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Southwest Power Pool, Inc. (SPP)

System Impact Study for Border Reactive Support

Final Report

REP-1518
Revision #02

March 2023

Submitted By:
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Report Revision Table

Revision	Report Revision Table	Date
0	Issue Draft Report for Review for Border Reactive Support	02/03/2023
1	Address comments, Issue Final Report	02/15/2023
2	Address typo for reactive size at Beckham County	03/03/2023

Title:	**System Impact Study for Border Reactive Support: Final Report REP-1518**	
Date:	March 2023	
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EXECUTIVE SUMMARY

Southern Power Pool (SPP) requested an additional System Impact Study (SIS) for the DISIS-2016-002 Group 06 Cluster due to recent changes to the Border 345 kV area and feedback from local Transmission Owners. The System Impact Study required a power flow analysis and stability analysis detailing the impacts on the DISIS-2016-002 Group 06 interconnection projects shown in Table ES-1 after implementing Project ID 81717 identified in the 4Q 2022 Project Tracking Appendix 1 and a proposed solution to install controls and circuit switchers on existing inline shunt reactors.

Table ES-1
Interconnection Projects Evaluated

Request	Size (MW)	Generator Model	Point of Interconnection
GEN-2016-121	110	SMA Sunny Central 2.5 MW	Roadrunner 115kV
GEN-2016-123	298	Vestas V110 2.0 MW	Crossroads 345kV
GEN-2016-124	150	Vestas V110 2.0 MW	Crossroads 345kV
GEN-2016-125	74	Vestas V110 2.0 MW	Crossroads 345kV

Border 345 kV is currently connected to Tuco 345 kV of Xcel Southwest Public Service (SPS) and Woodward 345 kV with shunt reactors on both transmission lines at Border 345 kV. Oklahoma Gas & Electric (OG&E) has raised concerns on the open line configuration for the Border to Woodward 345 kV transmission line with voltages at Border 345 kV being as high as 500 kV due to an identified solution of +275 MVAR capacitor banks at Border 345 kV. A Notice to Construct (NTC) has been issued in 2020 that will tap the Border to Woodward 345 kV transmission line with a new substation (Beckham County 345 kV) and connect to Chisholm 345 kV with a 0.84-mile transmission line. Additionally, OG&E is proposing to add circuit switchers and necessary controls to the existing shunt reactors at Border 345 kV.

The DISIS-2016-002-2 Group 06 Limited Operation System Impact Study (Scenario 4) models were updated to reflect current system conditions for DISIS-2016-002 requests. These study models were used to perform a steady-state analysis and a stability analysis to determine the impacts of implementing the changes above and determining the reactive support required after the addition of the Beckham County 345 kV substation.

SUMMARY OF POWER FLOW ANALYSIS

After implementing the topology changes near Border 345 kV, the power flow analysis determined 39 MVAR of reactive support located at Border 345 kV and Beckham County 345 kV (78 MVAR total) and installing circuit switchers on the shunt reactors on the Border to Tuco 345 kV line (located at Border) and Beckham County to Woodward 345 kV line (located at Beckham County) would resolve all non-converged events.

Additionally, it was determined there were no adverse impacts from this topology and reactive support update to area flows and voltages. There were no additional thermal or voltage constraints identified in the analysis.

SUMMARY OF STABILITY ANALYSIS

The stability analysis was performed for the NTC re-evaluation of the Border capacitor banks and new Beckham County substation based on the steady-state solution that was identified (39 MVAR of capacitor bank support at Border and Beckham County, shunt reactors offline). The stability analysis was performed on a select number of contingencies near the Border – Beckham County – Chisholm area. All faults resulted in stable voltage and rotor angle response. Several contingencies resulted in a high steady-state voltage recovery (greater than 1.1 p.u. but less than 1.2 p.u.) and were resolved by switching off the capacitor banks at Border or Beckham County following the fault events. There was no system instability or rotor angle instability observed with the Beckham County NTC project and after implementing the reactive support changes near Border for the 2017 Winter Peak, 2018 Summer Peak, and 2026 Summer Peak seasons.

Table of Contents

List of Tables

List of Figures

SECTION 1: OBJECTIVES

The objective of this report is to provide Southern Power Pool (SPP) with the deliverables for the "System Impact Study for the Border Reactive Support." SPP requested a System Impact Study for the existing Border Reactive support which requires a power flow analysis and a stability analysis with results in an Impact Study Report

SECTION 2: BACKGROUND

The Siemens Power Technologies International PSS/E power system simulation program Version 33.12.2 was used for this study. The DISIS-2016-002-2 Group 06 ERIS power flow models and DISIS-2016-002 Group 06 stability cases were provided by SPP. The study requests listed in Table 2-1 were ensured to be dispatched in the models and the models include the previously queued projects listed in Table 2-2. The study cases were updated to reflect known system conditions which included topology changes near Border and reactive support changes were implemented in the power flow and stability cases. Refer to Table 2-3 for the existing configuration near Border and the proposed changes. The stability models provided included the 2017 Winter Peak, 2018 Summer Peak, and 2026 Summer Peak.

Table 2-1
Interconnection Projects Evaluated

Request	Size (MW)	Generator Model	Point of Interconnection
GEN-2016-121	110	SMA Sunny Central 2.5 MW	Roadrunner 115kV
GEN-2016-123	298	Vestas V110 2.0 MW	Crossroads 345kV
GEN-2016-124	150	Vestas V110 2.0 MW	Crossroads 345kV
GEN-2016-125	74	Vestas V110 2.0 MW	Crossroads 345kV

Table 2-2
Previously Queued Nearby Interconnection Projects Included

Request	Size (MW)	Generator Model	Point of Interconnection
GEN-2001-033 (Commercial Operation)	120	WT1G1 (524890)	San Juan Tap 230kV
GEN-2001-036	80	WT1G1 (599138)	Norton 115kV Switching Station
GEN-2006-018	168.1	GENSAL	TUCO 230kV

Request	Size (MW)	Generator Model	Point of Interconnection
GEN-2006-026	604	GENROU (527901, 527902, 527903)	Hobbs 230kV & Hobbs 115kV
GEN-2008-022	299.65	Vestas	Eddy County-Tolk (Crossroads) 345kV
GEN-2010-006	180/205	GENROU	Jones 230kV
GEN-2011-025	79.96	GE 1.79MW	Tap Floyd County - Crosby County 115kV
GEN-2011-045	180/205	GENROU	Jones 230kV
GEN-2011-046	23	GENROU	Tucumcari 115kV
GEN-2011-048/ GEN-2012-036	172/182	GENROU	Mustang 230kV
GEN-2012-001	61.2	CCWE 3.6MW (WT4)	Tap Grassland Â• - Borden County 230 kv
GEN-2012-020	478	GE 1.68MW	TUCO 230kV
GEN-2004-015/ GEN-2012-034	157	GENROU (unit 4; 527164)	Mustang 230kV
GEN-2006-015/ GEN-2012-035	157	GENROU (unit 5; 527165)	Mustang 230kV (527151)
GEN-2012-037	196/203	GENROU (525844)	Tuco 345kV (525832)
GEN-2013-016 / GEN-2015-041	196/203	GE 7FA Gas CT 208 MW	Tuco 345 kV (525832)
GEN-2013-022	25	SMASC (524491)	Norton 115kV (524502)
GEN-2013-027	148.4	Siemens 2.3/2.415	Tap on Yoakum to Tolk 230kV (562480)
GEN-2014-033	70	17 X GE Prolec 4MVA, 2 X GE Prolec 1 MVA, & 5 X Schneider XC680 0.680 MVA PV inverter	Chaves County 115kV
GEN-2014-034	70	17 X GE Prolec 4MVA PVinverter	Chaves County 115kV
GEN-2014-035	30	8 X GE Prolec 4MVA PV inverter	Chaves County 115kV

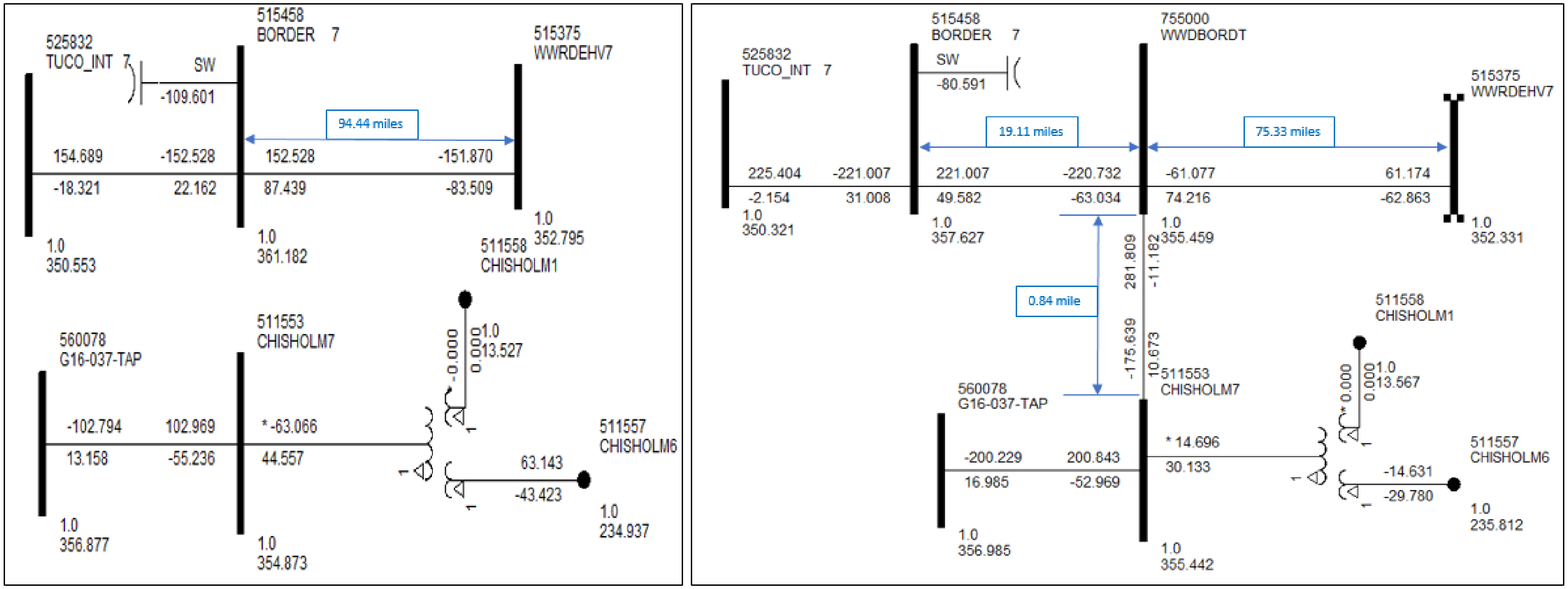
Request	Size (MW)	Generator Model	Point of Interconnection
GEN-2014-040	319.7	GE 2.3 MW	Castro 115 kV (524746)
GEN-2015-014	150.0	Vestas V110 2.0MW (584563)	Tap on Cochran – LG Plains 115kV (560030)
GEN-2016-177	17	Gas Turbine	XTO-Cornell 115 kV station

Table 2-3
Proposed Changes to Reactive Support near Border 345 kV

Equipment	Location	Existing Configuration	Configuration with Beckham County Project	Proposed Solution
Reactors	Tuco Line at Border	50 MVAR	50 MVAR	50 MVAR w/ automated controls
	Woodward EHV Line at Border	75 MVAR	N/A	-
	Woodward EHV Line at Beckham County	N/A	75 MVAR	75 MVAR w/ automated controls
Capacitors	Border 345 KV	275 MVAR	**Identified in this study**	**Identified in this study**
	Beckham County 345 kV	N/A	**Identified in this study**	**Identified in this study**

A power flow one-line diagram for the proposed topology changes is shown in Figure 2-1 and represents 2017 Winter Peak conditions when the NTC project would be in-service. The Stability Analysis determined the impacts of the changing the topology near Border and implementing the reactive support changes near Border on the stability and voltage recovery of the nearby system. If problems with stability or voltage recovery are identified, the need for reactive compensation or system upgrades were investigated. Three-phase faults and single line-to-ground faults were examined prior to any mitigation or curtailment implemented. With exception of transformers, the typical sequence of events for a three-phase fault is as follows (refer to Section 4 for a list and description of fault events analyzed):

- Apply fault at particular station
- Continue fault for five (5) cycles, clear the fault by tripping the faulted facility
- After an additional twenty (20) cycles, re-close the previous facility back into the fault
- Continue fault for five (5) additional cycles
- Trip the faulted facility and remove the fault



(i) (ii)

Figure 2-1. One-line diagram for the topology update for 2017 Winter Peak Conditions ((i) represents the previous topology and (ii) represents the updated topology near Border).

SECTION 3: POWER FLOW ANALYSIS

The objective of the power flow analysis was to determine the impacts to steady-state non-convergence, thermal flows, and voltages after changing the topology near Border and implementing the reactive support changes near Border. Following the implementation of the line reactor location changes as shown in Table 2-3, the analysis was performed with and without the shunt reactors in-service at Border 345 kV or Beckham County 345 kV.

3.1 Approach

MEPPI utilized the following seven (7) DISIS-2016-002-2 Group 06 power flow cases for this analysis:

- Steady-State Analysis
    - Year 1 (2017) Winter Peak (17WP)
    - Year 2 (2018) Spring (18G)
    - Year 2 (2018) Summer Peak (18SP)
    - Year 5 (2021) Light (21L)
    - Year 5 (2021) Summer Peak (21SP)
    - Year 5 (2021) Winter Peak (21WP)
    - Year 10 (2026) Summer Peak (26SP)

The power flow cases were dispatched in accordance with DISIS Manual, Table 1: Generation Dispatch in the Power Flow Models, and Business Practices 7250 that was applicable at the time of the DISIS-2016-002 study. Seven (7) Before Transfer (BC) cases were created by including the study requests but dispatched at 0 MW for ER dispatch scenarios. Seven (7) Transfer cases (TC) were created by including the study requests and dispatched at full output.

3.2 Steady-State Analysis Results

MEPPI performed a steady-state non-converged analysis on the seven (7) DISIS-2016-002-2 Group 06 power flow cases from Section 3.1. A non-converged event, loss of OKU (511456) to LES (511468) 345 kV line, was observed for 18SP (DIS1602TC06ALL-18SP2) and 21SP (DIS1602TC06ALL-21SP2) prior to the topology changes near Border 345 kV.

For the 18SP case, power flow converged after implementing the topology changes near Border 345 kV for the most limiting contingency - loss of OKU (511456) to LES (511468) 345 kV line.

For the 21SP case, power flow diverged for the loss of OKU (511456) to LES (511468) 345 kV line with the topology change near Border 345 kV and prior to the addition of any reactive support. It was determined that the power flow converges for the most limiting contingency - loss of OKU (511456) to LES (511468) 345 kV line for the following 4 possible mitigation options.

1. Installing 180 MVAR of capacitor banks at Border 345 kV only
2. Installing 225 MVAR of capacitor banks at Beckham 345 kV only
3. Installing 100 MVAR of capacitor banks at each Border 345 kV and Beckham 345 kV (200 MVAR total) with shunt reactors at Border 345 kV and Beckham 345 kV in-service
4. Installing 39 MVAR of capacitor banks at Border 345 kV and Beckham County 345 kV (78 MVAR total) with shunt reactors at Border 345 kV and Beckham 345 kV out-of-service

Refer to Table 3-1 for the complete set of steady-state non-converged analysis results for pre-fault conditions and for the results following the loss of the OKU – Tuco 345 kV line for each season. Refer to Table 3-2 for a summary of the mitigation and recommendations for reactive support at Border and Beckham County.

Table 3-1
Steady-State Analysis Results

Ref. No.	Case Name	Converge/Diverge	Voltage (p.u.) at Border 345 kV (515458)								
			Pre Fault (Base Case)		Loss of OKU (511456) to LES (511468) 345 kV line						
			Without Topology Upgrade	With Topology Upgrade (Border cap OFF)	Without Topology Upgrade (Border cap ON)	Without Topology Upgrade	With Topology Upgrade (Border cap OFF)	Topology Upgrade (only Border cap ON) MVAR	Topology Upgrade (only Beckham cap ON) MVAR	Topology Upgrade (Border/Beckham cap ON) MVAR	Topology Upgrade (Border/Beckham cap ON) MVAR
1	DIS1602TC06ALL-17WP2	Converge	1.0469	1.0202	1.0128	0.9762	0.9954				
		Diverge									
2	DIS1602TC06ALL-18G2	Converge	1.0429	1.0035	1.0046	0.9037	0.9464				
		Diverge									
3	DIS1602TC06ALL-18SP2	Converge	1.046	0.999	0.9592	Diverge	0.9278				
		Diverge									
4	DIS1602TC06ALL-21L2	Converge	1.0381	1.0059	1.003	0.9135	0.9441				
		Diverge									
5*	DIS1602TC06ALL-21SP2	Converge	1.049	0.9929	Diverge	Diverge	Diverge	0.9032	0.9000	0.9011	0.9004
		Diverge						180 MVAR	225 MVAR	200 MVAR Total (100 MVAR each)	78 MVAR Total 39 MVAR @ Border 39 MVAR @ Beckham*
6	DIS1602TC06ALL-21WP2	Converge	1.0434	1.0036	1.0038	0.9027	0.9457				
		Diverge									
7	DIS1602TC06ALL-26SP2	Converge	1.0491	1.0216	1.0203	0.9831	1.0054				
		Diverge									

Note: *Shunt reactors at Border and Beckham were turned off for the DIS1602TC06ALL-21SP2 case, there is a need of 78 MVARs at Border and Beckham

^Shunt reactors in service

^Shunt reactors out of service

Table 3-2
Summary of the Border 345 kV Area Recommendations

Equipment	Location	Existing Configuration	Configuration with Beckham County Project	Proposed Solution
Reactors	Tuco Line at Border	50 MVAR	0 MVAR	50 MVAR w/ automated controls
	Woodward EHV Line at Border	75 MVAR	N/A	N/A
	Woodward EHV Line at Beckham County	N/A	0 MVAR	75 MVAR w/ automated controls
Capacitors	Border 345 KV	275 MVAR	**39 MVAR**	39 MVAR w/ automated controls
	Beckham County 345 kV	N/A	**39 MVAR**	39 MVAR w/ automated controls

Based on the plausible mitigations, MEPPI recommends switching off the shunt reactors at Border 345 kV and Beckham County 345 kV, removing 275 MVAR capacitor bank at Border 345 kV, and installing 39 MVAR of capacitor banks at Border 345 kV and Beckham County 345 kV (specific size to be determined by transmission owner, i.e. 2 x 20 MVAR, 4 x 10 MVAR, etc.) with automated controls. Therefore, with the shunt reactors at Border and Beckham County out-of-service, it was determined that 39 MVAR of reactive support located at Border and Beckham County (78 MVAR total) would resolve the non-convergence event for the most limiting season (21SP).

Additionally, following this recommendation, it was determined there were no thermal constraints or voltage limitations resulting from the network upgrade near Border.

Refer to Table 3-3 for an estimated cost of installing the new capacitor banks and adding automated controls to the existing shunt reactors. Note for automated controls of the shunt reactors, the addition of a circuit breaker is assumed as part of the cost estimate but does not account for the cost of moving the existing shunt reactor on the Border to Woodward 345 kV line at Border to the new Beckham County substation. The costs presented in Table 3-3 are representative of SPP's standard costing estimates. A more detailed cost may be determined by each Transmission Owner and may differ slightly than those listed here.

Table 3-3
Summary of Cost Estimates

Network Upgrade Name	Equipment	Estimated Cost
50 MVAR Shunt Reactor w/ Automated Controls at Border	Add a 345 kV circuit breaker	$566,485
75 MVAR Shunt Reactor w/ Automated Controls at Beckham County	Add a 345 kV circuit breaker	$566,485
39 MVAR Capacitor Bank at Border 345 kV	Add 39 MVARs of capacitor banks	$968,409
39 MVAR Capacitor Bank at Beckham County 345 kV	Add 39 MVARs of capacitor banks	$968,409
	Total >>	**$3,069,488**

SECTION 4: STABILITY ANALYSIS

The objective of the stability analysis was to implement the solutions identified in the power flow analysis and analyze the impact of those changes on the stability and voltage recovery of the SPP transmission system. If problems with stability or voltage recovery were identified additionally mitigation would be considered.

4.1 Approach

MEPPI utilized the following three (3) DISIS-2016-002 power flow dynamic databases:

- MDWG16-17W_DIS16022
- MDWG16-18S_DIS16022
- MDWG16-26S_DIS16022

Each case was examined prior to the stability analysis to ensure the case contained the proposed study projects and any previously queued projects listed in Tables 2-1 and 2-2, respectively. The stability datasets were updated to reflect the topology changes identified in the power flow analysis. There was no suspect power flow data in the study area. The dynamic datasets were also verified and stable initial system conditions (i.e., “flat lines”) were achieved. Three-phase and single phase-to-ground faults listed in Table 4-1 were examined.

Table 4-1
Fault List with Contingency Description

Cont. No.	Cont. Name	Description
Border/Beckham/Chisholm Fault Events		
1	FLT01-3PH	3 phase fault on the Tuco (525832) to Border (515458) 345 kV line circuit 1, near Tuco. a. Apply fault at the Tuco 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
2	FLT02-3PH	3 phase fault on the Tuco (525832) to OKU (511456) 345 kV line circuit 1, near Tuco. a. Apply fault at the Tuco 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Cont. No.	Cont. Name	Description
3	FLT03-3PH	3 phase fault on the Tuco 345/230/13.8 kV (525832/525830/525824) transformer circuit 1, near Tuco 345 kV. a. Apply fault at the Tuco 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.
4	FLT04-3PH	3 phase fault on the Tuco (525830) to Tolk East (525524) 230 kV line circuit 1, near Tuco. a. Apply fault at the Tuco 230 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
5	FLT05-3PH	3 phase fault on the OKU (511456) to LES (511468) 345 kV line circuit 1, near OKU. a. Apply fault at the OKU 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line and remove the fault. c. Block the DC tie at OKU.
6	FLT06-3PH	3 phase fault on the OKU (511456) to LES (511468) 345 kV line circuit 1, near OKU. a. Apply fault at the OKU 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line and remove the fault.
7	FLT07-3PH	3 phase fault on the OKU (511456) to Oklaun (599891) 345 kV line circuit 1 (OKU DC tie), near OKU. a. Apply fault at the OKU 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line and remove the fault. c. Block the DC tie at OKU.
8	FLT08-3PH	3 phase fault on the Border (515458) to Beckham (755000) 345 kV line circuit 1, near Border. a. Apply fault at the Border 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
9	FLT09-3PH	3 phase fault on the Border (515458) to Tuco (525832) 345 kV line circuit 1, near Border. a. Apply fault at the Border 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.

Cont. No.	Cont. Name	Description
10	FLT10-3PH	3 phase fault on the Beckham (755000) to Border (515458) 345 kV line circuit 1, near Beckham. a. Apply fault at the Beckham 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
11	FLT11-3PH	3 phase fault on the Beckham (755000) to Woodward (515375) 345 kV line circuit 1, , near Beckham. a. Apply fault at the Beckham 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
12	FLT12-3PH	3 phase fault on the Beckham (755000) to Chisholm (511553) 345 kV line circuit, , near Beckham. a. Apply fault at the Beckham 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
13	FLT13-3PH	3 phase fault on the Chisholm (511553) to Beckham (755000) 345 kV line circuit 1, near Chisholm. a. Apply fault at the Chisholm 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
14	FLT14-3PH	3 phase fault on the Chisholm (511553) to G16-037-TAP (560078)) 345 kV line circuit 1, near Chisholm. a. Apply fault at the Chisholm 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted line. c. Wait 20 cycles, and then re-close the line in (b) back into the fault. d. Leave fault on for 5 cycles, then trip the line in (b) and remove fault.
15	FLT15-3PH	3 phase fault on the Chisholm (511553) to Chisholm (511557) to Chisholm (511558) 345 kV line circuit 1, near Chisholm. a. Apply fault at the Tuco 345 kV bus. b. Clear fault after 5 cycles by tripping the faulted transformer.

Bus voltages, machine rotor angles, and previously queued generation in the study area were monitored in addition to bus voltages and machine rotor angles in the following areas:

- 520 AEPW
- 524 OKGE
- 525 WFEC
- 526 SPS
- 531 MIDW
- 534 SUNC
- 536 WERE
- 540 GMO
- 541 KCPL

Requested and previously queued generation outside the above study area were also monitored.

4.2 Stability Analysis Results

The Stability Analysis determined that all NERC Category P1 contingencies resulted in system stability and acceptable voltage and rotor angle recovery for all scenarios examined. However, several NERC Category P1 events that include outage of the Border to Beckham 345 kV line resulted in high post-fault steady-state voltages when 39 MVAR of reactive support at Border was online. When the 39 MVAR reactive support at Border 345 kV substation was switched out-of-service, the voltage at Border 345 kV substation was observed to settle within an acceptable voltage range.

Refer to Tables 4-1 for a summary of the Stability Analysis results for the contingencies listed in Table 4-1. Tables 4-1 is a summary of the stability results for the 2017 Winter Peak, 2018 Summer Peak, and 2026 Summer Peak conditions whether the system remained stable, if generation tripped offline, if acceptable voltage recovery was observed after the fault was cleared, and if the voltage recovered to above 0.9 p.u. and below 1.1 p.u. post fault steady-state conditions. Voltage recovery criteria includes ensuring that the transient voltage recovery is between 0.7 p.u. within 2.5 seconds after the fault is cleared and 1.2 p.u. at any point after the fault is cleared and ending in a steady-state voltage (for N-1 contingencies) at the pre-contingent level or at least above 0.9 p.u. and below 1.1. p.u.

Table 4-2
Stability Analysis Summary of Results for 2017 Winter, 2018 Summer, and 2026 Summer Peak Conditions

Cont. No.	Cont. Name	2017 Winter Peak				2018 Summer Peak				2026 Summer Peak			
		Voltage Recovery		Post Fault Steady-State Voltage	System Stability	Voltage Recovery		Post Fault Steady-State Voltage	System Stability	Voltage Recovery		Post Fault Steady-State Voltage	System Stability
		Less than 0.7 p.u.	Greater than 1.2 p.u.			Less than 0.7 p.u.	Greater than 1.2 p.u.			Less than 0.7 p.u.	Greater than 1.2 p.u.		
1	FLT01-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
2	FLT02-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
3	FLT03-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
4	FLT04-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
5	FLT05-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
6	FLT06-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
7	FLT07-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
8	FLT08-3PH	-	-	V > 1.1 pu	Stable	-	-	V > 1.1 pu	Stable	-	-	V > 1.1 pu	Stable
9	FLT09-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
10	FLT10-3PH	-	-	V > 1.1 pu	Stable	-	-	V > 1.1 pu	Stable	-	-	V > 1.1 pu	Stable
11	FLT11-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
12	FLT12-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
13	FLT13-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
14	FLT14-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable
15	FLT15-3PH	-	-	Compliant	Stable	-	-	Compliant	Stable	-	-	Compliant	Stable

For all events analyzed, it was determined there was system stability and acceptable voltage recovery after changing the topology near Border and implementing the reactive support changes near Border. Voltage stability is maintained for pre-existing conditions and study request for changing the topology near Border and implementing the reactive support changes near Border for 2017 Winter Peak, 2018 Summer Peak, 2026 Summer Peak conditions.

System stability and acceptable voltage recovery was observed for all NERC Category P1 faults for all study years/seasons with changing the topology near Border and implementing the reactive support changes near Border. Refer to Figure 4-1 for a representative voltages response near Border for FLT08-3PH for 2018 Summer Peak Conditions, showing that system stability is maintained, and all voltages recover within SPP Performance Criteria. FLT08-3PH is a three-phase fault on the Border (515458) to Beckham (755000) 345 kV line circuit #1.

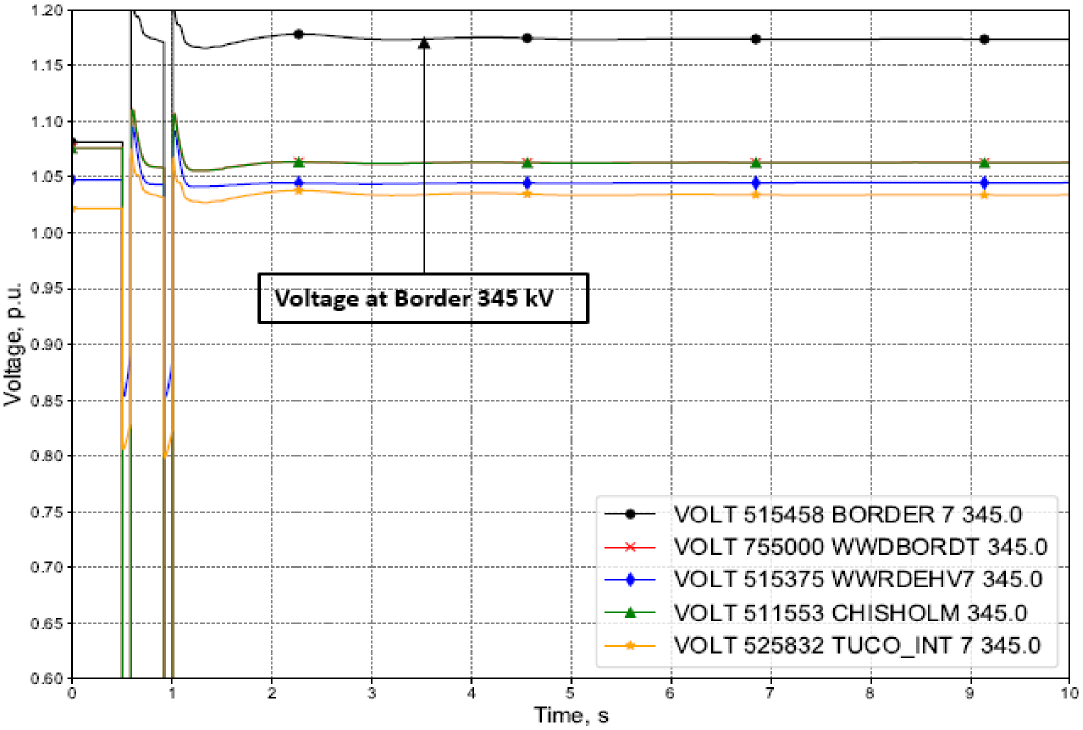


Figure 4-1: Representative plot of voltages near Border 345 kV for 2018 Summer Peak conditions for contingency FLT08-3PH.

As observed in Table 4-2, system stability is present in all study seasons/years. The results and figures discussed in this section represent the 2017 Winter Peak case but are indicative of all study years/seasons. For the following fault combinations, high post-faut steady-state voltage (less than 1.2 p.u.) at Border 345 kV substation is observed for the following events:

- FLT08-3PH: Outage of Border (515458) to Beckham (755000) 345 kV line circuit 1
- FLT10-3PH: Outage of Beckham (755000) to Border (515458) 345 kV line circuit 1

It was observed that a high post-fault steady-state voltage exists at Border 345 kV following the loss of Border to Beckham County 345 kV. Although the voltage does not exceed SPP Performance Criteria, the post-fault steady-state voltage above 1.1 p.u. may cause concern. It should be noted that following potential operator interaction, switching off the 39 MVAR reactive support at Border following the event will reduce the voltage at Border to within acceptable range. Refer to Figure 4-2 for representative plots of the voltage at Border 345 kV for FLT08-3PH. It is observed that with 39 MVAR reactive support at Border switched out-of-service at 6 seconds (5 seconds following fault clear), the Border 345 kV voltage is maintained within normal operating voltages. It is recommended that the transmission owner reviews the voltage limitations at Border and determine if the proposed actions (switching out the capacitor bank) are attainable.

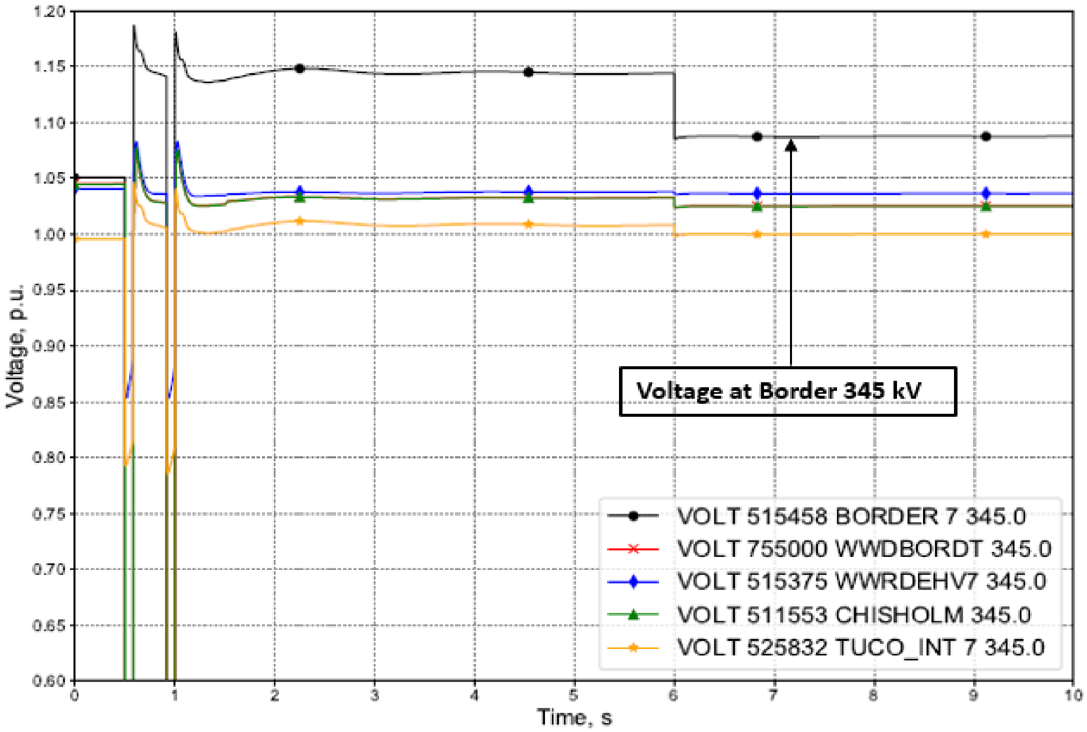


Figure 4-2: Representative plot of voltages near Border 345 kV for 2017 Winter Peak conditions for contingency FLT08-3PH with capacitor bank switching.

SECTION 5: CONCLUSIONS

SUMMARY OF POWER FLOW ANALYSIS

The power flow analysis determined the amount of reactive support that would be required at Border and Beckham County to resolve the non-converged contingency with the inline reactors out-of-service at Border and Beckham County. It was determined that 39 MVAR of reactive support located at Border and Beckham County (78 MVAR total) would resolve the non-converged event and is an acceptable form of mitigation for all seasons and conditions analyzed.

SUMMARY OF STABILITY ANALYSIS

The stability analysis determined that there were no contingencies in any of the seasonal cases that resulted in system instability or poor post-fault voltage recovery with the NTC Border project and power flow analysis solution (39 MVAR of capacitor banks at Border 345 kV and Beckham County 345 kV and shunt reactors at Border 345 kV and Beckham County 345 kV offline) applied to the cases.

APPENDIX A: PLOTS FOR 2017 WINTER PEAK CONDITIONS

17WP.pdf

APPENDIX B: PLOTS FOR 2018 SUMMER PEAK CONDITIONS

18SP.pdf

APPENDIX C: PLOTS FOR 2026 SUMMER PEAK CONDITIONS

26SP.pdf