Southwest Power Pool, Inc.

2011 TPL Stability Study

MAINTAINED BY

SOUTHWEST POWER POOL

ENIGINEERING GROUP

Modeling Group

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Southwest Power Pool

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Draft	12/01/2011	Initial Draft Publication
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Introduction

The objective of this study is to report findings from the 2011 Stability Compliance Assessment process to support compliance with NERC TPL- 001, TPL- 002, TPL-003 and TPL-004 Reliability Standards. This report along with Near Term and Long-Term Load Flow Assessment will help fulfill requirements of applicable TPL standards.

The goals of the Stability assessment are:

1. Perform a stability screening using 3 Phase faults for the SPP system operated above 100 kV
2. Perform a detailed stability assessment for those events identified as unstable in the screening analysis
3. Perform a detailed stability analysis for members submitted events (Category B, C and D)
4. Identify mitigation plan for those events that indicate potential stability violations

The scope of this report focuses on facilities 100 kV or above. This report will summarize potential 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 2011 Transmission Planning Compliance Statement for each TPL-00X-0 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.

Executive Summary

Steady State Results during Normal Conditions

The MDWG 2011 Series 2012 Light Load and 2017 Summer Load Cases were tested to be stable during no-fault conditions prior to this study.

2012 Light Load Case

The screening analysis showed that there was one potential area of instability inside the SPP footprint. The screening contingencies for the 2012 Light Load Case Screenings were made stable by adjusting the fault current values from the scan level of $-j2e^{9}$ MVA to the actual value based on a fault current study from the SPP Short Circuit Models. The original clearing time of 5 cycles showed to be stable for the actual fault current value for the CLECO bus. The details are contained in the stability analysis results in Appendix A under Table 7: Dynamic Screening Results.

There were no NERC Category B contingencies that were unstable during this analysis.

Events C5, C10, C23 required re-dispatch of the generation contained in the case in order to make the events stable for the specified clearing time of 3.6 cycles. An additional sensitivity simulation was performed on event C23 to look at adding a 345 kV Line out of the Wolf Creek 345 kV Substation using an SPP Member submitted IDEV. This new 345 kV line is from the Wolf Creek 345 kV Substation to the Emporia Energy Center 345 kV Substation. The addition of the line will result in not having to de-rate the unit at Wolf Creek any of the NERC Category C event simulations and more adequately damp the response.

Event D1 was made stable using the methodology of tripping the unstable unit and making sure that the rest of the transmission system remained stable. Event D4 needed additional case and simulation adjustments in order to reach a stable simulation. The case adjustment is that the

KERR units '2' and '3' at bus 512634 must be on and dispatched to a minimum of 15 MWs each. Additionally, the fault current value for bus 512650 was calculated and used in place of the –j2e^{9} fault current value. The detailed results of the Dynamic Simulations are contained in Appendix A under Table 8: 2017 Summer Review of Member Submitted Unstable Events from 2012 LL Study.

2017 Summer Load Case

The screening analysis showed that there were no areas of instability inside the SPP footprint based on the transient screening methodology.

The SPP Member Submitted Events that were unstable using the MDWG 2011 Series 2012 Light Load Case were also evaluated using the MDWG 2011 Series 2017 Summer Load Case. Events C23, D1 and D4 were found to be stable with the 2017 Summer case. Even though events C5 and C10 were stable for the specified parameters, the events were still simulated in the 2017 Summer case due to the Operation Guide. Events C5, C10, C23 required re-dispatch of the generation contained in the case to make the events stable for the specified clearing time of 3.6 cycles. The necessary re-dispatch in the 2017 Summer case for Wolf Creek was reducing its output from 1285MWs to 1000 MWs to achieve adequate damping and stable simulation.

The methodology of tripping the unstable unit was applied to the remaining NERC Category D events. The transmission system remained stable for Event D2 using the methodology of tripping the unit that was made unstable by the event offline. Event D4 needed simulation adjustments in order to reach a stable simulation. The fault current value for bus 512650 was calculated and used in place of the –j2e9 fault current value. The detailed results of the Dynamic Simulations are contained in Appendix A under Table 8: 2017 Summer Review of Member Submitted Unstable Events from 2012 LL Study

Study Scope

2012 Light Load Case System Dynamic Screen

An angular stability screening was performed on the SPP Transmission System using the MDWG 2011 Series 2012 Light Load Case using Powertech Labs DSA Tools software. The angular stability screen that was applied during the screening process assessed the angular stability of a machine based on the maximum angle difference between two generators belonging to the same powerflow sub-region, which contained the SPP footprint and the adjacent first tier and second tier companies, at a given time. Since it is the difference between two generator angles, a choice of reference is not necessary. This methodology will not indentify unstable situations regarding Wind Turbines or other types of asynchronous connections. The purpose of this assessment was to find areas of potential instability for SPP Member Baseline Generators which are synchronous machines. The future plans are to implement a Transient Voltage Response screening tool that will be able to detect voltage deviations that would cause the asynchronous machines to become unstable/go offline along with other voltage measurements (voltage recovery and stabilization) during transient events.

The transient scan was performed by applying N-1 contingencies on transmission lines above 100 kV. The scan was performed by faulting bus A for a specified period of time. Next, the fault was cleared based on the voltage level of the transmission line. The line was opened from bus A to bus B without re-closing. The simulation was run for 5 seconds. Transient Stability issues should manifest with a few cycles of the fault simulation therefore a 5 second simulation was sufficient to assess basic angular stability. There was one contingency that could potentially cause stability issues and is listed in Table 1.

Table 1: Potential Unstable Event for the 2012 Light Load Case Screening

Event	Contingency
SCR12L-1	Apply fault on bus 500250 and outage branch from Bus 500250 to Bus 507760

SPP Member Submitted Events

SPP Members provided SPP Staff with a list of seventy NERC Category (24) B, (23) C and (23) D reliability type contingencies and tower outages (events) to analyze for transient stability performance. These events were analyzed using the SPP MDWG 2011 series 2012 Light Load stability model and the Siemens PTI-PSS/E 30.3.3 software. The selected events that were provided to staff are listed in Table 2.

Table 2: NERC Category B, C, and D Events

Event	Contingency
B1	Rose Hill to Wolf Creek 345 kV 3-phase fault. No reclosing
B2	Benton to Wolf Creek 345 kV 3-phase fault. No reclosing
B3	Wolf Creek to LaCygne 345 kV 3-phase fault. No reclosing.
B4	Jeffrey Energy Center (JEC) to Hoyt 345 kV, No fault. Trip line. No reclosing.
B5	JEC Auburn 230 kV 3-phase fault. No reclosing
B6	Plant X to Tolk 230 kV line 3-phase fault -- no reclosing
B7	Tolk to Eddy 345 kV line outage -- typical reclosing
B8	Yoakum to Sundown 230 kV line outage with typical reclosing.
B9	Tolk to TUCO 230 kV line 3-phase fault, no reclosing
B10	Potter 345/230 kV transformer 3-phase fault, no reclosing
B11	Iatan to Stranger Creek 345 kV 3-phase fault. Reclosing on Stanger Creek breaker only.
B12	Iatan to St. Joseph 345 kV 3-phase fault. Reclosing on St. Joseph breaker only.
B13	3-Ø fault at S3451 on T3 transformer. Normal clearing.

B14	3-Ø fault at S1211 on the S1211-S1220 line. Normal clearing.
Event	**Contingency**
B15	3-Ø fault at S1206 on the S1206-S1232 line. Normal clearing.
B16	3-Ø fault at S3458 on the S3458 - Cooper line. Normal clearing.
B17	SERPTA to Longwood 345 kV 3-phase fault
B18	3PH fault at GGS on GGS-Sweetwater 345 kV Circuit #1; Normal clearing; No reclose attempts
B19	3PH fault at GGS on GGS-Red Willow 345 kV; Normal clearing; No reclose attempts
B20	3PH fault at GGS on GGS-North Platte 230 kV Circuit #1; Normal clearing; No reclose attempts
B21	3PH fault at GGS on high side of GGS 345/230 kV T-1 transformer; Normal clearing; No reclose attempts
B22	Brookline to Monett to Flint Creek 345 kV 3-phase fault, reclosing on one terminal only and rotated every year (549984 – 547481 – 506935).
B23	ANO – Ft. Smith 500 kV Line. Normal clearing.
B24	Grimes to Crocket 345 kV Line (Pirkey – Grimes 345 kV Line). Normal clearing.
C1	3-Ø fault on Auburn-JEC 230 kV; followed by 3-Ø fault on Hoyt-JEC 345 kV.
C2	Prior outage of GRDA 1 – Flint Creek 345 kV with a 3-Ø fault near GRDA 1 on GRDA – Tulsa 345 kV.
C3	Prior outage of Fairport-St Joe 345kV with a 3-phase fault near Cooper on Cooper - St Joe 345 kV. No Reclosing.
C4	Prior outage of Holcomb generating unit with an outage of Mingo – Red Willow 345 kV line.
C5	3-Ø fault on Benton - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing)

C6	Summit to Smoky Hills 230 kV 3-Ø fault and outage followed by Circle to Mullergren 230 kV 3-Ø fault, no reclosing.
Event	**Contingency**
C7	Knoll to Smoky Hills 230 kV 3-Ø fault and outage followed by Circle to Mullergren 230 kV 3-Ø fault, no reclosing.
C8	Prior outage of Tolk to Roosevelt #1 230 kV circuit with a 3-phase fault near Roosevelt on the Tolk to Roosevelt #2 230 kV circuit -- no reclosing.
C9	Iatan to St. Joseph 345 kV 3-Ø fault, reclosing on St. Joseph breaker only, then Iatan to Stranger Creek 345 kV 3-Ø fault, reclosing on Stranger Creek breaker only.
C10	3-Ø fault on Wolf Creek-LaCygne 345 kV line; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 302); 3-Ø fault on Wolf Creek-Benton 345 kV line, no reclosing.
C11	DLG fault at the S3451 end of the S3451-S3459 and S3451-S3454 lines. Normal clearing. 2246 - 24500 MVA
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.
C13	SLG fault at S1206 on the S1206 - S1232 line, followed by a stuck breaker and the opening of the S1206 - S1201 line.
C14	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
C15	Prior Outage of Brookline – Monett - Flint Creek 345 kV with a 3-phase fault near Brookline on Brookline - Morgan 345 kV, with reclosing first at Morgan and then Brookline
C16	3-phase fault and outage of the Brookline – John Twitty Energy Center (JTEC) 161 kV line followed by a 3-phase fault near JTEC on the JETC - Southwest Treatment Plant - Battlefield 161 kV line, no reclosing
C17	SLG fault on HOLCOMB 115kV bus which will trip Holcomb - Holcomb 345/115 kV transformer with breaker stuck which trips Holcomb to Jones 15 kV line (delayed trip).
C18	3-Phase fault on the 230 kV line from Spearville to MULGREN with stuck breaker which trips Spearville 345/230 kV transformer

C19	3-phase fault on the 230 kV line from Holcomb to Finney with stuck breaker which trips the 345 kV line from Holcomb to SETAB with 9 cycle delayed trip
Event	**Contingency**
C20	Prior outage of South Hays-Great Bend 230 kV Line followed by three-phase fault on Knoll-Smoky Hill 230 kV Line with reclose once at 90 cycles and trip permanently.
C21	Prior outage of Colby-Mingo 115 kV Line followed by three-phase fault on Colby-Hoxie-Beach 115 kV Line with reclose once at 20 cycles and trip permanently.
C22	Fault on Knoll 230/115 kV transformer with breaker 3010 failure resulting in clearing Knoll-Redline-Beach 115 kV line.
C23	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing
D1	3-Ø fault on Holcomb – SETAB 345 kV Line with breaker failure taking out the 345-115 kV auto-transformer.
D2	3-Ø fault on Jeffrey Energy Center (JEC) to Hoyt 345 kV Line, no reclosing, and trip JEC Unit #2
D3	3-Ø fault on Auburn-Jeffery Energy Center (JEC) 230 kV; followed by 3-Ø fault on Hoyt-JEC 345 kV, no reclosing, and trip JEC Unit#2
D4	Run fault on GRDA1 345 kV bus for 5 cycles. Then open Flint Creek end of Flint Creek-GRDA1 345 kV line, but stuck breaker 9580 at GRDA1. Run for 25 cycles and then drop GRDA 345/161 transformer #1 & breaker 9080 (GRDA bkr 500T opens correctly)
D5	Loss of Flint Creek 161 kV bus
D6	Loss of Ft. Smith 500/345/161 kV Substation
D7	Loss of AEP's NW Texarkana 345 kV bus
D8	3-Ø fault at the S3451 on T3 transformer, followed by a stuck breaker and the opening of the S3451-S3459 line.
D9	3-Ø fault at S3458 on the S3458 - Cooper line, followed by a stuck breaker and the opening of the west bus at S3458.

D10	Loss of the entire substation S3456, including the transformer to the 161-kV level.
D11	Valliant to Welsh to NW Texarkana 345 kV 3-phase fault
Event	**Contingency**
D12	NE Station to Tulsa North 345/138 kV double circuit 3-phase fault
D13	Simultaneous SLG fault on GGS-Sweetwater 345 kV Circuit #1 and 3PH fault on GGS-Sweetwater 345 kV Circuit #2 at cross point; Normal clearing; Reclose far end
D14	5 cycle SLG fault on the 84th & Bluff end of the 84th & Bluff - Waverly 115 kV line breaker #7502 fails, and the 84th & Bluff - 70th & Bluff 115 kV line is opened to clear the fault. There is no reclosure.
D15	Loss of Summit Substation plus transformers.
D16	Loss of the entire JEC 345 kV substation. This includes loss of JEC-Hoyt 345 kV, JEC-Morris 345 kV, JEC-Summit 345 kV, JEC 345-230 kV transformer #1, JEC 345-230 kV transformer #2, and trip JEC U3 and JEC U2.
D17	3-Ø fault on Hoyt-Stranger at Hoyt 345 kV. After 3.6 cycles, trip the Hoyt-Stranger 345 kV line at Stranger. After 8 cycles (breaker failure at Hoyt), trip Hoyt 345-115 kV transformer and trip JEC-Hoyt 345 kV.
D18	3-Ø fault on JEC-Hoyt 345 kV line near JEC. After 3.6 cycles, trip the JEC-Hoyt 345 kV line at Hoyt end only. After 8 cycles (345-16 breaker failure at JEC), clear the fault, trip the line and trip JEC U2.
D19	3-Ø fault on JEC-Summit 345 kV line near JEC. After 3.6 cycles, trip the JEC-Summit 345 kV line at Summit end only. After 8 cycles (345-25 breaker failure at JEC), clear the fault, trip the line and trip the 345-230 kV transformer #26
D20	3-Ø fault on JEC-Morris 345 kV line near JEC. After 3.6 cycles, trip the JEC-Summit 345 kV line at Morris end only. After 8 cycles (breaker failure at JEC), clear the fault, trip the line at JEC end and trip JEC U3.
D21	Loss of Knoll 115kV Substation.
D22	Loss of Heizer 115 KV Substation
D23	Brookline 345 kV double Circuit 3-phase fault on Brookline161 kV bus

2017 Summer Load Case

SPP also conducted an angular stability screening on the SPP Transmission System for the MDWG 2011 Series 2017 Summer Case. The angular stability criterion that was applied during the screening process assessed the angular stability of a machine based on the maximum angle difference between two generators belonging to the same powerflow island at a given time. Since it is the difference between two generator angles, a choice of reference is not necessary. This methodology will not indentify unstable situations regarding Wind Turbines or other types of asynchronous connections. The purpose of this assessment was to find areas of potential instability for SPP Member Baseline Generators which are synchronous machines. The future plans are to implement a Transient Voltage Response screening tool that will be able to detect voltage deviations that would cause the asynchronous machines to become unstable/go offline along with other voltage measurements (voltage recovery and stabilization) during transient events.

The transient scan was performed by applying N-1 contingencies on transmission lines above 100 kV. The scan was performed by faulting bus A for a specified period of time. Next, the fault was cleared based on the voltage level of the transmission line. The line was opened from bus A to bus B without re-closing. The simulation was run for 5 seconds. Transient Stability issues should manifest within a few cycles of the fault simulation therefore a 5 second simulation was sufficient to assess basic angular stability. There were no contingencies that could potentially cause stability issues in the SPP Footprint based on the transient screening of the 2017 Summer case.

Study Details

SPP Transmission System Screenings

An angular stability screening was performed on the SPP Transmission System using the MDWG 2011 Series 2012 Light Load Case applying the previously stated screening methodology. There was one contingency that could potentially cause stability issues. Event SCR12L_1 was made stable by adjusting the fault current values from the scan value of $-j2e^{9}$ MVA to the actual value based on a fault current study from the SPP Short Circuit Models. The original clearing time of 5 cycles showed to be stable for the actual fault current value for the CLECO Dolet Hills bus. The details are contained in the stability analysis results in Appendix A under Table 7: Dynamic Screening Results.

SPP Member Submitted Events evaluated using the MDWG 2011 Series 2012 Light Load Case

SPP Member Submitted NERC Category B Events

SPP Members provided staff with twenty-four NERC category B events that were to be evaluated for transient stability. There were no NERC Category B contingencies that were unstable during this analysis. The detailed results of the Dynamic Simulations are contained in Appendix A under Table 4: Member Submitted NERC Category B Detailed Results.

SPP Member Submitted Category C Events

SPP Members provided staff with twenty-three category C events that were to be evaluated for transient stability. Twenty-two of the twenty-three events were stable for the specified clearing times (provided by the SPP Members) in the initial evaluation using the MDWG 2011 Series 2012 Light Load Case. The event in question was not unstable based upon past practices. However, it is situation that is not adequately damped and could result in adverse affects to other machines in the SPP footprint. After additional simulations, staff determined that the remaining event, C23, was stable with a modified generator dispatch. To ensure transmission system stability for events C5 and C10, the Transmission Operating Guideline redispatch of 900 MWs

should remain the same. To ensure transmission system stability for event C23, the Transmission Operating Guideline redispatch of 900 MWs should be lowered to 800 MWs.

An additional sensitivity simulation was performed to look at adding a fourth 345 kV Line out of the Wolf Creek 345 kV Substation using an SPP Member submitted IDEV. This new 345 kV line is from the Wolf Creek 345 kV Substation to the Emporia Energy Center 345 kV Substation. The addition of the line will result in not having to de-rate the unit at Wolf Creek for any of the NERC Category C event simulations and the output is more than adequately damped. The detailed results of the Dynamic Simulations are contained in Appendix A under Table 5: Member Submitted NERC Category C Detailed Results.

SPP Member Submitted Category D Events

SPP members provided staff with twenty-three category D events that were to be evaluated for transient stability. Twenty-one of the twenty-three events were stable for an appropriate clearing time as specified by the SPP Member in the initial evaluation using the MDWG 2011 Series 2012 Light Load Case. Due to the severity of the event simulations, the units that were made unstable due to this simulation were tripped offline. Event D1 was shown to be stable when this methodology was applied to this event. Event D4 needed additional case and simulation adjustments in order to reach a stable simulation. The case adjustment is that the KERR units '2' and '3' at bus 512634 must be on and dispatched to a minimum of 15 MWs each. Additionally, the fault current value for bus 512650 was calculated and used in place of the $-j2e^{9}$ fault current value. The detailed results of the Dynamic Simulations are contained in Appendix A under Table 6: Member Submitted NERC Category D Detailed Results.

SPP Member Submitted Events evaluated using MDWG 2011 Series 2017 Summer Case

There were three unstable events from the SPP Member Submitted Events that were evaluated using the MDWG 2011 Series 2012 Light Load Case. Events C23, D1 & D4 were unstable for the clearing time as specified by the SPP Member in the initial evaluation using the MDWG 2011 Series 2017 Summer Load Case. Event C25 was made stable by reducing the output of

Wolf Creek to 1000 MWs. Even though events C5 and C10 were stable based on the conditions in the event simulation for the 2012L case, these events were also simulated using the 2017S case to test the de-rate of the Wolf Creek Unit and were stable.

Events D1 were made stable using the methodology of tripping the unstable unit and making sure that the rest of the transmission system remained stable. Event D4 needed simulation adjustments in order to reach a stable simulation. The fault current value for bus 512650 was calculated and used in place of the $-j2e^{9}$ fault current value. The detailed results of the Dynamic Simulations are contained in Appendix A under Table 8: 2017 Summer Review of Member Submitted Unstable Events from 2012 LL Study

APPENDIX A – Detailed Stability Results

Table 3: 2012 Light Load Case Studied Member Submitted NERC Category B Detailed Results

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
B1	**5.0**	Rose Hill to Wolf Creek 345 kV 3-phase fault. No reclosing	**2012 LL**	**0**	**0**	**390**	**1223**	**0**	**0**	**381**	**2046**	**2085**	**Stable**
B2	**5.0**	Benton to Wolf Creek 345 kV 3-phase fault. No reclosing	**2012 LL**	**0**	**0**	**390**	**1223**	**0**	**0**	**381**	**2046**	**2085**	**Stable**
B3	**3.6**	Wolf Creek to LaCygne 345 kV 3-phase fault. No reclosing.	**2012 LL**	**0**	**0**	**390**	**1223**	**0**	**0**	**381**	**2046**	**2085**	**Stable**
B4	**5.0**	Jeffrey Energy Center (JEC) to Hoyt 345 kV, No fault. Trip line. No reclosing.	**2012 LL**										**Stable**
B5	**5.0**	JEC Auburn 230 kV 3-phase fault. No reclosing	**2012 LL**										**Stable**
B6	**5.0**	Plant X to Tolk 230 kV line 3-phase fault -- no reclosing	**2012 LL**										**Stable**
B7	**5.0**	Tolk to Eddy 345 kV line outage -- typical reclosing	**2012 LL**										**Stable**
B8	**5.0**	Yoakum to Sundown 230 kV line outage with typical reclosing.	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
B9	5.0	Tolk to TUCO 230 kV line 3-phase fault, no reclosing	**2012 LL**										**Stable**
B10	5	Potter 345/230 kV transformer 3-phase fault, no reclosing	**2012 LL**										**Stable**
B11	5	Iatan to Stranger Creek 345 kV 3-phase fault. Reclosing on Iatan breaker only.	**2012 LL**										**Stable**
B12	7.5	Iatan to St. Joseph 345 kV 3-phase fault. Reclosing on Iatan breaker only.	**2012 LL**										**Stable**
B13	7.5	3-Ø fault at S3451 on T3 transformer. Normal clearing.	**2012 LL**										**Stable**
B14	8.5	3-Ø fault at S1211 on the S1211-S1220 line. Normal clearing.	**2012 LL**										**Stable**
B15	8.5	3-Ø fault at S1206 on the S1206-S1232 line. Normal clearing.	**2012 LL**										**Stable**
B16	4.5	3-Ø fault at S3458 on the S3458 - Cooper line. Normal clearing.	**2012 LL**										**Stable**
B17	**5.0**	Longwood to El Dorado 345 kV 3-phase fault	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
B18	**4.0**	3PH fault at GGS on GGS-Sweetwater 345 kV Circuit #1; Normal clearing; No reclose attempts	**2012 LL**										**Stable**
B19	**4.0**	3PH fault at GGS on GGS-Red Willow 345 kV; Normal clearing; No reclose attempts	**2012 LL**										**Stable**
B20	**4.0**	3PH fault at GGS on GGS-North Platte 230 kV Circuit #1; Normal clearing; No reclose attempts	**2012 LL**										**Stable**
B21	**5.0**	3PH fault at GGS on high side of GGS 345/230 kV T-1 transformer; Normal clearing; No reclose attempts	**2012 LL**										**Stable**
B22	**5.0**	Brookline to Monett to Flint Creek 345 kV 3-phase fault, reclosing on one terminal only and rotated every year (549984 – 547481 – 506935).	**2012 LL**										**Stable**
B23	**5.0**	3-Phase fault on the ANO - Ft. Smith 500 kV Line	**2012 LL**										**Stable**
B24	**5.0**	3-Phase fault on the Grimes to Crocket 345 Line (Pirkey - Grimes 345 kV Line)	**2012 LL**										**Stable**

Table 4: 2012 Light Load Case Studied Member Submitted NERC Category C Detailed Results

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C1	**5.0**	3-phase fault on Auburn-JEC 230 kV; followed by 3-phase fault on Hoyt-JEC 345 kV. No reclosing.	**2012 LL**										**Stable**
C2	**5.0**	Prior outage of GRDA 1–Flint Creek 345 kV with a 3-phase fault near GRDA 1 on GRDA – Tulsa 345 kV. No reclosing.	**2012 LL**										**Stable**
C3	**5.0**	Prior outage of Fairport-St Joe 345kV with a 3-phase fault near Cooper on Cooper - St Joe 345 kV. No Reclosing.	**2012 LL**										**Stable**
C4	**5.0**	Prior outage of Holcomb generating unit with an outage of Mingo–Red Willow 345 kV line. No reclosing.	**2012 LL**										**Stable**
C5	**3.6**	3-Ø fault on Benton - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing)	**2012 LL**	**250**	**0**	**463**	**900**	**0**	**0**	**386**	**2052**	**2085**	**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C6	**6.0**	Summit to Smoky Hills 230 kV 3-Ø fault and outage followed by Circle to Mullergren 230 kV 3-Ø fault, no reclosing.	**2012 LL**										**Stable**
C7	**6.0**	Knoll to Smoky Hills 230 kV 3-Ø fault and outage followed by Circle to Mullergren 230 kV 3-Ø fault, no reclosing.	**2012 LL**										**Stable**
C9	**5.0**	Iatan to St. Joseph 345 kV 3-Ø fault, reclosing on St. Joseph breaker only, then Iatan to Stranger Creek 345 kV 3-Ø fault, reclosing on St. Joseph breaker only.	**2012 LL**										**Stable**
C10	**5.0**	3-Ø fault on Wolf Creek-LaCygne 345 kV line; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 302); 3-Ø fault on Wolf Creek-Benton 345 kV line, no reclosing.	**2012 LL**	**250**	**0**	**463**	**900**	**0**	**0**	**386**	**2052**	**2085**	**Stable**
C11	**4.5**	DLG fault at the S3451 end of the S3451-S3459 and S3451-S3454 lines. Normal clearing.	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C12	**14.5**	SLG fault at the S3451 end of the S3451-Raun line, followed by a stuck breaker and the opening of transformer T4 at S3451.	**2012 LL**										**Stable**
C13	**19**	SLG fault at S1206 on the S1206 - S1232 line, followed by a stuck breaker and the opening of the S1206 - S1201 line.	**2012 LL**										**Stable**
C14	**13.5**	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	**2012 LL**										**Stable**
C15	**5**	Prior Outage of Brookline – Monett - Flint Creek 345 kV with a 3-phase fault near Brookline on Brookline - Morgan 345 kV, with reclosing first at Morgan and then Brookline	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C16	**5**	3-phase fault and outage of the Brookline - Southwest Power Station (SWPS) 161 kV line followed by a 3-phase fault near SWPS on the SWPS - Southwest Treatment Plant - SPRM Battlefield 161 kV line, no reclosing	**2012 LL**										**Stable**
C17	**10**	SLG fault on HOLCOMB 115kV bus which will trip Holcomb - Holcomb 345/115 kV transformer with breaker stuck which trips Holcomb to Jones 15 kV line (delayed trip).	**2012 LL**										**Stable**
C18	**12**	3-Phase fault on the 230 kV line from Spearville to MULGREN with stuck breaker which trips Spearville 345/230 kV transformer	**2012 LL**										**Stable**
C19	**10**	3-phase fault on the 230 kV line from Holcomb to Finney with stuck breaker which trips the 345 kV line from Holcomb to SETAB with 9 cycle delayed trip.	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C20	**5, 90, 5**	Prior outage of South Hays-Great Bend 230 kV Line followed by three-phase fault on Knoll-Smoky Hill 230 kV Line with reclose once at 90 cycles and trip permanently.	**2012 LL**										**Stable**
C21	**8, 20, 8**	Prior outage of Colby-Mingo 115 kV Line followed by three-phase fault on Colby-Hoxie-Beach 115 kV Line with reclose once at 20 cycles and trip permanently.	**2012 LL**										**Stable**
C22	**8**	Fault on Knoll 230/115 kV transformer with breaker 3010 failure resulting in clearing Knoll-Redline-Beach 115 kV line.	**2012 LL**										**Stable**
C23	**3.6, 3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2012 LL**										**Unstable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C23A	**3.6, 3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2012 LL**										**Added 4th line out of Wolf Creek Stable**
C23B	**3.6, 3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2012 LL**	**250**	**0**	**463**	**875**	**0**	**0**	**386**	**2052**	**2085**	**Stable - Poorly Damped**
C23C	**3.6, 3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2012 LL**	**275**	**0**	**463**	**850**	**0**	**0**	**386**	**2052**	**2085**	**Stable - Poorly Damped**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C23D	**3.6, 3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2012 LL**	**350**	**0**	**463**	**800**	**0**	**0**	**386**	**2052**	**2085**	**Stable**
C23D	**3.6, 3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2012 LL**	**400**	**0**	**463**	**750**	**0**	**0**	**386**	**2052**	**2085**	**Stable**

Table 5: 2012 Light Load Case Studied Member Submitted NERC Category D Detailed Results

Event	Fault Clearing Time (Cycles)	Contingency	Model										Result
D1	**11**	3-Ø fault on Holcomb – SETAB 345 kV with breaker failure taking out the 345-115 kV auto-transformer.	**2012 LL**										**Unstable**
D1A	**11**	3-Ø fault on Holcomb – SETAB 345 kV with breaker failure taking out the 345-115 kV auto-transformer.	**2012 LL**										**Trip unit 531447 Stable**
D2	**5**	Jeffrey Energy Center (JEC) to Hoyt 345 kV 3-Ø fault, no reclosing, and trip JEC Unit #2	**2012 LL**										**Stable**
D3	**11**	3-Ø fault on Auburn-Jeffery Energy Center (JEC) 230 kV; followed by 3-Ø fault on Hoyt-JEC 345 kV, no reclosing, and trip JEC Unit#2	**2012 LL**										**Stable**
D4	**30**	Run fault on GRDA1 345 kV bus for 5 cycles. Then open Flint Creek end of Flint Creek-GRDA1 345 kV line, but stuck breaker 9580 at GRDA1. Run for 25 cycles and then drop GRDA 345/161 transformer #1 & breaker 9080 (GRDA bkr 500T opens correctly)	**2012 LL**										**Unstable**

Event	Fault Clearing Time (Cycles)	Contingency	Model										Result
D4A	**15**	Run fault on GRDA1 345 kV bus for 5 cycles. Then open Flint Creek end of Flint Creek-GRDA1 345 kV line, but stuck breaker 9580 at GRDA1. Run for 25 cycles and then drop GRDA 345/161 transformer #1 & breaker 9080 (GRDA bkr 500T opens correctly)	**2012 LL**										**Trip Unit 512688 Unstable**
D4B	**15**	Run fault on GRDA1 345 kV bus for 5 cycles. Then open Flint Creek end of Flint Creek-GRDA1 345 kV line, but stuck breaker 9580 at GRDA1. Run for 25 cycles and then drop GRDA 345/161 transformer #1 & breaker 9080 (GRDA bkr 500T opens correctly)	**2012LL**										**Trip Unit 512688 and Applied calculated fault current, and Must run KERR Units 512634 '2 & 3'** **Stable**
D5	**N/A**	Loss of Flint Creek 161 kV bus	**2012 LL**										**Stable**
D6	**N/A**	Loss of Ft. Smith 500/345/161 kV Substation	**2012 LL**										**Stable**
D7	**N/A**	Loss of AEP's NW Texarkana 345 kV bus	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model										Result
D8	**16.5**	3-Ø fault at the S3451 on T3 transformer, followed by a stuck breaker and the opening of the S3451-S3459 line.	**2012 LL**										**Stable**
D9	**13.5**	3-Ø fault at S3458 on the S3458 - Cooper line, followed by a stuck breaker and the opening of the west bus at S3458	**2012 LL**										**Stable**
D10	**N/A**	Loss of the entire substation S3456, including the transformer to the 161-kV level.	**2012 LL**										**Stable**
D11	**5.0**	Valliant to Welsh to NW Texarkana 345 kV 3-phase fault	**2012 LL**										**Stable**
D12	**8.0**	NE Station to Tulsa North 345/138 kV double circuit 3-phase fault	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model										Result
D13	**4,27,4**	Simultaneous SLG fault on GGS-Sweetwater 345 kV Circuit #1 and 3PH fault on GGS-Sweetwater 345 kV Circuit #2 at cross point; Normal clearing; Reclose far end	**2012 LL**										**Stable**
D14	**26.0**	5 cycle SLG fault on the 84th & Bluff end of the 84th & Bluff - Waverly 115 kV line breaker #7502 fails, and the 84th & Bluff - 70th & Bluff 115 kV line is opened to clear the fault. There is no reclosure.	**2012 LL**										**Stable**
D15	**N/A**	Loss of Summit Substation plus transformers	**2012 LL**										**Stable**
D16	**N/A**	Loss of the entire JEC 345 kV substation. This includes loss of JEC-Hoyt 345 kV, JEC-Morris 345 kV, JEC-Summit 345 kV, JEC 345-230 kV transformer #1, JEC 345-230 kV transformer #2, and trip JEC U3 and JEC U2.	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model										Result
D17	**11.6**	3-Ø fault on Hoyt-Stranger at Hoyt 345 kV. After 3.6 cycles, trip the Hoyt-Stranger 345 kV line at Stranger. After 8 cycles (breaker failure at Hoyt), trip Hoyt 345-115 kV transformer and trip JEC-Hoyt 345 kV.	**2012 LL**										**Stable**
D18	**11.6**	3-Ø fault on JEC-Hoyt 345 kV line near JEC. After 3.6 cycles, trip the JEC-Hoyt 345 kV line at Hoyt end only. After 8 cycles (345-16 breaker failure at JEC), clear the fault, trip the line and trip JEC U2.	**2012 LL**										**Stable**
D19	**11.6**	3-Ø fault on JEC-Summit 345 kV line near JEC. After 3.6 cycles, trip the JEC-Summit 345 kV line at Summit end only. After 8 cycles (345-25 breaker failure at JEC), clear the fault, trip the line and trip the 345-230 kV transformer #26	**2012 LL**										**Stable**

Event	Fault Clearing Time (Cycles)	Contingency	Model										Result
D20	**11.6**	3-Ø fault on JEC-Morris 345 kV line near JEC. After 3.6 cycles, trip the JEC-Summit 345 kV line at Morris end only. After 8 cycles (345-20 breaker failure at JEC), clear the fault, trip the line at JEC end and trip JEC U3.	**2012 LL**										**Stable**
D21	**N/A**	Loss of Knoll 115kV Substation	**2012 LL**										**Stable**
D22	**N/A**	Loss of Heizer 115 KV Substation	**2012 LL**										**Stable**
D23	**N/A**	Brookline 345 kV double Circuit 3-phase fault on Brookline161 kV bus	**2012 LL**										**Stable**

Table 6: 2012 Light Load Case and 2017 Summer Case Dynamic Screening Results

Event	Fault Clearing Time (Cycles)	Contingency	Model										Result
SCR12L -1	**5**	Apply fault on bus 500250 and outage branch from Bus 500250 to Bus 507760	**2012 LL**										**Unstable**
SCR12L-1A	**5**	Apply fault on bus 500250 and outage branch from Bus 500250 to Bus 507760	**2012 LL**										**Applied calculated fault current Dolet Hills bus** **Stable**

Table 7: 2017 Summer Review of Member Submitted Unstable Events from 2012 LL Study

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
C23	**3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2017 S**	**695**	**695**	**695**	**1223**	**150**	**370**	**348**	**6620**	**6268**	**Unstable**
C23A	**3.6, 3.6**	3-Ø fault on Rose Hill - Wolf Creek 345 kV line with no reclosing; Reduce Wolf Creek output to 900 MW (Transmission Operating Directive 300); 3-phase fault on LaCygne - Wolf Creek 345 kV line with no reclosing	**2017S**	**744**	**740**	**742**	**1000**	**150**	**338**	**348**	**6620**	**6268**	**Stable**
D1	**10**	3-Ø fault on Holcomb – SETAB 345 kV with breaker failure taking out the 345-115 kV auto transformer.	**2017 S**										**Unstable**
D1A	**10**	3-Ø fault on Holcomb – SETAB 345 kV with breaker failure taking out the 345-115 kV auto transformer.	**2017 S**										**Trip Unit 531447 Unstable**

Event	Fault Clearing Time (Cycles)	Contingency	Model	JEC 1 (532651)	JEC 2 (532652)	JEC 3 (532653)	WC 1 (532751)	EEC 1 (532721)	EEC 2 (532722)	LEC 5 (532663)	Total Gen (MW)	WERE Load (MW)	Result
D1B	**10**	3-Ø fault on Holcomb – SETAB 345 kV with breaker failure taking out the 345-115 kV auto transformer.	**2017 S**										**Trip Unit 531447 and Applied calculated fault current** **Stable**
D4	**30**	Run fault on GRDA1 345 kV bus for 5 cycles. Then open Flint Creek end of Flint Creek-GRDA1 345 kV line, but stuck breaker 9580 at GRDA1. Run for 25 cycles and then drop GRDA 345/161 transformer #1 & breaker 9080 (GRDA bkr 500T opens correctly)	**2017 S**										**Unstable**
D4A	**15**	Run fault on GRDA1 345 kV bus for 5 cycles. Then open Flint Creek end of Flint Creek-GRDA1 345 kV line, but stuck breaker 9580 at GRDA1. Run for 25 cycles and then drop GRDA 345/161 transformer #1 & breaker 9080 (GRDA bkr 500T opens correctly)	**2017 S**										**Trip Unit 512688 and Apply calculated fault current at GRDA1-7 bus** **Stable**

APPENDIX B – Plots[i]

[i] Please contact SPP staff for access to the plots