Verde Transmission, LLC

Verde Project

System Impact Study Report

March 2017

Prepared by:

Public Service Company of New Mexico

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Any correspondence concerning this document, including technical and commercial questions should be referred to:

Tom Duane

Manager, Transmission Planning

Public Service Company of New Mexico

Alvarado Square MS-Z220

Albuquerque, NM 87158

Phone: (505) 241-4569

Fax: (505) 241-4363

Table of Contents

Executive Summary **5**

1. Introduction 12

2. Verde Project Description 13

3. NERC Compliance Considerations 14

4. Study Assumptions 15

4.1 Base Case Development 15

4.2 Generation Dispatch 16

4.3 Arroyo and Gladstone Phase-Shifting Transformer Settings 18

4.4 Eastern New Mexico Renewable Energy Additions 18

4.5 Verde Project Model 18

5. Other Assumptions 18

6. Study Methodology 19

6.1 Path 48 Transfer Capability Analysis 19

6.2 Northeast Area Transfer Capability Analysis 20

6.3 Eastern New Mexico Renewable Export Analysis 21

6.4 Steady State Contingency Analysis 21

6.5 Stability Analysis 21

7. Study Criteria 22

7.1 Performance Criteria 22

Steady State Criteria 23

Reactive Margin Criteria 24

Stability Criteria 25

Short Circuit Criteria 26

8. Study Results 26

8.1 Result 1 – Base Case Development 26

8.2 Result 2 – Path 48 Transfer Capability Analysis 27

8.3 Result 3 – Northeast Area Transfer Capability 30

8.4 Result 4 – Eastern New Mexico Renewable Export Analysis 31
8.5 Result 5 – Steady State Contingency Analysis 36
8.6 Result 6 – Stability Analysis 37
8.7 Result 7 – Short Circuit Analysis 40
8.8 Result 8 – Incremental Loss analysis 40
8.9 Result 9 – Estimated Cost of System Upgrades 42
Appendix A Power flow diagram of limiting cases 44
Appendix B Power Flow Analysis results 63
Appendix C Reactive Margin Curves 75
Appendix D Transient Stability Results 171
Appendix E Contingency List 347

EXECUTIVE SUMMARY

On January 6, 2016, Verde Transmission, LLC requested Public Service Company of New Mexico (PNM) initiate the studies for a non-tariff wires-to-wires interconnection of the Verde Transmission Project (Verde Project) to Public Service Company of New Mexico's (PNM) Ojo and Norton 345 kV Switching Stations. The Project is a 345 kV line of approximately 30 miles. This report discusses the System Impact Study (SIS) results produced in response to the study request.

The addition of the Ojo – Norton 345 kV line completes a 345 kV path to the central Rio Grande valley in northern New Mexico in parallel with the existing San Juan – Rio Puerco 345 kV line and Four Corner – Rio Puerco 345 kV line. The project was evaluated for benefits to the Path 48 transfer capability, ability to increase load serving in Northeast New Mexico and for benefits associated with transfer capability of renewable resources out of eastern New Mexico.

The Verde Project will increase the transfer capability of WECC Path 48 in conjunction with upgrades to the San Juan – Ojo 345 kV line. The total transfer capability increase will depend on the level of series compensation on the San Juan – Ojo 345 kV line which improves flowability on the project line. The analysis also looked at the use of a phase-shifting transformer (PST) to improve flowability in place of series compensation.

Path 48 Benefits

The following table summarizes the Path 48 import limits obtained for the pre – project and the post-project system with various series compensation levels or a PST in the San Juan – Ojo 345 kV line.

Item	Path 48 Limit and Conditions						
Verde Project Status	Pre-Project	Post-Project	Post-Project	Post-Project	Post-Project	Post-Project	Post Project
Other System Upgrades	None	None	San Juan-Ojo and Yah-Ta-Hey-Gallup Rating Increase	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase & 35% Ojo Series Compensation	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase & 40% Ojo Series Compensation	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase, & 60% Ojo Series Compensation	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase, & Ojo PST
Path 48 Limit	2174	1989	2436	2605	2635	2846	2541
Incremental Path 48 Increase	N/A	-185	262	431	461	672	367
Limiting Contingency	Four Corners-Rio Puerco 345 kV Line	San Juan-Cabezon 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners – Rio Puerco 345 kV Line
Limiting Element	San Juan-Cabezon 345 kV Line	Jicarilla – Ojo 345 kV line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan – Cabezon 345 kV Line

Upgrades to the San Juan – Ojo 345 kV line are required to realize the Verde Project benefits due to overloads that will otherwise occur under N-1 contingency conditions. Otherwise, a decrease in Path 48 import capability of 185 MW occurs. With the project and upgrades to the San Juan-Ojo 345 kV line, the transfer capability of Path 48 increases by 262 MW. Addition of series compensation in the San Juan – Ojo 345 kV line at Ojo further increases transfer capability limits but also identified a need to upgrade Tri-State's Yah-Ta-Hey-Gallup 115 kV line, PNM Ojo to Hernandez 115 kV line and possibly accelerate a rebuild of a 115 kV line serving Los Alamos County area to achieve the maximum benefits. The incremental increase in Path 48 import capability with upgrades to the Yah-Ta-Hey-Gallup 115 kV line, Ojo to Hernandez 115 kV line and addition of series compensation at Ojo are 431MW, 461 MW, and 672 MW for 35%, 40%, and 60% series compensation, respectively. Without the Yah-Ta-Hey – Gallup 115 kV line upgrades, import limits are up to 251 MW lower.

Addition of a phase shifting transformer (PST) at Ojo on the Ojo – Jicarilla 345 kV line resulted in a Path 48 import limit of 2541 MW. This is 367 MW increase in the Path 48 import limit compared to the limit without the Verde Project.

The study identified that up to 300 MVAR of additional reactive support in the Albuquerque area would be needed to maintain system voltages at the higher post-project import limits. It is expected that the reactive support would be added over-time with load growth.

Northeast Area (NEA) Import Benefits

The following table shows the import capability benefits in the Northeast Area with addition of the Verde Project and the San Juan-Ojo line upgrades. The import capability was determined based upon the maximum NEA import without causing any power flow criteria violations.

Item	Northeast Area Import Limit and Conditions				
Verde Project Status	Pre – Project	Post – Project	Post – Project	Post – Project	Post - Project
Other System Upgrades	None	San Juan – Ojo Rating increase	San Juan – Ojo Rating increase and 35% Ojo Series Compensation	San Juan – Ojo Rating increase and 40% Ojo Series Compensation	San Juan – Ojo Rating increase and 60% Ojo Series Compensation
Northeast Area Limit	787 MW	932 MW	1045 MW	1057 MW	1143 MW
Incremental NEA Limit Increase	N/A	145 MW	258 MW	270 MW	356 MW
Limiting Contingency	Ojo – Taos 345 kV line	Walsenburg – Gladstone 230 kV line	Walsenburg – Gladstone 230 kV line	Walsenburg – Gladstone 230 kV line	Walsenburg – Gladstone 230 kV line
Limiting Element	Ojo – Hernandz 115 kV line	Ojo 345 kV bus	Ojo 345 kV bus	Ojo 345 kV bus	Ojo 345 kV bus
Limit Type	Thermal Limit	Voltage Stability	Voltage Stability	Voltage Stability	Voltage Stability

Renewable Export Benefits

The study also reviews the ability of the Verde Project to accommodate increased wind exports from Eastern New Mexico. The project was found to benefit exports under double contingency scenarios or maintenance scenarios where a line between BA and Rio Puerco is out-of-service. Depending upon system load levels, the Verde Project can reduce the amount of wind generation that would need to be curtailed for these contingencies.

The table below provides the wind export limits before and after addition of the Verde Project and for various levels of series compensation at Ojo and with a PST at Ojo. The limits were found based upon the maximum wind injection at BA 345 kV without overloading the BA or Norton 345/115 kV transformers under the most limiting common mode contingencies.

System condition	Wind MW Injection on the B-A to Blackwater 345 kV line without station expansion	
	Heavy Summer	Light Winter
Pre - Project System	715 MW	717 MW
Post Project System with 0% Series Compensation	723 MW	845 MW
Post Project System with 35% Series Compensation	702 MW	869 MW
Post Project System with 40% Series Compensation	698 MW	874 MW
Post Project System with 60% Series Compensation	674 MW	898 MW
Post Project System with Ojo PST	933 MW	933 MW

The use of series compensation resulted in the ability to accommodate up to an additional 181 MW over the existing system under non-peak conditions. The greatest increases resulted with use of a PST at Ojo providing an increase of approximately 218 MW in both peak summer and non-peak conditions.

A wind export sensitivity was also reviewed where additional wind exports out of eastern New Mexico are accommodated by addition of a second 345 kV line between the BA and Clines Corners switching stations. The sensitivity assumes addition of a BA-2 switching station to allow for termination of the second line. The table below shows the export limits identified using heavy summer and light winter cases.

System condition	Wind MW Injection on the B-A to Blackwater 345 kV line using BA2 345 kV station	
	Heavy Summer	Light Winter
Pre - Project System	447MW	448 MW
Post Project System with 0% Series Compensation	641MW	895 MW
Post Project System with 35% Series Compensation	660 MW	930 MW
Post Project System with 40% Series Compensation	664 MW	938 MW
Post Project System with 60% Series Compensation	686 MW	972 MW
Post Project System with Ojo PST	1058 MW	1090 MW

The Verde project provided significant benefits under the worst N-2 condition with the addition of the BA2 station. In this situation, the Verde project along with a PST at Ojo allows approximately 640 MW of additional generation to be accommodated under the double contingency loss of the BA2-BA 345 kV lines.

Fault Duty Impacts

Analysis of the increased short circuit duty that results from the Verde Project addition did not identify fault duty levels that would result in a need to replace breakers due to insufficient interrupt ratings.

Loss Impacts

The Verde Project will decrease losses on the New Mexico transmission system at a given level of transfers on Path 48. The net decrease in system losses with the Verde Project at various levels of series compensation on the San Juan-Ojo 345 kV line is shown in the table below.

	Path 48 MW Loss									
	Without Project		With Project, San Juan – Ojo 345 kV line upgrade and various series compensation level							
			0%		35%		40%		60%	
Path 48 Import	Loss	Incremental Loss	Loss	Incremental Loss	Loss	Incremental Loss	Loss	Incremental Loss	Loss	Incremental Loss
500 MW	31.19	N/A	31.28	0.09	31.0	-0.19	31.24	0.05	31.71	0.52
600 MW	32.19	N/A	32.38	0.19	32.00	-0.19	31.94	-0.25	32.76	0.57
700 MW	34.17	N/A	33.93	-0.24	33.72	-0.45	33.61	-0.56	34.45	0.28
800 MW	36.77	N/A	35.69	-1.08	35.44	-1.33	35.88	-0.89	36.18	-0.59
900 MW	38.99	N/A	38.35	-0.64	38.27	-0.72	38.19	-0.8	38.96	-0.03
1000 MW	42.99	N/A	41.78	-1.21	41.50	-1.49	41.57	-1.42	42.25	-0.74
1200 MW	52.07	N/A	49.80	-2.27	49.58	-2.49	49.84	-2.23	50.51	-1.56
1400 MW	63.82	N/A	61.01	-2.81	60.49	-3.33	60.48	-3.34	61.45	-2.37
1600 MW	79.81	N/A	74.74	-5.07	73.90	-5.91	74.03	-5.78	74.98	-4.83
1800 MW	97.92	N/A	91.77	-6.15	90.37	-7.55	90.45	-7.47	91.42	-6.50
2000 MW	119.41	N/A	110.49	-8.92	109.28	-10.13	109.23	-10.18	110.14	-9.27
2100 MW	130.46	N/A	120.28	-10.18	119.61	-10.85	119.62	-10.84	120.81	-9.65
2200 MW	144.06	N/A	132.63	-11.43	130.76	-13.3	130.73	-13.33	131.91	-12.15
2500 MW	187.32	N/A	170.56	-16.76	167.97	-19.35	168.06	-19.26	168.91	-18.41
2600 MW	205.54	N/A	186.53	-19.01	182.81	-22.73	182.57	-22.97	182.02	-23.52

Applying the loss information above to actual imports in 2015 on Path 48 shows a potential annual loss reduction for 2015 of about 5000 MWH to 13,000 MWH depending on the series compensation level.

Required System Upgrades

The following system upgrades are identified in the SIS in order to maximize the transfer capability of the Verde Project addition. Except for the San Juan-Jicarilla-Ojo line clearance improvements, the upgrades would be added over time as Path 48 import requirements increase. The upgrades are needed to achieve the import levels identified at the thermal limits shown above.

1) *Clearance Improvements of San Juan-Jicarilla-Ojo 345 kV line*

Contingency flow on this path will exceed the 450 MVA rating of the line once the Verde Project is added. The maximum Path 48 transfer capability increase identified in the SIS requires a rating of at least 1050 MVA. The line conductor is bundled 795 MCM ACSR and PNM applies a

standard conductor rating of 2000 amperes (1195 MVA) assuming the line has sufficient clearance. The line will also need to be checked for any potential terminal limitations.

2) Ojo Series Compensation

The increase in Path 48 transfer capability is significantly enhanced by the addition of series compensation in the San Juan-Jicarilla-Ojo 345 kV line. Several levels were reviewed and discussed in the SIS. San Juan and possibly the Four Corners Generating Units will need to be screened for sub-synchronous resonance that can result from series compensated lines. SSR mitigation may be required if SSR risks are identified. Assessment of SSR risks is outside the scope of this analysis.

3) Upgrade of Yah Ta Hey – Gallup 115 kV line

The Yah Ta Hey – Gallup 115 kV line overloads when the Bisti – Pillar 230 kV line is out at high Path 48 import levels and low PEGS output levels. The line is clearance for operation up to 112 MVA. The minimum required MVA rating based upon the maximum loading of the 115 kV line found in the SIS during contingencies is 123 MVA. It is recommended that clearance improvements to allow the line to be operated up to 130 MVA be implemented.

4) Upgrade of Ojo-Hernandez 115 kV line

The Yah Ta Hey – Gallup 115 kV line overloads for a breaker failure scenario at the Ojo 345 kV station after addition of the Verde project with series compensation or a PST. The line is clearance for operation up to 180 MVA. The minimum required MVA rating based upon the maximum loading of the 115 kV line found in the SIS during contingencies is 258 MVA. It is recommended that clearance improvements to allow the line to be operated up to 300 MVA be implemented.

5) Additional reactive support in Albuquerque area

Shunt compensation is required to prevent the system from being voltage stability limited below the transfer capability identified in this analysis. The analysis showed the requirement of 300 MVAR of shunt capacitive compensation in the Albuquerque to maximize transfer capability up to the full thermal capability of the transmission lines. It is expected that modeling of underlying system expansion associated with the load increases used to stress Path 48 would show an actual reactive requirement that is somewhat lower.

6) Los Alamos County line upgrades

Overloads of the Norton-ETA 115 kV line serving Los Alamos County were observed during various outages. Although plans exists for upgrading this line when Los Alamos county load levels result in single contingency overloads of the line, the SIS shows the potential need to

accelerate these upgrades when the Verde Project is added. The stronger source at Norton results in higher normal flows and higher contingency flows for outage of the BA transformer. The existing rating of the Norton-ETA 115 kV line is 116 MVA with an increase to approximately 240 MVA with the planned upgrades.

Estimated Interconnection Cost and Schedule

The estimated cost and schedule for interconnection of the Verde Project to PNM's system at the Ojo and Norton Switching stations is shown below.

Interconnection item	Cost	Estimated Time for construction
Expansion of Ojo Switching Station	$3.3 M	18 months
Expansion of Norton Switching Station	$4.3 M	18 Months
Interconnection Total	$7.6M	18 Months

Estimated Cost of Other System Upgrades

The system upgrades required to maximize the transfer capability of the Verde project on Path 48 are shown below:

Interconnection item	Cost	Estimated Time for construction
San Juan-Jicarilla-Ojo 345 kV Line Clearance Improvements	$2.4 M	18 months
Ojo Series Capacitor 40% (37 Ohms)	$10.6 M	24 Months
Ojo Series Capacitor 60% (56 ohms)	$12.0 M	24 Months
Albuquerque Area Shunt Capacitor Additions	$5.4 M	18 Months
Tri-State Yah-Ta-Hey-Gallup Clearance Improvements	$1.5M	18 Months
Ojo – Hernandez 115 kV line upgrade	$5M	36 months

With the exception of the San Juan-Jicarilla-Ojo 345 kV line upgrades, the system improvements would be added over time based on the transfer capability requirements. Two levels of series compensation are included in the estimates for comparison, however, only one of the two levels is assumed to be selected for installation. The maximum amount of series compensation may be limited by SSR considerations at San Juan which is outside the scope of this analysis.

1. INTRODUCTION

On January 6, 2016, Verde Transmission, LLC (Verde) requested Public Service Company of New Mexico (PNM) perform a non-tariff wires-to-wires interconnection study of the Verde Transmission Project (Verde Project) which will add a new 30 mile 345 kV tie between Public Service Company of New Mexico's (PNM) Ojo and Norton 345 kV Switching Stations.

Figure 1 shows the location of the Verde Project.

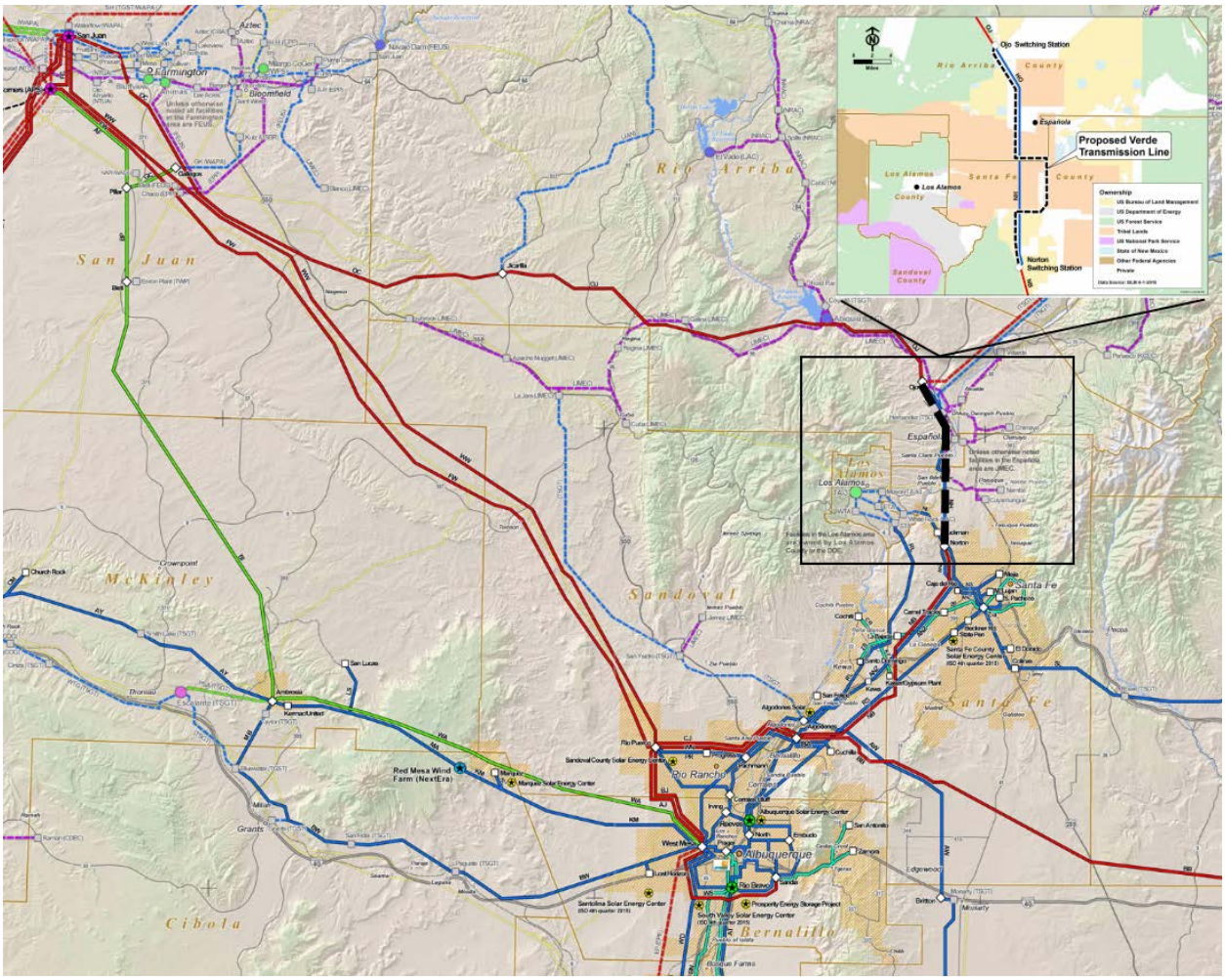

FIGURE 1 - PROJECT LOCATION

This report discusses the findings of the System Impact Study (SIS) performed in response to the request. The study includes 1) analysis to determine the transfer capability benefits for

delivering additional resources into Northern New Mexico over WECC Path 48 to serve loads in the central Rio Grande valley and Northeast New Mexico 2) analysis assessing whether the project would increase the amount of renewable generation that could be exported from eastern New Mexico to the Four Corners area and 3) analysis of the increase in imports to the Northeastern Area of New Mexico that includes Santa Fe, Los Alamos and Taos. Addition of the project would initially result in transmission loss reductions that are identified in the study. The SIS identifies interconnection facilities and system upgrades needed to maximize value of the project. Transmission service impacts on either the Verde Project or PNM's transmission system is beyond the scope of the analysis and will be subject to additional study per Open Access Transmission Tariff (OATT) requirements.

Clearance improvements to increase the rating of the San Juan-Jicarilla-Ojo 345 kV line are assumed in most analysis that includes the Project. The study showed that benefits of the Verde Project would be severely limited without these upgrades. The analysis also explores the benefits of adding series compensation to the San Juan-Jicarilla-Ojo 345 kV line.

2. VERDE PROJECT DESCRIPTION

Verde is developing the Verde Project, a proposed new, approximately 30 mile long 345 kV transmission line in southern Rio Arriba County and Santa Fe County, New Mexico. The Verde Project will interconnect the existing PNM Ojo station on the north to the existing PNM Norton station on the south. Verde has already secured right-of-way through Pueblo lands required to complete the project and is beginning the formal NEPA process with BLM acting as the lead federal agency for the project.

The Verde Project study scope included studying the Verde Project with addition of the Verde Project line by itself and with upgrades and series compensation on the San Juan-Jicarilla-Ojo 345 kV line as follows:

1. Verde Project: Add a 345 kV 30 mile transmission line from the Ojo 345 kV Switching Station to the Norton 345 kV Switching Station.
2. Increase the rating of the San Juan-Jicarilla-Ojo 345 kV line from 400 MVA to 1195 MVA. This line will require clearance improvements to get the higher rating and possibly minor terminal equipment upgrades.
3. Add series capacitors or a PST to the San Juan-Jicarilla-Ojo 345 kV line. The analysis reviews three levels of series compensation. Sub-synchronous Resonance Studies (SSR) of the San Juan Power Plant will be needed to confirm the feasibility of series compensation. SSR studies are outside the scope of this analysis.

Most analysis with the Verde Project includes item 2 as listed above. The study did not show any benefits of the Verde Project without the upgrade. The addition of series capacitors or a PST at Ojo is needed to maximize the transfer capability benefits of the project on Path 48. The timing of the series capacitor or a PST would potentially be at a later date than the initial Verde Project line when additional transfer capability is needed to accommodate load growth or renewable generation exports. The study does not attempt to determine the size of a PST at Ojo other than to recognize flows around 1000 MW will occur under contingency conditions. The study assumes a single PST based on the ratings and phase angle range of the PSTs used in the Southline WECC path rating studies. Determining a potentially more optimal design to coordinate with the Verde project is outside the scope of this analysis.

Interconnection Facilities

Figure 2 is a breaker level drawing of the proposed Verde Project showing the expected station expansion to accommodate the interconnection. The figure also shows the location of series compensation added on the Jicarilla-Ojo 345 kV line.

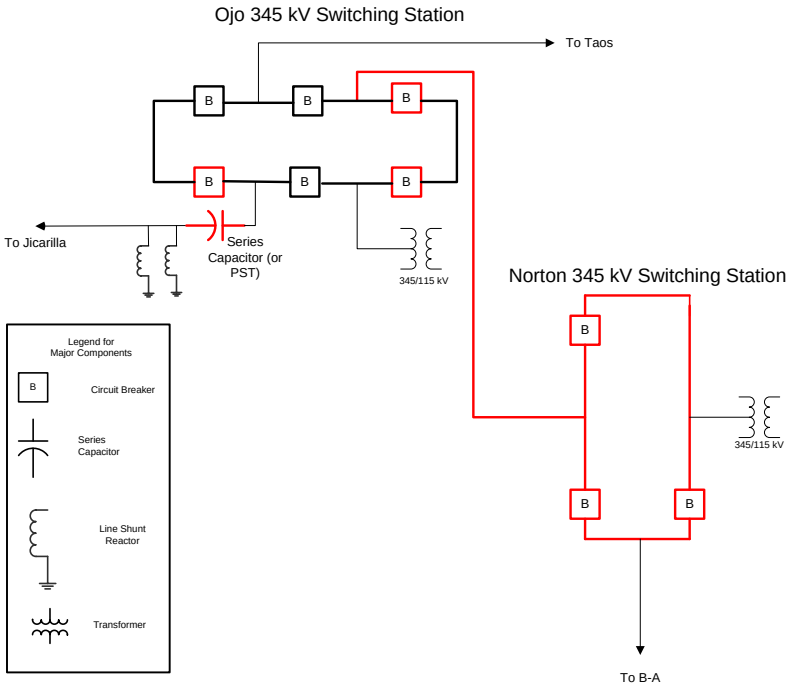

FIGURE 2 - BREAKER LEVEL ONE-LINE DRAWING OF THE PROPOSED VERDE TRANSMISSION LINE PROJECT

3. NERC COMPLIANCE CONSIDERATIONS

This study serves as evidence for compliance with North American Electric Reliability Corporation (NERC) standard FAC-002-2 which requires transmission planners and owners,

amongst other entities, to study the impact of interconnecting new or materially modified facilities on the Bulk Electric System. The standard addresses the following study requirements for new or modified interconnections:

1. The reliability impact of the new interconnection, or materially modified existing interconnection, on affected system(s);
2. Adherence to applicable NERC Reliability Standards; regional and Transmission Owner planning criteria; and Facility interconnection requirements;
3. Steady-state, short-circuit, and dynamics studies, as necessary, to evaluate system performance under both normal and contingency conditions; and
4. Study assumptions, system performance, alternatives considered and coordinated recommendations. While these studies may be performed independently, the results shall be evaluated and coordinated by the entities involved.

4. STUDY ASSUMPTIONS

4.1 Base Case Development

Evaluating the system impacts and benefits of the Verde Project required analysis for several scenarios. Peak summer load conditions were utilized to assess the highest load levels in New Mexico overall and the maximum transfers into Northern New Mexico. The Verde Project is located in the Northeast Area of the state that peaks in the winter and the impacts and benefits to this area will be assessed for winter peak conditions. The highest wind export out of eastern New Mexico occurs most frequently during light load conditions and is assessed in appropriate light load cases as well as some assessment of high wind during summer peak conditions.

The following cases were constructed to evaluate the proposed transmission project:

TABLE 1 – STUDY CASES

Starting Case	Case ID	Description
2018HS	18HS	2018 Heavy Summer system for assessing the project impacts under peak load and determining the Path 48 transfer capability of the pre- and post-project systems.
16HW3b	18HW	2018 Heavy Winter case for assessing project impacts under peak load conditions in the northeastern New Mexico area.
2018HS	18HS-HR	2018 Heavy Summer High Wind case to assess potential benefits associated within increased eastern New Mexico renewable generation resources.

16LW1a1	18LW	2018 Light Winter case for assessing the project impacts and possible reactive compensation needs under light load conditions.
16LW1a1	18LW-HR	2018 Light Winter High Wind case to assess potential benefits associated within increased eastern New Mexico renewable generation resources.
2018 HS	18HS-P48	18HS case adjusted to maximize Path 48 rating.

Using the cases above, pre- and post-project cases are developed for the assessments preformed in this analysis.

4.2 Generation Dispatch

TABLE 2 – GENERATION DISPATCH

Unit	Rating	18HS	18 HW	18LW	18HS-HR High Wind	18LW-HR High Wind	18HS-P48 Path 48 Rating
Coal							
San Juan Unit 1	373	360	360	360	360	360	360
San Juan Unit 2 (Retired)							
San Juan Unit 3 (Retired)							
San Juan Unit 4 (Area Swing)	544	540	536	486.4	400	20.4	478
Escalante Generating Station	245	243	255	154.3	135	154.3	0
Natural Gas/Oil							
Reeves 1 (Natural Gas)	44	44	0	0	0	0	0
Reeves 2 (Natural Gas)	44	43	0	0	0	0	0
Reeves 3 (Natural Gas)	67	60	0	0	30	0	30
Rio Bravo (Natural Gas/Oil)	132	0	0	0	0	0	0
Luna Energy Facility (Natural Gas)	600	570	520	330	520	330	570
Lordsburg (Natural Gas)	80	0	0	0	0	0	0
Afton (Natural Gas)	259	235	0	0	235	0	235

Unit	Rating	18HS	18 HW	18LW	18HS-HR High Wind	18LW-HR High Wind	18HS-P48 Path 48 Rating
Valencia Energy Facility (Natural Gas)	143	143	0	0	143	0	143
La Luz #1 (Natural Gas)	42.3	0	0	0	0	0	0
Pyramid Generating Station (Natural Gas)	168	109	0	0	107	0	109
Wind Resources							
Taiban Mesa Wind Project	204	10	100	200	200	200	10
Aragonne Mesa Wind Project	90	5	45	90	90	90	5
Red Mesa Wind Project	102	5	51	102	70	102	5
High Lonesome Mesa Wind Project	100	5	50	100	100	100	5
Broadview/Grady	497	16	249	500	497	500	16
El Cabo	700**	15	100	218	700	700	15
Solar Resources							
Ambrose Solar Project	9	6	0	0	6	0	6
Reeves Solar Project	2	1.1	0	0	2	0	1.1
Los Lunas Solar Project	7	5	0	0	5	0	5
Manzano Solar Project	8	4.4	0	0	6	0	4.4
Marquez Solar Project	7.6	5.8	0	0	7	0	5.8
Meadow Lake Solar	9	6	0	0	8	0	6
Prosperity Energy Storage (Studio) Solar	0.5	0	0	0	.5	0	0
Enchanted Mesa	9.8	6	0	0	6	0	6
Las Vegas Solar	5.0	3	0	0	3	0	3
Wahl North	10	7	0	0	7	0	7
South Valley	9.5	6	0	0	6	0	6
Santa Fe Solar	9.75	6	0	0	6	0	6
Cimarron Solar	30	10.3	10.3	0	20	0	10.3

** Assumes BA2 station and additional transmission between BA2 and Clines Corners Switching Station; otherwise output is limited to 200 MW.

The generation levels for the base cases were checked and adjusted as needed to insure the transmission system is within pre-Verde Project limits. The increased renewable generation in high-wind scenarios is modeled as exports to Arizona and California, however, potential limitations of the Arizona and California systems to accommodate the additional export was beyond the scope of this study and has not been assessed.

4.3 Arroyo and Gladstone Phase-Shifting Transformer Settings

The Arroyo phase-shifting transformer (PST) setting is based on case specific Load and Resource assumptions. The peak load summer case will model a schedule of 16 MW north to south based on expected Afton generation output. For the Path 48 rating case, this schedule was set to a 30 MW south to north for comparison against the current non-simultaneous Path 48 rating.

The Gladstone PST setting was 135 MW for peak summer and winter cases. For the light winter case, it was set to 100 MW.

4.4 Eastern New Mexico Renewable Energy Additions

The addition of the Broadview and Clines Corner wind facilities are included in all cases along with associated system upgrades. These facilities are scheduled to be placed in service in 2016 and 2017. The associated system upgrades include the interconnection stations and the Guadalupe SVC. A sensitivity is included that involves installation of a BA2 345 kV station and an expansion of Clines Corners in order to include a scenario with 1500 MW of resources connected to the BA-Blackwater 345 kV system.

4.5 Verde Project Model

Following are the modeling parameters for the Verde Project:

Rp.u. = 0.001024, Xp.u. = 0.014430, Bp.u. = 0.244730 for a line length = 28.79 Miles.

The rating of the project for normal and contingency conditions was 1200 MVA. The project did not include line connected shunt reactors at either terminal end. All Northern New Mexico contingencies for assessing system performance that is consistent with TPL-001-4 were used for the analysis.

5. OTHER ASSUMPTIONS

The San Juan-Jicarilla-Ojo 345 kV line was built with bundled 795 MCM ACSR conductor, however, the line is limited by clearance to 450 MVA. Cases that model clearance

improvements to the San Juan-Ojo 345 kV line assumed that the rating is increased up to PNM's standard continuous rating of 2000 amperes or 1195 MVA for this conductor size.

6. STUDY METHODOLOGY

6.1 Path 48 Transfer Capability Analysis

Prior to adding the Verde Project, the Path 48 transfer capability into Northern New Mexico was benchmarked and compared with the existing WECC rating for the Path. The analysis was based on the summer peak load level for the 2018 heavy summer base case with the Path 48 non-simultaneous rating.

To determine the maximum Path 48 capability, the Path 48 loading is increased by scaling load in the central Rio Grande valley area of PNM's system, reducing generation inside the Path 48 boundary and/or exporting power east through the Blackwater converter. Generation at San Juan is adjusted to match the load scaling and generation reductions. Additional import from Arizona and California were modeled to keep San Juan from exceeding its maximum output. The Albuquerque area load power factor was maintained at a minimum level of 0.987 lagging across a measured Albuquerque sum interface to match PNM planning and operating practices. Path 48 is not currently rated in the opposite direction.

The Path 48 rating was reassessed with addition of the Verde Project to determine any incremental transfer capability created by the project for the following improvement scenarios:

- Verde Project line with clearance upgrades to the San Juan-Jicarilla-Ojo line.
- Verde Project Line with clearance upgrades to the San Juan-Jicarilla-Ojo line and series compensation on the San Juan-Ojo line.
- Verde Project line with clearance upgrades to the San Juan-Jicarilla-Ojo line and Ojo PST on the San Juan-Ojo line.

The transfer capability assessment was based primarily on steady state analysis and the following P1 contingencies:

- San Juan – Rio Puerco 345 kV line
- Four Corner – West Mesa 345 kV line
- Bisti – Pillar 230 kV line

Power flow contingency analysis was performed using all Northern New Mexico contingencies to confirm the transfer limits. The contingency list is included in Appendix E. A PEGS generation dispatch sensitivity on the Path 48 transfer capability is also assessed to observe its effect on the import limits. Key buses within the Path 48 boundary will be checked through Q-V analysis to insure that these buses meet the WECC reactive margin criteria. The key buses include:

- West Mesa 345 kV
- BA 345 kV

6.2 Northeast Area Transfer Capability Analysis

The Northeast Area (NEA) is a winter peaking subset of Path 48 and includes Santa Fe, Las Vegas, Los Alamos, Taos, Springer and other small communities in Northeast New Mexico.

Prior to adding the Verde Project, the NEA transfer capability was benchmarked. The analysis is performed using the 2018 heavy winter base case.

To determine the maximum NEA capability, the NEA loading is increased by scaling load up proportionally in the Las Vegas, Santa Fe, Los Alamos County and Tri-State's northern New Mexico zone. Generation at San Juan or additional imports from Arizona and California are used to off-set the load changes.

The NEA rating is then reassessed with addition of the Verde Project to determine any incremental transfer capability created by the project for the following improvement scenarios:

- Verde Project line with clearance upgrades to the San Juan-Jicarilla-Ojo line.
- Verde Project Line with clearance upgrades to the San Juan-Jicarilla-Ojo line and series compensation on the San Juan-Ojo line.

The transfer capability assessment is based primarily on steady state analysis using the following P1 contingencies.

- San Juan – Jicarilla 345 kV line outage
- Norton – BA 345 kV line outage
- Walsenburg – Gladstone 230 kV line outage
- Ojo – Taos 345 kV line

The following buses are checked to insure that these buses meet the reactive margin criteria.

- Gladstone 230 kV
- Ojo 345 kV
- Norton 345 kV

6.3 Eastern New Mexico Renewable Export Analysis

This analysis focused on identifying the amount of renewable energy that can be accommodated through the BA 345 kV switching station from Eastern New Mexico without and with the Verde Project. The analysis is based on steady state and dynamic stability simulations for various contingencies out of the BA and Rio Puerco switching stations as well as contingencies between Four Corners, San Juan and Shiprock. For wind injections above 1000 MW, a new BA2 switching station is assumed that ties the BA-Guadalupe line to the BA-Norton 345 kV line at the point where the BA-Norton line turns north towards Norton. An additional transmission line from the Clines Corners switching station to the new BA2 switching station is also included.

Reactive margins are checked at the following buses at the limits identified in the analysis.

- Guadalupe 345 kV
- BA 345 kV
- Ojo 345 kV
- West Mesa 345 kV
- Norton 345 kV

6.4 Steady State Contingency Analysis

Steady state contingency analyses are performed on the cases defined in Section 4.1 and for the limiting cases identified in the Path 48 transfer capability analysis. The inclusion of the limiting cases insures underlying system impacts were not overlooked in establishing the transfer limits. Certain underlying system overloads are expected in the transfer capability analysis because load is scaled well above current load levels to stress the cases to import limits and numerous violations result from not modeling the underlying expansion that would be required for the load increase. These violations are considered independent of the Verde Project impacts.

The study does not assess impacts beyond PNM's systems.

6.5 Stability Analysis

Table 3 is the preliminary list of contingencies to be analyzed in the stability analysis.

TABLE 3 - LIST OF CONTINGENCIES FOR STABILITY ANALYSIS

	Disturbance	Category	Fault Location	Fault Type
0	No Disturbance	P0	N/A	N/A
1	Ojo-Norton 345 kV line	P1	Ojo 345	3-Phase
2	San Juan – Cabezon 345 kV line	P1	San Juan 345	3-Phase
3	San Juan – Jicarilla 345 kV line	P1	San Juan 345	3-Phase
4	Taos-Springer 115 kV line	P1	Taos 115	3-Phase
5	BA – Norton 345 kV line	P1	BA 345	3-Phase
6	Walsenburg – Gladstone 230 kV line	P1	Walsenburg	3-Phase
7	Valencia – Zia 115 kV line	P1	Valencia	3-Phase
8	BA-Rio Puerco 345kV ckts 1 & 2	P7	Rio Puerco 345	SLG
9	Rio Puerco-West Mesa 345 kV ckts 1 & 2	Extreme Event	Rio Puerco 345	3-phase
10	San Juan – Jicarilla – Ojo 345 kV lines	P4	Jicarilla 345	3-phase
11	BA-BA2 345 kV ckts 1 & 2	P7	BA 345	SLG

The stability simulations determined whether the system is stable and performs as required for the pre- and post-Verde Project system. Any system improvements identified in the contingency analysis were included in the post-project stability simulations. Additional mitigations are developed, if needed, to insure acceptable stability performance is maintained with the post-Verde project system.

7. STUDY CRITERIA

7.1 PERFORMANCE CRITERIA

Acceptable system performance is based on application of the following normal and contingency performance criteria.

Steady State Criteria

TABLE 4 – STEADY STATE CRITERIA

Area	Conditions	Loading Limits	Voltage (per unit)	Voltage Drop	Application
El Paso Electric	Normal (P0)	< Normal Rating	0.95 - 1.05		69kV and above
			0.95 - 1.07		Artesia 345 kV
			0.95 - 1.08		Arroyo 345 kV PST source side
			0.90 - 1.05		Alamo, Sierra Blanca and Van Horn 69kV
	Contingency (P1-P7)	< Emergency Rating	0.925 - 1.05	7%	60 kV to 115 kV
			0.95 - 1.07	7%	Artesia 345kV
			0.95 - 1.08	7%	Arroyo 345kV PST source side
			0.90 - 1.05		Alamo, Sierra Blanca and Van Horn 69kV
			0.95 - 1.05	7%	Hidalgo, Luna, or other 345 kV buses
PNM	Normal (P0)	< Normal Rating	0.95-1.05		46 kV and above
			0.95-1.1		Taiban Mesa, Guadalupe 345 kV and Jicarilla 345 kV buses
	Single Contingency (P1)	< Emergency Rating	0.925-1.08[1]	6 %	46 kV to 115 kV
			0.95-1.1	6 %	Taiban Mesa and Guadalupe 345 kV buses
			0.925-1.08[1]	7%	69 kV to 115 kV buses in southern New Mexico
			0.90 – 1.08[1]	6 %	230 kV and above
			0.90 – 1.08[1]	7%	230 kV and above buses in southern New Mexico
	Double Contingency (P2-P7)	< Emergency Rating	0.90-1.08[1]	10 %	46 kV and above
			0.95-1.1	10 %	Taiban Mesa and Guadalupe 345 kV buses

[1] PROVIDED OPERATOR ACTION CAN BE UTILIZED TO ADJUST VOLTAGES BACK DOWN TO 1.05 PER UNIT

Area	Conditions	Loading Limits	Voltage (per unit)	Voltage Drop	Application
Tri- State	Normal (P0)	< Normal Rating	0.95-1.05		All buses
	Single Contingency (P1)	< Emergency Rating	0.90-1.1	8 %	69 kV and above except Northeastern NM and Southern NM
			0.90-1.1	8%	69 kV and above in Northeastern NM and Southern NM
	Double Contingency (P2-P7)	< Emergency Rating	0.90-1.1	10%	All buses

All equipment loadings must be below the normal rating under all-lines-in-service conditions. All line loadings must be below their emergency rating for both single and double contingencies. All transformers and equipment with an emergency rating should be below the emergency rating for single and double contingencies.

It should be noted that WECC is expected to adopt an 8% voltage criteria as the default design standard for single contingency conditions. If single contingency voltage drop violations occur in excess of the amounts in Table 4, reactive margin analysis is used to determine if a higher voltage drop up to 8% is acceptable.

Reactive Margin Criteria

Transfer capability limits are checked for adequate reactive margin per WECC criteria as follows:

TABLE 5 - REACTIVE MARGIN CRITERIA

Conditions	Voltage Stability
Transfer Path Normal or Single Contingency (P0-P1)	Positive reactive margin at a minimum of 105 percent of transfer path flow.
Transfer Path Multiple Contingency (P2-P7)	Positive reactive margin at a minimum of 102.5 percent of transfer path flow.
Load Area Normal or Single Contingency (P0-P1)	Positive reactive margin at a minimum of 105 percent of forecasted peak load.
Load Area Multiple Contingency (P2-P7)	Positive reactive margin at a minimum of 102.5 percent of forecasted peak load.

Stability Criteria

The NERC/WECC transient stability performance requirements for transmission contingencies are as follows:

- All machines will remain in synchronism.
- All voltage swings will be well damped.
- Following fault clearing for Category P1(B), voltage on load buses may not dip more than 25% of the pre-fault voltage or dip more than 20% of the pre-fault voltage for more than 20 cycles. For Category P2-P7(C) contingencies, voltage on load buses may not dip more than 30% of the pre-fault voltage or dip more than 20% of the pre-fault voltage for more than 40 cycles
- Fault clearing times are shown in
- Ensure low voltage ride through on all faults.

Fault clearing times used are shown in Table 6.

TABLE 6 - REACTIVE MARGIN CRITERIA

Categories	Fault Type	Voltage (kV)	Clearing Time (near-far end breakers)
P1,P3,P6	3 Phase Normally Cleared	345	4–4 Cycles
		230	4–4 Cycles
		115	4–4 Cycles
	Fault Type	**Voltage (kV)**	Clearing Time (normally opened breaker both near and far end—breaker opened due to stuck breaker both near and far end
P2,P4,P5,P7	1 Phase Stuck Breaker	345	4-12 Cycles
		230	
		115	4-15 Cycles

Short Circuit Criteria

Breakers in excess of 92% are flagged for determining when the breaker should be considered for upgrading. Generally, based on age and maintenance related issues, those in excess of 95% are scheduled for upgrade.

8. STUDY RESULTS

Results of the SIS are discussed in this section for the transfer capability analysis, steady state contingencies analysis, reactive margin analysis, dynamic stability analysis, short circuit study, and loss impact analysis.

8.1 Result 1 – Base Case Development

The 18 HS base case was developed from the WECC 2018 HS3-S case and incorporated changes for the New Mexico area (Area 10) based on updates for the 2018 HS base case to be used in the 2016 Planning Assessment (TPL) study. The Verde Project is incorporated into the case using the data provided in Section 4.5. This case was used for transfer capability analysis of Path 48 and assessing contingencies under the 18 peak summer expected dispatch conditions.

The 18 LW case was developed from the 2017 LW case used in the 2015 Planning Assessment study. The starting WECC case is 16LW1. The case was adjusted to represent a very light load condition with maximum wind resources to achieve a maximum export out of the New Mexico area. This case is used in assessing potential benefits of the Verde project for exports of wind resources from New Mexico.

The 18HS-HR and 17LW-HR cases are developed by increasing the total wind resources connected to the B-A-Blackwater 345 kV line to 1500 MW. These cases are used for assessing

potential benefits of the Verde project assuming export capability out of eastern New Mexico is expanded by an additional 500 MW by adding the system improvements mentioned in Section 6.3 and increasing generation injected at Clines Corners by 500 MW. The additional wind displaces San Juan and Four Corners generation.

The 18 HW base case was developed from the WECC 16HW3b case and is being used in analysis with PNM's 2016 Planning Assessment. The case is used to assess the import capability into the NEA and for assessing contingency performance under 2018 peak winter conditions.

Cases are established according to the generation dispatch outlined in Section 4.2. The generation dispatch will be adjusted when establishing cases stressed to transfer limits.

8.2 Result 2 – Path 48 Transfer Capability Analysis

The Path 48 transfer capability was determined by scaling loads as described in Section 6.1. The pre-project transfer capability was found to be 2174 MW which is slightly greater than the 2150 MW defined in the most recent WECC Path 48 rating study[2]. The post-project transfer capabilities were determined with several levels of series compensation at Ojo and with various system improvements added to address limiting conditions on Path 48 that can be corrected with upgrades to existing equipment or needed to address voltage support requirements at the higher import levels. The results are discussed below and used to determine the incremental increase in the Path 48 import limit for the post-Verde Project system. The incremental increase in the Path 48 import limit is calculated by taking the pre-project Path 48 import limit as a reference.

The addition of the Verde Project completes an additional 345 kV line in parallel with the Four Corners-Rio Puerco 345 kV Line and the San Juan-Cabezon-Rio Puerco 345 kV Line which reduces the normal flow on the Four Corners-Rio Puerco 345 kV Line and the San Juan-Cabezon 345 kV Line while increasing the flow on San Juan – Ojo 345 kV line. As a result, the San Juan-Jicarilla-Ojo 345 kV line, if not upgraded, will become the limiting element for Path 48 under outages of the San Juan-Cabezon 345 kV Line. The import limit with the Verde Project and without the San Juan-Ojo line upgrades was reduced to 1989 MW.

The analysis also showed that upgrades to the Yah-Ta-Hey-Gallup 115 kV line at low PEGS output levels is needed to prevent the Yah-Ta-Hey-Gallup 115 kV line from becoming the limiting element. With the upgrade of both the San Juan – Ojo 345 kV line and the Yah Ta Hey –

[2] Rio Puerco Switching Station Expansion Comprehensive Progress Report with Path 48 Redefinition and Rating Review, Public Service Company of New Mexico, Transmission Planning Department, March 2015.

Gallup 115 kV line along with addition of the Verde Project, the Path 48 import limit increases to 2436 MW which is an incremental increase over the benchmark case of 262 MW.

Either series compensation or a PST on the San Juan – Ojo 345 kV line further increases the Path 48 import limit by better balancing the flow between the Four Corners-Rio Puerco 345 kV Line, San Juan-Cabezon 345 kV Line, and San Juan – Ojo 345 kV Line Series compensation levels of 35%, 40% and 60% were evaluated. The Path 48 import limit is increased by approximately 450 MW with compensation in the 35% to 40% range and a little less than 400 MW with the Ojo PST. The maximum increase in the import limit was found with 60% series compensation c. This resulted in a limit increase of 672 MW before the system becomes thermally limited by overloads of the San Juan-Cabezon 345 kV line under outages of the Four Corners-Rio Puerco 345 kV line.

Under peak load conditions, overloads of the Ojo-Hernandez 115 kV line occurred for the common mode double contingency of the Verde project and Ojo-Taos 345 kV line. As a result, the Ojo – Hernandez 115 kV line will be assumed to also need upgrades for the maximum transfer levels identified with series compensation or a PST at Ojo. It is possible that RAS schemes can be implemented to eliminate this overload scenario and should be explored in a separate analysis.

The Path 48 import limits and incremental increase under the various levels of series compensation and other upgrades are summarized in Table 7.

TABLE 7: PATH 48 TRANSFER CAPABILITY SUMMARY

Item	Path 48 Limit and Conditions						
Verde Project Status	Pre-Project	Post-Project	Post-Project	Post-Project	Post-Project	Post-Project	Post - Project
Other System Upgrades	None	None	San Juan-Ojo Rating, and Yah-Ta-Hey-Gallup line upgrade	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase & 35% Ojo Series Compensation	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase & 40% Ojo Series Compensation	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase & 60% Ojo Series Compensation	San Juan-Ojo, Ojo – Hernandez and Yah-Ta-Hey-Gallup Rating Increase & Ojo PST
Path 48 Limit	2174	1989	2436	2605	2635	2846	2542
Incremental Path 48 Increase	N/A	-185	264	431	461	672	368
Limiting Contingency	Four Corners-Rio Puerco 345 kV Line	San Juan-Cabezon 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners – Rio Puerco 345 kV Line
Limiting Element	San Juan-Cabezon 345 kV Line	Jicarilla – Ojo 345 kV line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan – Cabezon 345 kV Line

Powerflow one-line diagrams of the cases in Table 7 for the limiting contingency are included in

Appendix A. Reactive margin curves of some key buses within Path 48 boundary are shown in Appendix C.

Effect of PEGS Output Level on Path 48 Capability

The overloading of the Yah-Ta-Hey – Gallup 115 kV line depends on the level of PEGS generation which is modeled as off-line in the results developed in Table 7. The line was not found to be a limiting element in the pre-project case or any of the post-project cases if PEGS generation is at 100 MW or higher. The corresponding import limits with PEGS off-line and without the upgrades to the Yah-Ta-Hey-Gallup 115 kV line are shown in Table 8.

TABLE 8: PATH 48 IMPORT LIMITS WITHOUT THE UPGRADE OF YAH TA HEY – GALLUP 115 KV LINE UNDER DIFFERENT SYSTEM CONDITION

Item	Path 48 Limit and Conditions						
Verde Project Status	Pre-Project	Post-Project	Post-Project	Post-Project	Post-Project	Post-Project	Post Project
Other System Upgrades	None	None	San Juan-Ojo Rating Increase	San Juan-Ojo and Ojo – Hernandez Rating Increase & 35% Ojo Series Compensation	San Juan-Ojo, and Ojo – Hernandez Rating Increase & 40% Ojo Series Compensation	San Juan-Ojo, and Ojo – Hernandez Rating Increase & 60% Ojo Series Compensation	San Juan-Ojo, and Ojo – Hernandez Rating Increase & Ojo PST
Path 48 Limit	2174	1989	2414	2501	2520	2595	2515
Incremental Path 48 Increase	N/A	-185	240	327	346	421	341
Limiting Contingency	Four Corners-Rio Puerco 345 kV Line	San Juan-Cabezon 345 kV Line	Bisti – Pillar 230 kV line	Bisti – Pillar 230 kV line	Bisti – Pillar 230 kV line	Bisti – Pillar 230 kV line	Bisti – Pillar 230 kV line
Limiting Element	San Juan-Cabezon 345 kV Line	Jicarilla – Ojo 345 kV line	Yah Ta Hey – Gallup 115 kV line	Yah Ta Hey – Gallup 115 kV line	Yah Ta Hey – Gallup 115 kV line	Yah Ta Hey – Gallup 115 kV line	Yah Ta Hey – Gallup 115 kV line

The maximum Path 48 import is obtained with PEGS modeled off-line, however, under normal conditions, the unit is expected to be generating. And a higher total load in Northern New Mexico can be served when PEGS is generating even though there is a decrease in the portion of the load that can be served over Path 48. To put this in perspective, a sensitivity analysis has been added that shows the import capability with PEGS generating at 228 MW for the various buildout scenarios with the Verde Project. The results of the analysis are shown in Table 9.

TABLE 9- SUMMARY OF PATH 48 CAPABILITY WITH PEGS AT 228 MW

Item	Path 48 Limit and Conditions					
Verde Project Status	Pre-Project	Post-Project	Post-Project	Post-Project	Post-Project	Post - Project
Other System Upgrades	None	San Juan-Ojo Rating Increase	San Juan-Ojo, and Ojo – Hernandez Rating Increase & 35% Ojo Series Compensation	San Juan-Ojo, and Ojo – Hernandez Rating Increase & 40% Ojo Series Compensation	San Juan-Ojo, and Ojo – Hernandez Rating Increase & 60% Ojo Series Compensation	San Juan-Ojo, and Ojo – Hernandez Rating Increase & Ojo PST
Path 48 Limit	2074	2351	2510	2570	2669	2458
Incremental Path 48 Increase	N/A	277	436	496	595	384
Limiting Contingency	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners-Rio Puerco 345 kV Line	Four Corners – Rio Puerco 345 kV Line
Limiting Element	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan-Cabezon 345 kV Line	San Juan – Cabezon 345 kV Line

With PEGS at 228 MW the Verde project along with series compensation added a maximum of 595 MW to the Path 48 transfer capability.

Reactive Support Requirements for Increased Import Levels

The results obtained in Table 7 and Table 9 included the addition of load-side reactive support by modeling 192 MVAR and 300 MVAR of shunt capacitor banks in the Albuquerque area respectively. Without this support, the transfer capability will become limited by adherence to voltage stability criteria below the thermal limits of the system. It is expected that the reactive support would be added over time as import requirements increase and would be divided among multiple locations. The full 300 MVAR identified was needed to support the import increase modeled with the system at the transfer capability limits with 60% series compensation and PEGS generating 228 MW.

8.3 Result 3 – Northeast Area Transfer Capability

A cut-set defined as the Northeast Area has been utilized for many years in planning and operating studies to assess the capability of the system to serve the joint needs of Tri-State, Los Alamos County and PNM. The Verde Project addition will be located within the boundary of the Northeast Area. The area is a subset of the area within Path 48 and hits peak loads in the winter. The Northeast area transfer capability is assessed by scaling loads in Las Vegas, Santa Fe, Los Alamos County and Tri-State's Northern New Mexico zones. The NEA transfer limits obtained without and with the Verde Project are summarized in Table 10.

TABLE 10: NEA IMPORT LIMITS WITHOUT AND WITH THE VERDE PROJECT

Item	Northeast Area Import Limit and Conditions				
Verde Project Status	Pre – Project	Post – Project	Post – Project	Post – Project	Post - Project
Other System Upgrades	None	San Juan – Ojo Rating increase	San Juan – Ojo Rating increase and 35% Ojo Series Compensation	San Juan – Ojo Rating increase and 40% Ojo Series Compensation	San Juan – Ojo Rating increase and 60% Ojo Series Compensation
Northeast Area Limit	787 MW	932 MW	1045 MW	1057 MW	1143 MW
Incremental NEA Limit Increase	N/A	145 MW	258 MW	270 MW	356 MW
Limiting Contingency	Ojo – Taos 345 kV line	Walsenburg – Gladstone 230 kV line	Walsenburg – Gladstone 230 kV line	Walsenburg – Gladstone 230 kV line	Walsenburg – Gladstone 230 kV line
Limiting Element	Ojo – Hernandz 115 kV line	Ojo 345 kV bus	Ojo 345 kV bus	Ojo 345 kV bus	Ojo 345 kV bus
Limit Type	Thermal Limit	Voltage Stability	Voltage Stability	Voltage Stability	Voltage Stability

The capabilities identified with the 2018 HW case without the project was 787 MW. The power flow results at the determined NEA import limits are presented in Appendix B. Voltage stability was identified as limiting the system after addition of the Verde project during outages of the Walsenburg-Gladstone 230 line. Depending on the level of series compensation, the project increased the amount of load served in the Northeast Area by up to 356 MW. The reactive margin curves at the NEA import limits and at 5% above import limits under different system condition are shown in Appendix C. Also, the transient response during the limiting element out of system shows a stable response for all system conditions. This is shown in Appendix D.

8.4 Result 4 – Eastern New Mexico Renewable Export Analysis

This section discusses the analysis of the Verde Project benefits to exporting wind out of eastern New Mexico as discussed in Section 6.3. The analysis primarily deals with the ability to get power out of the BA 345 kV station under contingency conditions without overloading the underlying 115 kV system carrying power into the northern portions of Albuquerque and into the Santa Fe and Los Alamos areas. The total thermal outlet capacity from BA station is approximately 2700 MW based on the two 345 kV lines to Rio Puerco and the 448 MVA transformers at BA and Norton. The largest single contingency limiting transfers is the outage of one of the BA-Rio Puerco 345 kV lines. The outlet capacity is reduced to approximately 1700 MVA but this is sufficient to accommodate the full 1000 MW of wind resources included in eastern New Mexico. The BA-Rio Puerco 345 kV lines are built on a common structure and as a result, the system must also adhere to specific performance criteria under the potential

contingency of both lines which would reduce the total amount of wind generation that could be accommodated at BA to approximately 700 MW. Since the Verde project provides an additional outlet, it would be expected to allow for an increase in the wind accommodated under this contingency.

Since both BA-Rio Puerco 345 kV lines share a common structure, the loss of both lines must be considered and meet the performance criteria specified in the TPL standards for a P6 contingency. The standards also require system design considering two overlapping single contingencies where one line has been removed from service and, following system adjustments, meet criteria as specified in the TPL standards for loss of another line. To meet the performance criteria for the simultaneous loss of both lines, PNM plans to utilize a Remedial Action Scheme (RAS) that will trip a portion of the generation in eastern New Mexico. The RAS would be armed to operate when flows on the BA-Blackwater 345 kV line into BA station exceed 700 MW. For situations where one line is removed from service, wind generation will be curtailed down to approximately 700 MW to insure that the system meets performance criteria if a second line is lost. Addition of the Verde project adds a third full 345 kV path between BA and the San Juan/Four Corners hub which potentially would allow for greater injections into BA station under this double contingency scenario.

With the 18 peak summer case, the analysis with addition of the Verde Project and various levels of series compensation provided mixed results. In the 18 HS cases with series compensation, the Verde Project tended to increase flows into the BA station and slightly increased overloads of the BA transformer under the double line outage contingency. The addition of a PST at Ojo provided a better outcome for the 18 HS conditions. The PST improved flowability sufficiently to accommodate the full 1000 MW currently planned or in-service that flows into BA station. The summer results are summarized in Table 11.

TABLE 11: MAXIMUM WIND INJECTION AT BA 345 KV BUS BASED ON THE 18 HS CASE

Item	Maximum Eastern New Mexico Renewable Export at BA 345 kV bus and conditions					
Verde Project Status	Pre – Project	Post – Project	Post – Project	Post – Project	Post - Project	Post – Project
Other System Upgrades	None	San Juan – Ojo Rating increase	San Juan – Ojo Rating increase and 35% Ojo Series Compensation	San Juan – Ojo Rating increase and 40% Ojo Series Compensation	San Juan – Ojo Rating increase and 60% Ojo Series Compensation	San Juan – Ojo Rating Increase and Ojo PST
Maximum wind injection at BA 345 kV bus	715 MW	723 MW	702 MW	698 MW	674 MW	933 MW
Incremental wind injection at BA 345 kV bus	N/A	8 MW	-13 MW	-17 MW	-41 MW	218 MW
Limiting Contingency	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	None
Limiting Element	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	None
Limit Type	Thermal	Thermal	Thermal	Thermal	Thermal	Full Wind Output

The analysis using the light load case showed more favorable results with the Verde project and various level of series compensation. The Verde Project with series compensation increased the ability to export power from eastern New Mexico increasing the amount of wind that could be accommodated under the outage of both BA-Rio Puerco 345 kV lines by 128 to 181 MW depending on the level of series compensation. Similar to the heavy summer case, the Verde project with the Ojo PST instead of series compensation showed the most favorable results allowing the full wind generation to be accommodated for the double line contingency scenario. The results of the light winter analysis are summarized in Table 12.

TABLE 12: MAXIMUM WIND INJECTION AT BA 345 KV BUS BASED ON 18 LW CASE

Item	Maximum Eastern New Mexico Renewable Export at BA 345 kV bus and conditions					
Verde Project Status	Pre – Project	Post – Project	Post – Project	Post – Project	Post - Project	Post - Project
Other System Upgrades	None	San Juan – Ojo Rating increase	San Juan – Ojo Rating increase and 35% Ojo Series Compensation	San Juan – Ojo Rating increase and 40% Ojo Series Compensation	San Juan – Ojo Rating increase and 60% Ojo Series Compensation	San Juan – Ojo Rating increase and Ojo PST
Maximum wind injection at BA 345 kV bus	717 MW	845 MW	869 MW	874 MW	898 MW	933 MW
Incremental wind injection at BA 345 kV bus	N/A	128 MW	152 MW	157 MW	181 MW	216 MW
Limiting Contingency	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	None
Limiting Element	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	None
Limit Type	Thermal	Thermal	Thermal	Thermal	Thermal	Full Wind Output

Wind Sensitivity with Total Wind Increased to 1500 MW

A sensitivity case increasing the total wind in eastern New Mexico to 1500 MW was also reviewed. In order to accommodate the additional generation, a parallel 345 kV line between Clines Corners and a new BA2 switching station is included in the sensitivity case. The BA2 station takes advantage of existing line locations to allow termination of an additional line. The outlet from the station includes two 345 kV lines to BA and a 345 kV line to Norton. The most limiting contingency for power coming in from eastern New Mexico becomes the loss of both BA2-BA 345 kV lines which leaves the BA-Blackwater line connected only to the Norton Switching Station which limits transfers to the rating of the Norton 345/115 transformer. Addition of the Verde Project adds an additional outlet at Norton.

The results of analysis with the Verde Project are shown in Table 13 for the heavy summer conditions and Table 14 for the light winter conditions. For summer conditions, the Verde Project combined with series compensation increased the amount of power that could be injected into BA2 from eastern New Mexico for the worst double contingency by 194 MW to 239 MW depending on the amount of series compensation at Ojo. For the light winter conditions, the increase ranged from 447 MW to 524 MW. The Verde project combined with a PST at Ojo produced the most favorable results. With the PST, an additional 585 MW of wind

from eastern New Mexico could be accommodated during heavy summer conditions. Similarly, during light winter, this increase was found to be 615 MW.

TABLE 13: MAXIMUM WIND INJECTION AT BA 345 KV BUS DURING HEAVY SUMMER WITH BA2 AND CLINE CORNER STATION EXPANSION

Item	Maximum Eastern New Mexico Renewable Export without RAS for N-2					
Verde Project Status	Pre – Project	Post – Project	Post – Project	Post – Project	Post - Project	Post - Project
Other System Upgrades	None	San Juan – Ojo Rating Increase	San Juan – Ojo Rating increase and 35% Ojo Series Compensation	San Juan – Ojo Rating increase and 40% Ojo Series Compensation	San Juan – Ojo Rating increase and 60% Ojo Series Compensation	San Juan – Ojo Rating increase and Ojo PST
Maximum wind injection at BA 345 kV bus	447 MW	641 MW	660 MW	664 MW	686 MW	1032 MW
Incremental wind injection at BA 345 kV bus	N/A	194 MW	213 MW	217 MW	239 MW	585 MW
Limiting Contingency	BA – BA2 345 kV lines 1 and 2	BA – BA2 345 kV lines 1 and 2	BA – BA2 345 kV lines 1 and 2	BA – BA2 345 kV lines 1 and 2	BA – BA2 345 kV lines 1 and 2	BA – BA2 345 kV lines 1 and 2
Limiting Element	Norton 345/115 kV Transformer	Norton 345/115 kV Transformer	Norton 345/115 kV Transformer	Norton 345/115 kV Transformer	Norton 345/115 kV Transformer	Norton (Check this bus)
Limit Type	Thermal	Thermal	Thermal	Thermal	Thermal	Voltage Stability

TABLE 14: MAXIMUM WIND INJECTION AT BA 345 KV BUS DURING LIGHT WINTER WITH BA2 AND CLINES CORNER STATION EXPANSION

Item	Maximum Eastern New Mexico Renewable Export without RAS for N-2					
Verde Project Status	Pre – Project	Post – Project	Post – Project	Post – Project	Post - Project	Post – Project
Other System Upgrades	None	San Juan – Ojo Rating increase	San Juan – Ojo Rating increase and 35% Ojo Series Compensation	San Juan – Ojo Rating increase and 40% Ojo Series Compensation	San Juan – Ojo Rating increase and 60% Ojo Series Compensation	San Juan – Ojo Rating increase and Ojo PST
Maximum wind injection at BA 345 kV bus	448 MW	895 MW	930 MW	938 MW	972 MW	1063 MW
Incremental wind injection at BA 345 kV bus	N/A	447 MW	482 MW	490 MW	524 MW	615 MW
Limiting Contingency	BA – BA2 345 kV lines 1 and 2	Rio Puerco - BA – 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	Rio Puerco – BA 345 kV lines 1 and 2	BA – BA2 345 kV lines 1 and 2
Limiting Element	Norton 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	BA 345/115 kV Transformer	Norton
Limit Type	Thermal	Thermal	Thermal	Thermal	Thermal	Voltage Stability

Overall benefits of the Verde Project for exports of renewable energy from eastern New Mexico could possibly be enhanced by improving transformer and 115 kV outlet capacity at BA and Norton.

The corresponding power flow contingency results for the cases summarized in Tables 11-14 are shown in Appendix B

8.5 Result 5 – Steady State Contingency Analysis

Steady state contingency analysis was performed on the cases defined in Section 4.1 and for the limiting cases identified in the transfer capability analysis of Path 48 (Northern New Mexico) and the Northeast Area using the contingencies listed in Appendix E. The power flow analysis results are presented in Appendix B.

The following system upgrades are required based upon the Path 48 transfer capability analysis and power flow analysis results.

Required System Upgrades

The following system upgrades are identified in the SIS in order to maximize the transfer capability of the Verde Project addition. Except for the San Juan-Jicarilla-Ojo line clearance improvements, the upgrades would be added over time as Path 48 import requirements increase. The upgrades are needed to achieve the import levels identified at the thermal limits shown above.

1) *Clearance Improvements of San Juan-Jicarilla-Ojo 345 kV line*

Contingency flow on this path will exceed the 450 MVA rating of the line once the Verde Project is added. The maximum Path 48 transfer capability increase identified in the SIS requires a rating of at least 1050 MVA. The line conductor is bundled 795 MCM ACSR and PNM applies a standard conductor rating of 2000 amperes (1195 MVA) assuming the line has sufficient clearance. The line will also need to be checked for any potential terminal limitations.

2) *Ojo Series Compensation*

The increase in Path 48 transfer capability is significantly enhanced by the addition of series compensation in the San Juan-Jicarilla-Ojo 345 kV line. Several levels were reviewed and discussed in the SIS. San Juan and possibly the Four Corners Generating Units will need to be screened for sub-synchronous resonance that can result from series compensated lines. SSR mitigation may be required if SSR risks are identified. Assessment of SSR risks is outside the scope of this analysis.

3) *Upgrade of Yah Ta Hey – Gallup 115 kV line*

The Yah Ta Hey – Gallup 115 kV line overloads when the Bisti – Pillar 230 kV line is out at high Path 48 import levels and low PEGS output levels. The line has clearance for operation up to 112 MVA. The minimum required MVA rating based upon the maximum loading of the 115 kV line found in the SIS during contingencies is 123 MVA. It is recommended that clearance improvements to allow the line to be operated up to 130 MVA be implemented.

4) Upgrade of Ojo-Hernandez 115 kV line

The Yah Ta Hey – Gallup 115 kV line overloads for a breaker failure scenario at the Ojo 345 kV station after addition of the Verde project with series compensation or a PST. The line is clearance for operation up to 180 MVA. The minimum required MVA rating based upon the maximum loading of the 115 kV line found in the SIS during contingencies is 258 MVA. It is recommended that clearance improvements to allow the line to be operated up to 300 MVA be implemented.

5) Additional reactive support in Albuquerque area

Shunt compensation is required to prevent the system from being voltage stability limited below the transfer capability identified in this analysis. The analysis showed the requirement of 300 MVAR of shunt capacitive compensation in the Albuquerque area to maximize transfer capability up to the full thermal capability of the transmission lines. It is expected that modeling underlying system expansion associated with the load increases used to stress Path 48 would show an actual reactive requirement that is somewhat lower.

6) Los Alamos County line upgrades

Overloads of the Norton-ETA 115 kV line serving Los Alamos County were observed during various outages. Although plans exists for upgrading this line when Los Alamos county load levels result in single contingency overloads of the line, the SIS shows the potential need to accelerate these upgrades when the Verde Project is added. The stronger source at Norton results in higher normal flows and higher contingency flows for outage of the BA transformer. The existing rating of the Norton-ETA 115 kV line is 116 MVA with an increase to approximately 240 MVA with the planned upgrades.

8.6 Result 6 – Stability Analysis

Except for the high wind cases, the dynamic stability analysis of the base cases defined in Section 4.1 showed stable system response for the disturbances mentioned in Table 3. The cases at the Path 48 transfer capability limit and at the Northeast Area import limit were also found to be stable. The corresponding transient responses are shown in Appendix D.

The cases with high eastern New Mexico wind export are stable except for the double contingency outage of the BA-Rio Puerco 345 kV line. Since this outage also results in overloads out of the BA switching station, a RAS that will trip a portion of the wind generation is planned to mitigate the overloads. This is discussed in Section 8.4. For the purpose of the stability analysis, a RAS is simulated that trips the Taiban-Blackwater 345 kV line section which will disconnect the generation at Broadview and Grady.

Table 15 below summarizes the transient stability simulation results during the double circuit outages without and with the Verde project and when there is 1000 MW wind on the BA – Blackwater 345 kV line. The results, which model the RAS, did not identify any stability issues. As a result, acceptable system performance is expected with the post-Verde system.

TABLE 15: SUMMARY OF TRANSIENT STABILITY SIMULATION RESULTS FOR DOUBLE CIRCUIT OUTAGE OF RIO PUERCO - BA 345 KV LINES 1 AND 2 WHEN WIND INJECTION IS 1000 MW BEFORE FAULT

Case	System conditions and adjustments	Dynamic Performance
Heavy Summer Case with Wind Injection of 1000 MW at BA	Without Project	Stable
	With Project and Upgrade	Stable
	With Project, Upgrade and 35% Series Compensation	Stable
	With Project, Upgrade and 40% Series Compensation	Stable
	With Project, Upgrade and 60% Series Compensation	Stable
	With Project, Upgrade and Ojo PST	Stable
Light Winter Case with Wind Injection of 1000 MW at BA	Without Project	Stable
	With Project and Upgrade	Stable
	With Project, Upgrade and 35% Series Compensation	Stable
	With Project, Upgrade and 40% Series Compensation	Stable
	With Project, Upgrade and 60% Series Compensation	Stable
	With Project, Upgrade and Ojo PST	Stable

Wind Sensitivity with Total Wind Increased to 1500 MW

The stability analysis for the BA-Rio Puerco Line 1 and 2 contingency was repeated using the 1500 MW wind sensitivity case. The system was found to be stable for all cases with the tripping of the Taiban Mesa-Blackwater 345 kV line which trips the Broadview and Grady wind farms, however, additional wind resources would need to be tripped to handle post-contingency overloads identified earlier. The transient stability results are summarized in Table 16.

TABLE 16: SUMMARY OF TRANSIENT STABILITY SIMULATION RESULTS FOR DOUBLE CIRCUIT OUTAGE OF RIO PUERCO - BA 345 KV LINES 1 AND 2 WHEN WIND INJECTION IS 1500 MW BEFORE FAULT

Case	System conditions and adjustments	Dynamic Performance
Heavy Summer Case with Wind Injection of 1500 MW at BA	Without Project	Stable
	With Project and Upgrade	Stable
	With Project, Upgrade and 35% Series Compensation	Stable
	With Project, Upgrade and 40% Series Compensation	Stable
	With Project, Upgrade and 60% Series Compensation	Stable
	With Project and Ojo PST	Stable
Light Winter Case with Wind Injection of 1500 MW at BA	Without Project	Stable
	With Project and Upgrade	Stable
	With Project, Upgrade and 35% Series Compensation	Stable
	With Project, Upgrade and 40% Series Compensation	Stable
	With Project, Upgrade and 60% Series Compensation	Stable
	With Project and Ojo PST	Stable

Stability analysis is also performed for the BA-BA2 Line 1 and 2 contingency using the wind sensitivity case. The analysis showed that system improvements or additional wind curtailment are needed to prevent overloads that are not mitigated by tripping of the Broadview and Grady projects. Table 17 shows the summary of transient stability simulation results and the amount of addition wind generation that needed to be tripped for stable system performance.

TABLE 17: SUMMARY OF TRANSIENT STABILITY SIMULATION RESULTS FOR DOUBLE CIRCUIT OUTAGE OF BA - BA2 345 KV LINES 1 AND 2 WHEN WIND INJECTION IS 1500 MW BEFORE FAULT

Case	System conditions and adjustments	Additional Eastern New Mexico Wind MW curtailment	Dynamic Performance
Heavy Summer Case with Wind Injection of 1500 MW at BA	Without Project	213 MW	Stable
	With Project and Upgrade	107 MW	Stable
	With Project, Upgrade and 35% Series Compensation	0	Stable
	With Project, Upgrade and 40% Series Compensation	0	Stable
	With Project, Upgrade and 60% Series Compensation	0	Stable
	With Project and Ojo PST	107	Stable
Light Winter Case with Wind Injection of 1500 MW at BA	Without Project	264 MW	Stable
	With Project and Upgrade	107 MW	Stable
	With Project, Upgrade and 35% Series Compensation	0	Stable
	With Project, Upgrade and 40% Series Compensation	0	Stable
	With Project, Upgrade and 60% Series Compensation	0	Stable
	With Project and Ojo PST	107	Stable

The design and construction of the facilities in eastern New Mexico for the wind export levels is underway and final design parameters are needed to verify acceptable stability limits. This analysis used estimated design parameters for equipment that is currently under construction and modeled in the high wind cases.

8.7 Result 7 – Short Circuit Analysis

The SIS has reviewed the increase in fault duty that results from the addition of the Verde Project. The results did not identify a significant increase in fault duty or breaker's that would exceed the interrupt rating as a result of the project addition. The table below shows the fault duty identified at the Ojo and Norton buses before and after addition of the project assuming 60% series compensation at Ojo.

TABLE 18 - FAULT DUTY IMPACTS

	Pre-Project Amps / Short Circuit MVA		Post-Project Amps / Short Circuit MVA	
Bus	3-Phase	L-G	3-Phase	L-G
Ojo 345	2963/1771	3092/1848	7748/4630	6813/4071
Norton 345	5453/3259	4917/2938	9103/5439	8281/4949

8.8 Result 8 – Incremental Loss analysis

The Verde Project provides an additional 345 kV path in parallel to the two major 345 kV lines carrying power into Northern New Mexico. The addition of the project will reduce the normal flow on the parallel lines which results in reduction in total system losses at a given transfer level. Table 19 tabulates the total New Mexico area losses at various import levels on Path 48 with and without the Verde Project. The incremental losses at different import levels were calculated by comparing the losses without the project to the losses with the project.

TABLE 19: PATH 48 INCREMENTAL LOSS CALCULATIONS WITH VERDE PROJECT AND VARIOUS SERIES COMPENSATION LEVELS

	Path 48 MW Loss									
	Without Project		With Project, San Juan – Ojo 345 kV line upgrade and various series compensation level							
			0%		35%		40%		60%	
Path 48 Import	Loss	Incremental Loss	Loss	Incremental Loss	Loss	Incremental Loss	Loss	Incremental Loss	Loss	Incremental Loss
500 MW	31.19	N/A	31.28	0.09	31.0	-0.19	31.24	0.05	31.71	0.52
600 MW	32.19	N/A	32.38	0.19	32.00	-0.19	31.94	-0.25	32.76	0.57
700 MW	34.17	N/A	33.93	-0.24	33.72	-0.45	33.61	-0.56	34.45	0.28
800 MW	36.77	N/A	35.69	-1.08	35.44	-1.33	35.88	-0.89	36.18	-0.59
900 MW	38.99	N/A	38.35	-0.64	38.27	-0.72	38.19	-0.8	38.96	-0.03
1000 MW	42.99	N/A	41.78	-1.21	41.50	-1.49	41.57	-1.42	42.25	-0.74
1200 MW	52.07	N/A	49.80	-2.27	49.58	-2.49	49.84	-2.23	50.51	-1.56
1400 MW	63.82	N/A	61.01	-2.81	60.49	-3.33	60.48	-3.34	61.45	-2.37
1600 MW	79.81	N/A	74.74	-5.07	73.90	-5.91	74.03	-5.78	74.98	-4.83
1800 MW	97.92	N/A	91.77	-6.15	90.37	-7.55	90.45	-7.47	91.42	-6.50
2000 MW	119.41	N/A	110.49	-8.92	109.28	-10.13	109.23	-10.18	110.14	-9.27
2100 MW	130.46	N/A	120.28	-10.18	119.61	-10.85	119.62	-10.84	120.81	-9.65
2200 MW	144.06	N/A	132.63	-11.43	130.76	-13.3	130.73	-13.33	131.91	-12.15
2500 MW	187.32	N/A	170.56	-16.76	167.97	-19.35	168.06	-19.26	168.91	-18.41
2600 MW	205.54	N/A	186.53	-19.01	182.81	-22.73	182.57	-22.97	182.02	-23.52

Figure 4 shows the impact of Verde Project with series compensation addition in the Path 48 loss.

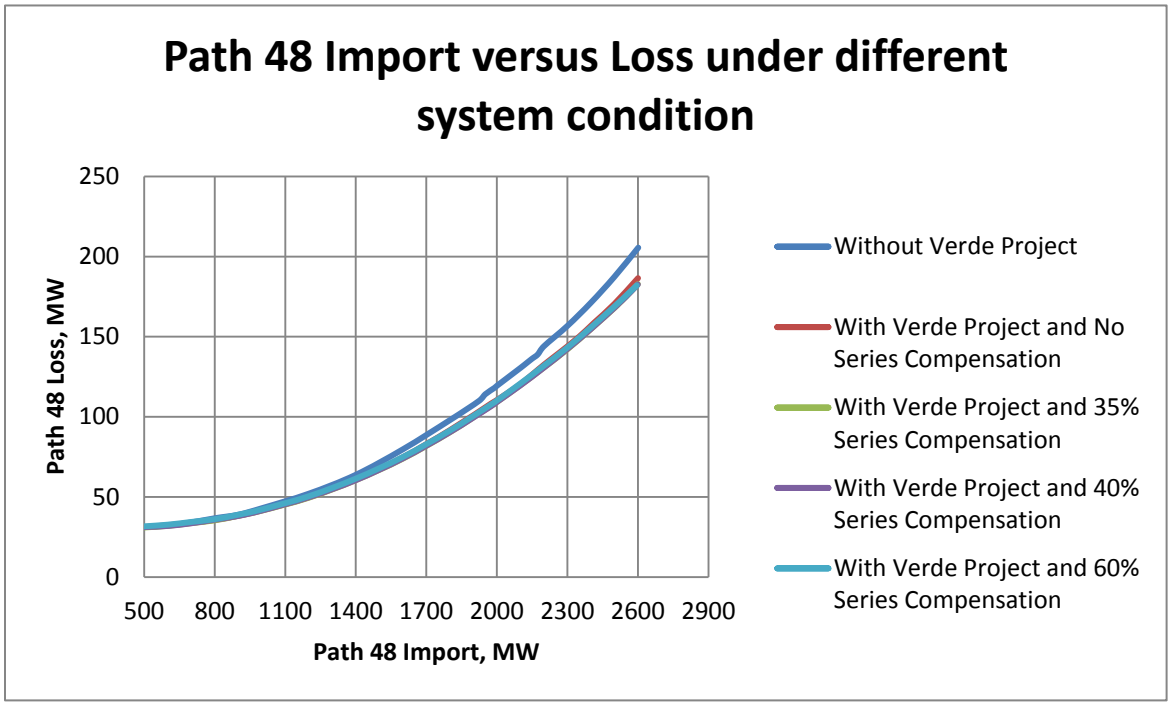

FIGURE 4: VERDE PROJECT IMPACTS ON PATH 48 LOSSES

Analysis was performed to estimate the annual loss savings by establishing equations of the New Mexico area losses as a function of the Path 48 import based on the information above. The results of applying the equations to actual imports in 2015 on Path 48 are shown in Table 20. The table includes a scenario where series compensation on the Four Corners-Rio Puerco 345 kV line and San Juan-Cabezon-Rio Puerco 345 kV line. This produces additional loss savings at lower import levels, however, the estimated amount of time that the system can be operated with the compensation out of service has not been considered in establishing the number.

TABLE 20: ANNUAL LOSS SAVINGS BASED ON 2015 PATH 48 IMPORTS

Item	Without Project	With Project and 0% Series Compensation	With Project and 35% Series Compensation	With Project and 40% Series Compensation	With Project and 60% Series Compensation	With Project, and No Series Compensation in FW and WW line
Average MW Losses	46.1	44.9	44.6	44.7	45.6	43.5
Difference	N/A	-1.19	-1.47	-1.39	-0.531	-2.
MWh Energy Saving	N/A	10392	12913	12146	4677	22788

8.9 Result 9 – Estimated Cost of System Upgrades

The estimated cost and schedule of connecting the Verde Project at the Ojo and Norton Switching stations is shown below. The estimates are based on the breaker additions shown in Figure 2.

Interconnection item	Cost	Estimated Time for construction
Expansion of Ojo Switching Station	$3.3 M	18 months
Expansion of Norton Switching Station	$4.3 M	18 Months
Interconnection Total	$7.6M	18 Months

The system upgrades required to maximize the transfer capability of the Verde project on Path 48 were also estimated. These upgrades are summarized in Section 8.5. With the exception of the San Juan-Jicarilla-Ojo 345 kV line upgrades, the timing of the upgrades would be added over time based on the transfer capability requirements. Two levels of series compensation are included in the estimates for comparison, however, only one of the two levels is assumed to be selected for installation. The system upgrade estimates are shown below:

Interconnection item	Cost	Estimated Time for construction
San Juan-Jicarilla-Ojo 345 kV Line Clearance Improvements	$2.4 M	18 months
Ojo Series Capacitor 40% (37 Ohms)	$10.6 M	24 Months
Ojo Series Capacitor 60% (56 ohms)	$12.0 M	24 Months
Albuquerque Area Shunt Capacitor Additions	$5.4 M	18 Months
Tri-State Yah-Ta-Hey-Gallup Clearance Improvements	$1.5M	18 Months
Ojo-Hernandez 115 kV line Upgrade	$5M	36 Months