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APPLICATION OF THE CITY OF GARLAND TO AMEND A CERTIFICATE OF CONVENIENCE AND NECESSITY FOR THE RUSK TO PANOLA DOUBLE-CIRCUIT 345-KV TRANSMISSION LINE IN RUSK AND PANOLA COUNTIES	§ § § § § § §	**BEFORE THE PUBLIC UTILITY COMMISSION OF TEXAS**

REBUTTAL TESTIMONY

OF

STAN GRAY

ON BEHALF OF

SOUTHERN CROSS TRANSMISSION LLC

MAY 24, 2016

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SOUTHERN CROSS TRANSMISSION LLC
REBUTTAL TESTIMONY OF STAN GRAY

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EXHIBIT

I. INTRODUCTION AND EXPERIENCE

Q1. PLEASE STATE YOUR NAME, BUSINESS ADDRESS, EMPLOYER, AND JOB TITLE.

A. My name is Stan Gray. My business address is 800 NE Tenney Rd, Ste 110-132, Vancouver, WA 98685. I'm employed by Pattern Energy Group LP, as Director, Transmission.

Q2. ON WHOSE BEHALF ARE YOU TESTIFYING?

A. I am testifying on behalf of Southern Cross Transmission LLC ("SCT") and in support of the application filed in this case by the City of Garland ("Garland"), doing business as Garland Power & Light ("GP&L").

Q3. PLEASE DESCRIBE YOUR EDUCATIONAL BACKGROUND AND EXPERIENCE.

A. I have a Bachelor of Science Degree in Electrical Engineering from Portland State University. I was a registered professional engineer for over 44 years. I practiced for 22 years as a transmission planning engineer working for Portland General Electric performing system studies including power flow, stability and electro-magnetic transient program studies to predict the behavior of power systems and aid in planning the expansion of the transmission network. My work included supporting the control room operators by running planning studies to predict the result of unplanned and planned outages and preparing operating plans to manage the outages. I also managed the electromagnetic field ("EMF") program for PGE.

I negotiated operating and facility sharing agreements between PGE and other northwest grid owners.

I left PGE to work for Enron where I was responsible for interconnection and delivery of generation projects worldwide. I worked at Renewable Energy Systems Americas ("RES") and then Babcock and Brown. While at Babcock and Brown, I participated in development of the Trans Bay Cable, a 400 MW HVDC under-sea cable project that serves about 40% of the San Francisco northern peninsula's peak load. Pattern Energy Group was formed in 2009 from a management buyout of Babcock and Brown employees with Riverstone Private Equity.

While at RES, B&B and Pattern I provided planning for interconnections, delivery and some operations support for over 5,000 MW of wind and solar projects in the US, Canada, Chile, Japan and Mexico. I have worked with the New England ISO, PJM, NYISO, ERCOT, CAISO and IESO in Ontario.

Q4. HAVE YOU TESTIFIED PREVIOUSLY BEFORE THE PUBLIC UTILITY COMMISSION OF TEXAS?

A. Yes, I testified before the PUCT in Docket No. 35665, *Commission Staff's Petition for the Selection of Entities Responsible for Transmission Improvements Necessary to Deliver Renewable Energy from Competitive Renewable Energy Zones.*

Q5. WHAT IS THE PURPOSE OF YOUR TESTIMONY?

A. My testimony responds to several intervener witnesses who address system upgrades, primary frequency response and reactive support, a congestion management plan, and ramp rate limitations.

II. DISCUSSION

Q6. SEVERAL INTERVENOR WITNESSES ARGUE THAT SCT SHOULD BE REQUIRED TO PAY FOR ANY TRANSMISSION SYSTEM UPGRADES NECESSARY TO SUPPORT EXPORTS OVER THE TIE (GRIFFEY AT 12; FRAZIER AT 8). HAS ONCOR STUDIED WHETHER SYSTEM UPGRADES WOULD BE REQUIRED TO SUPPORT EXPORTS OVER THE SCT TIE?

A. Yes. Oncor performed interconnection studies at the request of ERCOT that compared a benchmark case provided by ERCOT (without the SCT project) to two SCT project sizes, 1500 MW and 3000 MW, to identify potential upgrades for both imports and exports. In response to Staff RFI 1-1, ERCOT indicated that it believes Oncor's studies related to the Southern Cross project are sufficient to reliably interconnect the project to the ERCOT grid. The Oncor studies can give some insight into system upgrades that could allow more area deliverability of generation and SCT flows, but the upgrades are not necessary to interconnect SCT. A copy of Oncor's *Southern Cross DC Tie Study Report* is attached as Exhibit SG-1-R.

Q7. WHAT DOES THE ONCOR STUDY REPORT SHOW?

A. Based on the assumptions in the cases used, new reactive support is required to resolve voltage violations in the 1,500 MW and 3,000 MW cases. Tables 1, 2 and 3 in the summary of the report provide insight into the upgrade facilities required in each case. In comparison to the benchmark case, the 1,500 MW case shows the need for the addition of reactive devices for both imports and exports and the upgrade of the one-mile 138-kV Tyler Grande to Tyler GE line for imports. Since the SCT tie is now being planned to deliver 2,000 MW, the 3,000 MW case is no longer useful other than to allow some interpolation of line loading results between the two studied project sizes.

Q8. HOW CAN YOU INTERPOLATE RESULTS FOR SCT'S 2,000 MW TIE FROM THE 1,500 MW AND 3,000 MW CASES STUDIED BY ONCOR?

A. The study indicates that line capacity is left on the studied lines in the 1,500 MW case, and it is possible to interpolate increased flows on lines from the 1,500 MW case to the 3,000 MW case to form conclusions about line loading at 2,000 MW. This interpolation suggests that the study's conclusions for the 1,500 MW case would largely hold true for a 2,000 MW project. Oncor may complete a 2,000 MW study before construction using updated grid topology, but no network upgrades are required to interconnect SCT. In the end, ERCOT is a market and will limit market participants' production to mitigate system reliability concerns like line overloads or system instabilities with or without the addition of system upgrades.

Q9. PLEASE DESCRIBE THE ONCOR STUDY'S ANALYSIS OF WHETHER SYSTEM UPGRADES ARE NECESSARY TO SUPPORT EXPORT TRANSACTIONS OVER THE SCT TIE.

A. Assumptions in the ERCOT case used to study exports were changed to stress the transmission system. Stressing the system is an attempt to set load levels and generation dispatch to emulate power flows that are similar to the worst conditions one would expect to see on the system. In the export cases, the ERCOT system customer load level and generation near the SCT project were reduced. These conditions require generation exported by SCT to come from a greater distance through the ERCOT transmission system. Generation brought from a greater distance puts more demands on the transmission system. The study shows that, to allow exports under these conditions, voltage support is required. SCT will provide such support by adding capacitors near the Panola substation, and Oncor's study analyzes the addition of 400 or more MVAR of reactive support at Rusk station. There are no new lines or line upgrades required based on the study with 1,500 MW or 3,000 MW of export.

Q10. WHAT DID THE ONCOR STUDIES CONCLUDE ABOUT WHETHER SYSTEM UPGRADES ARE NECESSARY TO SUPPORT IMPORT TRANSACTIONS OVER THE SCT TIE?

A. In the Oncor study, the import case generation dispatch was changed to increase the amount of generation on line near the future Rusk station. Increasing the output of existing generators near Rusk stresses the system by adding generation that is in the same area as the connection of SCT. ERCOT customer loads were modeled at the summer peak level. Aside from the reactive support discussed above, there is only one additional upgrade required at the 1,500 MW import level, and that is the one mile section of 138-kV line mentioned in Q7 above. As discussed above, it is reasonable to interpolate that the same conclusion would result at a 2,000 MW import level. ERCOT will manage the grid so that the ERCOT transmission system is reliable without any network upgrades.

Q11. WHAT DO THE ONCOR STUDIES REFLECT CONCERNING REACTIVE POWER SUPPORT?

A. The studies show that the primary impact to the ERCOT system by adding additional flows for either imports or exports on SCT is a voltage drop near Rusk station. This voltage drop would be expected for greater flows on any transmission system or when generation dispatch is changed as generators are a source of reactive power that supports voltage in the system. The addition of capacitors can also supply the needed voltage support. Adding reactive devices like capacitors instead of relying on generators for the reactive supply is a useful solution especially because generation near Rusk tends to run a limited number of hours a year. As discussed above, reactive support will be installed by Rusk near Panola station and was included in Oncor's analysis at the Rusk station.

Q12. LUMINANT WITNESS FRAZIER SUGGESTS THAT NEW METHODS SHOULD BE DEVELOPED TO IDENTIFY TRANSMISSION UPGRADES TO SUPPORT EXPORTS (FRAZIER AT 8). DO YOU AGREE?

A. It is not entirely clear whether Ms. Frazier is addressing reliability or economic studies, but I don't agree that changes are needed for reliability studies. The same long established pre and post power flow and stability study methods used in the Oncor studies are the correct techniques used worldwide for reliability studies of power systems.

Q13. LUMINANT WITNESS FRAZIER PROPOSES THAT SCT BE REQUIRED TO PROVIDE PRIMARY FREQUENCY RESPONSE AND REACTIVE SUPPORT, WHILE ERCOT WITNESS WOODFIN TESTIFIES THAT IT WOULD BE HELPFUL FOR SCT TO BE ABLE TO PROVIDE SUCH SERVICES (FRAZIER AT 9, WOODFIN AT 16). PLEASE DESCRIBE SCT'S CAPABILITIES TO PROVIDE SUCH SERVICES.

A. SCT is not a generator, it is a controllable transmission line. But it does connect two large systems together and the HVDC control systems do have some capabilities where, with cooperation between power systems on both ends of SCT, some services like Primary Frequency Response ("PFR") could be provided. There are two categories of issues that would have to be addressed. One is technical and the other is administrative. Technically, the service being performed must be carefully defined so the HVDC controls can be appropriately programmed. Administratively, arrangements and agreements would have to be negotiated between the Balancing Authorities on both sides of the HVDC line as well as with SCT.

SCT could provide low frequency PFR by borrowing energy from an adjacent system, within the design capabilities of SCT components, to support the ERCOT system very quickly in the early stages of a change in ERCOT's system frequency. SCT could increase its exports during early stages of an ERCOT high frequency event. The transmission system supplying or absorbing the energy is impacted. An HVDC tie can be programmed to supply PFR, but again only with the agreement between systems on both sides of the tie. ERCOT doesn't have rules today that would allow SCT to participate in supplying PFR, so the ERCOT Regional Planning Group would have to consider rule changes to allow HVDC facilities to supply PFR. Similar considerations will be required by the Balancing Authority on the other side.

As far as reactive supply being provided by SCT, SCT does not have the capability within the HVDC equipment to supply reactive power. As discussed earlier, substation static or dynamic reactive devices will be used to provide additional reactive support to compensate for the Garland line between Rusk and Panola. SCT will include significant reactive capability by adding capacitors or other reactive dynamic devices near Panola station, and the Oncor studies reflect that Oncor analyzed addition of reactive support at Rusk station.

Q14. COULD THE SCT TIE ALSO HAVE THE CAPABILITY TO PROVIDE OTHER ANCILLARY SERVICES?

A. As discussed above, the HVDC tie could be controlled so a transmission system connected to the tie on one end could provide other ancillary services such as spinning and non-spinning reserves to the transmission system connected to the other end of the line. An agreement between Balancing Authorities, and with SCT, would be required, as was noted above for supply of PFR. These agreements could be complex to arrange, but SCT would be willing to participate in the process if ERCOT thought such discussions would be useful. One note of caution: the better the tasks expected of an HVDC facility can be defined in the early stages of design of the HVDC facility, the better the results that would be expected. Making changes to the HVDC facility controls after the facility is designed and constructed would be very costly.

Q15. WHAT OTHER RELIABILITY BENEFIT COULD THE SCT TIE PROVIDE?

A. During periods of high renewable generation and low ERCOT load there could be the need to curtail some wind generation, and/or for more conventional generation to be operated to support potential grid instability. As shown in Ms. Wolfe's economic studies, the SCT project will likely be exporting up to 2,100 MW during these periods. If renewable generation is exported during the oversupply times more conventional generation could be dispatched to stabilize the ERCOT grid.

Q16. SEVERAL INTERVENOR WITNESSES DISCUSS THE POSSIBILITY OF IMPLEMENTING A CONGESTION MANAGEMENT PLAN/SPECIAL PROTECTION SCHEME (SIDDIQI AT 12-14, WOODFIN AT 9-10). DOES SCT SUPPORT IMPLEMENTATION OF SUCH A PLAN?

A. SCT did not propose a special protection scheme ("SPS"), but would support the concept of a well-designed SPS implemented by ERCOT where all parties benefiting from the SPS participate in the SPS.

Q17. PLEASE DESCRIBE AN SPS AND EXPLAIN THE BENEFITS OF SUCH A PLAN AND HOW IT WOULD OPERATE.

A. Special Protection Schemes have been used successfully for many years around the United States. There are many forms of SPS but in concept an SPS is a system of relays, software and other devices that monitor parts of a power system and can automatically take appropriate actions to protect the transmission system. An example of what an SPS might be used for is a transmission line could be monitored and when the line trips off line in an N-1 contingency, or when the flow on a line exceeds a predetermined level, signals are sent to generators or a combination of generators and a controllable HVDC line like SCT to reduce the generator's output or change the HVDC tie's flow.

An SPS can allow for a more complete use of a transmission system. Absent an SPS, for example, generation output is scheduled in a way that if a line trips out of service or a generator trips off line, no system elements are overloaded. The result is some transmission capacity is left unused in the base case to prepare for N-1 conditions. With an SPS in place, more flow could be scheduled over the transmission system in the base case and the actions of the SPS would automatically reduce any overloads following the N-1 outage. In addition to limiting line overloads, an SPS could also act to mitigate voltage or dynamic instabilities in the transmission grid. An SPS could allow additional generation in the area near SCT to be dispatched in the base case. An SPS can make sense particularly when competition for transmission capacity is seasonal or the long term need is uncertain.

Q18. HOW WOULD AN SPS BE IMPLEMENTED?

A. A study would identify where overloads in the power system occur following N-1 outages. Physical devices would be placed in the system at appropriate locations that automatically take actions to reduce overloads such as reducing a generator's output or reducing the flow on a controllable device like an HVDC terminal.

Q19. ERCOT WITNESS WOODFIN TESTIFIES THAT RAMPING RESTRICTIONS OR INTEGRATION OF DC TIE SCHEDULES WITH OTHER MARKET TOOLS SHOULD BE IMPLEMENTED FOR SCT (WOODFIN AT 12-13). DOES SCT AGREE?

A. SCT agrees that ramp rate restrictions are required on a number of facilities including an HVDC tie. SCT has discussed ramp rate control strategies for the SCT tie with ERCOT several times and we are keenly aware that changes in the HVDC flows must be matched by changes in the power systems on both ends of the HVDC line. One of the benefits of a modern HVDC facility is controllability. Flows can be changed slowly or quickly depending on the needs of systems as defined by the system operators on both ends. SCT will work with ERCOT and stakeholders to address and resolve ERCOT's concerns about ramp rates over the SCT tie. The solutions for this issue are straightforward and not controversial.

Ms. Wolfe's economic study incorporated ramp-rate limits for each generator in ERCOT and in the eastern interconnect, and the model complied with all of these real generation ramp rate limitations. This resulted in changes in the direction of the SCT tie flow taking up to two hours to ramp. SCT fully understands that it will ramp in accordance with the capabilities of the ERCOT and southeastern systems

Q20. DOES THIS CONCLUDE YOUR REBUTTAL TESTIMONY?

A. Yes.

ERCOT Response to
Staff 1-3

Southern Cross HVDC Tie Study Report

Oncor Electric Delivery Company LLC
System Planning
June 14, 2013

Executive Summary

Oncor was commissioned to perform a Steady State contingency analysis and a Transient Stability analysis to examine the impacts of an asynchronous high voltage direct current (HVDC) tie between ERCOT and SERC. The intent of the study was to determine the impact of the HVDC tie on thermal loading, system voltages and stability of the Oncor / ERCOT transmission system.

The study was performed for six different scenarios: a Benchmark Import case, a 1500 MW Import case, a 3000 MW Import case, a Benchmark Export case, a 1500 MW Export case and a 3000MW Export case, with all six cases having a generation profile prepared by ERCOT. All thermal, voltage and stability violations were addressed with multiple planning actions to ensure the reliability of the Oncor and ERCOT transmission system under contingency. Table 1 gives a comprehensive look at the amount of construction and upgrades necessary to connect the HVDC tie at the proposed levels.

Table 1 – Total New and Upgraded Equipment Required for Southern Cross Project

	IMPORT				EXPORT		
	Benchmark	**1500 MW**	**3000 MW**		**Benchmark**	**1500 MW**	**3000 MW**
New circuit miles	147 miles	147 miles	407 miles		0	0	147 miles
Upgrade circuit miles	23 miles	24 miles	293.9 miles		0	0	99.4 miles
Autotransformer	750 MVA	750 MVA	750 MVA		750 MVA	750 MVA	750 MVA
New Reactive	80 MVar	480 MVar	1200 MVar		0	640 MVar	1800 MVar
Series Reactor	2-ohm	2-ohm	2-ohm		0	0	0

Table 2 details the needed upgrades and construction necessary to resolve all thermal and voltage violations for each of the respective import/export cases. Electric power can be exported from ERCOT to SERC with a minimum amount of transmission upgrades, particularly at the lower level of generation export. However, the ability to import the same amount of power into ERCOT requires a much greater amount of construction of new lines, upgrades of existing lines and additions of shunt capacitors and a series reactor.

Table 3 details the need for various equipment and system protection actions to resolve all stability violations for each studied case. Because of the sensitivity of the transmission system in the area around where the HVDC tie will connect to the Oncor Transmission system, a new breaker switching scheme and two small dynamic reactive devices (DRDs) were needed to maintain stability on the 138 kV system. For this project two Static Var Compensators (SVCs) were evaluated and provided the necessary dynamic support.

TABLE 2 - Upgrades Needed to Alleviate Thermal and Voltage Issues

Ref. No	Transmission Line and Equipment	kV	Ckt	Length	Existing (MVA)	New MVA Ratings for Upgraded Transmission Lines and Equipment [1]: IMPORT Benchmark (MVA)	IMPORT 1500 MW (MVA)	IMPORT 3000 MW (MVA)	EXPORT Benchmark (MVA)	EXPORT 1500 MW (MVA)	EXPORT 3000 MW (MVA)
1	Lufkin Switch - Nacogdoches SE	345	1	23	**NEW**	1631	1631	1631	-	-	1631
2	Martin Lake - Royse North	345	1	124	**NEW**	1631	1631	1631	-	-	1631
3	Martin Lake - Stryker Creek [2]	345	1	41	1631	-	-	1631	-	-	1631
4	Martin Lake - Navarro	345	1	130	**NEW**	-	-	1631	-	-	-
5	Martin Lake - Navarro	345	2	130	**NEW**	-	-	1631	-	-	-
6	Trinidad - Stryker Creek	345	1	68.6	1072	-	-	1631	-	-	-
7	Rusk - Trinidad	345	1	92	1072	-	-	1631	-	-	-
8	Rusk - Stryker Creek	345	1	23.4	1631	-	-	2390	-	-	1912
9	Rusk - Martin Lake	345	1	17.5	1631	-	-	-	-	-	1912
10	Rusk - Martin Lake	345	2	17.5	1631	-	-	-	-	-	1912
11	Tyler Grande - Tyler GE	138	1	1	326	-	484	484	-	-	-
12	Dialville - Neches Pump	138	1	15.5	214	-	-	326	-	-	-
13	Palestine South - Neches Pump	138	1	9.5	214	-	-	326	-	-	-
14	Trinidad - Malakoff	138	1	8.1	251	-	-	326	-	-	-
15	Forest Grove - Mabank Tap	138	1	3.7	251	-	-	326	-	-	-
16	Malakoff - Mabank Tap	138	1	3.7	251	-	-	326	-	-	-
17	Elkton - Tyler Southwest	138	1	5	214	326	326	326	-	-	-
18	Plano Tennyson - Preston Meadows	138	1	1	287	484	484	484	-	-	-
19	Flint - Jacksonville Switch	138	1	10.4	249	-	-	326	-	-	-
20	Collin - Northwest Carrollton (multiple branches)	138	1	17	-	326	326	326	-	-	-
	Elkton Switch Capacitors	345			**NEW**	-	-	320 MVar	-	240 MVar	320 MVar
	Rusk Switch Capacitors	345			**NEW**	-	400 MVar	560 MVar	-	400 MVar	1000 MVar
	Martin Lake Capacitors	345			**NEW**	-	-	240 MVar	-	-	240 MVar
	Nacogdoches Capacitors	345			**NEW**	-	-	-	-	-	240 MVar
	Murphy Capacitors	138			**NEW**	80 MVar	80 MVar	80 MVar	-	-	-
	Collin Switch 345/138 Autotransformer	345/138	2		**NEW**	750 MVA Autotransformer			750 MVA Autotransformer		
	Collin (series reactor for Autotransformer #2)	345			**NEW**	2 -ohm	2 -ohm	2 -ohm	-	-	-

Notes
1 - Values provided in columns are the upgraded MVA rating for the transmission lines and equipment to eliminate thermal loading violations during contingency. Cells with '_' require no upgrades.
2 - This line currently exists, before construction of the Rusk Switch. In the 1500 MW and 3000 MW cases this line becomes Martin Lake - Rusk and Rusk – Stryker Creek (Ref. Nos. 8 and 9)

TABLE 3 - Upgrades / Action Items Needed to Alleviate Stability Issues

				Action Items						
				IMPORT				EXPORT		
Ref. No	Transmission Line and Equipment	kV	Upgrade / Action Item	Benchmark	1500 MW	3000 MW		Benchmark	1500 MW	3000 MW
1	Crockett	69	+100 MVar SVC	Yes	Yes	Yes		Yes	Yes	Yes
2	Diboll	138	+80 MVar SVC	Yes	Yes	Yes		Yes	Yes	Yes
3	Crockett - Berea	138	Breaker Switching Scheme	Yes	Yes	Yes		Yes	Yes	Yes

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STEADY STATE ANALYSIS

1.0 STUDY PURPOSE

Southern Cross Transmission LLC submitted an interconnection request for an asynchronous high voltage direct current (HVDC) tie between the Electric Reliability Council Of Texas (ERCOT) transmission system and the Southeastern Electric Reliability Council (SERC) transmission system. This project consists of the construction of a proposed 345 kV Switching Station (Rusk Switch) in Rusk County Texas, an approximately 50-mile, double-circuit, 345 kV transmission line from Rusk Switch to the HVDC tie, currently proposed to be located in Louisiana.

The interconnection request was evaluated to determine the ability of the ERCOT transmission system to accommodate up to a 3000 MW import and export capacity of the Tie and identify any related reliability concerns. Oncor proposed to perform a Steady State contingency analysis and a Transient Stability analysis to examine the impacts of the HVDC tie on thermal loading, system voltages and stability of the Oncor transmission system. For this project there were six scenarios that were studied. These scenarios were:

1. A Benchmark Import case
2. A 1500 MW Import case with an 1500 MW power transfer from SERC into the ERCOT system
3. A 3000 MW Import case with an 3000 MW power transfer from SERC into the ERCOT system
4. A Benchmark Export case
5. A 1500 MW Export case with an 1500 MW power transfer from ERCOT into the SERC system
6. A 3000 MW Export case with an 3000 MW power transfer from ERCOT into the SERC system

2.0 ASSUMPTIONS

The Steady-State Study was performed with the following assumptions:

1. For Import into ERCOT from SERC
   - The project was studied with a 2015 Summer base case created and updated just prior to when the study commenced.

- ERCOT provided economic dispatch for the generation in each of the cases
    - Wind generation was dispatched as typical for summer cases
    - Generation in the Rusk County area was dispatched as
        - Martin Lake #1 – 805 MW
        - Martin Lake #2 – 810 MW
        - Martin Lake #3 – 810 MW
        - Tenaska Gateway – 846 MW
        - Stryker Creek #1 – 171 MW
        - Stryker Creek #2 – 502 MW
        - Aspen #1 – 50 MW
        - Nacogdoches #1 – 100 MW
- The Rusk County Switch was not modeled in the Benchmark case, but was modeled in the 1500 MW and 3000 MW cases.

2. For Export from ERCOT to SERC

- The project was studied with a 2015 Summer base case and scaling the load down to 41% of summer peak.
- ERCOT provided economic dispatch for the generation in each of the cases
    - Wind generation was modeled at CREZ build-out levels and dispatched at 80% of nameplate.
    - Generation in the Rusk County area was dispatched as
        - Martin Lake #1 – 805 MW
        - Martin Lake #2 – 810 MW
        - Martin Lake #3 – 0 MW
        - Tenaska Gateway – 0 MW
        - Stryker Creek #1 – 0 MW
        - Stryker Creek #2 – 0 MW
        - Aspen #1 – 50 MW
        - Nacogdoches #1 – 100 MW
- The Rusk County Switch was not modeled in the Benchmark case, but was modeled in the 1500 MW and 3000 MW cases.

The Siemens Power Technologies, Inc. PSS/E power system simulation program Version 32.1.1 was used for this study. The analysis examined the thermal and voltage violations observed in Oncor zones 130 through 148 for the 345 kV to 69 kV buses. The thermal and voltage violations observed for the contingencies simulated were examined and upgrades were selected to eliminate the violations. Each case had upgrades selected to eliminate the thermal and voltage violations for that configuration. The upgraded Benchmark, 1500 MW and 3000 MW Import and Export cases were then used for the Transient Stability Analysis.

2.1 Contingency Descriptions

The contingencies examined for this analysis are listed below:

- All "Special Contingencies" in the Southerncrossbasic.con file
- All Single-Circuit Contingencies in Area 1 examining branch, transformer, and generator outages
- All single-circuits out of Rusk County Switch 345 kV station
- All double-circuit contingencies out of Rusk County Switch, Stryker Creek, and Martin Lake 345 kV stations

Appendix A contains the complete lists of contingencies examined for the Steady State Contingency Analysis.

Note: Since the Rusk County Switch 345 kV station is not modeled in the Import or Export Benchmark Cases the single and double-circuit contingencies from Rusk County Switch station could not be simulated for the benchmark cases.

3.0 BASE CASE SYSTEM CONDITIONS

3.1 Oncor System Power Flow Conditions

The original 1500 and 3000 MW Import and Export power flow cases had the HVDC system modeled as a generator. The generator absorbed or produced 1500 MW of power to achieve the Export and Import, respectively. The reactive limits of the generators were fixed at 0 MVars. To achieve the 3000 MW Export and Import cases the generator absorbed or produced 3000 MW of power, respectively. For the 3000 MW Export case the generator was supplying 500 MVars. For the 3000 MW Import case the generator was supplying 318.8 MVar. The equivalent generator was replaced with the PSSE two-terminal HVDC model using parameters provided by Southern Cross Transmission LLC . The Collin 345/138 kV #2 Autotransformer was added to all the cases since it is already a planned upgrade to the Oncor system. Additionally, the shunt capacitor banks listed in Table 3.1-1 were added to allow the power flows to solve while Importing or Exporting 3000 MW of power.

ONCOR

Table 3.1-1
List of Additional Switched Shunt Capacitor Banks Added to the Import and Export 3000 MW Cases

Ref. No.	Bus Number	Bus Name	kV	Import 3000 MW Original Value (MVAR)	Import 3000 MW New Value (MVAR)	Export 3000 MW Original Value (MVAR)	Export 3000 MW New Value (MVAR)
1	3105	ELKTON_5	345	240	320	240	320
2	9997	RUSKSS_5	345	240	560	400	1000
3	3100	MLAKE	345	-	240	-	240
4	3119	Nacogdoches	345	-	-	-	240

Table 3.1-2 summarizes the Oncor system (Area 1) power flow conditions for the Import base cases and the final cases after adding the upgrades and eliminating the thermal and voltage violations.

Table 3.1-3 lists the Export base case and final power flow conditions. The only upgrade incorporated into the Export Benchmark and 1500 MW cases was the addition of the Collin 345/138 kV #2 Autotransformer. As mentioned earlier, the Export 3000 MW case required upgrades to allow all the contingencies to converge with an acceptable mismatch error and to eliminate any thermal or voltage violations that occurred.

Table 3.1-2
2015 Summer Import Cases

Case	Upgrades	Units	From Generation	To Load Area	To Bus Shunt	To GNE Bus	To Line Shunt	From Charging	To Loses	Net Interchange To Tie Lines	Net Interchange To Tie + Lines	Desired Net Int
Import Benchmark	Base	MW	29403.2	24466.7	0	0	0	0	676	4260.6	4260.6	0
		MVAR	2041.4	7049.1	-8573.2	0	0	6501	9735.4	331.2	331.2	
	Final	MW	29403.2	24466.7	0	0	0	0	650.9	4285.6	4285.6	0
		MVAR	1664.9	7049.1	-8570.5	0	0	6668.1	9534.1	230.3	320.3	
Import 1500 MW	Base	MW	30203.2	24466.7	0	0	0	0	883.4	4853.1	4853.1	0
		MVAR	3482.7	7049.1	-10023	0	0	6598.7	12823	231.5	231.5	
	Final	MW	30203.2	24466.7	0	0	0	0	830.4	4906.1	4906.1	0
		MVAR	2771.3	7049.1	-10183	0	0	6766.2	12422	250.1	250.1	
Import 3000 MW	Base	MW	30966.1	24466.7	0	0	0	0	1302.2	5197.1	5197.1	0
		MVAR	4692.1	7049.1	-13986	0	0	6611.1	17887	353.4	353.4	
	Final	MW	30966	24466.7	0	0	0	0	1118.6	5380.8	5380.8	0
		MVAR	3375.1	7049.1	-13452	0	0	7138.5	16485	433.1	433.1	

Table 3.1-3
2015 Summer Export Cases

Case	Upgrades	Units	From Generation	To Load Area	To Bus Shunt	To GNE Bus	To Line Shunt	From Charging	To Loses	Net Interchange To Tie Lines	Net Interchange To Tie + Lines	Desired Net Int
Export Benchmark	Base and Final	MW	11981.2	9508	0	0	0	0	249.7	2223.5	2223.5	0
		MVAR	924.9	2739.3	1510.9	0	0	6506.2	3458	-277.1	-227.1	
Export 1500 MW	Base and Final	MW	11111.8	9508	0	0	0	0	305.1	1298.7	1298.7	0
		MVAR	1201.9	2739.3	743.3	0	0	6503	5090.7	-868.5	-868.5	
Export 3000 MW	Base	MW	10113.6	9508	0	0	0	0	556.2	49.5	49.5	0
		MVAR	1993	2739.3	-1817	0	0	6495.8	8509	-942.3	-924.3	
	Final	MW	10113.6	9508	0	0	0	0	550	55.7	55.7	0
		MVAR	1741.8	2739.3	-1973	0	0	6699.7	6699.7	-703.4	-703.4	

3.2 Major East Texas Line Loading

The following tables list the major East Texas line loading for Base Case conditions:

- Table 3.2-1: Major East Texas line loading in the Import Benchmark Case
- Table 3.2-2: Major East Texas line loading in the Import 1500 MW Case
- Table 3.2-3: Major East Texas line loading in the Import 3000 MW Case
- Table 3.2-4: Major East Texas line loading in the Export Benchmark Case
- Table 3.2-5: Major East Texas line loading in the Export 1500 MW Case
- Table 3.2-6: Major East Texas line loading in the Export 3000 MW Case

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Table 3.2-1
Major East Texas Line Loading in the Import Benchmark Case

Ref. No.	To-From-CKT	To Bus	From Bus	Voltage (kV)	Length (Mi)	ONCOR Base [1]		MEPPI Base		MEPPI Final	
						Rating [2] (MVA)	% FLOW	Rating [2] (MVA)	% FLOW	Rating [2] (MVA)	% FLOW
1	2478-3103-1	Royse South	Shamburger	345	81	1072	56	1072	55	1072	42
2	2437-3105-1	Forney	Elkton	345	92	1072	52	956[3]	51	1072	40
3	3116-3124-1	Mount Enterprise	Trindad 2	345	93	1072	48	1072	50	1072	40
4	3100-3103-1	Martin Lake	Shamburger	345	44	1631	47	1631	46	1631	37
5	3100-3102-1	Martin Lake	Tyler Grande	345	43	1631	44	1631	44	1631	36
6	3100-3105-1	Martin Lake	Elkton	345	48	1631	41	1631	41	1631	34
7	3109-3123-1	Stryker Creek SES	Trindad 1	345	69	1072	41	1072	44	1072	37
8	3100-3109-1	Martin Lake	Stryker Creek	345	41	1631	23	1631	23	1631	14
9	3100-3116-1	Martin Lake	Mount Enterprise	345	19	1631	8	1631	6	1631	9

1 Data Provided in the " *Southern Cross HVDC Tie Steady-State Study Report*"
2 Values were the same for Rating A, B, and C unless otherwise noted
3 The MVA rating of these lines in PSSE was 956 MVA for Rating A and B and 1072 MVA for Rating C.

Table 3.2-2
Major East Texas Line Loading in the Import 1500 MW Case

Ref. No.	To-From-CKT	To Bus	From Bus	Voltage (kV)	Length (Mi)	ONCOR Base [1]		MEPPI Base		MEPPI Final	
						Rating [2] (MVA)	% FLOW	Rating [2] (MVA)	% FLOW	Rating [2] (MVA)	% FLOW
1	2478-3103-1	Royse South	Shamburger	345	81	1072	78	1072	79	1072	61
2	3124-9997-1	Trinidad 2	Rusk County Switch	345	92	1072	77	1072	77	1072	64
3	3109-3123-1	Stryker Creek	Trinidad 1	345	69	1072	75	1072	77	1072	65
4	2437-3105-1	Forney	Elkton	345	92	1072	73	956[3]	74	1072	52
5	3100-3103-1	Martin Lake	Shamburger	345	44	1631	63	1631	62	1631	50
6	3100-3102-1	Martin Lake	Tyler Grande	345	43	1631	59	1631	59	1631	48
7	3100-3105-1	Martin Lake	Elkton	345	48	1631	55	1631	55	1631	45
8	3109-9997-1	Stryker Creek	Rusk County Switch	345	24	1631	50	1631	49	1631	35
9	3116-9997-1	Mount Enterprise	Rusk County Switch (Circuit 1)	345	1	1631	21	1631	22	1631	17
10	3116-9997-2	Mount Enterprise	Rusk County Switch (Circuit 2)	345	1	1631	30	1072	32	1072	24
11	3100-9997	Martin Lake	Rusk County Switch (Circuits 1 & 2)	345	18	1631	14	1631	15	1631	22

1 Data Provided in the " *Southern Cross HVDC Tie Steady-State Study Report*"
2 Values were the same for Rating A, B, and C unless otherwise noted
3 The MVA rating of this lines in PSSE was 956 MVA for Rating A and B and 1072 MVA for Rating C.

Table 3.2-3
Major East Texas Line Loading in the Import 3000 MW Case

Ref. No.	To-From-CKT	To Bus	From Bus	Voltage (kV)	Length (Mi)	ONCOR Base[1]		MEPPI Base		MEPPI Final	
						Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW
1	2478-3103-1	Royse South	Shamburger	345	81	1072	106	1072	101	1072	62
2	3124-9997-1	Trinidad 2	Rusk County Switch	345	92	1072	104	1072	106	1631	49
3	3109-3123-1	Stryker Creek	Trinidad 1	345	69	1072	106	1072	105	1631	49
4	2437-3105-1	Forney	Elkton	345	92	1072	101	956[3]	93	1072	52
5	3100-3103-1	Martin Lake	Shamburger	345	44	-	-	1631	76	1631	51
6	3100-3102-1	Martin Lake	Tyler Grande	345	43	-	-	1631	73	1631	47
7	3100-3105-1	Martin Lake	Elkton	345	48	-	-	1631	67	1631	43
8	3109-9997-1	Stryker Creek	Rusk County Switch	345	24	-	-	1631	69	2390	30
9	3116-9997-1	Mount Enterprise	Rusk County Switch (Circuit 2)	345	1	-	-	1631	20	1631	17
10	3116-9997-2	Mount Enterprise	Rusk County Switch (Circuit 1)	345	1	-	-	1072	30	1072	24
11	3100-9997-1	Martin Lake	Rusk County Switch (Circuits 1)	345	18	-	-	1631	36	1631	57

1 Data Provided in the '*Southern Cross HVDC Tie Steady-State Study Report*'by ONCOR
2 Values were the same for Rating A, B, and C unless otherwise noted
3 The MVA rating of this lines in PSSE was 956 MVA for Rating A and B and 1072 MVA for Rating C.

Table 3.2-4
Major East Texas Line Loading in the Export Benchmark Case

Ref. No.	To-From-CKT	To Bus	From Bus	Voltage (kV)	Length (Mi)	ONCOR Base[1]		MEPPI Base		MEPPI Final	
						Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW
1	2478-3103-1	Royse South	Shamburger	345	81	1072	22	1072	23	1072	23
2	2437-3105-1	Forney	Elkton	345	92	1072	25	956[3]	23	1072	21
3	3116-3124-1	Mount Enterprise	Trindad 2	345	93	1072	23	1072	22	1072	22
4	3100-3103-1	Martin Lake	Shamburger	345	44	1631	20	1631	20	1631	20
5	3100-3102-1	Martin Lake	Tyler Grande	345	43	1631	20	1631	22	1631	22
6	3100-3105-1	Martin Lake	Elkton	345	48	1631	21	1631	20	1631	20
7	3109-3123-1	Stryker Creek SES	Trindad 1	345	69	1072	22	1072	21	1072	21
8	3100-3109-1	Martin Lake	Stryker Creek	345	41	1631	19	1631	18	1631	18
9	3100-3116-1	Martin Lake	Mount Enterprise	345	19	1631	20	1631	18	1631	18

1 Data Provided in the " *Southern Cross HVDC Tie Steady-State Study Report*"
2 Values were the same for Rating A, B, and C unless otherwise noted
3 The MVA rating of this lines in PSSE was 956 MVA for Rating A and B and 1072 MVA for Rating C.

Table 3.2-5
Major East Texas Line Loading in the Export 1500 MW Case

Ref. No.	To-From-CKT	To Bus	From Bus	Voltage (kV)	Length (Mi)	ONCOR Base[1]		MEPPI Base		MEPPI Final	
						Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW
1	3100-9997	Martin Lake	Rusk County Switch (Circuits 1&2)	345	18	1631	40	1631	40	1631	40
2	2437-3105-1	Forney	Elkton	345	92	1072	12	956[3]	9	1072	8
3	3109-3123-1	Stryker Creek	Trinidad 1	345	69	1072	12	1072	13	1072	13
4	3100-3105-1	Martin Lake	Elkton	345	48	1631	10	1631	10	1631	10
5	3124-9997-1	Trinidad 2	Rusk County Switch	345	92	1072	10	1072	12	1072	12
6	3109-9997-1	Stryker Creek	Rusk County Switch	345	24	1631	9	1631	8	1631	8
7	3100-3103-1	Martin Lake	Tyler Grande	345	43	1631	6	1631	5	1631	5
8	3100-3103-1	Martin Lake	Shamburger	345	44	1631	6	1631	5	1631	5
9	2478-3103-1	Royse South	Shamburger	345	81	1072	3	1072	6	1072	6
10	3116-9997-1	Mount Enterprise	Rusk County Switch (Circuit 1)	345	1	1631	1	1631	1	1631	1
11	3116-9997-2	Mount Enterprise	Rusk County Switch (Circuit 2)	345	1	1631	1	1072	1	1072	2

1 Data Provided in the " *Southern Cross HVDC Tie Steady-State Study Report*"
2 Values were the same for Rating A, B, and C unless otherwise noted
3 The MVA rating of this lines in PSSE was 956 MVA for Rating A and B and 1072 MVA for Rating C.

Table 3.2-6
Major East Texas Line Loading in the Export 3000 MW Case

Ref. No.	To-From-CKT	To Bus	From Bus	Voltage (kV)	Length (Mi)	ONCOR Base[1]		MEPPI Base		MEPPI Final	
						Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW	Rating[2] (MVA)	% FLOW
1	3100-9997	Martin Lake	Rusk County Switch (Circuits 1&2)	345	18	1631	65	1631	65	1912	54
2	2437-3105-1	Forney	Elkton	345	92	1072	22	956[3]	24	1072	21
3	3109-3123-1	Stryker Creek	Trinidad 1	345	69	1072	48	1072	50	1072	19
4	3100-3105-1	Martin Lake	Elkton	345	48	1631	11	1631	14	1631	9
5	3124-9997-1	Trinidad 2	Rusk County Switch	345	92	1072	45	1072	48	1072	43
6	3109-9997-1	Stryker Creek	Rusk County Switch	345	24	1631	32	1631	34	1912	54
7	3100-3103-1	Martin Lake	Tyler Grande	345	43	1631	10	1631	12	1631	9
8	3100-3103-1	Martin Lake	Shamburger	345	44	1631	10	1631	12	1631	9
9	2478-3103-1	Royse South	Shamburger	345	81	1072	22	1072	25	1072	21
10	3116-9997-1	Mount Enterprise	Rusk County Switch (Circuits 1)	345	1	1631	18	1631	5	1631	3
11	3116-9997-2	Mount Enterprise	Rusk County Switch (Circuits 2)	345	1	1631	18	1072	7	1072	5

1 Data Provided in the " *Southern Cross HVDC Tie Steady-State Study Report*"
2 Values were the same for Rating A, B, and C unless otherwise noted
3 The MVA rating of this lines in PSSE was 956 MVA for Rating A and B and 1072 MVA for Rating C.

3.3 HVDC Model Parameters

The following figures show one-line diagrams of the Rusk County Switching Station 345 kV and the HVDC tie from the final cases with all the upgrades selected:

- Figure 3.3-1: One-line diagram of the Rusk County Switching Station 345 kV and the HVDC tie for the 1500 MW Import final case
- Figure 3.3-2: One-line diagram of the Rusk County Switching Station 345 kV and the HVDC tie for the 3000 MW Import final case
- Figure 3.3-3: One-line diagram of the Rusk County Switching Station 345 kV and the HVDC tie for the 1500 MW Export final case
- Figure 3.3-4: One-line diagram of the Rusk County Switching Station 345 kV and the HVDC tie for the 3000 MW Export final case

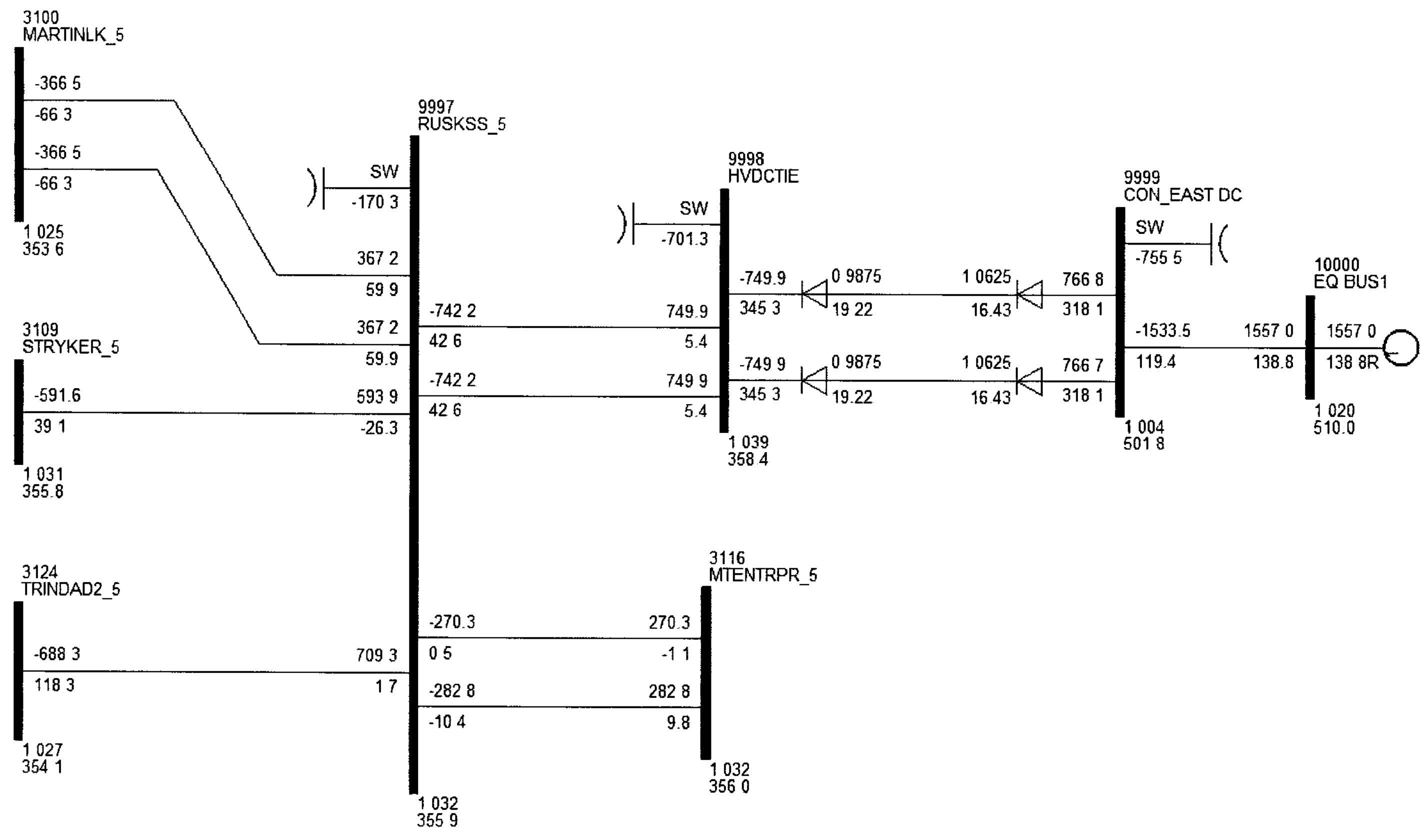

Figure 3.3-1: One-line diagram of the Rusk County 345 kV Switching Station and the HVDC tie for the 1500 MW Import final case.

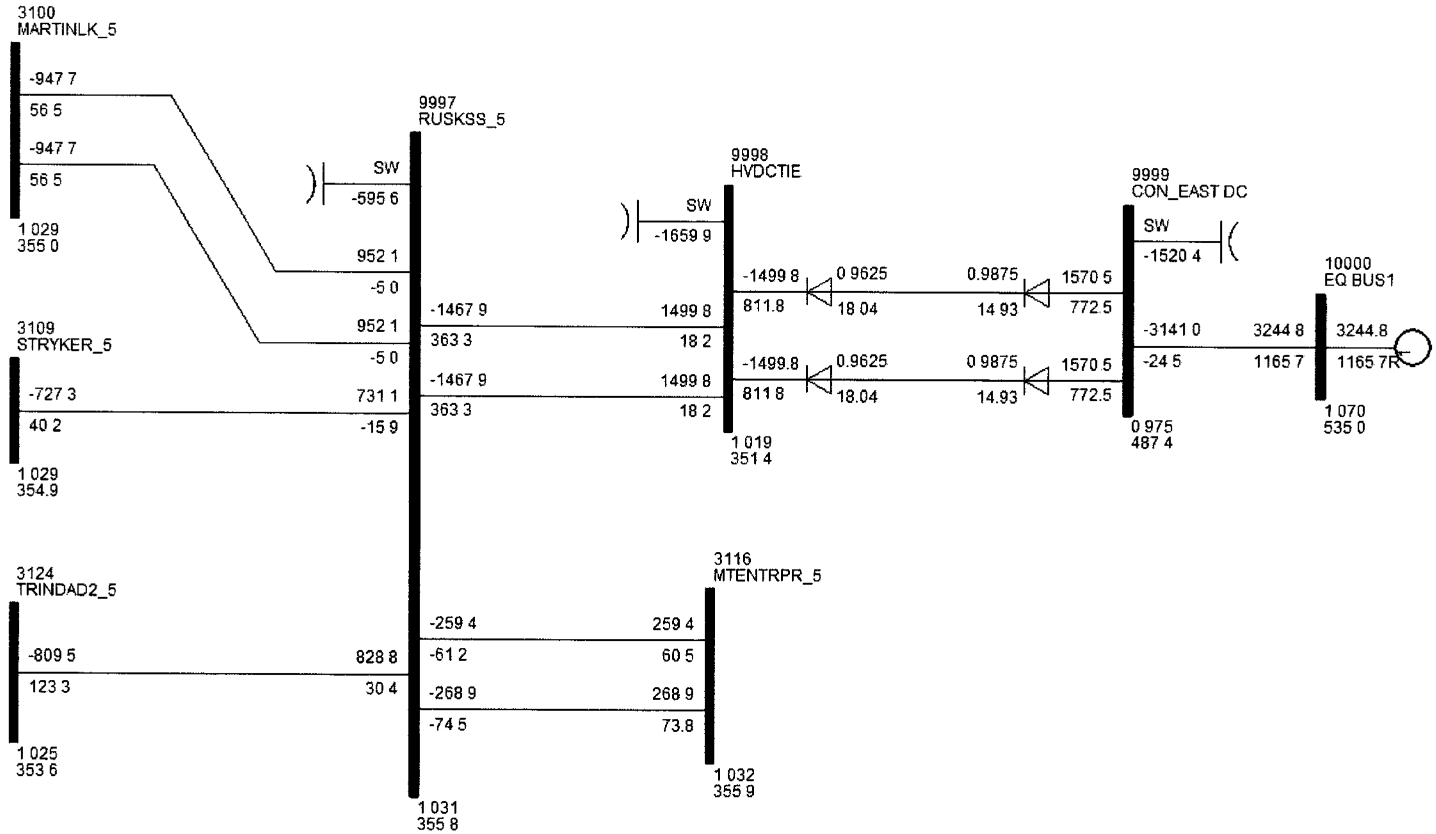

Figure 3.3-2: One-line diagram of the Rusk County 345 kV Switching Station and the HVDC tie for the 3000 MW Import final case.

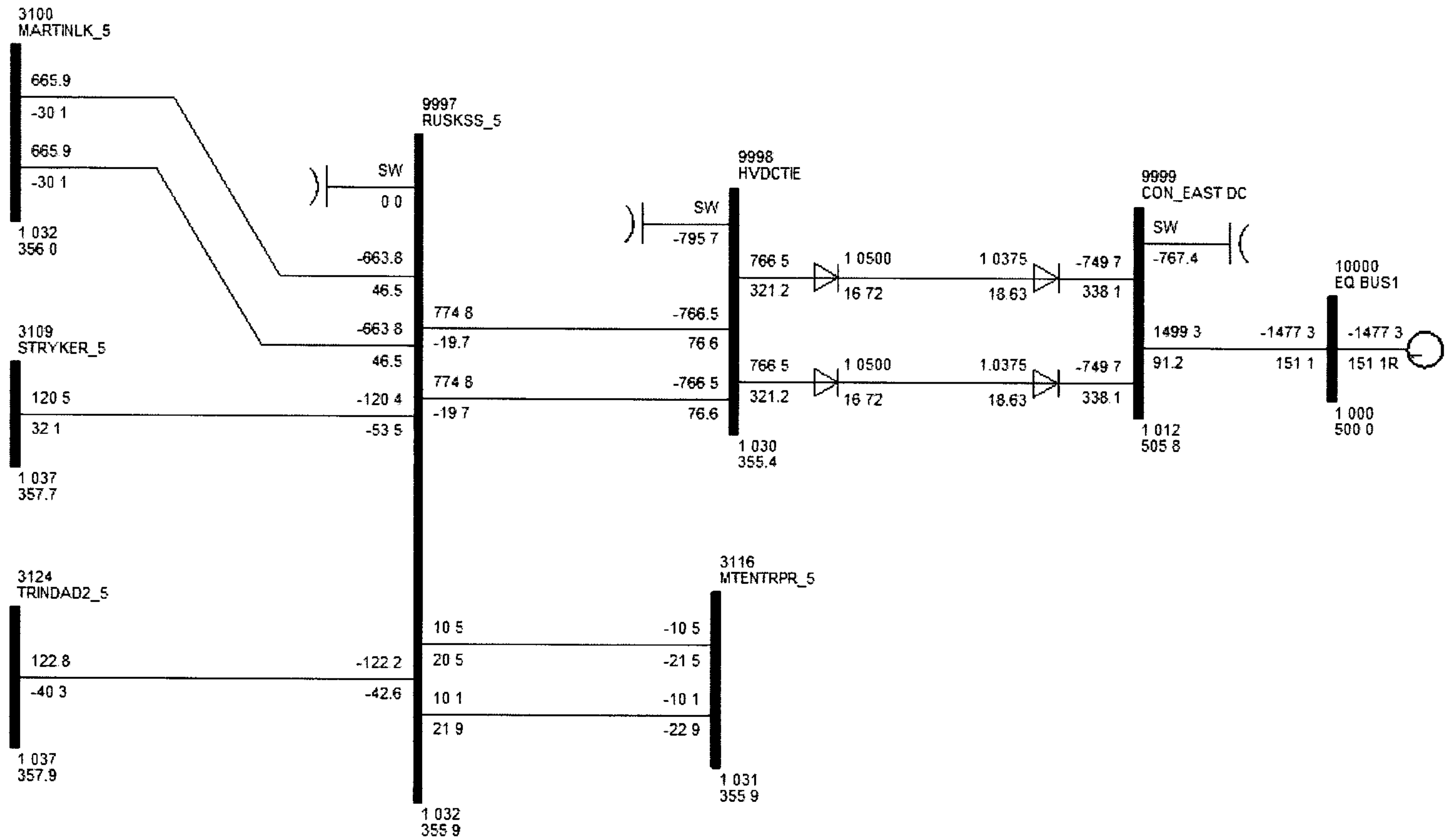

Figure 3.3-3: One-line diagram of the Rusk County 345 kV Switching Station and the HVDC tie for the 1500 MW Export final case.

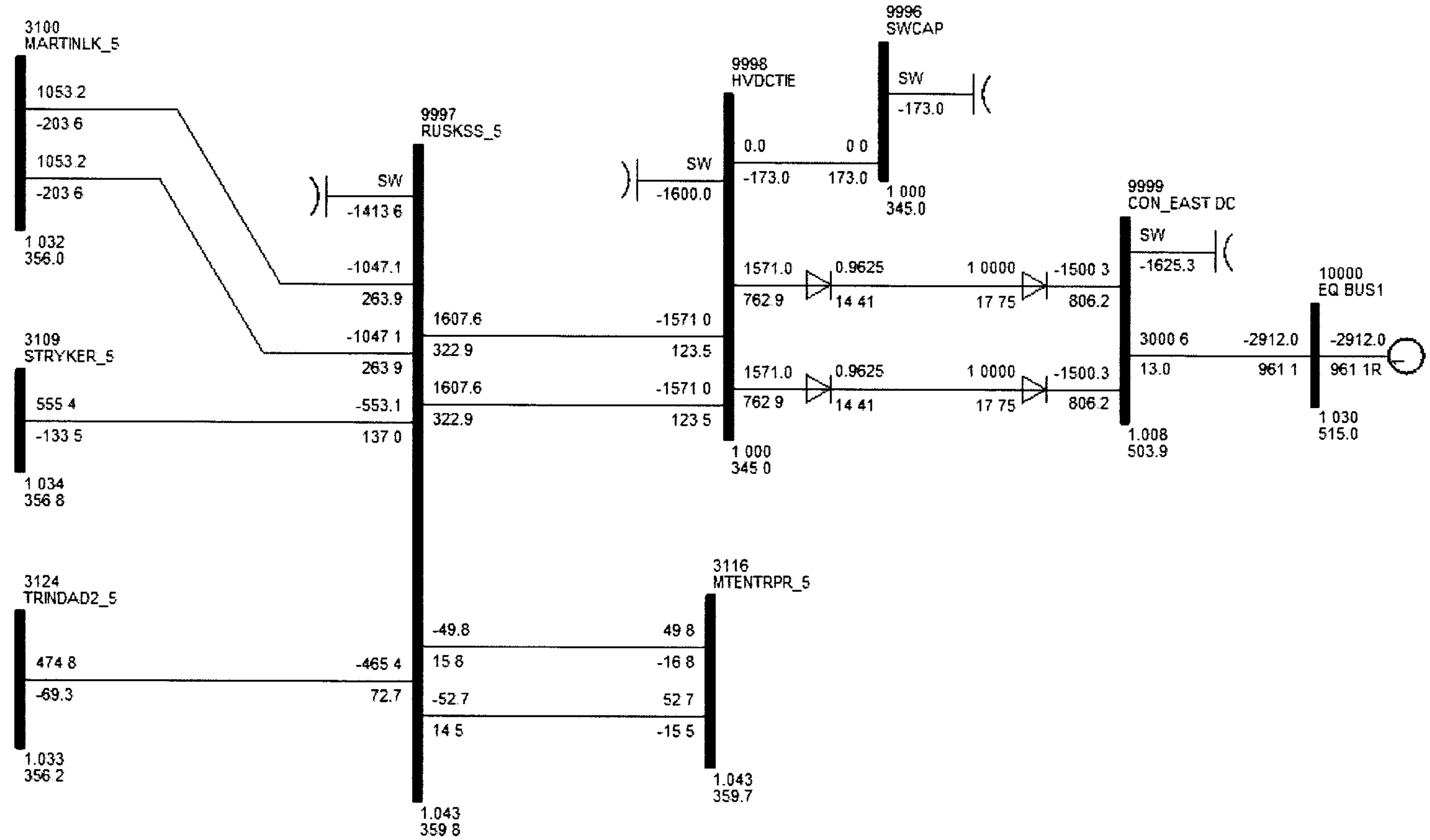

Figure 3.3-4: One-line diagram of the Rusk County 345 kV Switching Station and the HVDC tie for the 3000 MW Export final case.

Table 3.3-1 lists the model parameters for the HVDC model in PSSE for the Import cases. Table 3.3-2 lists the model parameters for the HVDC model in PSSE for the Export cases.

Table 3.3-1
Model Parameters for the HVDC Model in PSSE for the Import Cases

Ref. No.	PSSE 2-Term DC Parameters	Import 1500 MW Case		Import 3000 MW Case	
		Rectifier	Inverter	Rectifier	Inverter
1	Max firing angle (degree)	17	20	17	20
2	Min firing angle (degree)	13	17	13	17
3	Bridges in Series	2	2	2	2
4	Primary base (kV)	500	345	500	345
5	Commutating Resistance (Ohms)	0	0	0	0
6	Commutating Reactance (Ohms)	6.837	6.837	6.837	6.837
7	Transformer Ratio (p.u.)	0.425	0.55	0.425	0.553
8	Tap Setting (p.u.)	1.0625	1	0.9875	0.9625
9	Max Tap Setting (p.u.)	1.1	1.1	1.1	1.1
10	Min Tap Setting (p.u.)	0.9	0.9	0.9	0.9
11	Tap Step (p.u.)	0.0125	0.0125	0.0125	0.0125
12	Setval (amps or p.u.)	1533.5	1533.5	3141	3141
13	Filter (Mvar)	750	650	1600	1600

Table 3.3-2
Model Parameters for the HVDC Model in PSSE for the Export Cases

Ref. No.	PSSE 2-Term DC Parameters	Export 1500 MW Case		Export 3000 MW Case	
		Rectifier	Inverter	Rectifier	Inverter
1	Max firing angle (degree)	17	20	17	20
2	Min firing angle (degree)	13	17	13	17
3	Bridges in Series	2	2	2	2
4	Primary base (kV)	345	500	345	500
5	Commutating Resistance (Ohms)	0	0	0	0
6	Commutating Reactance (Ohms)	6.837	6.837	6.837	6.837
7	Transformer Ratio (p.u.)	0.594	0.408	0.577	0.4
8	Tap Setting (p.u.)	1.0625	1.0375	0.9625	1
9	Max Tap Setting (p.u.)	1.1	1.1	1.1	1.1
10	Min Tap Setting (p.u.)	0.9	0.9	0.9	0.9
11	Tap Step (p.u.)	0.0125	0.0125	0.0125	0.0125
12	Setval (amps or p.u.)	1533	1533	3142	3142
13	Filter (Mvar)	750	750	1800	1600

4.0 RESULTS FOR THE STEADY STATE CONTINGENCY ANALYSIS

This section reports on the upgrades examined to eliminate the thermal and voltage violations in Zones 130 through 148 for 345 kV to 69 kV buses for the Benchmark, 1500 MW, and 3000 MW Import and Export case. Table 4.0-1 is a summary of new/upgraded transmission lines and transformers that were added to eliminate thermal violations.

Table 4.0-1
New/Upgraded Equipment Examined to Eliminate Thermal Violations

Ref. No.	Transmission Lines and Equipment	kV	CKT	Base Case [1] (MVA)	Length (miles)	New MVA Ratings for Transmisison Lines and Equipment [2]					
						Import			Export		
						Benchmark Line (MVA)	1500 MW Line (MVA)	3000 MW Line (MVA)	Benchmark Line (MVA)	1500 MW Line (MVA)	3000 MW Line (MVA)
1	Lufkin Switch to Nacogdoches SE (3117-3119)	345	1	N/A	23	1631	1631	1631	-	-	1631
2	Martin Lake to Royse North (3100-2461)	345	1	N/A	124	1631	1631	1631	-	-	1631
3	Martin Lake to Stryker (3100-3109)	345	1	1631 [3]	41	-	-	1631	-	-	1631
4	Martin Lake to Nararro (3100-68091)	345	1	N/A	130	-	-	1631	-	-	-
5	Martin Lake to Nararro (3100-68091)	345	2	N/A	130	-	-	1631	-	-	-
6	Trinidad to Styker (3123-3109)	345	1	1072	68.6	-	-	1631	-	-	-
7	Rusk to Trinidad (9997-3124)	345	1	1072	92	-	-	1631	-	-	-
8	Rusk to Stryker (9997-3109)	345	1	1631	23.4	-	-	2390	-	-	1912
9	Rusk to Martin Lake (9997-3100)	345	1	1631	17.5	-	-	-	-	-	1912
10	Rusk to Martin Lake (9997-3100)	345	2	1631	17.5	-	-	-	-	-	1912
11	Tyler Grande to Tyler G.E. (3143-3213)	345	1	326	1	-	484	484	-	-	-
12	Dialville to Neches Pump (3160-3296)	138	1	214	15.5	-	-	326	-	-	-
13	Palestine South to Neches Pump (3271-3296)	138	1	214	9.5	-	-	326	-	-	-
14	Trinidad to Malakoff (3127-3276)	138	1	251	8.1	-	-	326	-	-	-
15	Forest Grove to Mabank Tap (3131-29266)	138	1	251	3.7	-	-	326	-	-	-
16	Malakoff to Mabank Tap (3276-29266)	138	1	251	3.7	-	-	326	-	-	-
17	Elkton to Tyler Southwest (3106-3139)	138	1	214	5	326	326	326	-	-	-
18	Tennyson Plano to Preston Meadows (2523-10010)	138	1	287	1	484	484	484	-	-	-
19	Flint to Jacksonville (3251-3253)	138	1	N/A	10.34	-	-	326	-	-	-
20	Collin to Northwest Carrolton (multiple branches)	138	2	N/A	17	326	326	326	-	-	-
21	Collin S.E.S. Auto Transformer	345/138	2	N/A	N/A	Rating A = 700 MVA Rating B and C = 750 MVA					

1 The Base Case (MVA) column shows either the current MVA rating for the transmission lines/transformer as modeled in the base cases or a N/A indicating that the branch does not exist in the base case and was selected as a new branch in certain cases.

2 The values provided in these column are the suggested MVA rating for the transmission lines/transformer to eliminate thermal loading violations during contingencies. If the cell contains a "-" then that line was not required to be upgraded/built for that case.

3 This line already exists in the Benchmark case before Rusk is modeled once Rusk is modeled in the 1500 MW and 3000 MW cases this line becomes Martin Lake to Rusk and Rusk to Stryker Creek. The Martin Lake to Strker Creek 345 kV was modeled in the Import 3000 MW case.

4.1 IMPORT CASES

New transmission lines were examined to determine their impacts on thermal overloading violations identified in the Import 1500 MW case. The base case 1500 MW Import thermal overloading results without any transmission line upgrades or additions modeled were compared to the 1500 MW Import case with one new transmission modeled at a time to determine the impact each upgrade had on the thermal overloading violations. Table 4.1-1 lists the results of the new transmission lines for the Import 1500 MW case on thermal overloads during contingency analysis for Base Case conditions (i.e., pre-upgrades).

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Table 4.1-1
Summary of the Impact of New Transmission Lines for the Import 1500 MW Case on Thermal Overloads

Ref. No.	To	To Bus	kV	From	From Bus	kV	CK	Contingency	Import 1500 MW Base Case (No Upgrades)				Import 1500 MW Base Case + New Transmission Line Flow (%)[1,2]							
									Flow (MVA)	Flow (Amps)	Rate A/B	Flow (%)	Mount Enterprise to Nacogdoches 345 kV CKT 2	Lufkin Switch to Jewett Switch 345 kV CKT 1	Lufkin Switch to Nacogdoches SE 345 kV CKT 1	Martin Lake to Royse North 345 kV CKT 1	Martin Lake to Stryker Creek 345 kV CKT 1	Rusk County to Navarro 345 kV CKT 1	Lufkin Switch to Big Brown 345 kV CKT 1	Lufkin Switch to Nacogdoches SE 345 kV CK1 and Martin Lake to Royse North 345 kV CKT 1
1	2370	COLLINSS1_8	138	629	ROMANJUAREZ	138	1	PLTNAUSTRNCH	-348.21	346.59	326	106.32	105.80	105.72	-	-	-	-	-	-
2	3128	TRINIDAD_9	69	3239	ATHENS_9	69	1	FG-MABK-ATH	-35.00	35.94	32	112.30	112.12	102.61	111.85	-	110.82	-	105.19	-
3	2437	FRNY1_5	345	3105	ELKTON_5	345	1	SHAM-ROY-TY1	-876.77	999.04	956	104.50	100.36	-	-	-	-	-	-	
4	3104	SHAMBRGR_8	138	3141	TYLERNW_8	138	1	SHAM-ROY-TY1	222.56	241.53	214	112.86	108.88	100.72	106.65		102.67	-	101.72	
5	3123	TRINDAD1_5	345	3109	STRYKER_5	345	1	SHAM-ROY-TY1	-1038.42	1111.71	1072	103 70	-	-	-	-	-	-	-	-
6	9991	RUSKSS_5	345	3124	TRINDAD2_5	345	1	SHAM-ROY-TY1	1029.22	1110.02	1072	103.55	-	-	-	-	-	-	-	-
7	3160	DIALVILL_8	138	3296	NECHESRI_8	138	1	STRY-SMR-TRO	229.49	230.02	214	107.49	107.33	-	107.88	-	108.49	-	-	-
8	3271	PALSTNS_8	138	3296	NECHESRI_8	138	1	STRY-SMR-TRO	-221.96	226.77	214	105.97	105.81	-	106.36	-	106.97	-	-	-
9	3131	FOREGROV_8	138	29266	MABANKTAP	138	1	TDAD-TRICORN	256.95	259.12	251	103 23	103.14	100.14	103.06	-	103.04		102.63	-
10	3276	MALAKOFF_8	138	29266	MABANKTAP	138	1	TDAD-TRICORN	-256.90	259.06	251	103.21	103 11	100.12	103.04	-	103.02	-	102.61	-
11	3118	LUFKNSS_8	138	3340	LUFKIN_8	138	1	SOUTHCR3	-275.46	308.48	251	122.90	120.96	146.82	-	119.94	121.52	121.66	142.65	
12	3119	NACOGDSE_5	345	3WNDTR	WND 1		1	SOUTHCR3	865.65	865.65	750	115.42	116.85	112.90	-	113.16	115.04	112.12	112.81	
13	3120	NACOGDSE_8	138	3311	NACOSFA_8	138	1	SOUTHCR3	-249 13	266.17	214	124.38	122 12	103 10	-	120.43	124.27	116.44	105.36	
14	3120	NACOGDSE_8	138	3315	NACOGSOU_8	138	1	SOUTHCR3	-294.81	315.72	249	126.80	124.76	128.94	-	122.43	125.86	120.84	127 65	-
15	3120	NACOGDSE_8	138	3319	HERTYNOR_8	138	1	SOUTHCR3	-272.59	304.12	214	142 11	139.99	145.21	-	137.02	141.00	135.26	143.60	-
16	3120	NACOGDSE_8	138	3WNDTR	WND 2		1	SOUTHCR3	834.75	834.75	750	111.30	112.52	110.87	-	110.88	111.20	110.97	110.87	-
17	3160	DIALVILL_8	138	3296	NECHESRI_8	138	1	SOUTHCR3	198.94	216.85	214	101.33	101 10	-	-	-	101.89	-	-	-
18	3301	GRESHRD_POI	138	3110	STRYKER_8	138	1	SOUTHCR3	246.45	262.61	186	141.19	139.60	115.73	-	135.21	140.84	129.90	118.38	-
19	3301	GRESHRD_POI	138	3304	GRESHRDSS	138	1	SOUTHCR3	102.07	108.77	100	108.77	107.09	102.35	100.91	103.46	107 98	100.27	102.44	-
20	3310	NACOGNOR_8	138	3311	NACOSFA_8	138	1	SOUTHCR3	-220.08	235 13	214	109.87	107 90	-	-	106 70	109.88	103.26	-	-
21	3314	NACOGSW_8	138	3315	NACOGSOU_8	138	1	SOUTHCR3	266.58	288.33	249	115 79	114.04	118.45	-	111.89	114.93	110.62	117.20	-
22	3314	NACOGSW_8	138	3316	NACOGST_8	138	1	SOUTHCR3	-253.55	274.73	249	110.33	108.69	113 37	-	106.75	109.51	105.71	112 14	-
23	3316	NACOGST_8	138	3340	LUFKIN_8	138	1	SOUTHCR3	253.53	274.71	186	147.69	145.49	151 76	-	142.91	146.60	141.51	150.12	-
24	2478	ROYSE_S5	345	3103	SHAMBRGR_5	345	1	FNYELK_TRISE	-1043.58	1193.61	1072	111.34	110.36	-	109.57	-	104.62	-		
25	3106	ELKTON_8	138	3196	TYLERSWE_8	138	1	FNYELK_TRISE	174.15	192.45	186	103.47	102 93	-	102.48	-	-	-	-	-
26	2478	ROYSE_S5	345	3103	SHAMBRGR_5	345	1	FNY-ELKSEAG	-1009.82	1142.55	1072	106.58	105.67	-	104.92	-	100.78	-		-
27	3106	ELKTON_8	138	3196	TYLERSWE_8	138	1	FNY-ELKSEAG	170.91	187.26	186	100.68	100.21	-	-	-	-	-	-	-
28	2478	ROYSE_S5	345	3103	SHAMBRGR_5	345	1	FNY-ELKTRI	-1035.87	1184.49	1072	110.49	109.49	-	108.70	-	105.28	-	-	-
29	3106	ELKTON_8	138	3196	TYLERSWE_8	138	1	FNY-ELKTRI	173.76	192.10	186	103.28	102.74	-	102.29	-	100.17		-	-
30	3133	RICHLND2_5	345	3380	BIGBRN__5	345	1	WTML-TNDTRI	1159.45	1119.06	1052	106.37	106.37	-	107 33	-	108.32	-	-	-

1 The % flow results shown for the Import 1500 MW Base Case + New Transmission Line Column are not all of the thermal overloads violations observed for that case. These results only show how the new transmission lines were able to eliminate the thermal overloading violations from the Import 1500 MW Base Case and do not show any new violtions caused by the new lines.
2 " - " indicates the % flow is below 100%

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The Lufkin Switch to Nacogdoches 345 kV #1, 23 mile long transmission line reduces the thermal overloading for the SOUTHCR3 double circuit 345 kV contingency from Rusk to Mt. Enterprise. The Martin Lake to Royse North 345 kV #1, 124 mile long transmission line reduces the thermal overloading for the thermal violations other than SOUTHCR3. These two transmission lines were chosen to be modeled together to eliminate thermal overloads observed in the Import 1500 MW base case.

4.1.1 Import Benchmark Case

Table 4.1-2 lists the number of thermal and voltage violations for the Import Benchmark case before making any upgrades to Oncor's system.

Table 4.1-2*
Summary of Thermal and Voltage Violations for Import Benchmark Case Before Upgrades

Ref. No.	Contingency Set	Number of Thermal Violations	Number of Voltage Violations
1	Special Contingencies	13	24
2	Single Circuit Area 1	11	176

*These violations occur before the SPS or manual switching operations have been implemented.

Table 4.1-3 lists the transmission lines and transformer upgrades selected for the Import Benchmark case. Table 4.1-4 lists the shunt capacitor bank upgrades examined for the Import Benchmark case at MURPHY1_8.

Table 4.1-3
Transmission Lines and Transformer Upgrades Selected for Import Benchmark Case

Ref. No.	To	To Bus	From	From Bus	kV	CK	MVA	R (p.u.)	X (p.u.)	B (p.u.)	Length (miles)	New or Upgrade
1	3117	Lufkin Switch	3119	Nacogdoches SE	345	1	1631	0.00074	0.00970	0.23455	23	New
2	3100	Martin Lake	2461	Royse North	345	1	1631	0.00401	0.05228	1.26451	124	New
3	3106	ELKTON_8	3139	TYLERWES_8	138	1	326	0.00181	0.01809	0.00598	5	Upgrade
4	2523	PL_TENNY_8	10010	PRSTMDWS_8	138	1	484	0.00013	0.00153	0.01976	2.64	Upgrade
5	Collin to Northwest Carrolton (multiple branches)				138	2	326	0.00036[1]	0.00362[1]	0.00120[1]	17	New
6	2370	COLLINSS1_8	2372	COLLINSS1_5	138/345	2	Rating A =700 MVA Rating B, C = 750 MVA					New

1 The units for these values are in (p.u./mile) not in (p.u.) as the rest of the impedance values in this table.

Table 4.1-4
Shunt Capacitor Banks Examined for the Import Benchmark Case at MURPHY1_8 (bus 2696)

Ref. No.	Contingnecy	Binit (MVAR)	Bus Voltage (p.u.)
1	Base Case	-	1
2	BD-MURPMC	0	0.93
3		10	0.94
4		20	0.95
5		30	0.96
6		40	0.98
7		50	0.99
8		60	1
9		70	1.01
10		80	1.03
11		90	1.04

The BD-MURPMC contingency consists of the loss of the Ben Davis to Murphy 138 kV and Ben Davis to Parker-Maxwell Creek 138 kV transmission lines. This was the only contingency observed where voltage violations observed could not be solved by switching existing shunt capacitor banks or by changing transformer tap settings. The voltage violations for this contingency are eliminated if a shunt capacitor is added at MURPHY1_8 (bus #2696) and is sized between 10 to 90 MVAR. An 80 MVAR bank was chosen since it provides voltage support for the surrounding area.

The remaining voltage violations observed for the Import Benchmark case were eliminated using SPS and manual switching operations such as switching bus tie breakers, turning on/off shunt capacitor banks, or changing transformer tap ratios.

The Collin #2 345/138 kV autotransformer was observed overloading when the Collin #1 345/138 kV autotransformer was switched out and the transformer taps settings on Collin #2 were not at 1 p.u. on both sides. Series reactors were examined at the high side terminals of the Collin #2 345/138 kV autotransformer to eliminate the loading violations over 100% that were occurring. Table 4.1-5 lists the results of the series reactor's impacts on the Collin #2 345/138 kV autotransformer loading during the Import Benchmark case with the Collin #1 autotransformer out. It was determined that a 2-ohm series reactor would eliminate the thermal loading if the transformer taps were coordinated correctly.

Table 4.1-5
Series Reactor Impacts on the Collin 345/138 kV #2 Transformer Loading During the Import Benchmark Case with the Collin #1 Transformer Out

Ref. No.	Series Reactor (ohms)	Transformer Tap Settings (p.u.) 345 kV	Transformer Tap Settings (p.u.) 138 kV	Loading (%)
1	2	1	1	88
2		0.924[1]	1[1]	99
3		0.9	1	105
4		0.879	1	109
5	3	1	1	86
6		0.924[1]	1[1]	96
7		0.9	1	101

1 These transformer tap settings were obtained by allowing the transformer taps to step. The other tap settings were examined to see what other loading values could occur.

The 2-ohm series reactor, the transmission lines and transformer listed in Table 4.1-3, and the shunt capacitor bank upgrades were chosen to be modeled eliminating the thermal and voltage violations observed for the Import Benchmark case.

Refer to Table B-1 and Table B-4 in Appendix B for the list of loading violations and voltage violations, before implementing SPS or manual switching operations, for the Import Benchmark case for the "Special Contingencies" and the Single Circuit Area 1 Contingencies.

4.1.2 Import 1500 MW Case

Table 4.1-6 lists the number of thermal and voltage violations for the Import 1500 MW case before making any upgrades to Oncor's system.

Table 4.1-6*
Summary of Thermal and Voltage Violations for Import 1500 MW Case Before Any Upgrades

Ref. No.	Contingency Set	Number of Thermal Violations	Number of Voltage Violations
1	Special Contingencies	30	77
2	Single Circuit Area 1	41	224
3	Single and Double Circuits out of Rusk	16	39

*These violations occur before the SPS or manual switching operations have been implemented.

Table 4.1-7 lists the transmission lines and transformer upgrades selected for the Import 1500 MW case. Table 4.1-8 lists the shunt capacitor bank upgrades examined for the Import 1500 MW case at MURPHY1_8.

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Table 4.1-7
Transmission Lines and Transformer Upgrades Selected for the Import 1500 MW Case

Ref. No.	To	To Bus	From	From Bus	kV	CK	MVA	R (p.u.)	X (p.u.)	B (p.u.)	Length (miles)	New or Upgrade
1	3117	Lufkin Switch	3119	Nacogdoches SE	345	1	1631	0.00074	0.00970	0.23455	23	New
2	3100	Martin Lake	2461	Royse North	345	1	1631	0.00401	0.05228	1.26451	124	New
3	3106	ELKTON_8	3139	TYLERWES_8	138	1	326	0.00181	0.01809	0.00598	5	Upgrade
4	2523	PL_TENNY_8	10010	PRSTMDWS_8	138	1	484	0.00013	0.00153	0.01976	2.64	Upgrade
5	3143	TYLERGND_8	3213	TYLERGE_8	138	1	484	0.00005	0.00058	0.00748	1	Upgrade
6	Collins to Northwest Carrolton (multiple branches)				138	2	326	0.00036[1]	0.00362[1]	0.00120[1]	17	New
7	2370	COLLINSS1_8	2372	COLLINSS1_5	138/345	2	Rating A =700 MVA Rating B, C = 750 MVA					New

1 The units for these values are in (p.u./mile) not in (p.u.) as the rest of the impedance values in this table.

Table 4.1-8
Shunt Capacitor Banks Examined for the Import 1500 MW Case at MURPHY1_8 (bus 2696)

Ref. No.	Contingnecy	Binit (MVAR)	Bus Voltage (p.u.)
1	Base Case	-	1
2	BD-MURPMC	0	0.93
3		10	0.94
4		20	0.95
5		30	0.96
6		40	0.98
7		50	0.99
8		60	1
9		70	1.02
10		80	1.03
11		90	1.04

BD-MURPMC was the only contingency observed where voltage violations observed could not be solved by switching existing shunt capacitor banks or by changing transformer tap settings. The voltage violations for this contingency are eliminated if a shunt capacitor is added at MURPHY1_8 (bus #2696) and is sized between 10 to 90 MVAR. An 80 MVAR bank was chosen since it provides voltage support for the surrounding area.

The remaining voltage violations observed for the Import 1500 MW case were eliminated using SPS and manual switching operations such as switching bus tie breakers, turning on/off shunt capacitor banks, or changing transformer tap ratios.

The Collin #2 345/138 kV autotransformer was observed overloading when the Collin #1 345/138 kV autotransformer was switched out and the transformer taps settings on Collin #2 were not at 1 p.u. on both sides. Series reactors were examined at the high side terminals of the Collin #2 345/138 kV autotransformer to eliminate the loading violations over 100% that were occurring. Table 4.1-9 lists the results of the series reactor's impacts on the Collin #2 345/138 kV autotransformer loading during the Import 1500 MW case with the Collin #1 autotransformer out. It was determined that a 2-ohm series reactor would eliminate the thermal loading if the transformer taps were coordinated correctly.

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Table 4.1-9
Series Reactor Impacts on the Collin 345/138 kV #2 Transformer Loading During the Import 1500 MW Case with the Collin #1 Transformer Out

Ref. No.	Series Reactor (ohms)	Transformer Tap Settings (p.u.) 345 kV	Transformer Tap Settings (p.u.) 138 kV	Loading (%)
1	2	1	1	88
2		0.924[1]	1[1]	99
3		0.9	1	105
4		0.879	1	109
5	3	1	1	86
6		0.924[1]	1[1]	96
7		0.9	1	101

1 These transformer tap settings were obtained by allowing the transformer taps to step. The other tap settings were examined to see what other loading values could occur.

The two ohm series reactor, the transmission lines and transformer listed in Table 4.1-7, and the shunt capacitor bank upgrades were chosen to be modeled eliminating the thermal and voltage violations observed for the Import 1500 MW case.

Refer to Table B-5 and Table B-10 in Appendix B for the list of loading violations and voltage violations, before implementing SPS or manual switching operations, for the Import 1500 MW case for the "Special Contingencies," the Single Circuit Area 1 Contingencies, and the single and double circuit contingencies out of Rusk County 345 kV Switching Station.

4.1.3 Import 3000 MW Case

When the Import 3000 MW base case was examined for the steady state contingency analysis thermal and voltage violations were observed, however several of the single and double circuit contingency cases did not converge. Table 4.1-10 lists the number of thermal violations, voltage violations, and convergence errors for the Import 3000 MW case before making any upgrades to Oncor's system.

Table 4.1-10*
Summary of Thermal and Voltage Violations and Convergence Errors for the Import 3000 MW Case Before Any Upgrades

Ref. No.	Contingency Set	Number of Thermal Violations	Number of Voltage Violations	Number of Convergence Errors
1	Special Contingencies	16	42	17
2	Single Circuit Area 1	68	22	35
3	Single and Double Circuits out of Rusk	4	11	7

*These violations occur before the SPS or manual switching operations have been implemented.

Table 4.1-11 lists the single and double circuit contingencies from the Import 3000 MW cases that did not converge. The upgrades for the 3000 MW case were selected by first modeling the upgrades selected in the Import 1500 MW case. Additional upgrades were then made based on the contingencies that still had violations or did not converge. Table 4.1-12 lists the final lines and transformers added or upgraded to eliminate all violations. Table 4.1-13 lists the shunt capacitor bank upgrades examined for the Import 3000 MW case at MURPHY1_8.

Table 4.1-11
Summary of Single Circuit Contingencies from the Import 3000 MW Case With a Mismatch Greater Than One Before Making Any Upgrades

Ref. No.	Contingency Name	Contingency Description	Converged	Convergence State[1]
1	ALN*MON-RYS	OPEN BRANCH FROM BUS 2514 [ALLENSW2_5 345.00] TO BUS 1696 [MOSES1_T5 345.00] CKT 1 OPEN BRANCH FROM BUS 2513 [ALLENSW1_5 345.00] TO BUS 2461 [ROYSE_N5 345 00] CKT 1 OPEN BRANCH FROM BUS 1695 [MOSES_5 345 00] TO BUS 1696 [MOSES1_T5 345.00] CKT BC	FALSE	Blown up
2	MLAK_FRY_TRI	OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 3105 [ELKTON_5 345.00] CKT 1 OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 3102 [TYLERGND_5 345.00] CKT 1	FALSE	Blown up
3	MLAKE-SHAM	OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 3103 [SHAMBRGR_5 345.00] CKT 1 OPEN BRANCH FROM BUS 3103 [SHAMBRGR_5 345 00] TO BUS 3104 [SHAMBRGR_8 138.00] CKT 1	FALSE	Blown up
4	ML-EL_TG-TRI	OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 3105 [ELKTON_5 345 00] CKT 1 OPEN BRANCH FROM BUS 3102 [TYLERGND_5 345 00] TO BUS 2432 [TRICRN1_5 345.00] CKT 1	FALSE	Blown up
5	RICHLND-TDAD	OPEN BRANCH FROM BUS 3123 [TRINDAD1_5 345.00] TO BUS 3133 [RICHLND2_5 345.00] CKT 1 OPEN BRANCH FROM BUS 3124 [TRINDAD2_5 345.00] TO BUS 3134 [RICHLND1_5 345 00] CKT 1	FALSE	Blown up
6	SHAM-ROY-TY1	OPEN BRANCH FROM BUS 3103 [SHAMBRGR_5 345.00] TO BUS 2478 [ROYSE_S5 345 00] CKT 1 OPEN BRANCH FROM BUS 3104 [SHAMBRGR_8 138.00] TO BUS 3201 [LINDALE_8 138.00] CKT 1	FALSE	Blown up
7	STRY-SMR-TRO	OPEN BRANCH FROM BUS 3110 [STRYKER_8 138.00] TO BUS 3112 [SMRFLDMT_8 138.00] CKT 1 OPEN BRANCH FROM BUS 3110 [STRYKER_8 138.00] TO BUS 3147 [TROUPSS_8 138.00] CKT 1	FALSE	Blown up
8	TDAD-TRICORN	OPEN BRANCH FROM BUS 3123 [TRINDAD1_5 345.00] TO BUS 2427 [WATMLL_W5 345.00] CKT 1 OPEN BRANCH FROM BUS 3124 [TRINDAD2_5 345.00] TO BUS 2432 [TRICRN1_5 345.00] CKT 1	FALSE	Blown up
9	TLRG-ELK-FRN	OPEN BRANCH FROM BUS 3102 [TYLERGND_5 345.00] TO BUS 2432 [TRICRN1_5 345.00] CKT 1 OPEN BRANCH FROM BUS 3105 [ELKTON_5 345.00] TO BUS 2437 [FRNY1_5 345.00] CKT 1	FALSE	Blown up
10	SOUTHCR2	OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 9997 [RUSKSS_5 345.00] CKT 1 OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 9997 [RUSKSS_5 345 00] CKT 2	FALSE	Blown up
11	SOUTHCR3	OPEN BRANCH FROM BUS 3116 [MTENTRPR_5 345.00] TO BUS 9997 [RUSKSS_5 345.00] CKT 1 OPEN BRANCH FROM BUS 3116 [MTENTRPR_5 345.00] TO BUS 9997 [RUSKSS_5 345.00] CKT 2	FALSE	Blown up
12	SOUTHCR6	OPEN BRANCH FROM BUS 9997 [RUSKSS_5 345 00] TO BUS 3109 [STRYKER_5 345.00] CKT 1 OPEN BRANCH FROM BUS 9997 [RUSKSS_5 345.00] TO BUS 3124 [TRINDAD2_5 345.00] CKT 1	FALSE	Blown up
13	FNYELK_TRISE	OPEN BRANCH FROM BUS 2437 [FRNY1_5 345.00] TO BUS 3105 [ELKTON_5 345.00] CKT 1 OPEN BRANCH FROM BUS 2432 [TRICRN1_5 345 00] TO BUS 2433 [SGVLSW1_5 345 00] CKT 1	FALSE	Blown up
14	FNY-ELKSEAG	OPEN BRANCH FROM BUS 2437 [FRNY1_5 345.00] TO BUS 2433 [SGVLSW1_5 345.00] CKT 1 OPEN BRANCH FROM BUS 2437 [FRNY1_5 345.00] TO BUS 3105 [ELKTON_5 345.00] CKT 1	FALSE	Blown up
15	FNY-ELKTRI	OPEN BRANCH FROM BUS 2437 [FRNY1_5 345.00] TO BUS 3105 [ELKTON_5 345 00] CKT 1 OPEN BRANCH FROM BUS 2437 [FRNY1_5 345.00] TO BUS 2433 [SGVLSW1_5 345.00] CKT 1 OPEN BRANCH FROM BUS 2433 [SGVLSW1_5 345.00] TO BUS 2432 [TRICRN1_5 345.00] CKT 1	FALSE	Blown up
16	BB-RICHLAND	OPEN BRANCH FROM BUS 3380 [BIGBRN__5 345.00] TO BUS 3134 [RICHLND1_5 345.00] CKT 1 OPEN BRANCH FROM BUS 3380 [BIGBRN__5 345.00] TO BUS 3133 [RICHLND2_5 345.00] CKT 1	FALSE	Blown up
17	BIG_BRN-NAV	OPEN BRANCH FROM BUS 3380 [BIGBRN__5 345.00] TO BUS 68091 [NAVARRO 345.00] CKT 1 OPEN BRANCH FROM BUS 3380 [BIGBRN__5 345.00] TO BUS 68091 [NAVARRO 345.00] CKT 2	FALSE	Blown up

1 PSSE was set to solve using 100 iterations.

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Table 4.1-11 (Continued)
Summary of Single Circuit Contingencies from the Import 3000 MW Case With a Mismatch Greater Than One Before Making Any Upgrades

Ref. No.	Contingency Name	Contingency Description	Converged	Convergence State[1]
18	OVRLOD 1	OPEN LINE FROM BUS 3358 [CENTVILL_8 138.00] TO BUS 3394 [JEWETTA_T_8 138.00] CKT 1	FALSE	Blown up
19	OVRLOD 2	OPEN LINE FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 3103 [SHAMBRGR_5 345.00] CKT 1	FALSE	Blown up
20	OVRLOD 3	OPEN LINE FROM BUS 3355 [GRPLMGTA_8 138.00] TO BUS 3357 [PLSNTSPG_8 138.00] CKT 1	FALSE	Iteration limit exceeded
21	OVRLOD 4	OPEN LINE FROM BUS 3357 [PLSNTSPG_8 138.00] TO BUS 3358 [CENTVILL_8 138.00] CKT 1	FALSE	Iteration limit exceeded
22	OVRLOD 5	OPEN LINE FROM BUS 3354 [CROCKETT_8 138.00] TO BUS 3355 [GRPLMGTA_8 138.00] CKT 1	FALSE	Iteration limit exceeded
23	OVRLOD 6	OPEN LINE FROM BUS 2478 [ROYSE_S5 345.00] TO BUS 3103 [SHAMBRGR_5 345.00] CKT 1	FALSE	Blown up
24	OVRLOD 7	OPEN LINE FROM BUS 3109 [STRYKER_5 345.00] TO BUS 3123 [TRINDAD1_5 345.00] CKT 1	FALSE	Blown up
25	OVRLOD 8	OPEN LINE FROM BUS 2437 [FRNY1_5 345.00] TO BUS 3105 [ELKTON_5 345.00] CKT 1	FALSE	Blown up
26	OVRLOD 9	OPEN LINE FROM BUS 2432 [TRICRN1_5 345.00] TO BUS 3102 [TYLERGND_5 345.00] CKT 1	FALSE	Blown up
27	OVRLOD 10	OPEN LINE FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 3102 [TYLERGND_5 345.00] CKT 1	FALSE	Blown up
28	OVRLOD 11	OPEN LINE FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 3105 [ELKTON_5 345.00] CKT 1	FALSE	Blown up
29	OVRLOD 14	OPEN LINE FROM BUS 2432 [TRICRN1_5 345.00] TO BUS 3124 [TRINDAD2_5 345.00] CKT 1	FALSE	Blown up
30	OVRLOD 16	OPEN LINE FROM BUS 2427 [WATMLL_W5 345.00] TO BUS 3123 [TRINDAD1_5 345.00] CKT 1	FALSE	Blown up
31	OVRLOD 19	OPEN LINE FROM BUS 3110 [STRYKER_8 138.00] TO BUS 3111 [STRYKERTA_8 138.00] CKT 1	FALSE	Blown up
32	OVRLOD 21	OPEN LINE FROM BUS 3111 [STRYKERTA_8 138.00] TO BUS 3160 [DIALVILL_8 138.00] CKT 1	FALSE	Blown up
33	OVRLOD 27	OPEN LINE FROM BUS 2428 [WATMLL_E5 345.00] TO BUS 2432 [TRICRN1_5 345.00] CKT 1	FALSE	Blown up
34	OVRLOD 38	OPEN LINE FROM BUS 3110 [STRYKER_8 138.00] TO BUS 3112 [SMRFLDMT_8 138.00] CKT 1	FALSE	Blown up
35	OVRLOD 39	OPEN LINE FROM BUS 3112 [SMRFLDMT_8 138.00] TO BUS 3253 [JAXVLSW_8 138.00] CKT 1	FALSE	Blown up
36	OVRLOD 40	OPEN LINE FROM BUS 3116 [MTENTRPR_5 345.00] TO BUS 3119 [NACOGDSE_5 345.00] CKT 1	FALSE	Blown up
37	OVRLOD 41	OPEN LINE FROM BUS 3119 [NACOGDSE_5 345.00] TO BUS 3120 [NACOGDSE_8 138.00] TO BUS 3135	FALSE	Blown up
38	OVRLOD 56	OPEN LINE FROM BUS 3110 [STRYKER_8 138.00] TO BUS 3147 [TROUPSS_8 138.00] CKT 1	FALSE	Blown up
39	OVRLOD 75	OPEN LINE FROM BUS 3133 [RICHLND2_5 345.00] TO BUS 3380 [BIGBRN__5 345.00] CKT 1	FALSE	Blown up
40	OVRLOD 76	OPEN LINE FROM BUS 3147 [TROUPSS_8 138.00] TO BUS 3156 [WALNUT_POI 138.00] CKT 1	FALSE	Iteration limit exceeded
41	OVRLOD 77	OPEN LINE FROM BUS 3156 [WALNUT_POI 138.00] TO BUS 3227 [WHITEHSE_8 138.00] CKT 1	FALSE	Iteration limit exceeded
42	OVRLOD 178	OPEN LINE FROM BUS 3160 [DIALVILL_8 138.00] TO BUS 3296 [NECHESRI_8 138.00] CKT 1	FALSE	Blown up
43	OVRLOD 482	OPEN LINE FROM BUS 1431 [GRHAMSES1_8 138.00] TO BUS 1601 [GRAHAME_8 138.00] CKT 1	FALSE	Iteration limit exceeded
44	OVRLOD 517	OPEN LINE FROM BUS 1596 [GRAHAMSW_8 138.00] TO BUS 1601 [GRAHAME_8 138.00] CKT 1	FALSE	Iteration limit exceeded
45	OVRLOD 629	OPEN LINE FROM BUS 3271 [PALSTNS_8 138.00] TO BUS 3296 [NECHESRI_8 138.00] CKT 1	FALSE	Blown up
46	OVRLOD 782	OPEN LINE FROM BUS 1596 [GRAHAMSW_8 138.00] TO BUS 1599 [BARTON_8 138.00] CKT 1	FALSE	Iteration limit exceeded
47	OVRLOD 1913	OPEN LINE FROM BUS 3105 [ELKTON_5 345.00] TO BUS 3106 [ELKTON_8 138.00] TO BUS 29150 [EL	FALSE	Blown up
48	OVRLOD 2037	OPEN LINE FROM BUS 3123 [TRINDAD1_5 345.00] TO BUS 3133 [RICHLND2_5 345.00] CKT 1	FALSE	Blown up
49	OVRLOD 2077	OPEN LINE FROM BUS 3124 [TRINDAD2_5 345.00] TO BUS 3134 [RICHLND1_5 345.00] CKT 1	FALSE	Blown up
50	UNIT 120101	REMOVE UNIT C1 FROM BUS 120101 [TGCCS_CT1 18.000]	FALSE	Blown up
51	UNIT 120102	REMOVE UNIT C2 FROM BUS 120102 [TGCCS_CT2 18.000]	FALSE	Blown up
52	UNIT 120103	REMOVE UNIT C3 FROM BUS 120103 [TGCCS_CT3 18.000]	FALSE	Blown up

1 PSSE was set to solve using 100 iterations.

Table 4.1-12
Transmission Lines and Transformer Upgrades Selected for the Import 3000 MW Case

Ref. No.	To	To Bus	From	From Bus	kV	CK	MVA	R (p.u.)	X (p.u.)	B (p.u.)	Length (miles)	New or Upgraded
1	3117	Lufkin Switch	3119	Nacogdoches SE	345	1	1631	0.00070	0.00970	0.23450	23	New
2	3100	Martin Lake	2461	Royse North	345	1	1631	0.00401	0.05228	1.26452	124	New
3	3100	Martin Lake	3109	Stryker	345	1	1631	0.00132	0.01729	0.41811	41	New
4	3100	Martin Lake	68091	Navarro	345	1	1631	0.0042	0.05481	1.3257	130	New
5	3100	Martin Lake	68091	Navarro	345	2	1631	0.0042	0.05481	1.3257	130	New
6	3143	TYLERGND_8	3213	TYLERGE_8	345	1	484	0.00005	0.00058	0.00748	1	Upgraded
7	3123	Trinidad	3109	Stryker	345	1	1631	0.00222	0.02892	0.69956	68.6	Upgraded
8	9997	Rusk_5	3124	Trinidad2_5	345	1	1631	0.00297	0.03879	0.93819	92	Upgraded
9	9997	Rusk_5	3109	Stryker	345	1	2390	0.00076	0.00987	0.23863	23.4	Upgraded
10	3160	Dialvill-8	3296	Nechesri_8	138	1	326	0.00562	0.05609	0.01853	15.5	Upgraded
11	3106	ELKTON_8	3139	TYLERWES_8	138	1	326	0.00181	0.01809	0.00598	5	Upgraded
12	2523	PL_TENNY_8	10010	PRSTMDWS_8	138	1	484	0.00013	0.00153	0.01976	2.64	Upgraded
13	3271	PALSTNS_8	3296	NECHESRI_8	138	1	326	0.00344	0.03438	0.01136	9.5	Upgraded
14	3131	FOREGROV_8	29266	MABANKTAP	138	1	326	0.00134	0.01339	0.00416	3.7	Upgraded
15	3276	MALAKOFF_8	29266	MABANKTAP	138	1	326	0.00134	0.01339	0.00416	3.7	Upgraded
16	3127	TRINIDAD_8	3276	MALAKOFF_8	138	1	326	0.00294	0.02931	0.00911	8.1	Upgraded
17	3251	FLINTSUB_8	3253	JAXVLSW_8	138	1	326	0.00375	0.03741	0.01236	10.34	Upgraded
18	Collins to Northwest Carrolton (multiple branches)				138	2	326	0.00036[1]	0.00362[1]	0.00120[1]	17	New
19	2370	COLLINSS1_8	2372	COLLINSS1_5	138/345	2	Rating A =700 MVA Rating B, C = 750 MVA					New

1 The units for these values are in (p.u./mile) not in (p.u.) as the rest of the impedance values in this table.

Table 4.1-13
Shunt Capacitor Banks Examined for the Import 3000 MW Case at MURPHY1_8 (bus 2696)

Ref. No.	Contingnecy	Binit (MVAR)	Bus Voltage (p.u.)
1	Base Case	-	1
2	BD-MURPMC	0	0.935
3		10	0.95
4		20	0.96
5		30	0.97
6		40	0.98
7		50	1
8		60	1
9		70	1.02
10		80	1.03
11		90	1.05

BD-MURPMC was the only contingency observed where voltage violations observed could not be solved by switching existing shunt capacitor banks or by changing transformer tap settings. The voltage violations for this contingency are eliminated if a shunt capacitor is added at MURPHY1_8 (bus #2696) and is sized between 10 to 90 MVAR. An 80 MVAR bank was chosen since it provides voltage support for the surrounding area.

The remaining voltage violations observed for the Import 3000 MW case were eliminated using SPS and manual switching operations such as switching bus tie breakers, turning on/off shunt capacitor banks, or changing transformer tap ratios.

The Collin #2 345/138 kV autotransformer was observed overloading when the Collin #1 345/138 kV autotransformer was switched out and the transformer taps settings on Collin #2 were not at 1 p.u. on both sides. Series reactors were examined at the high side terminals of the Collin #2 345/138 kV autotransformer to eliminate the loading violations over 100% that were occurring. Table 4.1-13 lists the results of the series reactor's impacts on the Collin #2 345/138 kV autotransformer loading during the Import 3000 MW case with the Collin #1 autotransformer out. It was determined that a 2-ohm series reactor would eliminate the thermal loading if the transformer taps were coordinated correctly.

Table 4.1-13
Series Reactor's Impacts on the Collin 345/138 kV #2 Transformer Loading During the Import 3000 MW Case with the Collin #1 Transformer Out

Ref. No.	Series Reactor (ohms)	Transformer Tap Settings (p.u.)[1]		Loading (%)
		345 kV	138 kV	
1	2	1	1	94
2		0.97[1]	1[1]	97
3		0.95	1	106
4	3	1	1	92
5		0.97[1]	1[1]	95
6		0.95	1	98

1 These transformer tap settings were obtained by allowing the transformer taps to step. The other tap settings were examined to see what other loading values could occur.

The two ohm series reactor, the transmission lines and transformer listed in Table 4.1-13, and the shunt capacitor bank upgrades were chosen to be modeled eliminating the thermal and voltage violations observed for the Import 3000 MW case.

Refer to Table B-11 and Table B-19 in Appendix B for the list of loading violations and voltage violations, before implementing SPS or manual switching operations, for the Import 3000 MW case for the "Special Contingencies," the Single Circuit Area 1 Contingencies, and the single and double circuit contingencies out of Rusk County Switching Station 345 kV.

4.1.4 Summary

Table 4.1-14 lists the line and transformer upgrades required for the Benchmark, 1500 MW, and 3000 MW Import cases. In addition to these upgrades, a shunt capacitor located at the Murphy 138 kV bus and a 2-ohm series reactor located at the Collin #2 345/138 kV autotransformer eliminates all voltage and thermal violations observed for the Import case during the contingency analysis.

Table 4.1-14
Summary of New/Upgraded Equipment to Eliminate the Thermal Violations for the Import Cases

Ref. No.	Transmission Lines and Equipment	kV	CKT	Base Case[1] (MVA)	Length (miles)	New MVA Ratings for Transmisison Lines and Equipment for Import Cases[2]		
						Benchmark Line (MVA)	1500 MW Line (MVA)	3000 MW Line (MVA)
1	Lufkin Switch to Nacogdoches SE (3117-3119)	345	1	N/A	23	1631	1631	1631
2	Martin Lake to Royse North (3100-2461)	345	1	N/A	124	1631	1631	1631
3	Martin Lake to Stryker (3100-3109)	345	1	1631[3]	41	-	-	1631
4	Martin Lake to Nararro (3100-68091)	345	1	N/A	130	-	-	1631
5	Martin Lake to Nararro (3100-68091)	345	2	N/A	130	-	-	1631
6	Trinidad to Stryker (3123-3109)	345	1	1072	68.6	-	-	1631
7	Rusk to Trinidad (9997-3124)	345	1	1072	92	-	-	1631
8	Rusk to Stryker (9997-3109)	345	1	1631	23.4	-	-	2390
9	Rusk to Martin Lake (9997-3100)	345	1	1631	17.5	-	-	-
10	Rusk to Martin Lake (9997-3100)	345	2	1631	17.5	-	-	-
11	Tyler Grande to Tyler G.E. (3143-3213)	345	1	326	1	-	484	484
12	Dialville to Neches Pump (3160-3296)	138	1	214	15.5	-	-	326
13	Palestine South to Neches Pump (3271-3296)	138	1	214	9.5	-	-	326
14	Trinidad to Malakoff (3127-3276)	138	1	251	8.1	-	-	326
15	Forest Grove to Mabank Tap (3131-29266)	138	1	251	3.7	-	-	326
16	Malakoff to Mabank Tap (3276-29266)	138	1	251	3.7	-	-	326
17	Elkton to Tyler Southwest (3106-3139)	138	1	214	5	326	326	326
18	Tennyson Plano to Preston Meadows (2523-10010)	138	1	287	1	484	484	484
19	Flint to Jacksonville (3251-3253)	138	1	249	10.34	-	-	326
20	Collin to Northwest Carrolton (multiple branches)	138	2	N/A	17	326	326	326
21	Collin S.E.S. Auto Transformer	345/138	2	N/A	N/A	Rating A = 700 MVA, Rating B and C = 750 MVA		

1 The Base Case (MVA) column shows either the current MVA rating for the transmission lines/transformer as modeled in the base cases or a N/A indicating that the branch does not exist in the base case and was selected as a new branch in certain cases.

2 The values provided in these column are the suggested MVA rating for the transmission lines/transformer to eliminate thermal loading violations during contingencies. If the cell contains a "-" then that line was not required to be upgraded/built for that case.

3 This line already exists in the Benchmark case before Rusk is modeled once Rusk is modeled in the 1500 MW and 3000 MW cases this line becomes Martin Lake to Rusk and Rusk to Stryker Creek. The Martin Lake to Stryker Creek 345 kV line was modeled in the Import 3000 MW case.

4.2 EXPORT CASES

4.2.1 Export Benchmark Case

Table 4.2-1 lists the number of thermal and voltage violations for the Export Benchmark case before making any upgrades to Oncor's system.

Table 4.2-1*
Summary of Thermal and Voltage Violations for Export
Export Benchmark Case Before Any Upgrades

Ref. No.	Contingency Set	Number of Thermal Violations	Number of Voltage Violations
1	Special Contingencies	1	4
2	Single Circuit Area 1	1	84

*These violations occur before the SPS or manual switching operations have been implemented.

The only thermal violation for the Export Benchmark case was the Gresham Road POI to Gresham Road Switch 138 kV line (3301-3304) at 100.09% in the base case. This violation is due to the MW output of the NACPW_UNIT1 was set to 100 MW which is also the Pmax for this unit. Decreasing this generator below its Pmax rating eliminated this thermal violation for the Export Benchmark case.

The voltage violations observed for the Export Benchmark case were eliminated using SPS and manual switching operations such as switching bus tie breakers, turning on/off shunt capacitor banks, or changing transformer tap ratios.

The Collin #2 345/138 kV autotransformer was added to the Export Benchmark case because it was already a planned upgrade to the Oncor system. No additional transmission lines or upgrades were required to eliminate the thermal and voltage violations for the Export Benchmark case.

Refer to Table C-1 and Table C-4 in Appendix C for the list of loading violations and voltage violations, before implementing SPS or manual switching operations, for the Export Benchmark case for the "Special Contingencies" and the Single Circuit Area 1 Contingencies.

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4.2.2 Export 1500 MW Case

Table 4.2-2 lists the number of thermal and voltage violations for the Export 1500 MW case before making any upgrades to Oncor's system.

Table 4.2-2*
Summary of Thermal and Voltage Violations for Export 1500 MW Case Before Any Upgrades

Ref. No.	Contingency Set	Number of Thermal Violations	Number of Voltage Violations
1	Special Contingencies	1	7
2	Single Circuit Area 1	1	88
3	Single and Double Circuits out of Rusk	1	1

*These violations occur before the SPS or manual switching operations have been implemented.

The only thermal violation for the Export Benchmark case was the Gresham Road POI to Gresham Road Switch 138 kV line at 100.31% in the base case. This violation is due to the MW output of the NACPW_UNIT1 being set to 100 MW which is also the Pmax for this unit. Decreasing this generator below its Pmax rating eliminated this thermal violation for the Export 1500 MW case.

The voltage violations observed for the Export 1500 MW case were eliminated using SPS and manual switching operations such as switching open breakers, turning on/off shunt capacitor bank steps, or changing transformer tap ratios.

The Collin #2 345/138 kV autotransformer was added to the Export 1500 MW case because it was already a planned upgrade to the Oncor system. No additional transmission lines or upgrades were required to eliminate the thermal and voltage violations for the Export 1500 MW case.

Refer to Table C-5 and Table C-10 in Appendix C for the list of loading violations and voltage violations, before implementing SPS or manual switching operations, for the Export 1500 MW case for the "Special Contingencies," the Single Circuit Area 1 Contingencies, and the single and double circuit contingencies out of Rusk County 345 kV Switching Station.

One double circuit contingency would not solve for the 1500 MW case and is shown in Table 4.2-3. The case did not diverge but the solution was outside the mismatch tolerance. To solve this contingency 200 MVAR of the filter bank at the HVDC converter station was allowed to switch. This allowed the case to solve and no thermal or voltage violations were observed.

Table 4.2-3
List of Contingencies with a Mismatch Greater Than One for the Export 1500 MW Case

Ref. No.	Contingency Name	Contingency Description
1	SOUTHCR2	OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 9997 [RUSKSS_5 345.00] CKT 1
		OPEN BRANCH FROM BUS 3100 [MARTINLK_5 345.00] TO BUS 9997 [RUSKSS_5 345.00] CKT 2

4.2.3 Export 3000 MW Case

When the Export 3000 MW base case was examined for the steady state contingency analysis only one thermal violation was observed, however several of the single and double circuit contingencies did not converge. Table 4.2-4 lists the number of thermal and voltage violations for the Export 3000 MW case before making any upgrades to Oncor's system. Table 4.2-5 lists the single and double circuit contingencies from the Export 3000 MW case that did not converge. These contingencies were examined and then upgrades that were applied to the 3000 MW Import case were incorporated into the 3000 MW Export case to eliminate violations and help the cases converge.

Table 4.2-4*
Summary of Thermal and Voltage Violations for the Export 3000 MW Case Before Any Upgrades

Ref. No.	Contingency Set	Number of Thermal Violations	Number of Voltage Violations	Number of Convergence Errors
1	Special Contingencies	1	9	13
2	Single Circuit Area 1	1	108	17
3	Single and Double Circuits out of Rusk	1	0	2

*These violations occur before the SPS or manual switching operations have been implemented.