation shortages occur, or transmission bottlenecks arise. In recent years they have had increasing difficulty confirming that there is a drop in demand when voltage is reduced 5% or 8%.

There are differences between the load on the systems in the Pacific Northwest and the load on other systems. The load in the Northwest, during winter peak conditions when the system is at highest risk of voltage problems, contains a large amount of resistance heating load. This contrasts with systems in other regions, such as the Northeast where the motor content of the load is large due to heavy industry, heat pumps, conventional air conditioners, and other factors. However, though the loads are very different, the nature of the loads in terms of their sensitivity to voltage is not so different. Motors and resistance heat both exhibit nearly a constant power characteristic in the steady state. The chief difference is that resistance heat returns to its initial power in about 20 minutes, while motors return to their initial power in several seconds. This

difference gives operators in the Northwest some time to deal with the voltage problem that may be useful, for instance, to manually reduce load through tripping of distribution circuits.

The share of the load that is voltage-sensitive is important if consideration is being given to using load characteristics to provide a stable operating point when there is a reactive shortage. Loads in Pennsylvania, New Jersey, and the Midwest have demonstrated that there is enough voltage-sensitive load in these systems to provide a stable operating point below the voltage at which LTCs reach their limits (about 90% of nominal). However, how secure this operating point is and the relationship between amount of compensation and voltage (the slope of the V-Q curve at the stable operating point (curve 3 or 5 in Figure 7) have not been determined. As noted in the previous section, BPA studies and field tests raise doubts as to whether there is enough voltage-sensitive load to provide a sufficiently stable operating point to be useful. Though other systems have demonstrated that a stable operating point exists, and have unwittingly used it to prevent collapse on many occasions, to my knowledge, only Ontario Hydro has planned portions of its system to take advantage of it. Ontario Hydro uses LTC blocking in substations feeding voltage sensitive loads to provide a stable operating point at a voltage of about 95% of nominal. I understand Ontario Hydro also provides undervoltage load shedding as backup to LTC blocking.

BPA plans to proceed on the assumption that load characteristics do not offer a solution to the voltage stability problem are prudent. However, further knowledge of load characteristics would be helpful. If there are some distribution substation in the system that serve largely voltage-sensitive load, LTC blocking (see next section) in those substations could offer significant benefits including, possibly, the deferral of some of the planned shunt capacitor banks.

LTC Blocking

At this time BPA does not plan to use LTC blocking to provide temporary load relief when voltages fall. LTC blocking, or advanced LTCs that reduce distribution voltage when the upstream voltage drops below some threshold, have the following potential advantages:

- Avoid the rapid drop in voltage that occurs in the first several minutes after a disturbance (after which voltages decay more slowly), instead providing a gradual voltage decay over 20 minutes, and

- Allows whatever voltage-sensitive non-restoring load there is to be taken greater advantage of (that load sees essentially the transmission voltage instead of a voltage 8 to 10% higher).

The largest benefit is the additional time operators would have to deal with the disturbance. However, the low voltage on utility customer devices would provide some permanent load relief, and could, in a marginal situation, provide stability where it would not otherwise occur. The permanent load relief could, alternatively, save some investment in shunt capacitor banks.

Modifying or retrofitting many existing distribution substation LTCs to provide blocking would be a major task. However, it would seem prudent to estimate the cost and benefit of this option. If it can be done for several thousand dollars per transformer, it might be worth doing. The cost may be not much over one million dollars (400 distribution substation transformers at \$3000 each).

LTC blocking should only be used in distribution substations serving load that is known to have sufficient voltage-sensitive component to provide a benefit. If the industrial content is high, the high concentration of shunt compensation and induction motor load may yield a load characteristic in which the drop in power factor more than offsets any drop in active load when voltage is allowed to drop. Tests at each substation are necessary to determine the best course of action for each substation.

There are several approaches to blocking LTCs. The simplest may be to adjust the tap mechanism boost limit switch so that it operates at one or two tap steps below the highest boost tap that is normally used. If this can be done on most transformers, the total cost could be just several hundred dollars per transformer.

Voltage Control of Capacitor Banks

It would be highly desirable to automatically bring off-line capacitor banks on-line quickly and automatically when a disturbance poses a voltage stability threat. BPA engineers have studied the benefits of getting the off-line banks on quickly when a disturbance threatens voltage stability, but also has found that voltages only drop one or two percent in the first minute or two after a disturbance, and that a secure and reliable scheme to apply the banks during this period will be difficult to design. A scheme that would switch on capacitor banks following such small changes might switch them on inadvertently often enough to create a nuisance or overvoltage hazard. A disturbance that causes

capacitor banks to be switched on but also causes system break-up could aggravate break-up overvoltages.

Capacitor banks near SVSs could be controlled by SVS controllers. In fact, capacitor banks some distance away might also be controlled by the SVS controllers. This approach would be less likely to cause nuisance switching of the banks, and should switch them off within minutes or seconds if they are switched on when not needed. If unnecessary bank switching occurs only a few times per year, it would be acceptable (that is, operators could deal with the events, and mechanical switch life and reliability would not be unduly reduced).

Operators will, of course, also have control of the banks. If operators have enough information, such as SVS reactive loadings, coastal area generator reactive loadings, cogenerator reactive loadings, and key area voltages, they should be able to make prompt decisions about capacitor switching when disturbances occur. Because voltage instability occurs over a period of minutes, operators will be able to take actions to halt voltage decay that they cannot take for problems such as steady state monotonic instability (which occurs over a few seconds).²

Also as recognized in BPA studies, inverse time undervoltage relays set somewhat above undervoltage load shedding relays can be used as backup to the operators and any extended SVS controls to ensure all capacitor banks are on-line before voltages reach the point where undervoltage load shedding begins. *As long as there are enough banks available to meet system steady state reactive requirements with some margin at the voltage setting of the capacitor bank undervoltage relays, the system voltage decay will be halted by these relays.*

Capacitor Bank Undervoltage Relay Settings

The undervoltage relay settings are somewhat arbitrary. The relays should be set in the vicinity of 95% voltage and have enough time delay to ride through faults, including reclosing on downstream distribution circuits. Banks in the same station should have different time delays to ensure they will not be switched on simultaneously. All banks can have similar voltage settings

² Steady state monotonic instability is the current IEEE term for what previously was called steady state instability. It is the problem of angles between voltage control points reaching 90 degrees, at which time a drop in voltage or any further attempt to increase transfer results in a drop in transfer, acceleration of the sending end machines, deceleration of the receiving end machines, and the "slipping of poles" or operation of distance relays to split the system. The corresponding term for what used to be called dynamic instability is now steady state oscillatory instability.

because there will be enough voltage difference from one substation to the next to ensure that the bank in the substation with the lowest voltage will be switched on first. When that bank comes on the voltage will rise and additional banks will not be switched on until voltage again drifts down to the relay setting. The dynamics of voltage instability is slow enough, even while LTCs are moving, that banks will switch on one by one, even with time delays of just a few seconds. These considerations are discussed further in the following paragraphs.

The capacitor bank undervoltage relays should be set somewhat below the point at which the SVSs hit ceiling. Hence the system will be operating without automatic regulation as the voltages fall toward the bank relay settings, and *may* be on the left side of the V-Q curve. However, this is not a problem *so long as the total capacity of the banks exceeds the steady state reactive requirements of the system at the voltage at which the capacitor bank undervoltage relays are set.* Once enough banks have switched on to provide some reactive margin above the steady state V-Q curve, voltages will stop decaying and will drift up as shown earlier in Figure 6a.

Figure 8 shows how voltage will behave if the system is voltage-unstable and relays on capacitor banks begin switching them on at 95% voltage. The voltage will rise and fall as the banks are switched on. If the last bank does not provide enough capacity to take the system above the steady state V-Q curve, voltage will continue to fall until collapse occurs. Also shown in Figure 8 is the voltage trajectory that will occur if one of the banks moves the system above the

Figure 8

steady state V-Q curve. When this occurs, voltages will drift up. It can be seen in Figure 8 that the level of compensation required to initiate upward movement of the voltage may be considerably larger than the reactive power needed to sustain nominal voltage. Also, an unacceptably high final voltage may occur unless one or more of the banks are switched off manually, or an SVS takes control as the voltage closes in on the nominal voltage. Figure 9 shows how an SVS will take control of the voltage when voltage rises to the point that the SVS will come off ceiling.

The following points may help clarify the system dynamics that can occur if a disturbance lands the system in the vicinity of the left side of the steady state V-Q curve.

Figure 9

- Thermostats and similar loads and LTCs will cause the downward drift in voltage after each capacitor bank switching because of the dynamics shown in Figure 7.
- If the voltages change as little as shown in Figure 8 when each bank is switched on, LTCs may not move significantly during this period because of the deadband that is included in their control to prevent unnecessary operation. If this is the case, thermostats will dominate the system response, and the process shown in Figure 8 will occur over 10 or 15 minutes.
- Once the system is above the steady state V-Q characteristic, voltage will drift upward with no further operator action or bank switching. Because thermostats are slow to respond, the voltage may move very slowly at first.
- Once thermostats have responded sufficiently to allow the voltage to rise about 2%, through the LTC deadband, or into the LTC range if the voltage is in the vicinity of 92%, LTCs will respond and allow voltage to rise further. LTCs are likely to start and stop, as the voltage moves into and out of their deadband. This may slow the voltage rise because of the one minute initial delay on each LTC.
- Figure 8 assumes the capacitor banks will be switched on at 95% voltage. It also assumes a V-Q curve shape and position. Neither are necessarily correct for the Northwest, but do indicate the behavior that can be expected.

Because it is always desirable to keep voltages in the vicinity of nominal, an extension of the SVS controls to apply available banks when the SVS hits, or approaches ceiling, will be very attractive. Such a system could continue applying mechanically switched banks at intervals until the voltage is within the SVS dynamic range, even when a disturbance has put the SVS on ceiling.

This would have to be done at a pace that is fast compared to LTC response. For instance, if LTCs begin moving about one minute after a drop in voltage, the controller should be applying banks at intervals of 5 to 15 seconds so that several banks can be switched on during the one to two minute period of LTC activity that follows the trip of a line.

The extension of SVS controls to control nearby capacitor banks can be made more secure by supervising signals to switch on banks with undervoltage relays at the bank locations. This would be a relay set 2 or 3% above the voltage at which the SVS controls are expected to start bringing on banks. For instance, if the SVS has a 3% droop and will start bringing banks on at about 98% of its voltage reference setting, the undervoltage relays at the banks would be set at about 100% of nominal voltage. Because the primary purpose of these relays is to avoid banks being inadvertently applied when voltages are above normal, a setting at the nominal voltage is appropriate.

The bank inverse time undervoltage relays would not need to operate quickly. Because the LTCs move over a period of minutes (typically they will correct voltage and reset several times as voltages drop, thus extending the time it will take to reach limits), the delay on the undervoltage relays can be 15 to 30 seconds or more which will allow them to ride through most normal voltage excursions. Also, voltage differences between substations will prevent more than one bank from coming on at a time. Instantaneous reset should not be used because it could delay the switching of the banks (when one is switched on the others would reset and then could not come on for another 30 seconds). An integral reset, or slow reset, would allow the banks to come on as quickly as necessary.

I suggest that undervoltage relays, extensions to the SVS controls, *and* operators all have the ability to apply the large capacitor banks when voltages are low. The 1978 New York City blackout occurred in part because of a communications problem (people and equipment) that caused operators to think they had reclosed a line when they hadn't. The system might have been saved if the operators had known about the open line. Having undervoltage relays on the capacitor banks would help guard against problems in the control center and failure, or too slow operation of the SVS control.

Undervoltage Load Shedding

BPA plans undervoltage load shedding for the Pacific Northwest. Undervoltage load shedding is absolutely essential, and should virtually eliminate the risk of voltage collapse and blackout from voltage instability. It will also virtually

eliminate the risk of angular instability *if* the system is stable at the settings of the undervoltage load shedding relays.

Few utilities have experience with large scale undervoltage load shedding, so BPA will be largely breaking new ground in this area. The extended term simulations discussed later in this report will be very important to understanding the intricacies of undervoltage load shedding, and the selection and setting of undervoltage load shedding relays.

Load should be shed in modest steps in order to minimize the load that must be shed. If load shedding is done at the distribution substation level (like underfrequency load shedding), load will inherently be shed in modest steps, regardless of relay voltage or time settings. The slow dynamic nature of the voltage changes will ensure this. Because voltages will be moving relatively slowly compared with relay timer settings, each relay will have ample time to operate before others once voltage reaches its setpoint. Because voltages vary slightly from one bus to another, even similar voltage settings will not cause several relays to operate in close time proximity. As each relay operates, the load it drops will raise voltage and delay the operation of nearby relays, even if they are set the same.

With load shed in modest steps, the load shedding will, effectively, regulate the system voltage at the relay settings. As resistance heating load 'self-restores' over a period of 20 minutes or so, load will increase gradually, voltages will fall slowly, and load will be shed periodically. Each segment of load that is dropped will cause voltage to rise slightly. As resistance load increases further and pulls voltage back down, another segment of load will drop. Voltage will remain at the undervoltage relay settings and load will continue to grow and be shed until the steady state V-Q curve intersects the capacitor characteristic, or the 0 Mvar axis, at a point below the undervoltage relay settings. Once the steady state V-Q curve is below the capacitor characteristic at the undervoltage relay settings, voltage will begin rising and no further load shedding will occur. The voltage will slowly rise to a stable operating point on the right side of the V-Q curve.

This process is demonstrated in Figure 10. Figure 10 is simplified in that the dynamics of self-restoration of resistance heating load is not shown, and load shedding is assumed to occur in three steps. Visualize the voltage below 92% so LTCs are on limits, and sliding down the capacitor curve as the resistance load is in the process of self-restoration (as shown in Figure 7). When a step of load shedding occurs, the operating point will jump to the intersection of the

capacitor and transient V-Q curve of the remaining load. As remaining load continues to increase, this process repeats. When the steady state V-Q curve drops below the capacitor characteristic, voltages will begin rising and no further load shedding will occur. The whole process of load shedding to a point where voltages will rise will take about 20 minutes — the time it takes self-restoring load to completely return to its initial power level.

Figure 10

Figure 10 assumes that the undervoltage relay settings are to the left of the critical voltage of the V-Q curve. This may not be the case. Figure 11 shows a situation similar to that shown in Figure 10, except the system is to the right of the critical voltage at the undervoltage relay voltage settings. The process is similar.

Figure 11

In the above discussions, it has been assumed that there is little or no load that is not self-restoring. That is, the V-Q curve is roughly a parabola. If there is more non self-restoring load than we anticipate, the system may stabilize at a voltage slightly above the load shedding relay setpoints rather than drifting up to a higher value. This is shown in Figure 12. The V-Q curve in Figure 12 has the 'S' shape (perhaps somewhat exaggerated) that has provided a stable operating point in some systems. There is enough shape to the S curves in Figure 12 to provide two stable operating points for a small range of system load, though the actual S curve may be too flat for this to be the case. In any event, operators could drop additional load until the system moves up to a higher voltage.

Figure 12

The order in which various feeders in a given substation are to be tripped to provide undervoltage load shedding can be controlled by selecting three voltage

levels such as 92, 91 and 90% and the same time settings. It can also be done by selecting time delay settings such as the 3.5, 5, and 8 second settings presently being considered by BPA, and the same voltage settings. A combination of staggered time and voltage settings could also be used.

Neither time delay or voltage settings will provide good selectivity among loads in different substations. There are two reasons for this:

- There will be normal differences in voltage from one substation to the next across the system, and these voltages will not be known well enough to take them into account in selecting the relay voltage settings. The voltage relays would have to have settings differing by 2% or more to provide even modest selectivity from one substation to the next. Also, attempting significant coordination of load shedding across large areas is not desirable if load dropped in the area where voltages are the lowest will be most effective (see further discussion of this below).
- Because reasonable timer settings will be very short compared to the 'slow dynamics' of unstable voltages (see Figure 7), they will have little impact on the order in which relays in different substations will operate. Once LTCs are on limits, voltages will decay so slowly that timer settings of several minutes would be needed to overcome voltage differences from one substation to the next.

Voltage or timer settings will provide selectivity within a substation. Voltage settings will provide some selectivity from one substation to the next in an area. Attempts to provide selectivity from one area to another are unlikely to be successful and may be undesirable.

Allowing undervoltage load shedding to occur where voltage is lowest is not a safe approach in some systems, but appears reasonable in the Northwest. The concern is that load shedding may increase loading on the weakened portion of the system. For instance, if load shedding along the coast could occur because of transmission outages to the south, and could also increase flows on those lines because power from the north (Canada) is not reduced, then the undervoltage load shedding could accelerate the decline in voltage. If load shedding along the coast will result in reduced loading on the weakened 500 kV lines across the Cascades, then it will improve voltages. That AGC systems will reduce loading on the stressed portion of the system following load shedding should be confirmed.

Timer setting need to ride through faults, including the last re-close that may be prolonged to force lateral fuses to blow. As noted, undervoltage load shedding timer settings are somewhat arbitrary, but delays in the 5 to 15 second range seem reasonable. Extended term simulations may provide additional insights.

Reactive Power Margin

The 500 Mvar reactive power margin planned for the system appears reasonable. For instance, there will still be a 200 Mvar margin if one of the 300 Mvar banks, or an SVS, initially floating, does not respond to a disturbance or fails during a disturbance.

However, I suggest that this margin be checked in terms of the additional load it will support, and the risk that loads may exceed that level. The errors in annual load forecasts that have occurred over the last 10 years or so should be reviewed. A credible margin for error in the MW prediction should be established, then the reactive plan should be set to cover this load, plus provide a modest reactive margin. For instance, the reactive power could cover the largest anticipated error in load forecast, plus provide 200 Mvar of margin to ensure continuous automatic control if that load level does occur. As a point of reference, if the reactive losses are about 3 Mvar per MW of load in the mid nineties, a peak load 167 MW above the expected peak would exhaust the presently planned reactive margin (500 Mvar). An additional 200 Mvar, or a total of 700 Mvar would be indicated in this case. However, some other action such as manual load shedding by operators or undervoltage load shedding could be considered as a means to deal with such load forecast errors.

Extended Term Simulations

Though I feel confident that my knowledge of voltage stability is adequate to confirm that BPA analysis of load and LTC characteristics and power flow studies have resulted in good decisions regarding system adequacy to avoid voltage instability, I also urge that present BPA work on extended term simulation models continue and ultimately be used to confirm and refine present plans.

Extended term simulations will be very useful for a variety of reasons:

- Simulations will provide a full understanding and confirmation of the impact of load and LTC dynamics on reactive requirements.

- The selection, location, and setting of inverse time undervoltage load shedding relays will be much more reliable if tested in simulations.
- The selection and setting of primary and backup systems, including operator actions, to switch capacitor banks on following disturbances will be greatly eased by simulations.
- Simulations would confirm to the satisfaction of all that operation on the left side of the V-Q curve is feasible and can be achieved by the planned compensation,
- Extended term simulations will very effectively show the adequacy of the shunt capacitor banks and the SVSs. For instance, successive cases might be run with capacitor bank and SVS sizes changed to see the impact on voltages and show the reactive margins available through time after a disturbance.
- Cases showing the effect of normal load variations on reactive loading of the SVS during contingencies could help confirm SVS adequacy and indicate the best operating point for SVSs during the contingency.
- Cases with different initial SVS settings (voltage and Mvar) may help define the best defensive settings for the SVSs under winter peak and other conditions.

The extended term simulations will require large amounts of engineering time and will take many months to complete. However, they provide the only means to set SVS controls, to set undervoltage relays on capacitor banks, and to set undervoltage load shedding relays with confidence. The confidence in final settings will be much higher than it could be with the conventional approach using power flows and stability type simulations.

Closing

The material presented in this report covers a wide range of voltage stability concepts and comments and recommendations. The presentation of this material is not intended in any way to imply any short-comings in the work done by BPA engineers. The voltage stability problem is a new one for the industry, and few engineers have experience with it. BPA engineers have done well in defining the problem and identifying solutions, and I hope this material will help them continue on a sound basis, understand all aspects of the problem and choose the best solutions.

-----//-----

Attachment 7

ATTACHMENT 7

***GE Industrial
& Power Systems***

Final Report

**Voltage Stability of the
Puget Sound System
Under Abnormally Cold Weather Conditions**

**Puget Sound Power & Light Company
Bellevue, Washington**

Puget Power Contract ZZ-02287-W-LS

**Principal Contributors:
Nicholas W. Miller, Project Engineer
Robert D'Aquila**

October 31, 1991

EXECUTIVE SUMMARY

The potential for voltage collapse in the Puget Sound area during conditions of abnormally cold weather has been revealed through recent engineering studies by PSP&L, BPA and others in WSCC. Concerns about this condition led to the "Puget Sound Reinforcement Project". The project is to evaluate measures for coping with these extreme conditions.

The interested parties were particularly concerned about the level of understanding of the voltage collapse phenomena and the suitability of tools for analyzing such behavior. On behalf of the project participants, PSP&L contracted this study to GE because of recent GE activity in the development of new power system software for the analysis of voltage stability and related phenomena.

The objective of this study was to address the following questions:

1. Is there a problem?
2. How will the system behave, if there is a problem?
3. Which measures will be most effective in correcting the problem, if there is one?

In order to answer these questions, a relatively detailed model of the Puget Sound area system was developed from a large data set provided by PSP&L. The behavior of the system in response to severe loading and critical disturbances, under a range of conditions and proposed remedial measures was examined. The answers to these questions, based on the results of this study are as follows:

Yes, there is a problem.

The system behavior is typical of highly stressed, winter peaking networks. The total import of power to the Puget Sound area in the base case is very close to the steady-state maximum. Loss of critical system components, most notably both of the Coulee-Raver 500 kV lines, stresses the system beyond its ability to serve the load. Once such an outage occurs, the voltage regulating action of the LTC's at the

distribution voltage levels throughout the system drives the system into voltage collapse, over a period of about five minutes.

Subsequent to the action of the load LTC's, thermostatic effects on the loads will tend to drive the system into progressively more distressed conditions. Unless corrective actions are taken, such as start-up of local generation, the system will eventually (20 minutes for our modeling assumptions) breakup. The normal action of the system dispatchers to adjust the taps on the EHV transformers substantially aggravates this voltage collapse.

The total Puget Sound area import capability, for the base system as modeled, is reduced to around 7800 MW, more that 500 MW less than the base case import, following trip of the Coulee-Raver double circuit.

The candidate measures for correcting the problem fall into two categories:

1. Stiffen the system, so that the voltage is supported and the load is served under the condition of increased stress.
2. Relieve the stress on the system by reducing the amount of load to be served.

Remedial measures of the first type include shunt and series compensation options, while remedial measures of the second type include undervoltage load shedding (UVLS) and locking of LTC taps.

A summary ranking of the effectiveness of the proposed measures is presented below in Tables 1 and 2. Details of the various schemes are included in Sections 2 and 3. The ranking presented in Table 1 is based on the steady-state "System Normal" capacity of the system. No lines or plants are tripped, and normal manual regulation of the EHV transformer taps is assumed. The results summarized in Table 2 are based on the system response following loss of the Coulee-Raver double circuit line. The ranking here is based on the voltage of the Maple Valley 500 kV bus 20 minutes after the disturbance. These results include the assumption that system dispatchers will *not* move the EHV taps, and that thermostatic effects will slowly change the system loads. Comparison of the two classes of remedial action must be

done with care, since the latter category necessarily involves some adverse impacts on the utility customers (i.e., tripped loads or depressed voltages).

Table 1
Effect of Candidate Remedial Measure
on Maximum Power Transfer into the Puget Sound Area
(in increasing order of effectiveness)

<u>Condition</u>	<u>Maximum Power Import (MW)</u>
Base w/Taps Locked	8600
Base	8700
Base w/UVLS (1)	8700
Kittitas Reinforcement	8950
Base w/Shunt Caps only	9100
Base w/Shunt Compensation	9250
Kittitas w/Shunt Compensation	9650

(1) UVLS does not affect the maximum transfer

Table 2
Effect of Candidate Remedial Measures
on 500 kV System Voltage for Double Circuit
Outage of the Coulee-Raver Lines
(in increasing order of effectiveness)

<u>Condition</u>	<u>Maple Valley 500 kV Voltage</u>			<u>Power flow (@ 20 mins)</u>	
	<u>Initial</u>	<u>5 min</u>	<u>20 min</u>	<u>Cross Mtn</u>	<u>Total Import</u>
Base	1.07	.94	.84	6620	6850
Base w/Shunt Caps only	1.07	.99	.94	7500	7750
Kittitas	1.08	1.0	.95	7620	7820
Base w/UVLS	1.07	.97	.97	7380	7650
Base w/Shunt Comp	1.07	1.02	.98	7800	8120
Base w/UVLS Modified	1.07	1.00	1.01	7500	7750
Kittitas w/Shunt Comp	1.08	1.04	1.06	8220	8400

The first 25 minutes of system time response for the trip of the 500 kV lines east from Raver over the mountains is shown in Figure E-1. The solid curves are for the base system and the dotted curves are for the system with all of the planned shunt and

series compensation installed. These curves dramatically illustrate the collapse of the base system and the satisfactory recovery of the future system.

This study supports the overall plans for reinforcement of the Puget Sound area bulk power system, including addition of mechanically switched capacitors, SVC's, series capacitors and new switching stations. The location and size of these devices appears to be well chosen. Substantial potential benefits from undervoltage load shedding and centralized or more sophisticated LTC control were identified. With further design effort, these could be exploited in a fashion which is complementary to the reinforcement plans.

The net result of implementation of the planned system reinforcements and undervoltage load shedding will be a system which is substantially better prepared to handle conditions of abnormal cold in the Puget Sound area than is the base system.

MAPLE V 500

1.1
1.0
0.9
0.8

Legend

— Base Case
- - - All Planned Reinforcements

East-Cascades Interface

9000
8000
7000
6000

Total Puget Sound Imports

8500
8000
7500
7000
6500

Time in Seconds

Figure E-1. Response of System to Trip of Raver → East 500 kV Double Circuit.

END

**DATE
FILMED**

6 / 25 / 92