SOUTHWESTERN PUBLIC SERVICE VOLTAGE AND STABILITY CONSTRAINED EXPORT LIMITS 2002 SUMMER STUDY

SOUTHWEST POWER POOL

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I. EXECUTIVE SUMMARY

The objective for this project is to determine the Total Transfer Capability (TTC) based on the 'voltage stability limit' and on the 'first swing angular stability limit' for Southwestern Public Service Company (SPS) exports in 2002 summer. **Section II** discusses the "Voltage Stability Analysis" and **Section III** contains the "First Swing Angular Stability Analysis" for SPS exports. The limits in this report do not include thermal ratings of transmission lines or transformers. The transfer limits will be lower due to thermal ratings. The thermal analysis will be considered in another report.

The voltage stability limits for SPS east export capability is 700 MW for the normal system and 620 MW for the single contingency (N-1) system condition. The first swing angular stability limits for SPS east export capability are 900 MW for N-1 and 500 MW for the N-2 outages. The SPS export is limited by voltage stability. **Table 1** shows SPS export limits for 2002 Summer Peak conditions for the base case and the N-1 case.

Table 1: Voltage Stability Limits

Contingency	TTC (MW)	Violations	Criteria
Base	700	50827 GRAPEVN6230.00 (Area 526, SPS): V=0.95	0.95 PU
N-1 Contingency 1	620	54295 SHAM 3WT 115 (Area 520, AEPW): V=0.90	0.02 PU voltage drop or <=0.90 PU

II. VOLTAGE STABILITY ANALYSIS

II.1. OBJECTIVE

To determine the voltage stability limit for Southwestern Public Service's (SPS) total east export capability using the 2002 summer peak power flow model.

II.2. METHODOLOGY

To search for contingencies and buses which are vulnerable to voltage instability, two power flow cases are created – one with 0MW and the other one with 600MW SPS east export. Then, for all facilities 69kV and above, all single branch and single tie line contingencies (7140 single contingencies in total) in SPP and EES have been simulated on both the 0MW and 600 MW cases using ACCC activity of PSS/E. All buses 110 kV and above in SPP and EES are monitored. The comparisons of the results of the 0MW and 600 MW cases show:

> The SPS east export limit would be zero if the 0.90 per unit (PU) voltage criteria had to be reinforced for single contingencies. This is because even when SPS is not exporting to east at all, there are 160 single contingencies in SPP and EES which cause the voltages of 324 buses in SPP and EES to drop below 0.90 PU. However, most of the 324 bus voltages are not sensitive to SPS east export – most of the 324 bus voltages do not drop further when SPS east export increases. When increasing SPS east export from 0 to 600 MW, voltages of only 40 buses drop more than 1% and 15 buses drop more than 2%.

The details of the results and comparisons are in a separate EXCEL file, **DEGRADE-BUS.xls** which is available up request. Only buses with decreasing voltages for increasing SPS east exports are included. Buses of which voltages increase when increasing SPS east export are excluded.

Instead of using only 0.90 PU as the limit for voltage instability, the percentage voltage drop is also used as the limit for assessing SPS east export capability.

Most limiting contingencies are defined as contingencies which cause bus voltages to drop more than 1% when SPS east export increases from 0 to 600 MW. Critical buses are defined as buses of which voltages drop more than 1% when SPS east export increases from 0 to 600 MW. These limiting contingencies and critical buses are then monitored in VSAT to find the voltage stability limits for SPP east export.

Table 2 provides details for the most limiting contingencies for voltage stability. Comparing the ACCC results of the 0MW and 600 MW show that only 5 contingencies cause bus voltages to drop more than 1%. They are the first five contingencies in the table. The Tuco to Oklaunion line is not identified by ACCC results as a limiting contingency. However, it was added to the list because transfers above 620 MW showed the Shamrock 115 kV bus to drop below 0.90 PU.

Table 3 provides details for the critical buses. Voltages of only 40 buses drop below 0.90 PU and more than 1% when 7140 single contingencies apply and when SPP east export increases from 0 to 600 MW. They are the first 40 buses in the table. Eighteen other buses (No. 41 to 58) are added to the monitor list since critical buses for system intact are different from those of the system with contingencies. The 18 buses are critical buses for system intact.

Table 2: Most Limiting Contingencies

No.	From Bus	To Bus	Ckt
1	50827 [GRAPEVN6230.00] Area 526 SPS	50915 [NICHOL6 230.00] Area 526 SPS	1
2	55814 [ANADARK4138.00] Area 525, WFEC	56024 [PARADSE4138.00] Area 525 WFEC	1
3	56429 [MINGO 3115.00] Area 534 SUNC	56555 [COLBY 3115.00] Area 531 MIDW	1
4	56451 [MINGO 7345.00] Area 534 SUNC	56453 [MINGXFR6230.00] Area 534 SUNC	1
5	99349 [3ARKA-N 115.00] Area 151 EES	99407 [3FRIEND 115.00] Area 151 EES	1
6	51534 [TUCO 345] Area 526 SPS	54119 [OKLAUNION 345] Area 526 SPS	1

Table 3: Critical Buses								
No.	Bus No.	Bus Name	No.	Bus No.	Bus Name	No.	Bus No.	Bus Name
1	56555	COLBY 3 115	21	56615	RULTON 3 115	41	51533	TUCO6 230
2	99349	3ARKA-N 115	22	56614	NSI 3 115	42	54119	OKLAUNION 345
3	56458	OBERLIN3 115	23	56355	NSI 115	43	50669	MOORE6 230
4	56371	JOHNSON3 115	24	56351	BREWSTR3 115	44	50888	POTTRC7 345
5	56367	HERNDON3 115	25	56610	BRWSTR 3 115	45	50887	POTTRC6 230
6	56365	BIRDCTY3 115	26	56356	NSI TAP3 115	46	50827	GRAPEVN6 230
7	56554	ATWOOD 3 115	27	56453	MINGXFR6 230	47	50840	MCLEAN3 115
8	56457	OBER T 3 115	28	56429	MINGO 3 115	48	50932	KIRBY3 115
9	56370	STFRAN 3 115	29	56613	KANRADO3 115	49	51534	TUCO7 345
10	56369	NATWOOD3 115	30	56354	KANARAD3 115	50	50858	FINNEY7 345
11	56441	CSTFRAN3 115	31	56373	RHOADES3 115	51	50600	TXPHSF3 115
12	56364	ATWODSW3 115	32	56024	PARADSE4 138	52	54153	ELKCITY6 230
13	56471	STFRANT3 115	33	56559	PH RUN 3 115	53	54276	JERICHO3 115
14	56368	LAWNRID3 115	34	56052	SNYDER 4 138	54	54119	O.K.U.-7 345
15	56556	HOXIE 3 115	35	56412	GRINNEL3 115	55	56449	HOLCOMB7 345
16	56444	GOODCTY3 115	36	56352	CHASE 3 115	56	58772	E-LIBER3 115
17	56443	GODLNDT3 115	37	56358	SHARNSP3 115	57	54293	SHAM 4WT 138
18	56612	GOODLAN3 115	38	56611	CHASET 3 115	58	54295	SHAM 3WT 115
19	56353	GOODLND3 115	39	56616	SHARSPR3 115			
20	56357	RULETON3 115	40	50827	GRAPEVN6 230			

II.3. <u>CRITERIA</u>

For system intact (no outages), SPS east export limit is defined as the transfer capability when one of the critical buses falls below 0.95 PU. For single contingencies (N-1), no criteria are trying to be established here. Instead, the transfer limit for 0.02 PU bus voltage drop is reported. That is, the bus voltages with incremental SPS east export are compared to the bus voltages with no SPS east export. For example, if a bus voltage is 0.88 PU when SPS east export is zero for N-1 conditions the transfer limit is defined when the bus voltage drops below 0.86 PU. If the no transfer bus voltage is higher than 0.92 PU the transfer limit is defined when the bus voltage drops below 0.90 PU for a single contingency. The most limiting condition will define the transfer limit.

II.4. RESULTS

The transfer limits are in **Table 4** below.

Table 4: Voltage Stability Limits			
Contingency	TTC (MW)	Violations	Criteria
Base	700	50827 GRAPEVN6230.00 (Area 526, SPS): V=0.95	0.95 PU
N-1 Contingency 1	620	54295 SHAM 3WT 115 (Area 520, AEPW): V=0.90	0.02 PU voltage drop or <=0.90 PU

II.5. MODEL

The 2002 Summer Peak model, 2001 series, is modified to create two cases, one with zero SPS east export, one with 600 MW SPS east export.

The following conditions have been added to the 0 MW case:

A. QMAX of all SPP generators are set to 90% of their original values to account for reactive power reserve.
B. The ERCOT North HVDC is a source of 200 MW, a load of 100 MVAR with three 30 MVAR of switched capacitors and one 50 MVAR switched reactor available on the Oklaunion 345 kV bus. Power is flowing from ERCOT to SPP.
C. The Blackwater HVDC is a load of 150 MW and 75 MVAR with four 30 MVAR and one 54 MVAR of switched capacitors available. Power is flowing from SPP to WSCC.
D. No power flows across the Eddy County. Four 30 MVAR of switched capacitors available.
E. The SPS Phase shifter located at Texas County is set to 0 MW.

The following conditions have been added to the 600 MW case:

A. QMAX of all SPP generators are set to 90% of their original values to account for reactive power reserve. The assumption of using 90% generator reactive limits is not part of the SPP criteria.

The ERCOT North HVDC is a source of 200 MW, a load of 100 MVAR with three 30 MVAR of switched capacitors and one 50 MVAR switched reactor available on the Oklaunion 345 kV bus. Power is flowing from ERCOT to SPP.

B. The Blackwater HVDC is a source of 200 MW, a load of 100 MVAR with four 30 MVAR and one 54 MVAR of switched capacitors available. Power is flowing from WSCC to SPP.
C. The Eddy County HVDC is a source of 100 MW and a load of 50 MVAR with four 30 MVAR of switched capacitors available.
D. The SPS Phase shifter located at Texas County is set to 0 MW.
E. 200 MW from SPS to AMEREN.
F. 100 MW from SPS to Northern States Power (NSP).
G. An unplanned 8 Mvar capacitor was added to the Ruleton 115 kV (56357) bus to eliminate a local voltage problem. A 8 Mvar bank was already on in the model.
H. The SPS Nichols and Harrington units voltage schedule was increased to 1.04 and 1.01 respectively to improve the base case voltage at Shamrock 115 kV (bus 54295).
I. The Grapevine 230/115 kV transformer taps were fixed at 1.05 PU to balance the voltage on both sides of the transformer for contingency 1.

II.6. <u>DISCUSSION</u>

The first swing angular stability limits for SPS east export capability is 900 MW for N-1 and 500 MW for the N-2 outages. The voltage stability limits for SPS east export capability is 700 MW for the normal system and 620 MW for the N-1 system condition. The Shamrock 115 kV bus voltage is the transfer limit (<0.90 PU) for contingency 1. The N-1 voltage stability limit is lower than that of first swing angular stability limit. Two major factors contribute to the lower voltage stability limits are:

A. QMAX of all SPP generators are set to 90% of their original values in voltage stability study.
B. Loads are modeled as constant power loads in voltage stability study. Loads are modeled as constant current and constant admittance loads in first swing angular stability.

III. 1^{ST} SWING ROTOR ANGLE STABILITY ANALYSIS

III.1. OBJECTIVE

A. This study determines the stability TTC for SPS for 2002 Summer using the transient stability models published by the Southwest Power Pool (SPP) Model Development Working Group (MDWG) May 24^{th}, 2001.

B. The study used single outage (N-1) and double outage (N-2) events that are described below.

1) The N-1 simulation sequence of events:
   - A) 0 to 1 second
     - ÷ no disturbance simulation.
   - B) At 1 second
     - ÷ apply a 3 phase, 4 cycle fault on the Potter 345 kV bus.
   - C) Clear fault
     - ÷ trip Potter-Finney-Holcomb 345 kV circuit.
   - D) 30 cycles after fault clears
     - ÷ close Potter-Finney 345 kV circuit (Finney breaker open),
     - ÷ apply a 3 phase, 4 cycle fault on the Potter 345 kV bus.
   - E) Clear fault
     - ÷ trip Potter-Finney-Holcomb 345 kV circuit.
   - F) At 20 seconds
     - ÷ end simulations.

2) The N-2 simulation sequence of events:
   - A) Potter-Finney-Holcomb 345 kV circuit open in base model power flow.
   - B) 0 to 1 second
     - ÷ no disturbance simulation.
   - C) At 1 second
     - ÷ apply a 3 phase, 4 cycle fault on the Oklaunion 345 kV bus.
   - D) Clear fault
     - ÷ trip Oklaunion-Lawton 345 kV circuit,
     - ÷ trip ERCOT North HVDC tie (200 MW flowing North into SPP).

÷!trip reactors and capacitors at North HVDC.

E) At 20 seconds

÷ end simulations.

C. This study is restricted to determining the TTC in mega-watts (MW) as defined by the following first swing angular stability criteria:

1) All machines remain in synchronism.
2) The machine rotor angle transients must be well damped.

D. The following conditions were added to the N-1 limiting case model (TS02SP4-FG):

1) The Electric Reliability Council of Texas (ERCOT) North HVDC (NDC) is a source of 200 MW, a load of 100 Mvar with three 30 Mvar of switched capacitors and one 50 Mvar switched reactor available on the Oklaunion 345 kV bus. The NDC was already supplying 200 MW from ERCOT to SPP in the transient stability base model.
2) Blackwater HVDC is a source of 200 MW, a load of 100 Mvar with four 30 Mvar and one 54 Mvar of switched capacitors available. Power is flowing from WSCC to SPP.
3) The Eddy County HVDC is a source of 100 MW and a load of 50 Mvar with four 30 Mvar of switched capacitors available. Power is flowing from WSCC to SPP.
4) The SPS Phase shifter located at Texas County is set to 0 MW.
5) All SPS generation is on-line and at maximum real power output.

E. The following conditions were added to the N-2 limiting case model (TS02SP4-HA):

1) The Potter-Finney-Holcomb 345 kV circuit was opened.
2) The Electric Reliability Council of Texas (ERCOT) North HVDC (NDC) is a source of 200 MW and a load of 100 Mvar, with three 30 Mvar of switched capacitors and one 50 Mvar switched reactor available on the Oklaunion 345 kV bus. The NDC was already supplying 200 MW from ERCOT to SPP in the transient stability base model.

3) Blackwater HVDC is a load of 100 MW and a load of 50 Mvar, with four 30 Mvar and one 54 Mvar of switched capacitors available.
4) The Eddy County HVDC is a source of 0 MW and a load of 0 Mvar, with four 30 Mvar of switched capacitors available. There is 0 Power flowing across the HVDC.
5) The SPS Phase shifter located at Texas County is set to 0 MW.
6) All SPS generation is on-line and at maximum real power output.

F. The results of the study are documented.

III.2. STUDY APPROACH

The 2002 Summer SPP transient stability model was modified to include the effects of the NDC, Eddy County HVDC, Blackwater HVDC, and the Texas County Phase Shifter and the N-1 and N-2 pre-fault base models were created. The base models were screened by the Power Technologies, Incorporated "Dynamic Simulation Program" (PSSDS4) to determine how much power could be exported from SPS before first swing generator rotor angle instability for the faults tested. The SPS to Ameren (AMRN) 200 MW and the SPS to Northern States Power Company (NSP) 100 MW transactions were added to models before the SPS to Entergy (EES) transfer was applied. NSP is in MAPP, AMRN is in MAIN, and EES is in SERC.

III.3. ASSUMPTIONS

A. Models

The SPP 2002 Summer Peak transient stability model was used to create the base models used to test the first-swing rotor angle stability for varying levels of SPS exports. The modifications to the base model to create the transient stability simulation cases are in **ATTACHMENT A** in **section III.7.** All attachments are in **section III.7**.

Base Model	Year	Season	Load
TS02SP4	2002	Summer	Peak

B. Loads

1). Transient Stability Model

The majority of load in the transient stability models is modeled 100 % constant current for the real part and 100 % constant admittance reactive part. The time frame studied (0 to 20 seconds) is before autotransformer regulation and distribution load tap changing (LTC) transformers can adjust system voltages.

C. Generation

1) Reactive Reserve

Generator reactive output is determined by system condition during the simulation.

2) Real Power Dispatch

The analysis scales generation up in the Source (SPS) and scale generation down in the Sink (AMRN, NSP, and EES) for the transfers. The unit participation will be based on the current generation dispatch in the model.

3) Exciter Limiters

Over-excitation limiters are not modeled; however, the generator reactive output was checked at the endpoint of the simulation (20 seconds).

D. Shunts

Automatic switching of capacitors and reactors was not modeled; however, the SPS Eddy County SVC is modeled.

E. Transformers

1) Power Transformers

Transformers with voltage regulation and tap changers was not modeled in the dynamic simulation.

2) Phase Shifters

Operation of phase shifting transformers was not modeled in the dynamic simulation.

F. High Voltage Direct Current Converters Stations

1) ERCOT North (Oklaunion)-see section III.1.D.
2) Blackwater-see section III.1.D.
3) Eddy County-see section III.1.D.
4) Steady state model

The Blackwater, Eddy County, and Oklaunion HVDC ties were modeled with 100% constant current real power and 100% constant admittance reactive power loads.

G. SPS EHV Transmission Plan

1) The Potter (SPS) to Holcomb Sunflower Electric Power Corp. (SUNC) 345 kV is in service by fall 2001.

H. Transactions

Refer to Study Approach-section III.2.

I. Model Overloads and Voltage Violations

Overloads and voltage violations in the models are ignored for the dynamic simulation.

J. Contingency and Fault Selection

The SPS Export limiting outages for this study are:

1) N-1, is the loss of the Potter-Finney-Holcomb 345 kV circuit due to a 3 phase, 4 cycle fault on the Potter 345 kV bus.
2) N-2, is the loss of the Oklaunion-Lawton 345 kV circuit and the North HVDC for a 3 phase, 4 cycle fault on the Oklaunion 345 kV bus. This fault is initiated when the Potter to Finney circuit is out of service.

K. First-swing Rotor Angle Stability transfer limit

Transfer limit is reached before any machines in the model go unstable. An approximate 25 MW margin was left before units became unstable.

III.4. TASKS

Task 1 Model Preparation

The base models were modified by making the changes to create the N-1 (see **ATTACHMENT A**) and N-2 (see **ATTACHMENT B**) SPS export models.

Task 2 Analyze SPS export N-1 and N-2 export limits using first-swing transient simulations

Perform transient simulations on increasing SPS exports for N-1 and N-2 conditions until rotor angle synchronism is lost. Then determine acceptable SPS export limit.

Task 3 Report SPS Export TTC for first-swing rotor angle stability

Report results of the SPS Export TTC for 2002 Summer.

III.5. PROJECT DELIVERABLES

A. Report the SPS Export TTC for first-swing rotor angle stability.

The SPS Export TTC is 900 MW for N-1 conditions and 500 MW for N-2 conditions. The SPS Export TTC is base on 1st swing rotor angle loss of synchronism. Please note that the SPS machines collectively (in a common mode) loose synchronism with all other machines in the N-1 scenario at 1000 MW and in the N-2 scenario at 550 MW.

The N-1 and N-2 transfer levels of 900 MW and 500 MW respectively violate SPS tie line Rate B thermal limits (see **ATTACHMENT C**). Therefore, the SPS export stability TTC limits exceed the thermal limits.

The N-1 stability plots are in **ATTACHMENT D (1-6)**. The Tolk unit 2 rotor angle is plotted in **Attachment D.1** for the 20 second simulation for different SPS exports.

The N-2 stability plots are in **ATTACHMENT E (1-6)**. The Tolk unit 2 rotor angle is plotted in **Attachment E.1** for the 20 second simulation for different SPS exports.

The N-1 and N-2 simulations showed numerous SPS to SPP tie bus voltages below 0.9000 PU (see **ATTACHMENT F**). Therefore, the SPS export stability limits exceed the voltage criteria. The time frame of the study is before autotransformer LTC action and EHV switch capacitor banks are not modeled (all available capacitor banks are probable on due to the season modeled). The load modeled in this simulation is softer than a constant real and reactive power load. Conclusion, low voltages indicate that voltage collapse might happen at the define N-1 and N-2 SPS export stability limits. Again the TTC is an upper limit.

III.6. CONTACTS

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III.7. ATTACHMENT A: N-1 SPS Export stability base case model setup.

SOUTHWEST POWER POOL										
SPS EXPORT STABILITY LIMIT N-1 MODELS										
(October 5, 2001)										
Plot File (*.OUT)	**TS02SP4-F0**	**TS02SP4-FA**	**TS02SP4-FB**	**TS02SP4-FC**	**TS02SP4-FD**	**TS02SP4-FE**	**TS02SP4-FF**	**TS02SP4-FG**	**TS02SP4-FGX**	**TS02SP4-FH**
SPS Exports to SPP ties (MW)	0	300	400	500	600	700	800	900	900	1000
North HVDC (MW to ERCOT)	-200	-200	-200	-200	-200	-200	-200	-200	-200	-200
Blackwater HVDC (MW to WSCC)	150	150	150	100	0	-100	-200	-200	-200	-200
Eddy County HVDC (MW to WSCC)	0	0	0	0	0	0	0	-100	-100	-200
Potter-Holcomb 345kV	A	A	A	A	A	A	A	A	IN	A
Grapevine-Elk City 230kV	IN	IN	IN	IN	IN	IN	IN	IN	IN	IN
Tuco-Oklaunion 345kV	IN	IN	IN	IN	IN	IN	IN	IN	B	IN
Monitored data	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
Potter-NW 345 kV	-	-	-	-	-	-	-	-	-	-
SPS to AMRN (MW)	0	200	200	200	200	200	200	200	200	200
SPS to NSP (MW)	0	100	100	100	100	100	100	100	100	100
SPS to EES (MW)	0	0	100	200	300	400	500	600	600	700
Fault Type:	A) 4 cycle 3 phase fault on Potter 345 kV bus, trip Pot-Fin-Holc 345 kV ckt, reclose into fault									
	(Potter end of line only), L/O ckt.									
Fault Type:	B) 4 cycle 3 phase fault on Oklaunion 345 kV bus, trip Oklaunion-Lawton Eastside 345 kV ckt,									
	L/O ckt, trip North HVDC tie.									
Monitored data:	1) All SPP machine speed, angle, real and reactive power is monitored. Tolk 230, 345 kV,									
	Harrington 230 kV, and Nichols 230 kV bus voltage and angle.									
	2) Date in (1) above and SPS to SPP tie flows (P & Q).									
Notes:	(#1) Jones max. rotor angle spread is 36.93 degrees for 773 MW (estimated) SPS to SPP tie flow									
	without Potter-NW 345 kV in and 1000 MW with Potter-NW 345 kV in.									

ATTACHMENT B: N-2 SPS Export stability base case model setup.

SOUTHWEST POWER POOL						
SPS EXPORT STABILITY LIMIT N-2 MODELS						
(October 5, 2001)						
Plot File (*.OUT)	**TS02SP4-HA**	**TS02SP4-HB**	**TS02SP4-HC**	**TS02SP4-HD**	**TS02SP4-HE**	**TS02SP4-HF**
SPS Exports to SPP ties (MW)	500	600	550	525	0	300
North HVDC (MW to ERCOT)	-200	-200	-200	-200	-200	-200
Blackwater HVDC (MW to WSCC)	100	-50	0	25	150	150
Eddy County HVDC (MW to WSCC)	0	0	0	0	0	0
Potter-Holcomb 345kV	OUT	OUT	OUT	OUT	OUT	OUT
Grapevine-Elk City 230kV	IN	IN	IN	IN	IN	IN
Tuco-Oklaunion 345kV	B	B	B	B	B	B
Monitored data	1,2	1,2	1,2	1,2	1,2	1,2
Potter-NW 345 kV	-	-	-	-	-	-
SPS to AMRN (MW)	200	200	200	200	0	200
SPS to NSP (MW)	100	100	100	100	0	100
SPS to EES (MW)	200	300	250	225	0	0

Fault Type: B) 4 cycle 3 phase fault on Oklaunion 345 kV bus, trip Oklaunion-Lawton Eastside 345 kV ckt, L/O ckt, trip North HVDC tie.

Monitored data: 1) All SPP machine speed, angle, real and reactive power is monitored. Tolk 230, 345 kV, Harrington 230 kV, and Nichols 230 kV bus voltage and angle.

2) Date in (1) above and SPS to SPP tie flows (P & Q).

ATTACHMENT C: SPS tie flow at the stability limit for the pre-fault and post-fault transfers.

SOUTHWEST POWER POOL

SPS EXPORT STABILITY LIMIT

SPS-SPP TIE FLOW 900 MW
DISTURBANCE= N-1
TRIP POTTER-FINNEY-HOLCOMB 345 KV CKT.

													POWER FLOW = TS02SP4-1-FG			TS02SP4-3-FG		
													*****PRE-FAULT CONDITIONS****			POST-FAULT AT 20 SEC.		
															RATE A			RATE B
SPS TIE FLOW											SUMMER	SUMMER	BASE MODEL	BASE MODEL	FROM BUS	N-1	N-1	FROM BUS
FROM AREA					TO AREA						RATE A	RATE B	MW	MVAR	I%	MW	MVAR	I%
SPS	526	50827	GRAPEVN6	230	AEPW	520	54153	ELKCITY6	230	1	319	350	248.5	-81.7	90	322.6	37.6	107
SPS	526	50840	MCLEAR3	115	AEPW	520	54295	SHAM 3WT	115	1	69	90	48.4	-9.5	77	58.1	-2.7	74
SPS	526	50932	KIRBY3	115	AEPW	520	54276	JERICHO3	115	1	69	90	31.0	-6.2	47	35.5	-2.9	42
SPS	526	51534	TUCO7	345	AEPW	520	54119	O.K.U.-7	345	1	956	1051	333.9	-57.1	39	462.5	-12.7	48(2)
SPS	526	50858	FINNEY7	345	SUNC	534	56449	HOLCOMB7	345	1	1042	1355	238.3	-31.2	23	-	-	OPEN
SPS	526	50600	TXPHSF3	115	WEPL	539	58772	E-LIBER3	115	1	150	150	0.0	5.6	4	65.8	-13.5	45
								SPS-SPP TIE FLOW TOTAL					900.1	-180.1		944.5	5.8	
SPS	526	51203	ROOSEVL6	230	WSCC	999	59995	PNM-DC6	230	1	-	-	-200.0	-75.5				
SPS	526	52185	EDDYCO6	230	WSCC	999	59996	EPTNP-D6	230	1	-	-	-100.0	20.0				

SPS-SPP TIE FLOW 500 MW
DISTURBANCE= N-2
OPEN POTTER-FINNEY-HOLCOMB 345 KV CKT.
TRIP OKLAUNION-L.E.S 345 KV CKT., TRIP NORTH HVDC.

													POWER FLOW = TS02SP4-1-HA			TS02SP4-3-HA		
													*****PRE-FAULT CONDITIONS****			POST-FAULT AT 20 SEC.		
															RATE A			RATE B
SPS TIE FLOW											SUMMER	SUMMER	BASE MODEL	BASE MODEL	FROM BUS	N-2	N-2	FROM BUS
FROM AREA					TO AREA						RATE A	RATE B	MW	MVAR	I%	MW	MVAR	I%
SPS	526	50827	GRAPEVN6	230	AEPW	520	54153	ELKCITY6	230	1	319	350	218.9	-64.8	77	343.9	64.5	121
SPS	526	50840	MCLEAR3	115	AEPW	520	54295	SHAM 3WT	115	1	69	90	43.6	-8.8	68	61.0	2.1	83
SPS	526	50932	KIRBY3	115	AEPW	520	54276	JERICHO3	115	1	69	90	27.6	-3.8	41	36.3	2.3	45
SPS	526	51534	TUCO7	345	AEPW	520	54119	O.K.U.-7	345	1	956	1051	209.7	-17.4	26	0.4	-139.3	13(1)
SPS	526	50858	FINNEY7	345	SUNC	534	56449	HOLCOMB7	345	1	1042	1355	-	-	OPEN	-	-	OPEN
SPS	526	50600	TXPHSF3	115	WEPL	539	58772	E-LIBER3	115	1	150	150	0.1	5.0	3	64.7	-13.8	45
								SPS-SPP TIE FLOW TOTAL					499.9	-89.8		506.3	-84.2	
SPS	526	51203	ROOSEVL6	230	WSCC	999	59995	PNM-DC6	230	1	-	-	99.9	-123.5				
SPS	526	52185	EDDYCO6	230	WSCC	999	59996	EPTNP-D6	230	1	-	-	0.0	-30.0				

NOTES: (1) TUCO to Oklaunion 345 kV circuit open on the Oklaunion end.
(2) TUCO 230/345 kV autotransformer at 91% of its 560 MVA rating.

ATTACHMENT D: N-1 transfer model plots.

D.1) Tolk unit 2 rotor angle for SPS exports of 0, 300, 500, 700, 900, and 1000 MW
1) **Trip Potter-Finney-Holcomb 345 kV circuit**
2) **(---X---) 900 MW of SPS exports (TS02SP4-FG.OUT).**

D.2) Tolk 230 kV bus voltage for loss of either 345 kV SPS tie
1) SPS exports 900 MW

D.3) Nichols 230 kV bus voltage for loss of either 345 kV SPS tie
1) SPS exports 900 MW

D.4) Tolk unit 1, Jones unit 1, and Harrington unit 1 machine speed
1) **SPS exports 900 MW**
2) **Scale is +/- 0.3 HZ**

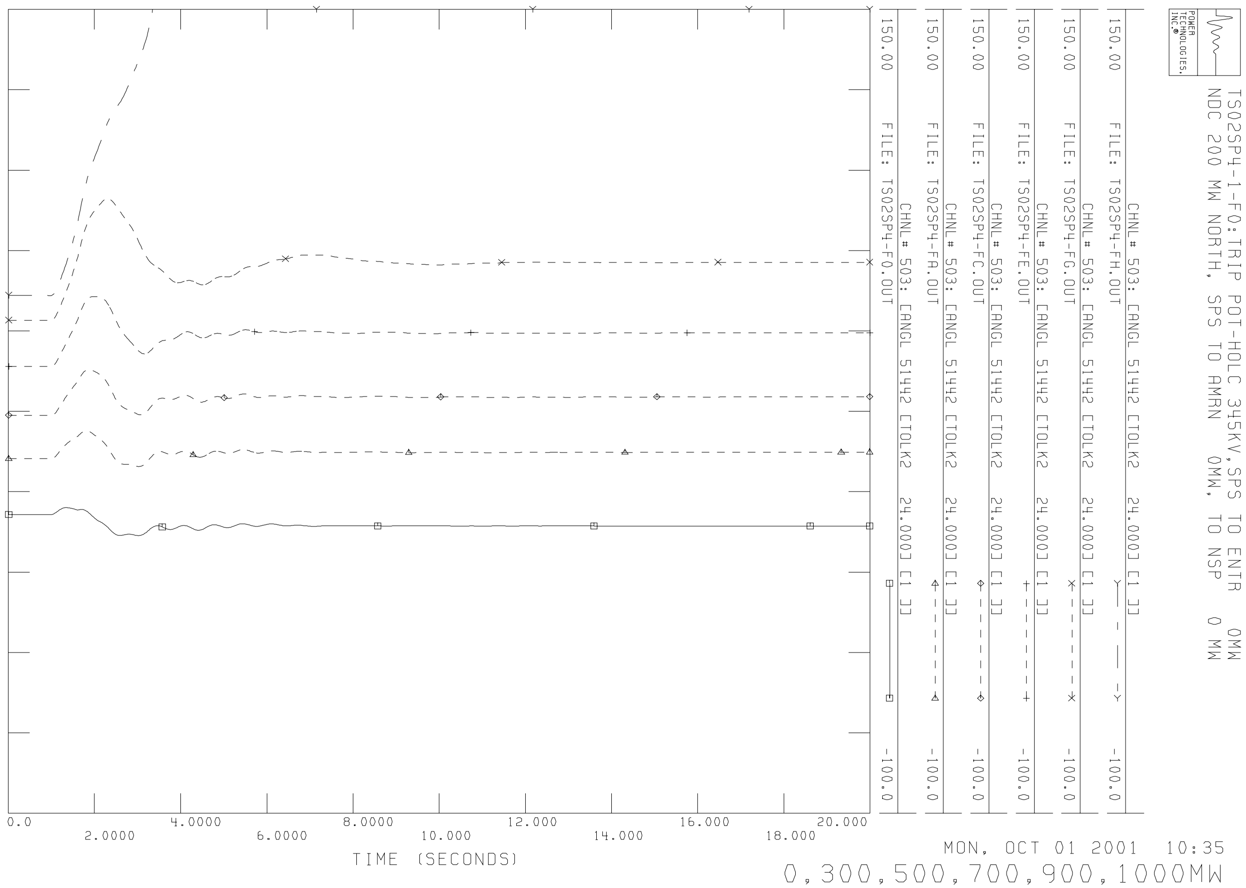
D.5) SPS to SPP tie flow in MW
1) SPS exports 900 MW

D.6) TUCO 230 kV and Oklaunion 345 kV bus voltage
1) SPS exports 900 MW

ATTACHMENT D: N-1 transfer model plots.

D.1) Tolk unit 2 rotor angle for SPS exports of 0, 300, 500, 700, 900, and 1000 MW

1) **Trip Potter-Finney-Holcomb 345 kV circuit**
2) **(---X---) 900 MW of SPS exports (TS02SP4-FG.OUT).**



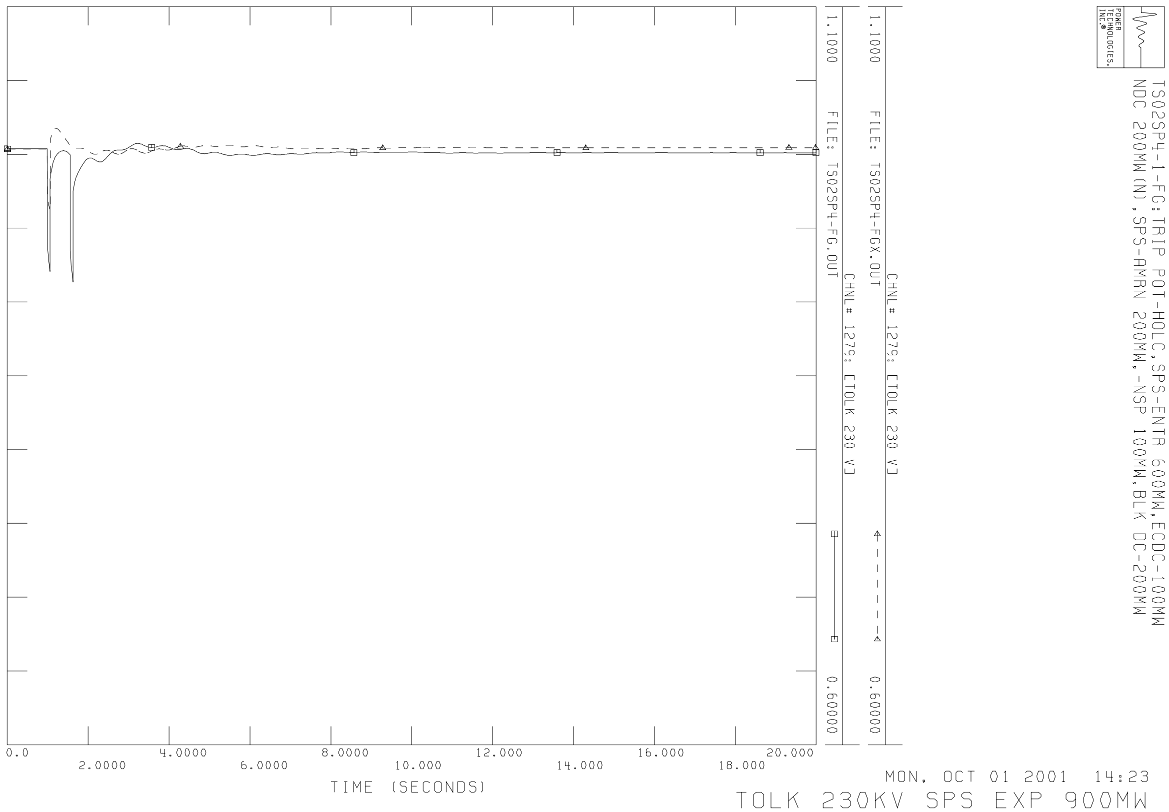
ATTACHMENT D: N-1 transfer model plots.

D.2) Tolk 230 kV bus voltage for loss of either 345 kV SPS tie

1) SPS exports 900 MW

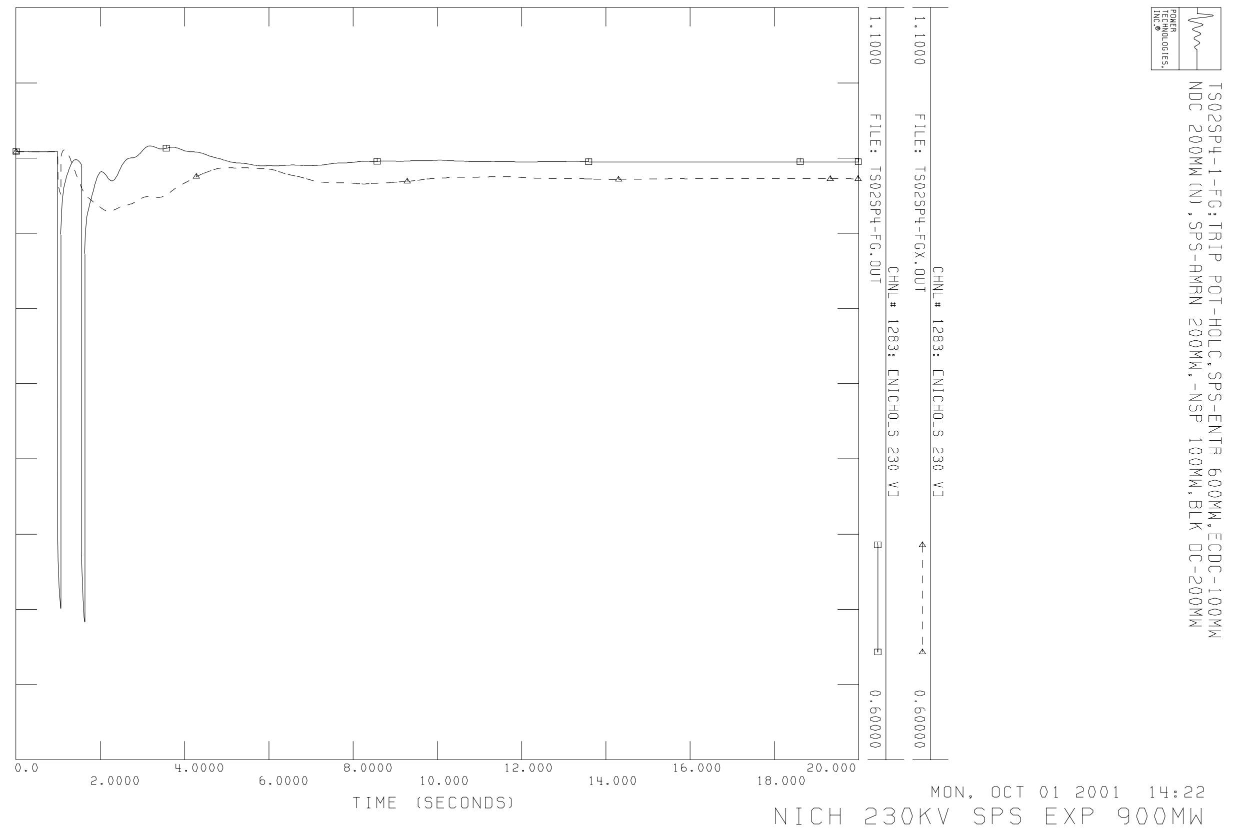
2) (. .) TRIP POTTER-FINNEY-HOLCOMB 345 KV CKT..

3) (--E--) TRIP OKLAUNION-LES 345 KV CKT AND NORTH HVDC



ATTACHMENT D: N-1 transfer model plots.

D.3) Nichols 230 kV bus voltage for loss of either 345 kV SPS tie
1) SPS exports 900 MW
2) (. .) TRIP POTTER-FINNEY-HOLCOMB 345 KV CKT..
3) (--E--) TRIP OKLAUNION-LES 345 KV CKT AND NORTH HVDC

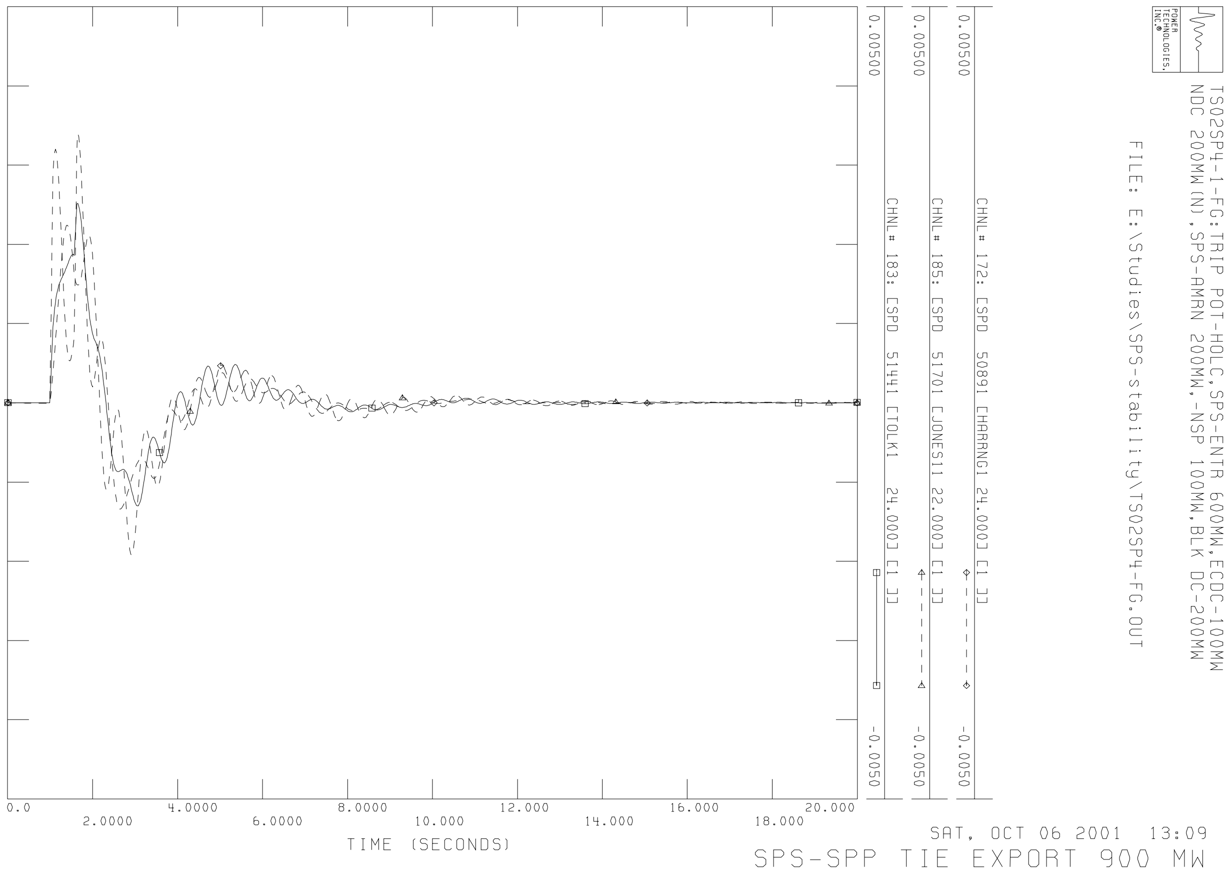


ATTACHMENT D: N-1 transfer model plots.

D.4) Tolk unit 1, Jones unit 1, and Harrington unit 1 machine speed

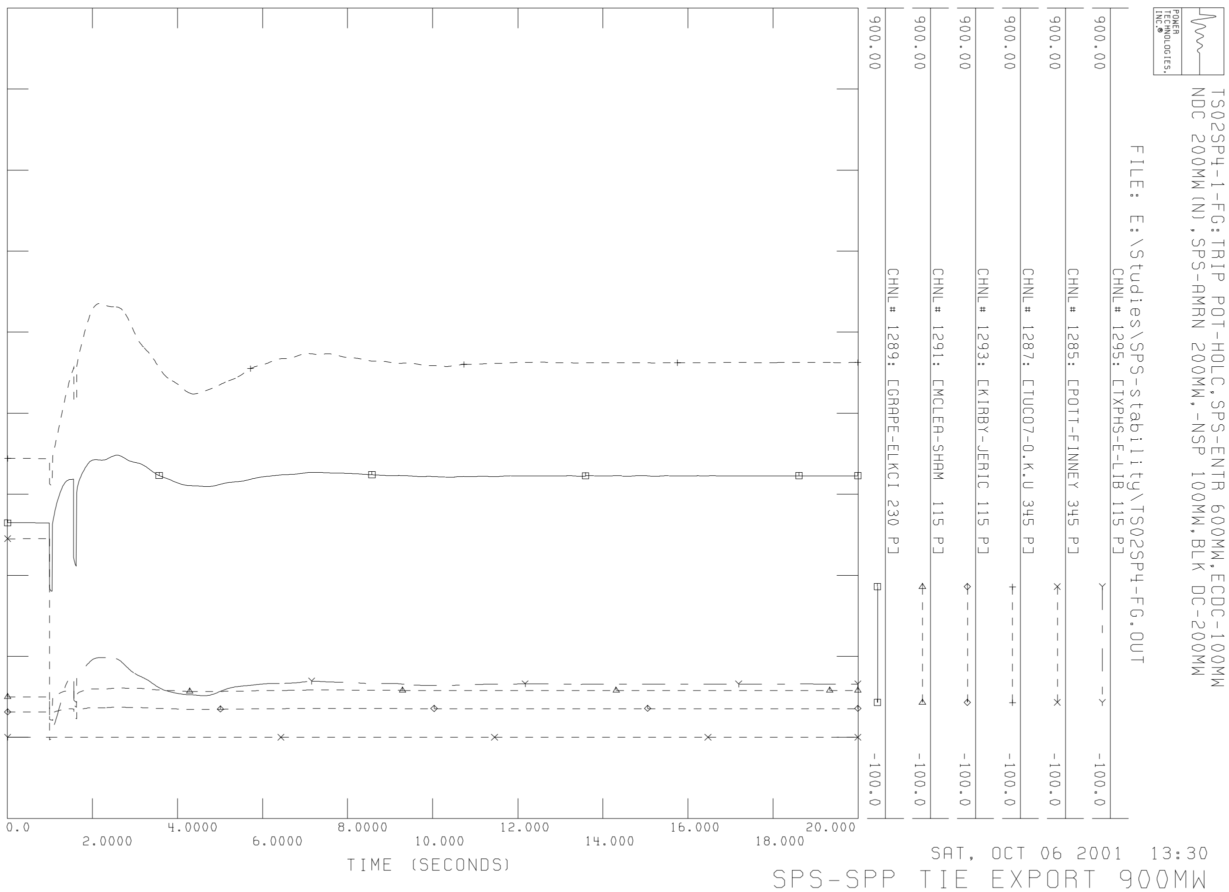
3) SPS exports 900 MW

4) Scale is +/- 0.3 HZ



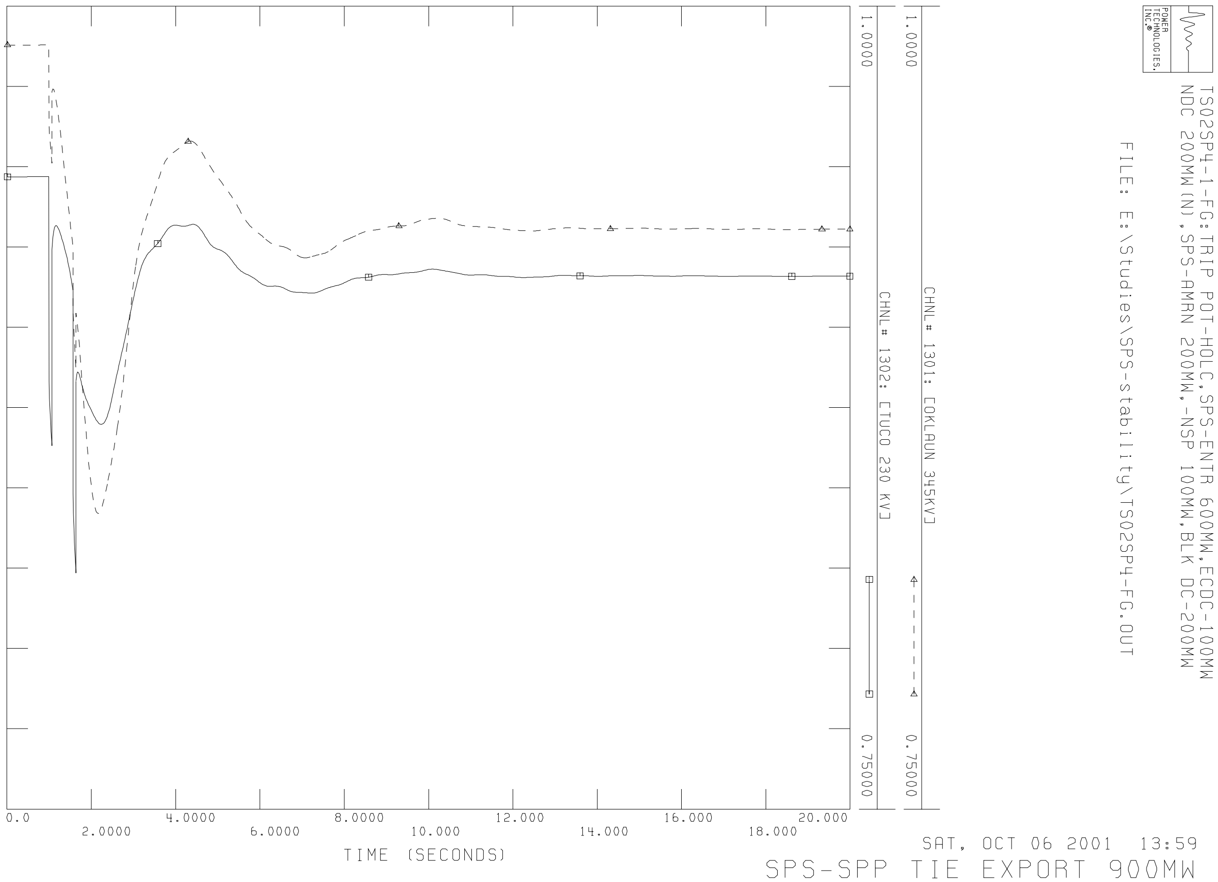
ATTACHMENT D: N-1 transfer model plots.

D.5) SPS to SPP tie flow in MW
1) SPS exports 900 MW



ATTACHMENT D: N-1 transfer model plots.

D.6) TUCO 230 kV and Oklaunion 345 kV bus voltage
1) SPS exports 900 MW



ATTACHMENT E: N-2 transfer model plots.

E.1) Tolk unit 2 rotor angle for SPS exports of 0, 300, 500, 525, and 550 MW

1) **Trip Oklaunion-Lawton 345 kV circuit and North HVDC (200 MW, source)**
2) **(---♥---) 500 MW of SPS exports limit (TS02SP4-HA.OUT)**

E.2) Tolk 230 kV bus voltage for loss of either 345 kV SPS tie

1) SPS exports 525 MW

E.3) Nichols 230 kV bus voltage for loss of either 345 kV SPS tie

1) SPS exports 525 MW

E.4) Tolk unit 1, Jones unit 1, and Harrington unit 1 machine speed

5) **SPS exports 500 MW**
6) **Scale is +/- 0.3 HZ**

E.5) SPS to SPP tie flow in MW

1) SPS exports 500 MW

E.6) TUCO 230 kV and Oklaunion 345 kV bus voltage

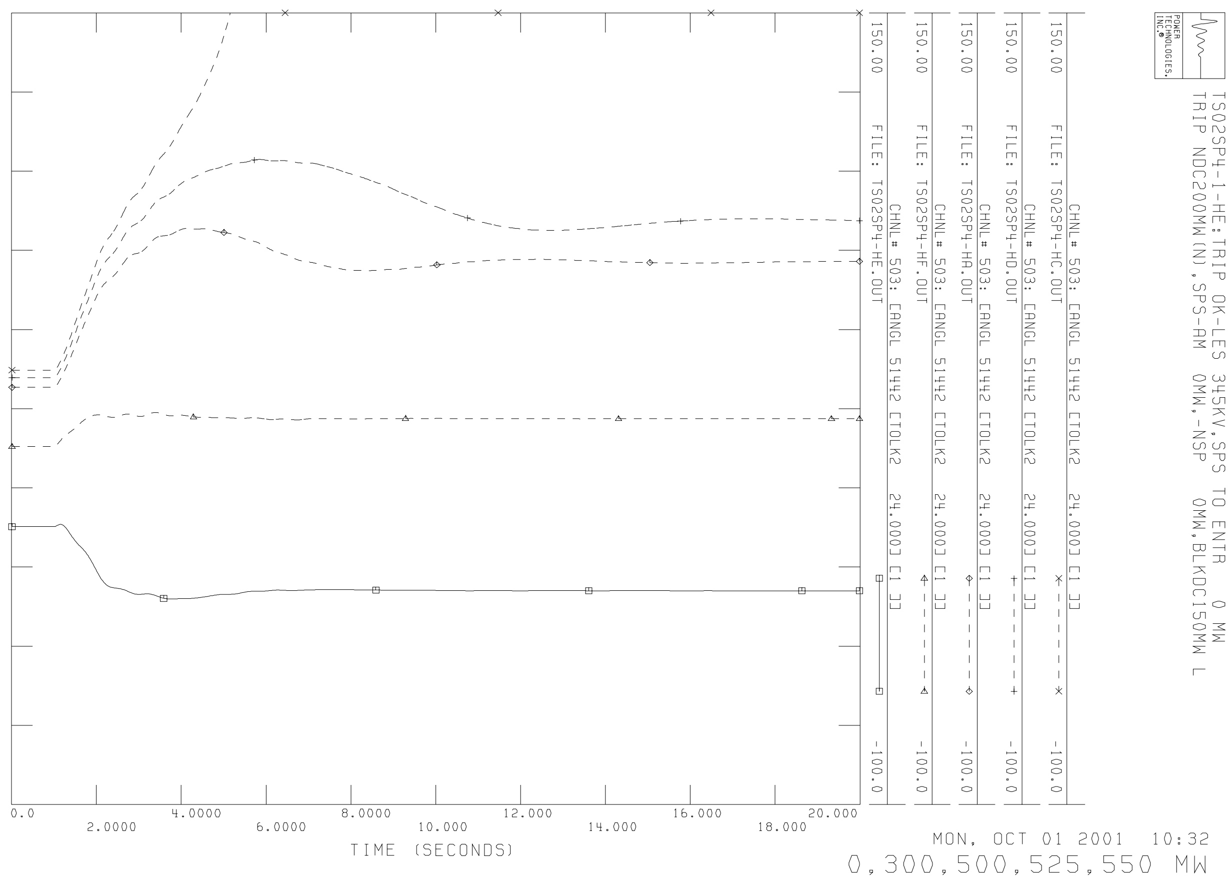
1) SPS exports 500 MW

ATTACHMENT E: N-2 transfer model plots.

E.1) Tolk unit 2 rotor angle for SPS exports of 0, 300, 500, 525, and 550 MW

1) Trip Oklaunion-Lawton 345 kV circuit and North HVDC (200 MW, source)

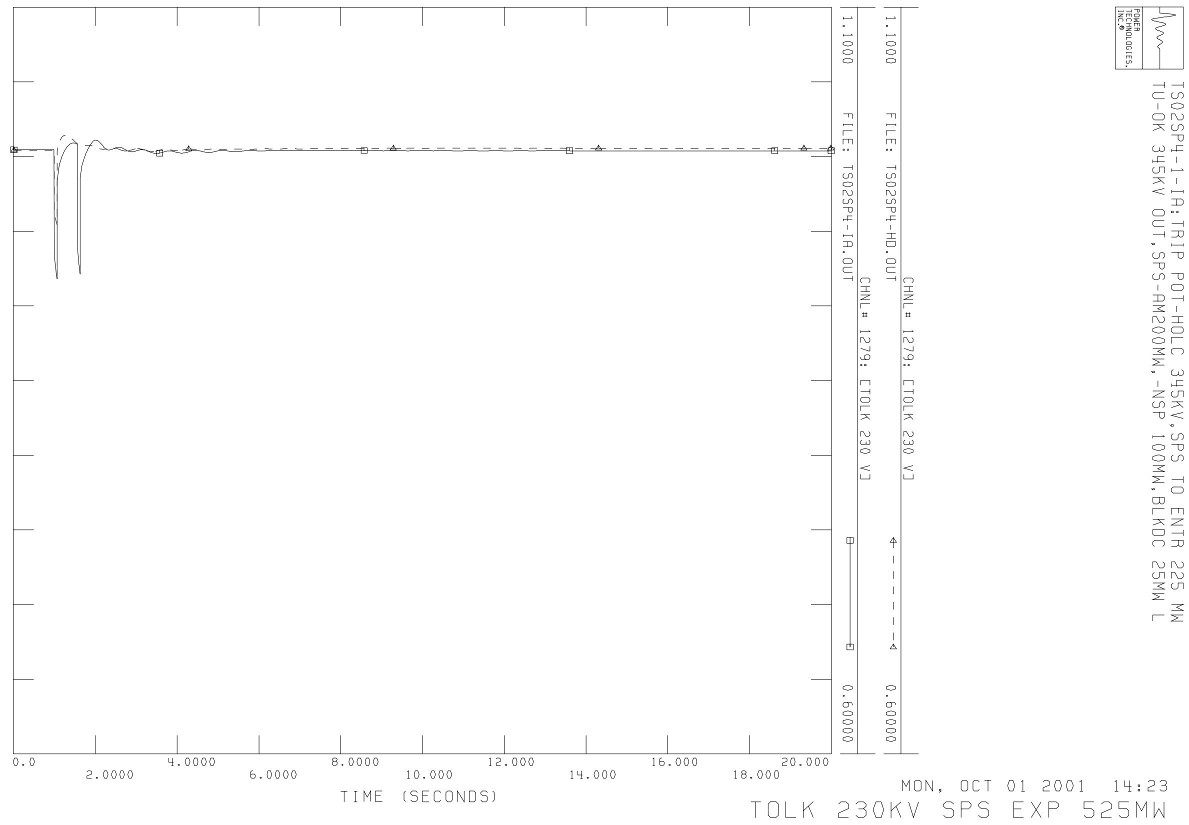
2) (---♥---) 500 MW of SPS exports limit (TS02SP4-HA.OUT)



ATTACHMENT E: N-2 transfer model plots.

E.2) Tolk 230 kV bus voltage for loss of either 345 kV SPS tie

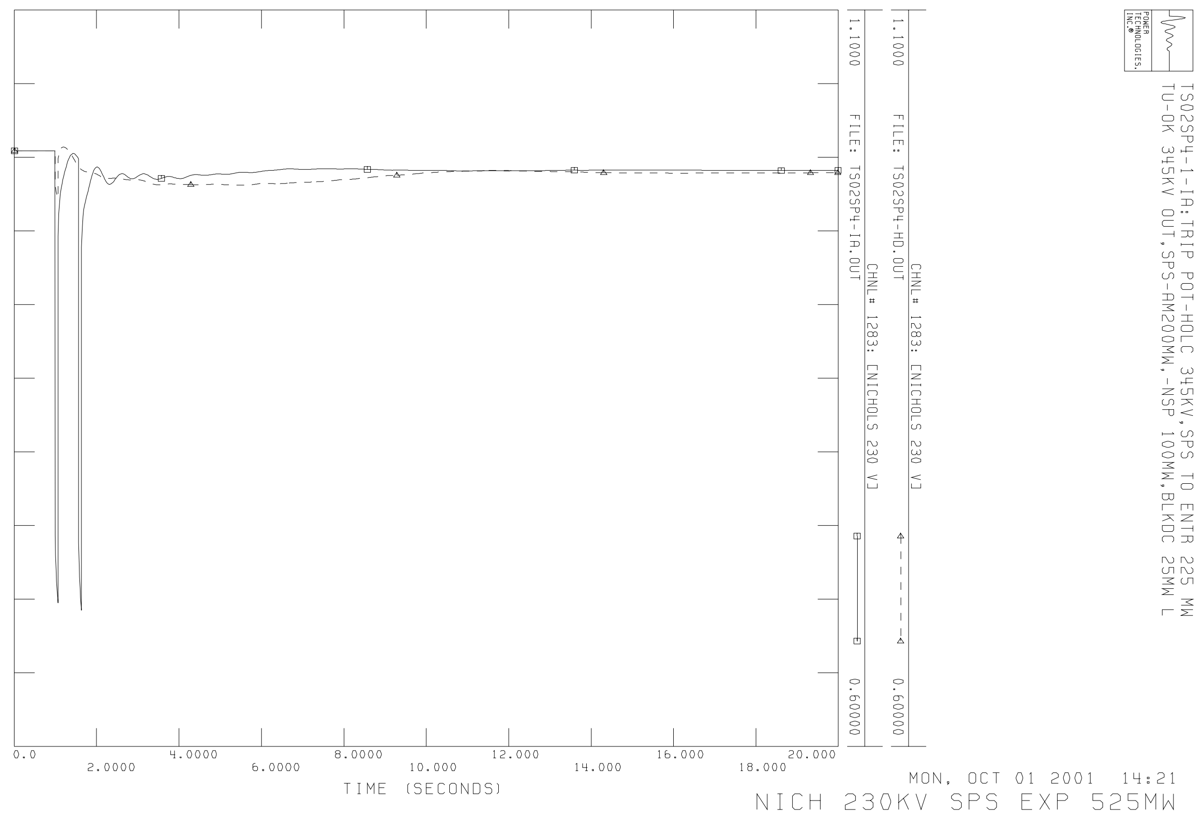
1) **SPS exports 525 MW**
2) **(. .) TRIP POTTER-FINNEY-HOLCOMB 345 KV CKT. TUCO-OKLAUNION 345 KV CKT OPEN IN BASE CASE.**
3) **(--E--) TRIP OKLAUNION-LES 345 KV CKT AND NORTH HVDC. POTTER-FINNEY-HOLCOMB 345 KV CKT OPEN IN BASE CASE.**



ATTACHMENT E: N-2 transfer model plots.

E.3) Nichols 230 kV bus voltage for loss of either 345 kV SPS tie

1) SPS exports 525 MW
2) (. .) TRIP POTTER-FINNEY-HOLCOMB 345 KV CKT. TUCO-OKLAUNION 345 KV CKT OPEN IN BASE CASE.
3) (--E--) TRIP OKLAUNION-LES 345 KV CKT AND NORTH HVDC. POTTER-FINNEY-HOLCOMB 345 KV CKT OPEN IN BASE CASE

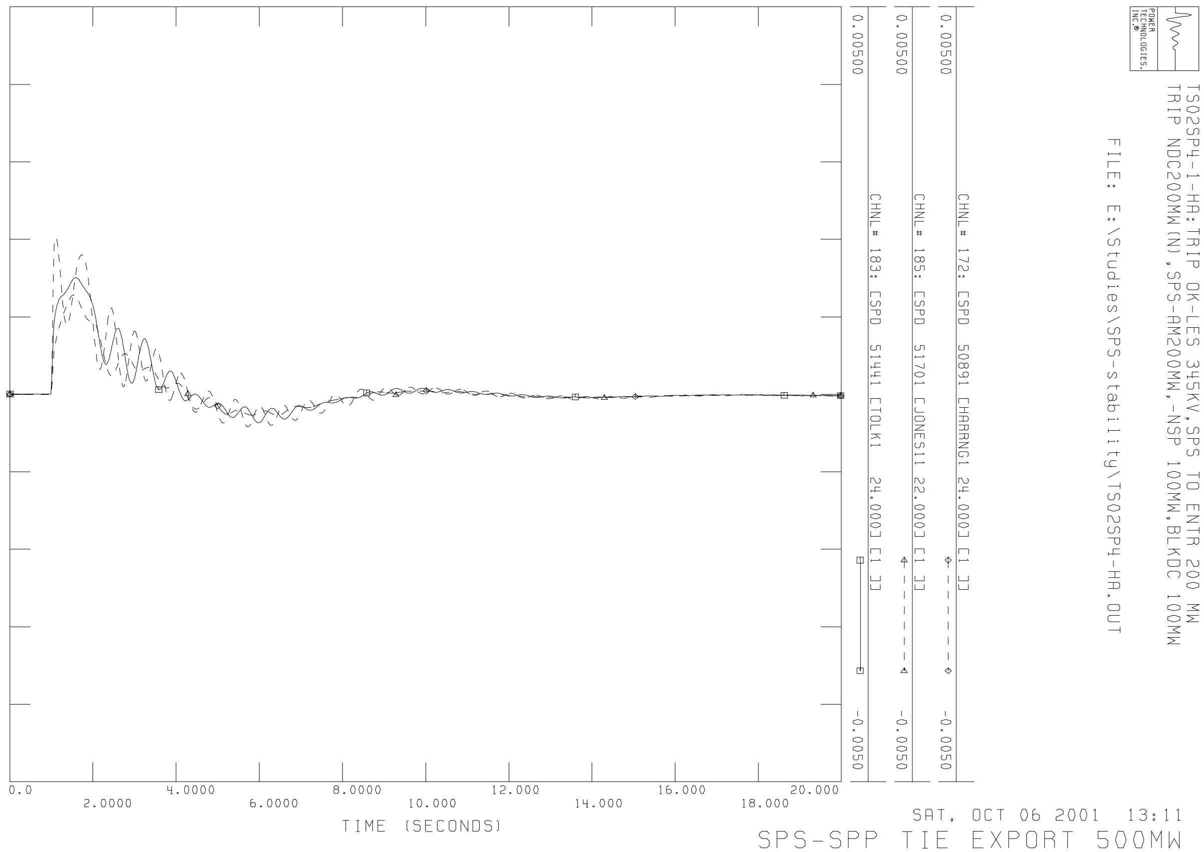


ATTACHMENT E: N-2 transfer model plots.

E.4) Tolk unit 1, Jones unit 1, and Harrington unit 1 machine speed

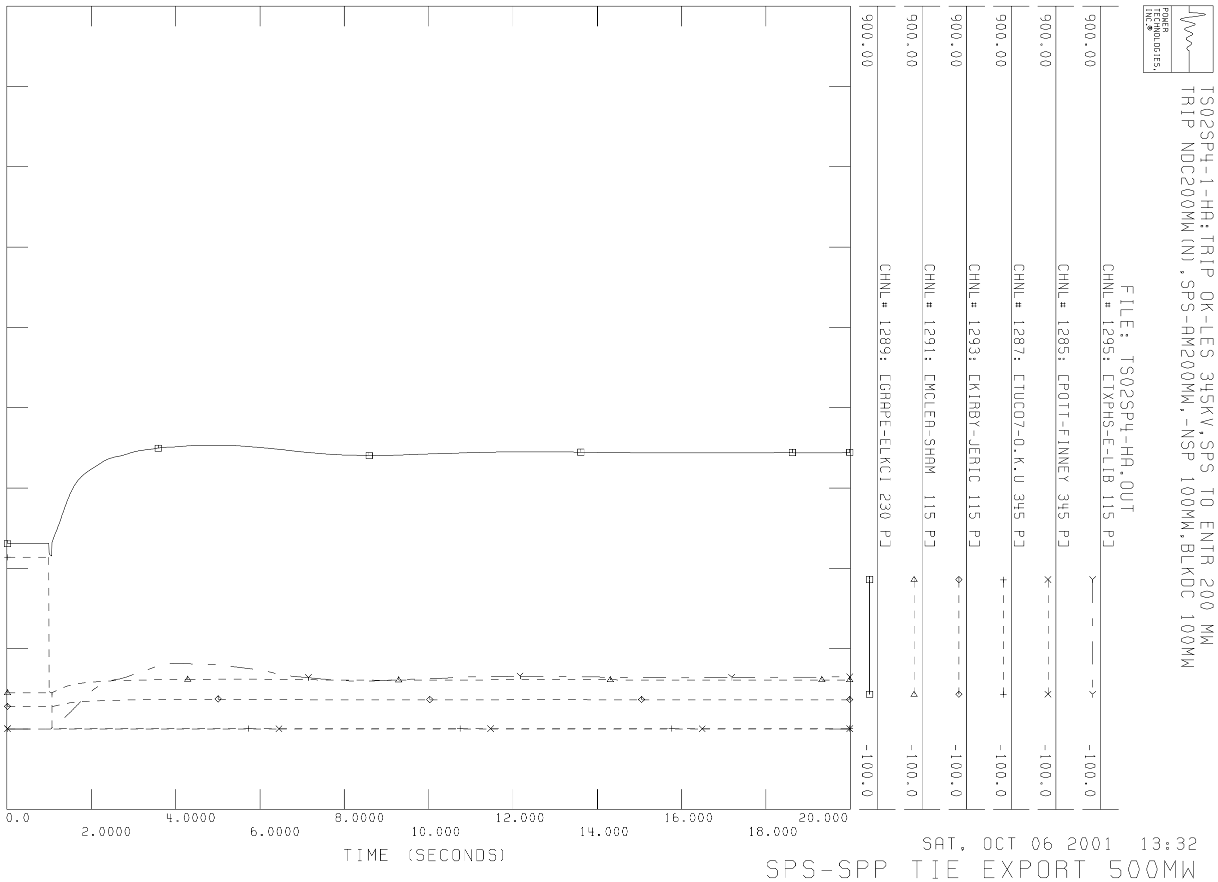
7) SPS exports 500 MW

8) Scale is +/- 0.3 HZ



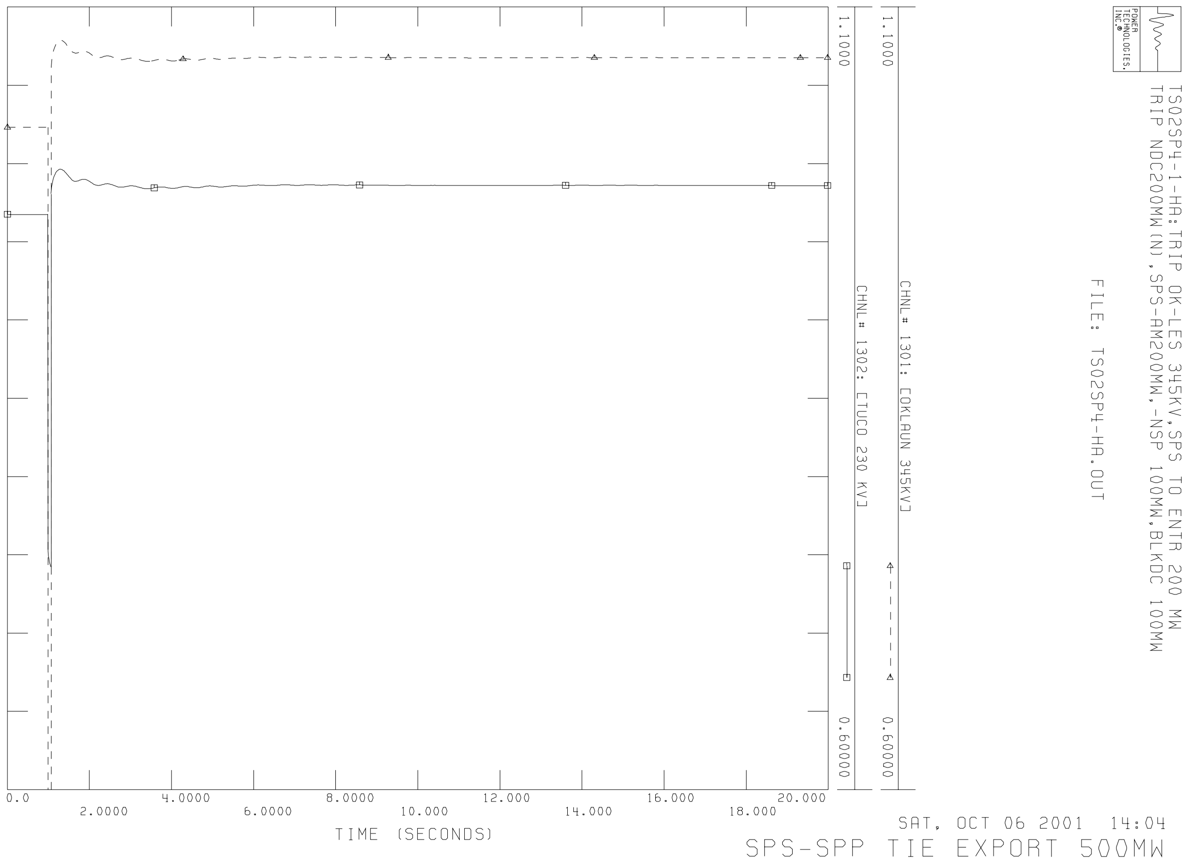
ATTACHMENT E: N-2 transfer model plots.

E.5) SPS to SPP tie flow in MW
1) SPS exports 500 MW



ATTACHMENT E: N-2 transfer model plots.

E.6) TUCO 230 kV and Oklaunion 345 kV bus voltage
1) SPS exports 500 MW



ATTACHMENT F: SPS Tie bus voltage at 20 seconds for the N-1 and N-2 transfer limits simulations.

SOUTHWEST POWER POOL
SPS EXPORT STABILITY LIMIT

SPS-SPP TIE FLOW 900 MW
DISTURBANCE= N-1
TRIP POTTER-FINNEY-HOLCOMB 345 KV CKT.
SPS-SPP TIE BUS Voltage at 20 seconds(19 seconds after initial fault).

SPS TIE FLOW FROM AREA				Nominal kV	Actual kV	PU	TO AREA				ID	Nominal kV	Actual kV	PU
SPS	526	50827	GRAPEVN6	230	199.54	0.8676	AEPW	520	54153	ELKCITY6	1	230	197.29	0.8578
SPS	526	50840	MCLEAR3	115	100.67	0.8754	AEPW	520	54295	SHAM 3WT	1	115	96.77	0.8415
SPS	526	50932	KIRBY3	115	107.09	0.9312	AEPW	520	54276	JERICHO3	1	115	106.47	0.9258
SPS	526	51534	TUCO7	345	314.93	0.9129	AEPW	520	54119	O.K.U.-7	1	345	321.04	0.9306
SPS	526	50887	POTTRC6	230	227.63	0.9897	SUNC	534	56449	HOLCOMB7	1	345	350.88	1.0170
SPS	526	50600	TXPHSF3	115	113.67	0.9885	WEPL	539	58772	E-LIBER3	1	115	113.47	0.9867

SPS-SPP TIE FLOW 500 MW
DISTURBANCE= N-2
OPEN POTTER-FINNEY-HOLCOMB 345 KV CKT.
TRIP OKLAUNION-L.E.S 345 KV CKT., TRIP NORTH HVDC.
SPS-SPP TIE BUS Voltage at 20 seconds(19 seconds after initial fault).

SPS TIE FLOW FROM AREA				Nominal kV	Actual kV	PU	TO AREA					Nominal kV	Actual kV	PU
SPS	526	50827	GRAPEVN6	230	190.45	0.8281	AEPW	520	54153	ELKCITY6	1	230	186.52	0.8110
SPS	526	50840	MCLEAR3	115	94.36	0.8205	AEPW	520	54295	SHAM 3WT	1	115	89.24	0.7760
SPS	526	50932	KIRBY3	115	102.53	0.8915	AEPW	520	54276	JERICHO3	1	115	101.64	0.8839
SPS	526	51534	TUCO7	345	348.23	1.0094	AEPW	520	54119	O.K.U.-7	1	345	368.32	1.0676
SPS	526	50887	POTTRC6	230	225.65	0.9811	SUNC	534	56449	HOLCOMB7	1	345	350.18	1.0150
SPS	526	50600	TXPHSF3	115	113.34	0.9856	WEPL	539	58772	E-LIBER3	1	115	113.30	0.9852