



SPP 2013 TPL Dynamic Stability Study

Approved by Transmission Working Group: December 18, 2013

Engineering
R&D and Special Studies

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Introduction

The objective of this study is to report findings from the 2013 Stability Compliance Assessment process to support compliance with NERC TPL- 001, TPL- 002, TPL-003, and TPL-004 Reliability Standards for future years 2014 and 2019. This report along with the Near-Term and Long-Term Load Flow Assessments will help fulfill requirements of applicable TPL Standards.

This report will summarize potential transient stability violations anticipated by SPP and the applicable mitigation plans developed by SPP Member Entities and SPP Engineering Staff.

A separate, comprehensive report will be issued detailing the 2012 Transmission Planning Compliance Statement for each TPL Standard. These statements will address how each requirement defined in the TPL Standards is fulfilled by one or more mechanism in the TPL Near-Term or Longer-Term Compliance Assessments.

Study Scope

Compliance with TPL Standards with respect to system stability requires that the following be completed:

- **Fast Fault Screening and Dynamic Assessment**

Perform a Fast Fault Screening analysis of the SPP Transmission System on the MDWG 2013 Series 2014 Light Load and 2019 Summer Peak Case and provide a list of potential severe fault locations, their ranking, and fault sequences for all potential category B, C, and D contingencies. Perform transient stability analysis on those screened contingencies with computed critical clearing times less than 9 cycles for both the 2014 and 2019 case.

Compute the critical clearing time for all member-submitted contingencies for both the 2014 and 2019 cases.

- **Dynamic Assessment of Member Specified Events**

SPP Members provided SPP Staff with a list, shown in Table 4 of Appendix A, of thirty-eight (38) NERC Category B, C and D reliability events for transient stability performance analysis. Complete this analysis for both the 2014 Light Load and 2019 Summer Peak Cases.

- **Mitigation of Unstable Events**

Determine mitigation measures for any events found to be unstable that will, by implementation, provide system stability.

Methodology

Fast Fault Screening and Dynamics Analysis

The Fast Fault Screening (FFS) tool in the POM-TS application screens potential transmission fault locations for grid stability analysis and quickly identifies the most severe locations and ranks them in the order of severity. The tool begins by identifying the most severe fault locations within the entire SPP footprint based on the most recent MDWG models (above 100kV). The tool identifies buses which are considered relative weak points in the system. Faults at each of the identified locations are then ranked according to severity using a Ranking Index (RI) for category B, C, and D contingencies. The fault severity is classified as:

- Most severe are the faults that lead to steady-state stability violation (e.g., post-fault regime does not exist);
- The next level of severity are faults leading to large loss of generation;
- The rest of the locations are ranked based on the Ranking Index.

Once the RI is known, the critical clearing time (CCT) is computed. The Critical Clearing Time is the maximum time during which a disturbance can be applied without the system losing its transient stability (e.g., difference between post-fault and pre-fault rotor angle exceeds 180 degrees). Details on the methodology are given in [1]. The RI and CCT are used as metrics to determine fault locations needing further examination.

Transient stability analysis was performed on ranked contingencies having a steady state stability violation, a loss of generation, or a critical clearing time of 9 cycles or using PTI's PSS/E Dynamics Package and the PSSPLT Plotting Package. Generator rotor speed, rotor angle, real power, and reactive power output were monitored for all SPP generators. Those generators exhibiting rotor speed and angle instability were marked for further analysis. This analysis consisted of determining and correcting the cause of instability and is further detailed in Appendix B of this report.

Some events necessitated a change in generation differing from that amount in the powerflow models. In such cases, an offset amount was included to balance generation prior to event simulation.

Member Specified Events

These events were simulated in PTI's PSS/E Dynamics Package and the PSSPLT Plotting Package. Generator rotor speed, rotor angle, real power, and reactive power output were monitored for all SPP generators. Those generators exhibiting rotor speed and angle instability were marked for further analysis. This analysis consisted of determining and correcting the cause of instability and is further detailed in Appendix B of this report.

Some events necessitated a change in generation differing from that amount in the powerflow models. In such cases, an offset amount was included to balance generation prior to event simulation.

[1] [1] M. Y. Vaiman, A. Gaikwad, "Fast Fault Screening Methodology for Transient Stability Analysis of Bulk Power Systems", Presented at 2013 IEEE Power and Energy General Meeting, pp:1-5.

Results

Fast Fault Screening (FFS)

The screening identified eighteen (18) severe fault locations for the 2014 Light Load case and nineteen (19) for the 2019 Summer case. These locations (buses) were ranked according to their Ranking Index (RI) and Critical Clearing Time (CCT) for NERC category B, C, and D contingencies. The results are shown in Appendix A, Tables 1, 2, and 3. The outaged elements associated with each fault are shown in Appendix C, Tables 6 through 11.

Transient Stability Analysis of Most Severe FFS Events

The list of faults identified in the FFS was narrowed for time domain analysis by selecting those faults having a steady state stability violation, a loss of generation, or a critical clearing time of 9 cycles or less. These are identified in Appendix A, Tables 1, 2, and 3 in **bold red** text. As shown, four (4) Category B, six (6) Category C, and twelve (12) Category D faults were selected for transient stability analysis. These were simulated in PSS/E's dynamics package, the results of which are shown in Appendix B, Table 5.

Event FFS-2014LL-C3 caused the WOLFCREEK unit to be unstable when a fault occurs on the WOLKREEK 345kV bus with a prior outage on the LACYGNE or BENTON 345kV line and one other line is outaged. This event has been previously identified and an existing operating guide is in place to limit the WOLFCREEK output to 800MW for the loss of a 345 kV line.

Event FFS-2014LL-C4 caused the IATAN units to be unstable when a fault occurs on the IATAN 345kV bus with a prior outage on the STRANGER CREEK or EASTOWN 345kV line and one

other line is outaged. Therefore, an operating guide is needed such that the prior outage of the IATAN - STRANGER CREEK 345kV or the IATAN – EASTOWN 345kV line will necessitate the combined output of the IATAN units be curtailed to a maximum net output of 715 MW, which is the emergency rating of the IATAN 345/161kV transformer. This action will protect the units from instability in the event of the fault and trip of the remaining 345kV line. The owners are developing an operating-guide to ensure stability.

Member Specified Events

The CCT was computed for the list of member specified events using the FFS tool and the results are shown in Appendix A, table 4. These may be compared with actual relay clearing times. The table also shows that for both the 2014 Light Load and 2019 Summer Peak Cases, members provided six (6) Category B, eighteen (18) Category C, and fourteen (14) Category D events for examination. All thirty-eight (38) events were found to be stable. It is noted that any category D events showing instability were made stable by disconnecting the unstable generator(s) according to allowable NERC TPL mitigation practices.

Conclusion

The MDWG 2013 Series 2014 Light Load and 2019 Summer Peak Load Cases were tested and found to be stable during normal conditions prior to this study, satisfying NERC TPL Category A requirements. The Category B events specified in Appendix B, tables 1 and 4, were found to be stable, satisfying NERC TPL Category B requirements. Category C, Event FFS-2014LL-C3, confirms the need for an existing operating guide and Category C, Event FFS-2014LL-C4, requires a new operating guide, which the owners will develop. The remainder of the Category C events specified in Appendix B, tables 2 and 4 were found to be stable. NERC TPL Category C requirements are thereby satisfied. All unstable, member specified events shown in Appendix B, Tables 3 and 5 were found to be stable when the specified mitigation measures were applied, thereby satisfying NERC TPL Category D requirements. .

APPENDIX A - Events

Table 1: NERC Category B, Fast Fault Scan Results

14LL Event	Faulted Bus Number	Faulted Bus Number	RI	CCT (cy)	19SUM Event	Faulted Bus Number	Faulted Bus Name	RI	CCT (cy)
FFS-14LL-B1	500250	DOLHILL7	23.55	4.2	FFS-19SUM-B1	507789	STLGENS4	18.59	Loss of Gen 496 MW
FFS-14LL-B2	532797	WOLFCRK7	21.74	4.2	FFS-19SUM-B2	500250	DOLHILL7	17.99	4.8
FFS-14LL-B3	549954	JTEC 5	19.33	7.2	FFS-19SUM-B3	500770	RODEMR 6	14.73	8.4
FFS-14LL-B4	549969	BROOKLINE 5	15.04	7.8	FFS-19SUM-B4	507454	TURK 4	12.66	8.4
FFS-14LL-B5	542982	IATAN 7	11.01	12.6	FFS-19SUM-B5	500020	ACADIA 4	10.11	9.6
FFS-14LL-B6	500770	RODEMR 6	10.55	12	FFS-19SUM-B6	510396	N.E.S.-4	6.52	10.8
FFS-14LL-B7	512650	GRDA1 7	8.02	11.4	FFS-19SUM-B7	503902	FITZHUGH 5	5.78	12
FFS-14LL-B8	532853	LAWHILL6	5.92	12	FFS-19SUM-B8	510406	N.E.S.-7	5.43	11.4
FFS-14LL-B9	645458	S3458 3	5.02	13.8	FFS-19SUM-B9	512656	GRDA1 5	4.91	12
FFS-14LL-B10	645451	S3451 3	3.95	15	FFS-19SUM-B10	507760	SW SHV 7	4.05	15
FFS-14LL-B11	542995	MONTROS 5	3.75	15	FFS-19SUM-B11	500230	COUGH 4	4.03	14.4
FFS-14LL-B12	507454	TURK 4	3.74	15	FFS-19SUM-B12	500880	VILPLT 6	3.48	15
FFS-14LL-B13	542968	STILWEL7	2.78	15	FFS-19SUM-B13	500820	TECHE 4	3.37	14.4
FFS-14LL-B14	508583	ESTGEN4	2.58	15	FFS-19SUM-B14	508583	ESTGEN4	2.49	15
FFS-14LL-	532766	JEC N 7	2.49	15	FFS-19SUM-	509800	36LEWIS4	1.25	15

B15					B15				
FFS-14LL-B16	542969	STILWEL5	2.06	15	FFS-19SUM - B16	511437	COMANC-4	-0.02	14.4
FFS-14LL-B17	541250	SIBLEYPL	-0.72	15	FFS-19SUM - B17	510380	DELWARE7	-0.22	20.4
FFS-14LL-B18	510406	N.E.S.-7	-1.18	15	FFS-19SUM - B18	500360	FRONTST6	-0.49	20.4
					FFS-19SUM - B19	500720	PLAISAN4	18.59	20.4

Table 2: NERC Category C, Fast Fault Scan Results

14LL Event	Faulted Bus Number	Faulted Bus Number	RI	CCT (cy)	19SUM Event	Faulted Bus Number	Faulted Bus Name	RI	CCT (cy)
FFS-14LL-C1	500250	DOLHILL7		Loss of Gen 638 MW	FFS-19SUM-C1	500250	DOLHILL7		Loss of Gen 580 MW
FFS-14LL-C2	508583	ESTGEN4		Loss of Gen 155 MW	FFS-19SUM-C2	500020	ACADIA 4		Loss of Gen 580 MW
FFS-14LL-C3	532797	WOLFCRK7	37.0	0.6	FFS-19SUM-C3	507789	STLGENS4		Loss of Gen 496 MW
FFS-14LL-C4	542982	IATAN 7	32.27	1.2	FFS-19SUM-C4	508583	ESTGEN4		Loss of Gen 155 MW
FFS-14LL-C5	549954	JTEC 5	28.6	6.6	FFS-19SUM-C5	500770	RODEMR 6	18.84	7.8
FFS-14LL-C6	549969	BROOKLINE 5	15.14	7.8	FFS-19SUM-C6	507454	TURK 4	16.36	6.6
FFS-14LL-C7	500770	RODEMR 6	11.26	12	FFS-19SUM-C7	510396	N.E.S.-4	11.21	10.8
FFS-14LL-C8	532853	LAWHILL6	11.19	10.2	FFS-19SUM-C8	510406	N.E.S.-7	10.24	10.8
FFS-14LL-C9	512650	GRDA1 7	8.50	10.8	FFS-19SUM-C9	503902	FITZHUGH 5	7.76	11.4
FFS-14LL-C10	542995	MONTROS5	6.61	15	FFS-19SUM-C10	512656	GRDA1 5	5.73	12
FFS-14LL-C11	645458	S3458 3	6.30	13.2	FFS-19SUM-C11	507760	SW SHV 7	5.39	15
FFS-14LL-C12	507454	TURK 4	5.57	15	FFS-19SUM-C12	500230	COUGH 4	4.59	14.4
FFS-14LL-C13	532766	JEC N 7	4.28	15	FFS-19SUM-C13	500820	TECHE 4	4.53	14.4
FFS-14LL-C14	645451	S3451 3	4.04	15	FFS-19SUM-C14	500880	VILPLT 6	4.03	15
FFS-14LL-C15	542968	STILWEL7	2.82	15	FFS-19SUM-C15	509800	36LEWIS4	2.49	15

FFS-14LL-C 16	510406	N.E.S.-7	2.57	15	FFS-19SUM - C16	511437	COMANC-4	2.44	14.4
FFS-14LL-C 17	542969	STILWEL5	2.02	20.4	FFS-19SUM - C17	510380	DELWARE7	-.06	20.4
FFS-14LL-C 18	541250	SIBLEYPL	0.48	15	FFS-19SUM - C18	500360	FRONTST6	-.22	20.4
					FFS-19SUM - C19	500720	PLAISAN4	-1.21	20.4

Table 3: NERC Category D, Fast Fault Scan Results

14LL Event	Faulted Bus Number	Faulted Bus Number	RI	CCT (cy)	19SUM Event	Faulted Bus Number	Faulted Bus Name	RI	CCT (cy)
FFS-14LL-D1	532797	WOLFCRK 7		Loss of Gen 1283 MW					
FFS-14LL-D 2	500770	RODEMR 6		Loss of Gen 1030 MW	FFS-19SUM - D 2	500770	RODEMR 6		Loss of Gen 1469 MW
FFS-14LL-D 3	542982	IATAN 7		Loss of Gen 950 MW	FFS-19SUM - D 3	510396	N.E.S.-4		Loss of Gen 852 MW
FFS-14LL-D 4	500250	DOLHILL7		Loss of Gen 638 MW	FFS-19SUM - D 4	500250	DOLHILL7		Loss of Gen 638 MW
FFS-14LL-D 5	645451	S3451 3		Loss of Gen 528 MW	FFS-19SUM - D 5	500020	ACADIA 4		Loss of Gen 580 MW
FFS-14LL-D 6	512650	GRDA1 7		Loss of Gen 490 MW	FFS-19SUM - D 6	507789	STLGENS4		Loss of Gen 496 MW
FFS-14LL-D 7	532766	JEC N 7		Loss of Gen 390 MW	FFS-19SUM - D 7	500820	TECHE 4		Loss of Gen 280 MW
FFS-14LL-D 8	532853	LAWHILL6		Loss of Gen 341 MW	FFS-19SUM - D 8	511437	COMANC-4		Loss of Gen 168 MW
FFS-14LL-D 9	542995	MONTRO S5		Loss of Gen 261 MW	FFS-19SUM - D 9	508583	ESTGEN4		Loss of Gen 155 MW
FFS-14LL-D 10	549954	JTEC 5		Loss of Gen 230 MW	FFS-19SUM - D 10	510406	N.E.S.-7	10.24	10.8
FFS-14LL-D 11	508583	ESTGEN4		Loss of Gen 155 MW	FFS-19SUM - D 11	512656	GRDA1 5	10.19	11.4
					FFS-19SUM - D 12	503902	FITZHUGH 5	7.76	11.4
FFS-14LL-D 13	549969	BROOKLINE 5	15.78	7.8	FFS-19SUM - D 13	500230	COUGH 4	6.5	14.4
FFS-14LL-D 14	645458	S3458 3	8.59	12.6	FFS-19SUM - D 14	507760	SW SHV 7	6.1	15

FFS-14LL-D 15	542968	STILWEL7	3.08	15	FFS-19SUM - D 15	500880	VILPLT 6	4.03	15
FFS-14LL-D 16	510406	N.E.S.-7	2.57	15	FFS-19SUM - D 16	509800	36LEWIS4	2.49	15
FFS-14LL-D 17	541250	SIBLEYPL	2.15	15	FFS-19SUM - D 17	510380	DELDWARE 7	-.06	20.4
FFS-14LL-D 18	542969	STILWEL5	2.02	20.4	FFS-19SUM - D 18	500360	FRONTST6	-.22	20.4
					FFS-19SUM - D 19	500720	PLAISAN4	-1.21	20.4

Table 4: Member Submitted NERC Category B, C, and D Events

Event	Contingency	Results
B14	3-Ø fault at S3451 on T3 transformer. Normal clearing.	Stable
B16	3-Ø fault at S1206 on the S1206-S1232 line. Normal clearing.	Stable
B19	N01A: 3PH fault at GGS on GGS-Sweetwater 345 kV Circuit #1; Normal clearing; No reclose attempts	Stable
B20	N07A: 3PH fault at GGS on GGS-Red Willow 345 kV; Normal clearing; No reclose attempts.	Stable
B21	N25A: 3PH fault at GGS on GGS-North Platte 230 kV Circuit #1; Normal clearing; No reclose attempts.	Stable
B22	3PH fault at GGS on high side of GGS 345/230 kV T-1 transformer; Normal clearing; No reclose attempts.	Stable
C1	Prior outage of JEC-Auburn 230kV line; 3-Ø fault at JEC 345 kV for 3.6 cycles; Trip JEC-Hoyt line; No reclosing.	Stable
C5	3-Ø fault at Wolf Creek 345 kV for 3.6 cycles; Trip Wolf Creek-Benton line; No reclosing; Reduce Wolf Creek output to 800 MW (Transmission Operating Directive 300); 3-Ø fault for 3.6 cycles at Wolf Creek 345 kV; Trip Wolf Creek-LaCygne line; No reclosing	Stable

Event	Contingency	Results
C10	3-Ø fault at Wolf Creek 345 kV for 3.6 cycles; Trip Wolf Creek-LaCygne 345 kV line; No reclosing; Reduce Wolf Creek output to 800 MW (Transmission Operating Directive 302); 3-Ø fault at Wolf Creek 345 kV for 3.6 cycles; Trip Wolf Creek-Benton 345 kV; No reclosing.	Stable
C12	SLG fault at the S3451 end of the S3451-Raun line, followed by a stuck breaker and the opening of transformer T4 at S3451. Fault Admittance 576 - j 6089 MVA for 2014LL and 578 - j 6099 MVA for 2019SP for initial fault. Fault Admittance 450 - j 5339 MVA for 2014LL and 451 - j 5350 MVA for 2019SP after opening S3451-Raun.	Stable
C14	N915: SLG fault at GGS on GGS-Sweetwater 345 kV Circuit #2, Stuck Breaker (GGS 3322), Drop GGS-Red Willow 345 kV line; Delayed clearing; No reclose attempts.	Stable
C25	3-Ø fault at Wolf Creek for 3.6 Cycles; Trip Wolf Creek-Rose Hill line; No reclosing; Reduce Wolf Creek output to 800 MW (Transmission Operating Directive 301); 3-Ø fault at Wolf Creek 345 kV for 3.6 cycles; Trip Wolf Creek-LaCygne line; No reclosing	Stable
C28	Prior outage of Muskogee - Fort Smith 345 kV; 3-phase fault and trip Valliant - Lydia 345 kV.	Stable
C29	Prior outage of Diana - SW Shreveport 345 kV; 3-phase fault and trip Wilkes - Longwood 345 kV.	Stable
C30	Prior outage of Welsh - Lydia 345 kV; 3-phase fault and trip Welsh - NW Texarkana 345 kV. Welsh generation at Pmax.	Stable
C31	Prior outage of Dolet Hills - Carroll 230 kV; 3-phase fault and trip Dolet Hills - SW Shreveport 345 kV. Dolet Hills Plant at Pmax.	Stable
C32	Prior outage of Flint Creek Generator; 3-phase fault and trip GRDA1 - Flint Creek 345 kV.	Stable
C33	3-Ø fault and trip Welsh - Wilkes / Welsh - NW Texarkana 345 kV DCT. Welsh generation at Pmax.	Stable

Event	Contingency	Results
C34	3-Ø fault and trip Diana - SW Shreveport / Longwood - SW Shreveport 345 kV DCT	Stable
C35	Phase-to-ground fault Welsh - NW Texarkana 345 kV with CB (#10610) failure at Welsh. 15-cycle delayed clearing removing Welsh - Wilkes 345 kV. Welsh generation at Pmax.	Stable
C36	Phase-to-ground fault Wilkes - Longwood 345 kV with CB (#1W10) failure at Wilkes. 15-cycle delayed clearing removing Wilkes - Welsh 345 kV. Wilkes generation at Pmax.	Stable
C47	SLG Fault on Knoll-Post Rock 230 kV line with breaker failure of 6002 (clears the Knoll 230/115 kV transformer and Knoll-Smoky Hill 230 kV line)	Stable
C48	SLG fault on Heizer 230/115 kV transformer with normal clearing followed by three phase fault on Heizer-Great Bend 115 kV	Stable
C49	SLG fault on Heizer 230/115 kV transformer with normal clearing followed by three phase fault on Heizer-Great Bend 115 kV	Stable
D9	3-Ø fault at the S3451 on T3 transformer, followed by a stuck breaker and the opening of the S3451-S3459 line.	Stable
D10	3-Ø fault at S3458 on the S3458 - Cooper line, followed by a stuck breaker and the opening of the west bus at S3458.	Stable
D22	Loss of Knoll 115kV Substation.	Stable
D23	Loss of Heizer 115 KV Substation.	Stable
D27	Loss of Wolf Creek 345 kV Substation.	Stable
D28	3-Ø fault Welsh - NW Texarkana 345 kV with CB (#10610) failure at Welsh. 15-cycle delayed clearing removing Welsh - Wilkes 345 kV. Welsh generation at Pmax.	Stable
D29	3-Ø fault Wilkes - Longwood 345 kV with CB (#1W10) failure at Wilkes. 15-cycle delayed clearing removing Wilkes - Welsh 345 kV. Wilkes generation at Pmax.	Stable
D30	3-Ø fault and trip NW Texarkana 345 kV Station.	Stable

Event	Contingency	Results
D31	3-Ø fault and trip Flint Creek 161 kV Station.	Stable
D32	3-Ø fault and trip Diana 345 kV Station.	Stable
D33	3-Ø fault and trip Welsh 345 kV Station.	Stable
D53 ¹	Loss of Woodward District EHV Bus	Stable
D54 ¹	Loss of Mustang Bus	Stable
D55 ¹	Loss of Pleasant Valley Bus	Stable

APPENDIX B - Results

Table 5: Fast Fault Screening Unstable Events

Event	Faulted Bus Number	Faulted Bus Name	CCT	Simulation Result	Mitigation Required for Stability
FFS-14LL- C 3	532797	WOLFCRK7	0.6	Unstable	None. Existing operating guide provides mitigation
FFS-14LL- C 4	542982	IATAN 7	1.2	Unstable	New operating guide required

APPENDIX C – Outaged Branches

Table 6: 2014LL, NERC Category B Outaged Branches

14LL Event	Faulted Bus	Outaged Branch
FFS-14LL-B1	DOLHILL7	DOLHILL7 345 - SW SHV 7 345 1
FFS-14LL-B2	WOLFCRK7	WOLFCRK7 345 - LACYGNE7 345 1
FFS-14LL-B3	JTEC 5	JTEC 5 161 - SW DISP PLT 5 161 1
FFS-14LL-B4	BROOKLINE 5	SPRGFLD5 161 - BROOKLINE 5 161 1
FFS-14LL-B5	IATAN 7	STRANGR7 345 - IATAN 7 345 1
FFS-14LL-B6	RODEMR 6	RAPIDES6 230 - RODEMR 6 230 1
FFS-14LL-B7	GRDA1 7	GRDA1 7 345 - TONECE 7 345 1
FFS-14LL-B8	LAWHILL6	LAWHILL6 230 - LAWHILL1 13.8 - LWRNCHL3 115 1
FFS-14LL-B9	S3458 3	S3458 3 345 - 103&ROKEBY3 345 1
FFS-14LL-B10	S3451 3	RAUN 3 345 - S3451 3 345 1
FFS-14LL-B11	MONTROS5	5CLINTN 161 - MONTROS 5 161 1
FFS-14LL-B12	TURK 4	TURK 4 138 - TURK 7 345 - TURK 1 13.8 1
FFS-14LL-B13	STILWEL7	PECULR7 345 - STILWEL7 345 1
FFS-14LL-B14	ESTGEN4	NTXEAST4 138 - ESTGEN4 138 1
FFS-14LL-B15	JEC N 7	JEC N 7 345 - MORRIS 7 345 1
FFS-14LL-B16	STILWEL5	STILWEL5 161 - REDEL 5 161 1

FFS-14LL-B17	SIBLEYPL	DUNCAN 5 161 - SIBLEYPL 161
FFS-14LL-B18	N.E.S.-7	T.N.O. --7 345 - N.E.S. - 7 345 1

Table 7: 2019SUM, NERC Category B Outaged Branches

19Summ Event	Faulted Bus	Outaged Branch
FFS-19SUM-B1	STLGENS4	ARSHILL4 138 - STLGENS4 138 1
FFS-19SUM -B2	DOLHILL7	DOLHILL7 345 - SW SHV 7 345 1
FFS-19SUM -B3	RODEMR 6	COLFAX6 230 - RODEMR 6 230 1
FFS-19SUM -B4	TURK 4	TURK 4 138 - TURK 7 345 - TURK 1 13.8 1
FFS-19SUM -B5	ACADIA 4	8RICHARD 500 - ACADIA 4 138 2
FFS-19SUM -B6	N.E.S.-4	RICE CK4 138 - N.E.S. -4 138 1
FFS-19SUM -B7	FITZHUGH 5	FITZHUGH 5 161 - HELBERG5 161 1
FFS-19SUM -B8	N.E.S.-7	DELAWARE7 345 - N.E.S-7 345 1
FFS-19SUM -B9	GRDA1 5	MAID 5 161 - GRDA1 5 161 1
FFS-19SUM -B10	SW SHV 7	SW SHV 4 138 - SW SHV 7 345 - SWSHV2-1 13.8 2
FFS-19SUM -B11	COUGH 4	COUGH 4 138 - PLAISAN4 138 1
FFS-19SUM -B12	VILPLT 6	VILPLT 6 230 - WSTFORK6 230 1
FFS-19SUM -B13	TECHE 4	BSALES 4 138 - TECHE 4 138 1
FFS-19SUM -B14	ESTGEN4	NTXEAST4 138 - ESTGEN4 138 2
FFS-19SUM -B15	36LEWIS4	52DELTP4 138 - 36LEWIS4 138 1
FFS-19SUM -B16	COMANC-4	COMANC-4 138 - 112GORE4 138 1

FFS-19SUM -B17	DELWARE7	DELWARE7 345 - NEOSHO 7 345 1
FFS-19SUM -B18	FRONTST6	6SLIDEL 230 - FRONTST6 230 1
FFS-19SUM -B19	PLAISAN4	4CHAMPNE 138 - PLAISAN4 138 1

Table 8: 2014LL, NERC Category C Outaged Branches

14LL Event	Faulted Bus	Outaged Branch
FFS-14LL-C1	DOLHILL7	DOLHILL7 345 - SW SHV 7 345 1 DOLHILL7 345 - DOLHILL6 230 1
FFS-14LL-C2	ESTGEN4	NTXEAST4 138 - ESTGEN4 138 1 NTXEAST4 138 - ESTGEN4 138 2
FFS-14LL-C3	WOLFCRK7	WOLFCRK7 345 - LACYGNE7 345 1 ROSEHIL7 345 - WOLFCRK7 345 1
FFS-14LL-C4	IATAN 7	STRANGR7 345 - IATAN 7 345 1 EASTOWN7 345 - IATAN 7 345 1
FFS-14LL-C5	JTEC 5	JTEC 5 161 - SW DISP PLT 5 161 1 JTEC 5 161 - BROOKLINE 5 161 1
FFS-14LL-C6	BROOKLINE 5	SPRGFLD5 161 - BROOKLINE 5 161 1 JUNCTION 5 161 - BROOKLINE 5 161 1
FFS-14LL-C7	RODEM6	RAPIDES6 230 - RODEMR 6 230 1 HINSTON 6 230 - RODEMR 6 230 1
FFS-14LL-C8	LAWHILL6	LAWHILL6 230 - LAWHILL1 13.8 - LWRNCHL3 115 1 LAWHILL6 230 - SWISVAL6 230 1
FFS-14LL-C9	GRDA1 7	GRDA1 7 345 - TONECE7 345 1 GRDA1 7 345 - GRDA1 5 161 - GRDA2 13.8 2
FFS-14LL-C10	MONTROS5	5CLINTN 161 - MONTROS 5 161 1 ARCHIE 5 161 - MONTROS5 161 1
FFS-14LL-C11	S3458 3	103&ROKEBY 3 345 - S3458 3 345 1 S3458 3 345 - S3456 3 345
FFS-14LL-C12	TURK 4	TURK 4 138 - TURK 7 345 - TURK 1 13.8 1 TURK 4 138 - SUGARHL4 138 1
FFS-14LL-C13	JEC N 7	JEC N 7 345 - MORRIS 7 345 1 JEC N 7 345 - SUMMIT 7 345 1
FFS-14LL-C14	S3451 3	RAUN 3 345 - S3451 3 345 1 S3451 3 345 - S1251 5 161 - S3451T39 13.8 1
FFS-14LL-C15	STILWEL7	PECULR 7 345 - STILWEL7 345 1 STILWEL7 345 - STILWEL5 161 - STIL T22 13.8 22

FFS-14LL-C16	N.E.S.-7	T.NO.--7 345 - N.E.S.-7 345 1 DELWARE7 345 - N.E.S.-7 345 1
FFS-14LL-C17	STILWEL5	STILWEL5 161 - REDEL 5 161 1 STILWEL5 161 - ANTIOCH5 161 1
FFS-14LL-C18	SIBLEYPL	DUNCAN 5 161 - SIBLEYPL 161 1 SIBLEYPL 161 - ECKLES-161 161 1

Table 9: 2019SUM, NERC Category C Outaged Branches

19Summ Event	Faulted Bus	Outaged Branch
FFS-19SUM-C1	DOLHILL7	DOLHILL7 345 - SW SHV 7 345 1 DOLHILL7 345 - DOLHILL6 230 1
FFS-19SUM -C2	ACADIA 4	8RICHARD 500 - ACADIA 4 138 2 ACADIA 4 138 - RORK 6 230 1
FFS-19SUM -C3	STLGENS4	ARSHILL4 138 - STLGENS4 138 1
FFS-19SUM -C4	ESTGEN 4	NTXEAST4 138 - ESTGEN4 138 2 NTXEAST4 138 - ESTGEN4 138 1
FFS-19SUM -C5	RODEMR 6	COLFAX 6 230 - RODEMR 6 230 1 RAPIDES6 230 - RODEMR 6 230 1
FFS-19SUM -C6	TURK 4	TURK 4 138 - TURK 7 345 - TURK 1 13.8 1 OKAY 4 138 - TURK 4 138 1
FFS-19SUM -C7	N.E.S.-4	RICE CK4 138 - N.E.S.-4 138 1 4OOLOGAH 138 - N.E.S.-4 138 1
FFS-19SUM -C8	N.E.S.-7	DELWARE7 345 - N.E.S.-7 345 1 T.NO.--7 345 - N.E.S.-7 345 1
FFS-19SUM -C9	FITZHUGH 5	FITZHUGH 5 161 - HELBERG5 161 1 FITZHUGH 5 161 - ALTUS 161 1
FFS-19SUM -C10	GRDA1 5	MAID 5 161 - GRDA1 5 161 1 MAID 5 161 - GRDA1 5 161 2
FFS-19SUM -C11	SW SHV 7	SW SHV 4 138 - SW SHV 7 345 - SWSHV2-1 13.8 2 SW SHV 4 138 - SW SHV 7 345 - SWSHV1-1 13.8 1
FFS-19SUM -C12	COUGH 4	COUGH 4 138 - PLAISAN4 138 1 COUGH 4 138 - PNPRARIE 4 138 1
FFS-19SUM -C13	TECHE 4	BSALES 4 138 - TECHE 4 138 1 MORBHAN4 138 - TECHE 4 138 1
FFS-19SUM -C14	VILPLT 6	VILPLT 6 230 - WSTFORK6 230 1

FFS-19SUM -C15	36LEWIS4	52DELTP4 138 - 36LEWIS4 138 1
FFS-19SUM -C16	COMANC-4	COMANC-4 138 - 112GORE4 138 1 COMANC-4 138 - COMMTAP4 138 1
FFS-19SUM -C17	DELWARE7	DELWARE7 345 - NEOSHO 7 345 1 DELAWAR1 13.8 - DELWARE4 138 - DELWARE7 345 1
FFS-19SUM -C18	FRONTST6	6SLIDEL 230 - FRONTST6 230 1
FFS-19SUM -C19	PLAISAN4	4CHAMPNE 138 - PLAISAN4 138 1 4VEAZIE 138 - PLAISAN4 138 1

Table 10: 2014LL, NERC Category D Outaged Branches

14LL Event	Faulted Bus	Outaged Branch
FFS-14LL-D1	WOLFCRK7	WOLFCRK7 345 - LACYGNE7 345 1 ROSEHIL7 345 - WOLFCRK7 345 1 BENTON 7 345 - WOLFCRK7 345 1 WOLFCRK7 345 - WOLFCRK2 69 1
FFS-14LL-D2	RODEMR 6	RAPIDES6 230 - RODEMR 6 230 1 HINSTON 6 230 - RODEMR 6 230 1 ELEESV 6 230 - RODEMR 6 230 1 RODEMR 6 230 - SHERWD 6 230 1 COLFAX 6 230 - RODEMR 6 230 1
FFS-14LL-D3	IATAN 7	STRANGR7 345 - IATAN 7 345 1 EASTOWN7 345 - IATAN 7 345 1 IATAN 11 13.8 - IATAN5 161 - IATAN 7 345 11
FFS-14LL-D4	DOLHILL7	DOLHILL7 345 - SW SHV 7 345 1 DOLHILL7 345 - DOLHILL6 230 1
FFS-14LL-D5	S3451 3	RAUN 3 345 - S3451 3 345 1 S3451 3 345 - S1251 5 161 - S3451T39 13.8 1 S3451 3 345 - S1251 5 161 - S3451T49 13.8 1 S3451 3 345 - S3459 3 345 1 S3451 3 345 - S3454 3 345 1
FFS-14LL-D6	GRDA1 7	GRDA1 7 345 - TONECE 7 345 1 GRDA1 7 345 - GRDA1 5 161 - GRDA2 13.8 2 GRDA1 7 345 - GRDA1 5 161 - GRDA1 13.8 1 7SPORTSMAN 345 - GRDA1 7 345 1 T.NO.--7 345 - GRDA1 7 345 1
FFS-14LL-D7	JEC N 7	JEC N 7 345 - MORRIS 7 345 1 JEC N 7 345 - SUMMIT 7 345 1 JEC N 7 345 - JEC 26 1 14.4 - JEC 6 230 1

		JEC N 7 345 - JEC 13 1 14.4 - JEC 6 230 1 HOYT 7 345 - JEC N 7 345 1 JEC U2 26 - JEC N 7 345 1
FFS-14LL-D8	LAWHILL6	LAWHILL6 230 - LAWHILL1 13.8 - LWRNCHL3 115 1 LAWHILL6 230 - SWISVAL6 230 1 LAWHILL6 230 - MIDLAND6 230 1
FFS-14LL-D9	MONTROS5	5CLINTN 161 - MONTROS 5 161 1 ARCHIE 5 161 - MONTROS5 161 1 NRAYMORE 161 - MONTROS5 161 1 KCSOUTH5 161 - MONTROS5 161 1 STILWEL5 161 - MONTROS5 161 1
FFS-14LL-D10	JTEC 5	JTEC 5 161 - SW DISP PLT 5 161 1 JTEC 5 161 - BROOKLINE 5 161 1 JTEC 5 161 - JAMES RIVER5161 1 5BTLFD 161 - JTEC 5 161 1
FFS-14LL-D11	ESTGEN4	NTXEAST4 138 - ESTGEN4 138 2 NTXEAST4 138 - ESTGEN4 138 11
FFS-14LL-C13	BROOKLINE 5	SPRGFLD5 161 - BROOKLINE 5 161 1 JUNCTION 5 161 - BROOKLINE 5 161 1 5MORGAN 161 - BROOKLINE 5 161 1
FFS-14LL-D14	S3458 3	S3458 3 345 - 103&ROKEBY3 345 1 S3456 3 345 - S3458 3 345 1 S3458 3 345 - S3740 3 345 1 NEBCTY1G 18 - S3458 3 345 1
FFS-14LL-D15	STILWEL7	PECULR 7 345 - STILWEL7 345 1 STILWEL7 345 - STILWEL5 161 - STIL T22 13.8 22 STILWEL7 345 - STILWEL5 161 - STIL T11 13.8 11
FFS-14LL-D16	N.E.S.-7	T.NO.--7 345 - N.E.S.-7 345 1 DELWARE7 345 - N.E.S.-7 345 1
FFS-14LL-D17	SIBLEYPL	DUNCAN 5 161 - SIBLEYPL 161 1 SIBLEYPL 161 - ECKLES-161 161 1 HLLMRK 5 161 - SIBLEYPL 161 1 ORRICK 5 161 - SIBLEYPL 161 1 SIBLEYPL 161 - SIBLEY 2 69 2 SIBLEYPL 161 - SIBLEY 2 69 1
FFS-14LL-D18	STILWEL5	STILWEL5 161 - REDEL 5 161 1 STILWEL5 161 - ANTIOCH5 161 1 STILWEL5 161 - HICKMAN5 161 1 STILWEL5 161 - BUCYRUS5 161 1 S.HARP 5 161 - STILWEL5 161 1 STILWEL5 161 - LACKMAN5 161 1

Table 11: 2019SUM, NERC Category D Outaged Branches

19Summ Event	Faulted Bus	Outaged Branch
FFS-19SUM - D2	RODEMR 6	COLFAX 6 230 - RODEMR 6 230 1 RAPIDES6 230 - RODEMR 6 230 1 ELEESV 6 230 - RODEMR 6 230 1 RODEMR 6 230 - SHERWD 6 230 1 HINSTON 6 230 - RODEMR 6 230 1
FFS-19SUM - D3	N.E.S.-4	RICE CK4 138 - N.E.S.-4 138 1 4OOLOGAH 138 - N.E.S.-4 138 1 OWASO2_4 138 - N.E.S.-4 138 1 WATOVA 4 138 - N.E.S.-4 138 1 CLARTOK4 138 - N.E.S.-4 138 1 OWAS1094 138 - N.E.S.-4 138 1 T.NO.--4 138 - N.E.S.-4 138 1 N.E.S.-4 138 - HAWTHRN4 138 1
FFS-19SUM - D4	DOLHILL7	DOLHILL7 345 - SW SHV 7 345 1 DOLHILL7 345 - DOLHILL6 230 1
FFS-19SUM - D5	ACADIA 4	8RICHARD 500 - ACADIA 4 138 2 ACADIA 4 138 - RORK 6 230 1
FFS-19SUM -D6	STLGENS4	ARSHILL4 138 - STLGENS4 138 1
FFS-19SUM -D7	TECHE 4	BSALES 4 138 - TECHE 4 138 1 MORBHAN4 138 - TECHE 4 138 1 PATOUT 4 138 - TECHE 4 138 1 JULTAP 4 138 - TECHE 4 138 1 TECHE 4 138 - TECHE 1 34.5 2 TECHE 4 138 - TECHE 1 34.5 1 TECHE 4 138 - TECHE 1 34.5 G2TECHE 13.2 1
FFS-19SUM -D8	COMANC-4	COMANC-4 138 - 112GORE4 138 1 COMANC-4 138 - COMMTAP4 138 1 COMANC-4 138 - L.E.S.-4 138 1
FFS-19SUM -D9	ESTGEN4	NTXEAST4 138 - ESTGEN4 138 2 NTXEAST4 138 - ESTGEN4 138 1
FFS-19SUM -D10	N.E.S.-7	DELWARE7 345 - N.E.S.-7 345 1 T.NO.--7 345 - N.E.S.-7 345 1
FFS-19SUM -D11	GRDA1 5	MAID 5 161 - GRDA1 5 161 1 MAID 5 161 - GRDA1 5 161 2 CLARMR 5 161 - GRDA1 5 161 1 GRDA1 5 161 - WAGNOR 5 161 1 GRDA1 5 161 - WMAIN ST5 161 1 GRDA1 5 161 - GRDA1 2 69 - GRDA2 13.8 1
FFS-19SUM -D12	FITZHUGH 5	FITZHUGH 5 161 - HELBERG5 161 1 FITZHUGH 5 161 - ALTUS 161 1

FFS-19SUM -D13	COUGH 4	COUGH 4 138 - PLAISAN4 138 1 COUGH 4 138 - PNPRARIE 4 138 1 COUGH 4 138 - MANUEL 4 138 1 COUGH 4 138 - MARKSVL4 138 1 COUGH 4 138 - SHOAKS 4 138 1
FFS-19SUM -D14	SW SHV 7	SW SHV 4 138 - SW SHV 7 345 - SWSHV2-1 13.8 2 SW SHV 4 138 - SW SHV 7 345 - SWSHV1-1 13.8 1 SW SHV 7 345 - DIANA 7 345 1
FFS-19SUM -D15	VILPLT 6	VILPLT 6 230 - WSTFORK6 230 1
FFS-19SUM -D16	36LEWIS4	52DELTP4 138 - 36LEWIS4 138 1
FFS-19SUM -D17	DELWARE7	DELWARE7 345 - NEOSHO 7 345 1 DELWAR1 13.8 - DELWARE4 138 - DELWARE7 345 1
FFS-19SUM -D18	FRONTST6	6SLIDEL 230 - FRONTST6 230 1
FFS-19SUM -D19	PLAISAN4	4CHAMPNE 138 - PLAISAN4 138 1 4VEAZIE 138 - PLAISAN4 138 1

APPENDIX D: Plots and Sequence Files

Fault Sequence files and generator responses showing the six (6) largest excursions for rotor speed, rotor angle, electrical power, and reactive power output were plotted in .pdf format and posted on Trueshare at:
TWG >TPL Compliance Reports>2013 TPL Assessment>Results