



**Interconnection System Impact Study Report
550 MW Coal Generation
Portage County, Wisconsin**

**G522
MISO Queue #38503-01**

**March 24, 2006
American Transmission Company, LLC**

**Tom Dagenais
System Planning**

**Terry Stulo
System Protection**

**Mike Anderson
Engineering and Construction Services**

**Travis Peterson
Project Management**

Table of Contents

1. SUMMARY	3
1.1 INJECTION LIMITS	5
1.2 OPERATION RESTRICTIONS	5
1.3 INTERCONNECTION FACILITIES	5
1.4 NETWORK UPGRADES	5
1.5 RESERVE AUXILIARY TRANSFORMER OPTIONS	6
1.6 FURTHER STUDY.....	6
2. CRITERIA, METHODOLOGY AND ASSUMPTIONS	9
2.1 STUDY CRITERIA	9
2.2 STUDY METHODOLOGY	9
2.2.1 <i>Competing Generation Requests</i>	9
2.2.2 <i>Linear Transfer Analysis and A.C. Power Flow Analysis Methods</i>	10
2.2.3 <i>Base Cases</i>	10
2.2.4 <i>Generation Facility Modeling</i>	11
3. ANALYSIS RESULTS	12
3.1 POWER FLOW ANALYSIS RESULTS	12
3.1.1 <i>Results of Single Contingencies (N-1)</i>	12
3.1.2 <i>Results of Double Contingencies (N-2)</i>	13
3.2 ANGULAR STABILITY ANALYSIS RESULTS	14
3.2.1 <i>Results of Delayed Clearing Contingencies</i>	15
3.2.2 <i>Results of Prior Outage Primary Fault Contingencies</i>	15
3.2.3 <i>Results of Bus Section Fault and/or Internal Breaker Fault Contingencies</i>	16
3.3 SHORT-CIRCUIT & BREAKER DUTY ANALYSIS RESULTS	16
3.4 DELIVERABILITY ANALYSIS RESULTS	16
APPENDIX A: POWER FLOW ANALYSIS RESULTS	17
APPENDIX B: SUMMARY OF OPERATION RESTRICTIONS	21
APPENDIX C: ANGULAR STABILITY ANALYSIS RESULTS.....	24
APPENDIX D: SHORT CIRCUIT / BREAKER DUTY ANALYSIS RESULTS	28
APPENDIX E: DELIVERABILITY ANALYSIS RESULTS.....	30
APPENDIX F: RESERVE AUXILIARY TRANSFORMER OPTIONS	32
APPENDIX G: STUDY CRITERIA	37

1. Summary

This report contains the Interconnection System Impact Study (ISIS) for the Midwest Independent System Operator (“MISO”) Generation Interconnection Request identified as MISO Project #G522, MISO Queue #38503-01. This study evaluates the impacts of interconnecting the proposed 550 MW coal-fired generating unit in Portage County, Wisconsin. The requested back-feed date for this project is November 1, 2010 and the requested in-service date is June 1, 2011.

The G522 generation is proposed to connect to Line L6831 [Rocky Run – Werner West (future) – North Appleton] at 345 kV. Another proposed option includes the above 345 kV connection as well as two additional 115 kV connections at Line J-114 [Plover – Coyne] and Line N-92 [Rocky Run – Coyne]. The one-line diagrams for each interconnection option are shown in Figure 1a and Figure 1b.

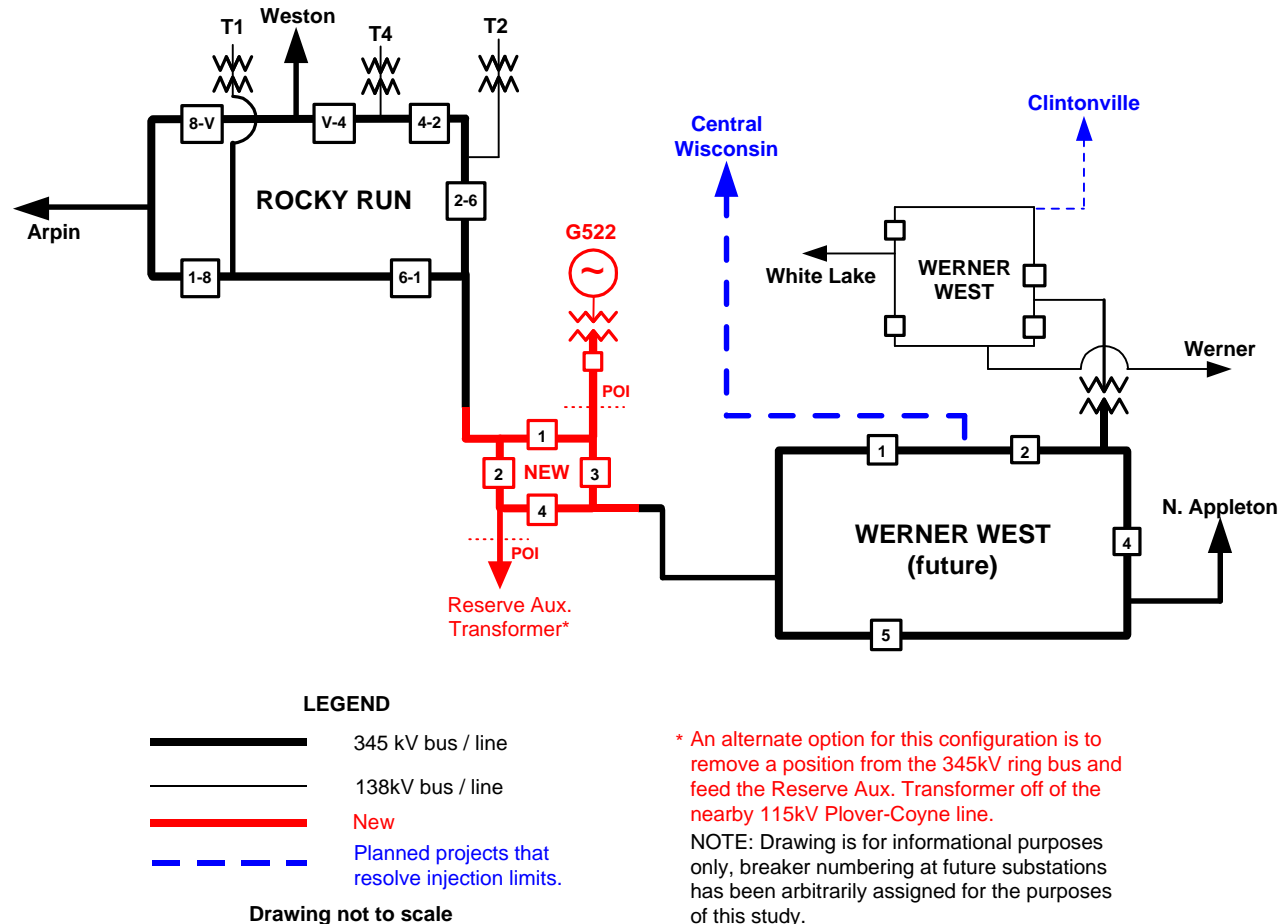


Figure 1a: Conceptual G522 345kV Interconnection Configuration

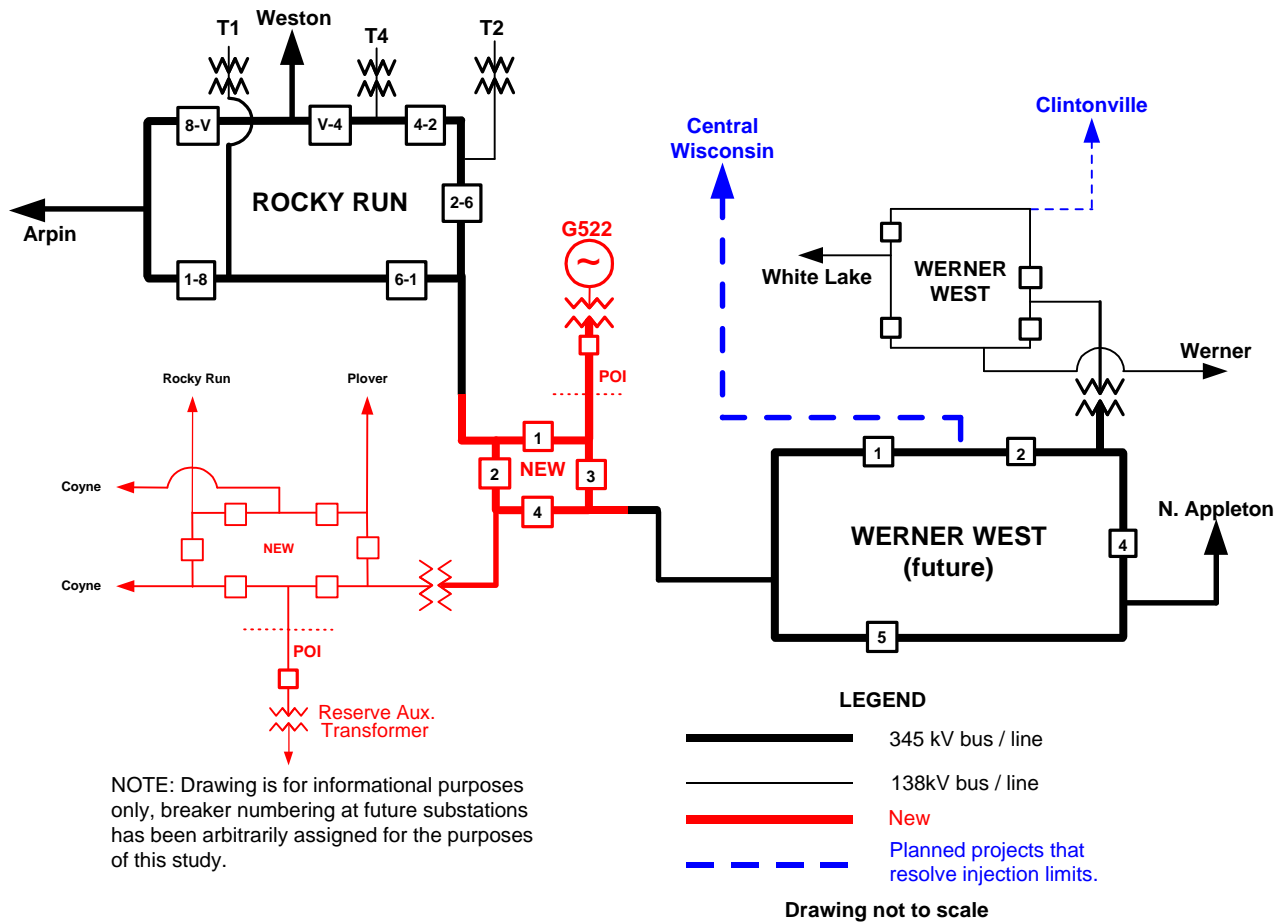


Figure 1b: Conceptual G522 345-115kV Interconnection Configuration

This study identifies the steady state thermal violations, the breaker clearing time violations, and breaker fault duty violations associated with the interconnection of G522. The identified violations are based on Linear Transfer and AC power flow analyses, angular stability simulations, and short circuit analysis respectively. The study also identifies the interconnection facilities and network upgrades required, along with preliminary good faith cost estimates, that will eliminate any unacceptable system impacts and allow the generator to interconnect to the system as an Energy Resource (ER) or as a Network Resource (NR).

In order for G522 to interconnect as an ER it is necessary to complete the network upgrades required to resolve the injection limits along with any network upgrades to resolve stability and circuit breaker over-duty violations. In order for G522 to qualify as an NR, any additional system upgrades that are identified based on the Deliverability Study performed by MISO must also be completed.

1.1 Injection Limits

Injection limits are thermally overloaded facilities that either have a Distribution Factor (DF) of at least 20% in relation to real power injected at the generator Point of Interconnection (POI) and delivered to all of MISO, or they are direct outlets from the generator POI. The study identified 19 steady-state thermal violations for NERC Category B events (single contingencies), as shown in Table A.1 in Appendix A. Three of these thermal violations meet the criteria of injection limits, and are identified below:

1. Werner West – Werner 138kV future line,
2. Werner – Hintz 138kV tie line, and
3. Hintz – Ellington 138kV line.

Solutions to all three injection limits are required for both ER and NR interconnection services for the full 550 MW of requested capacity of G522.

1.2 Operation Restrictions

The study identified 21 steady-state thermal violations for NERC Category C events (double contingencies) requiring potential operation restrictions on G522. These operation restrictions were identified based on N-2 linear transfer analysis on the Summer 2011 model that included the three planned projects identified as Injection Upgrades in Section 1.4 below. A summary of the operation restrictions on G522 under prior outage conditions is provided in Table B.1 in Appendix B. No additional operation restrictions were identified based on prior outage stability simulations.

1.3 Interconnection Facilities

Interconnection Facilities include all facilities and equipment between the interconnecting generating facility and the generator POI. New interconnection facilities will consist of facilities between the proposed generator and the G522 interconnection substation terminal. Note that the generator POI, which is the bus side of the disconnecting device on the high (345kV) side of the G522 GSU transformer, is also the Point of Change of Ownership (PCO). Table 1.1 describes the required interconnection facilities and provides good faith cost estimates for them.

1.4 Network Upgrades

Existing Network Upgrades Before G522 Operation (See Table 1.2)

Breaker Duty Related

Prior to G522, the fault current interruption duty of four breakers at the Rocky Run 115kV station and one breaker at the Whiting Ave 115kV station is exceeded. ATC has scheduled upgrades for these five breakers by end of 2008.

Network Upgrades Required Due to G522 Addition (See Table 1.3)

Upgrades to facilitate the G522 interconnection

Construct a new 345kV three terminal ring bus at the proposed site and loop the Rocky Run – Werner West 345kV line into the new substation. A fourth terminal may have to be added for the G522 Reserve Auxiliary Transformer or for a 345/115kV transformer. The final configuration

will need to be determined prior to the Facility Study. Table 1.3 describes these facilities and provides a good faith cost estimate.

Injection Upgrades

Injection upgrades refer to those network upgrades that eliminate the injection limits (see Section 1.1). The injection upgrades are required for both NR and ER interconnection services. The inclusion of three planned projects with an in-service date of Summer 2009 in the study model resolved all injection limits. The following planned projects resolve the injection limits identified in the power flow analysis and are included in Table 1.3:

- 1) Construct Gardner Park-Central Wisconsin 345kV line
- 2) Construct Morgan-Central Wisconsin-Werner West 345kV line
- 3) Construct Clintonville-Werner West 138kV line

Angular Stability Related

In addition to the three planned projects identified for resolving injection limits, the following upgrades/reconfigurations included in Table 1.3 are required to achieve adequate breaker clearing time margins for angular stability:

- 1) 345 kV breakers installed at the new G522 interconnection substation bus are required to be 2-cycle IPO breakers.
- 2) Install one SEL421 relay on breaker #2 at the new G522 345kV interconnection substation (see Figures 1a and 1b for breaker numbering).
- 3) Replace relays on breakers 6-1 and 2-6 at Rocky Run with SEL421 relays.

Breaker Duty Related

There are no upgrades required due to additional fault duty from G522. Refer to Section 3.3 for more discussion on this subject and Appendix D for detailed results.

Network Resource (NR) Certification Related

Upgrades to resolve all deliverability limits have not yet been identified. If the customer wishes to be certified as a Network Resource, then an addendum to this report will be posted listing solutions to deliverability limits. Refer to Sections 1.6, 2.2.3 and 3.4 and Appendix E for more discussion on this subject.

1.5 Reserve Auxiliary Transformer Options

ATC has investigated several options for the connection of the G522 Reserve Auxiliary Transformer. Please see Appendix F for detailed descriptions and cost estimates of the options studied. ATC and the customer need to discuss this issue prior to the Facility Study.

1.6 Further Study

The next step in the Generator Interconnection Request process is for the customer to decide whether to proceed to a Facility Study as an ER or proceed with an addendum to the ISIS for the purpose of identifying solutions to the deliverability constraints. A Facility Study will specify in more detail the time and cost of the equipment, engineering, procurement and construction of the system upgrades identified in this ISIS report.

Table 1.1 – Required Interconnection Facilities for G522

Location	Facilities
G522	Item#1 –19/345kV Generation Step-Up Transformer (GSU), 19kV circuit breaker and disconnect switch, and 345kV disconnect switch.

Notes: These facilities to be provided by customer.

Table 1.2– Existing System Upgrades Required before Operation of G522

Location	Upgraded Facilities	Reason
Rocky Run 115kV sub	Replace breakers 1151, T-20, 166, and 266	Breaker Duty
Whiting Ave 115kV sub	Replace breaker 1151	Breaker Duty

Table 1.3 – Required Network Upgrades due to the Addition of G522

Location	Facilities	Reason	Good Faith Cost Estimate	Year Basis for Cost
G522 Interconnection 345kV Substation	Three terminal 345kV ring bus – three 345kV 2-cycle IPO circuit-breakers, SEL421 relays, and associated buses and bus supports and equipment. A fourth terminal and breaker may also have to be added for the G522 Reserve Auxiliary Transformer or for a 345/115kV transformer.	Interconnection & Stability	\$4.8 M (3-terminal) \$6.1 M (4-terminal)	2006
	Approximately 5 mile long 345kV line connections to Rocky Run-Werner West 345kV line.	Interconnection	\$8.4 M	2006
POSSIBLE OPTIONS¹ - G522 Interconnection 115kV Substation	Two 0.6 mile connections from the G522 Reserve Aux. Transformer to tap into the Plover-Coyne 115kV circuit (line J-114) with disconnects facing in each direction.	Alternate Interconnection Options	\$0.5 M	2006
	A three terminal 115kV bus connecting G522 Reserve Aux. Transformer to 115kV system – two 115kV circuit breakers, and associated buses and bus supports and two 0.6 mile connections to Plover – Coyne 115kV line.		\$2.9 M	
	One 345/115 kV 300 MVA transformer, a six terminal 115kV ring bus, six 115kV circuit breakers, SEL421 relays, associated buses and bus supports and equipment, and four 0.6 mile connections to the Plover – Coyne 115kV and Rocky Run – Coyne 115kV lines.		\$7.8 M	
Central Wisconsin 345kV Substation	Construct Central Wisconsin Substation ²	Injection	\$131.5 M	2009
	Construct Gardner Park-Central Wisconsin 345kV line ²	Injection		
	Construct Morgan-Central Wisconsin 345kV and Central Wisconsin-Werner West 345kV lines ²	Injection	\$125.5 M	2009
Werner West	Construct Clintonville-Werner West 138kV line ²	Injection		
Rocky Run	Replace relays on breakers 6-1 and 2-6 at Rocky Run with SEL421 relays	Stability	\$65 K	2006
Multiple (TBD)	Solutions to deliverability limits to be provided in study Addendum.	NR Certification	Unknown	N/A

Notes:

1. Final interconnection configuration will be determined in the Facility Study.
2. These projects, identified in the ATC 10-Year Assessment, are planned for completion in 2009.

2. Criteria, Methodology and Assumptions

2.1 Study Criteria

All relevant MISO-adopted NERC Reliability Criteria and the American Transmission Company contingency criteria are to be met for both thermal and angular stability analysis. Details of the analysis criteria used in this study can be found in Appendix G.

2.2 Study Methodology

The results of this study are subject to change. The results of the Study are based on data provided by the Generator and other ATC system information that was available at the time the study was performed, and the injection study does not guarantee deliverability to the MISO energy market. If there are any significant changes in the generator and controls data, earlier queue Generator Interconnection Requests, related Transmission Service Requests, or ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this request is subject to restudy. The Generator is responsible for communicating any significant generation facility data changes in a timely fashion to MISO and ATC prior to commercial operation.

2.2.1 Competing Generation Requests

ATC has determined that 14 earlier queue position Generator Interconnection have impact on the G522 study results. These requests are considered as competing requests for the interconnection of this generator and were therefore included in each base case. The list of competing generation is provided in table 2.1 below.

Queue Number	Control Area	MW	Expected In-Service Year
G144	WPS	550	2008
G173	XEL	300	2006
G237	XEL	313	2008
G238	XEL	125	2009
G261	XEL	380	2006
G351	GRE	200	2007
G352	GRE	200	2009
G369	XEL	385	2005
G389	GRE	178	2007
G390	GRE	92	2009
G428	XEL	10	2006
G443	XEL	19	2006
G444	XEL	19	2007
G477	MP	531	2010

Public information related to Generator Interconnection Request queue can be found via the MISO web site at <http://oasis.midwestiso.org/documents/ATC/queue.html>

2.2.2 Linear Transfer Analysis and A.C. Power Flow Analysis Methods

Thermal overloads were identified using linear transfer analysis and then verified with AC solutions. The linear transfer analysis was used to evaluate the intact system, N-1, N-2 and certain ATC multiple contingency conditions. The linear transfer analysis utilized adjusted MW ratings to account for reactive power flows and a 5% transmission reserve margin (“TRM”). All AC solutions utilized actual equipment ratings minus 5% TRM with real and reactive line flows.

The linear transfer analysis was performed using the Linear Transfer Analysis modules of the Managing and Utilizing System Transmission-7.0 (MUST, Version 7.0) program from Power Technologies, Inc (PTI). All AC solutions were performed using the Power Flow module of the Power System Simulation/Engineering-29 (PSS/E, Version 29) program from Power Technologies, Inc (PTI). These programs are accepted industry-wide for power flow analysis.

2.2.3 Base Cases

2.2.3.1 Power flow analysis

Base cases used in the thermal analysis for this study were developed based upon the ATC summer peak 2005 model and the July 2005 build of MISO seasonal cases of winter peak 2010/11 and summer peak of 2011. Cases modeling the winter peak of 2010/11, shoulder peak of 2011, and summer peak of 2011 were created for use in this study. The ATC system was modified by updating all loads to the expected coincident peak value and including all planned and proposed projects through 2007 and all planned projects through 2008 as listed in the ATC Ten Year Assessment. The output of G522 was delivered to all on-line MISO generation, unless specified otherwise. The MISO seasonal cases are accessible through the MISO Extranet.

Power flow analysis includes identifying limiting elements that incur thermal violations for an intact system and under N-1 contingencies by using linear transfer analysis and AC power flow analysis. For N-2 contingencies, thermal analysis includes evaluating thermal violations and prior outage operating restrictions based on linear transfer analysis only.

2.2.3.2 Angular Stability analysis

The 2011 light load base case used in the angular stability analysis for this study was developed based upon the 2005 ATC 50-percent peak load stability model. The 2005 stability model was modified by including all proposed projects through 2007 and all planned projects through 2008 as listed in the ATC Ten Year Assessment. All loads in the resulting model were updated to the expected 2011 coincident peak value based on EIA-411 forecast for Summer 2011 and additional generation was dispatched to supply the increased load plus losses. All constant loads at buses within ATC footprint were applied to the model and generation dispatch was accordingly changed to obtain the 2011 ATC 50-percent peak load stability model. To convert this into the G522 stability base case, all existing generators at Weston and the proposed G522 generator were dispatched at their full output in accordance with ATC generator interconnection study methodology. The resulting additional generation in WPS control area was delivered to ComEd (75%) and Northern States Power (25%) control areas. To meet the minimum criteria for angular

stability, it was necessary to enhance the G522 stability base case by adding the three planned ATC projects that were identified by the injection study (see Table 3.1 in Section 3) to the model.

Angular stability analysis includes screening for stable operation at acceptable primary and delayed breaker clearing times for breaker failure contingency conditions, and acceptable primary breaker clearing times for prior outage conditions. These cases are typically the worst conditions for angular stability performance.

2.2.3.3 Deliverability analysis

The deliverability analysis case was developed by MISO from the 2004 series Midwest ISO Transmission Expansion Planning (MTEP) case for the 2009 Summer Peak season, incorporating feedback from Transmission Owners and following the MISO deliverability study methodology. Details on the MISO deliverability study methodology can be found in the whitepaper posted at the following link:

[MISO Deliverability Whitepaper](#)
(see appendix E for full web address)

2.2.4 Generation Facility Modeling

The G522 facility was modeled at 550 MW with a high-side bus voltage to 1.02 per unit unless specified otherwise. The G522 generator was modeled with a generator step-up transformer connecting G522 to the 345kV transmission system. G522 will be required to maintain a voltage schedule of 1.02 pu at the POI, unless directed otherwise by the ATC system operator.

3. Analysis Results

3.1 Power Flow Analysis Results

3.1.1 Results of Single Contingencies (N-1)

An injection study was performed by delivering 100% of the G522 output to the entire MISO footprint. Study of the 550 MW injection from G522 identified no steady-state thermal violations for NERC Category A events. Nineteen violations on unique transmission elements for NERC Category B events (post-contingent overloads) were identified. Of these 19 violations, three transmission elements were identified as injection limits (limits with a distribution factor of 20% or greater). The injection limits were resolved by the addition of three planned projects to the model.

This thermal analysis was performed on each seasonal base case with and without the inclusion of the three planned projects listed in Table 3.1. The inclusion of these projects eliminated all three of the injection constraints listed in Table A.1 of Appendix A. An additional study scenario was examined including the projects from Table 3.1 and further stressing the system by reducing counter-flow generation south of Green Bay and replacing it with generation north and west of G522 (50%) and from the Milwaukee area (50%). No additional injection limits were identified in this scenario.

Table 3.1: Transmission Projects relieving G522 injection limits

Project Description	Expected In-Service Year	Project Status
Construct Morgan – Werner West 345kV line	2009	Planned
String a new 138kV line from Clintonville to Werner West primarily on the Morgan – Werner West 345kV line structures	2009	Planned
Construct new Central Wisconsin 345kV substation along Morgan-Werner West 345kV line and construct Gardner Park – Central Wisconsin 345kV line	2009	Planned

For each of the non-injection limit violations identified in the N-1 analysis, a solution of limited scope was identified in Appendix A of the Feasibility Study. Solutions not identified in the ATC 10-Year Assessment are shown in Table 3.2 and were developed in the following order.

1. If the line is not limited by the conductor rating, then replace the terminal equipment.
2. If the line is limited by the conductor rating, then increase phase conductor clearance to the maximum operating temperature of the conductor.
3. If the maximum operating temperature of the conductor does not resolve the limit, then a line reconductor or rebuild is proposed.

Table 3.2: Potential Transmission Projects Resolving G522 N-1 "non-injection" violations

Limiting Element	Potential Solution	Good Faith Cost Estimate (2006 Dollars)
Arpin-Sigel 138kV Line X-33	Replace CT and jumpers at Sigel and replace jumpers at Arpin to achieve 1226 Amp SE rating.	\$263 K
Rocky Run-Whiting Ave 115kV Line M-91	Replace two bus jumpers at Whiting Ave to achieve 1467 Amp SE rating.	\$18 K
Rocky Run – Plover 115kV Line S-45	Replace two bus jumpers at Plover to achieve 1326 Amp SE rating.	\$18 K
Rocky Run 345/115 kV Transformer T1	Replace unit with larger transformer OR add 345/115kV transformer and 115kV interconnection at G522 POI.	\$2.8 M OR \$7.8 M
Coyne-Baker St 115 kV Line T-72 *	Increase clearance on 795.0 Drake line conductor to 230°F and replace two bus jumpers at Coyne to achieve 1378 Amp SE rating and replace wave trap at Coyne to achieve 1378 Amp SE rating.	\$98 K
G522-Coyne 115 kV Segment of Line J-114 *	Replace two relays at Coyne to achieve 1146 Amp SE rating.	\$234 K

* These facilities overloaded when the 345/115 kV interconnection option is chosen.

3.1.2 Results of Double Contingencies (N-2)

Thermal constraints were evaluated for NERC Category C events (N-2 contingencies) in the electrical proximity of G522. The purpose of the N-2 analysis is to reveal potential violations and identify potential operating restrictions to eliminate the violations under prior outage conditions. The N-2 analysis was performed only on the summer peak model that included the projects listed in Table 3.1.

Thermal violations under a selected number of N-2 contingencies were evaluated using linear transfer analysis and are listed in Table A.2 in Appendix A. The table includes all limiting elements that were identified in the N-1 analysis and lists only the most limiting double contingency for each. The double contingency constraints are not required to be resolved for the generator to attain either Energy Resource or Network Resource status.

The required operating restrictions for the double contingencies are listed in Table B.1 in Appendix B. The restrictions are based on the most limiting element, some of which were identified in the N-1 analysis (and were therefore included in Table A.2). These restrictions have been reviewed and a complete description of all N-2 limits and operating restrictions is listed in Appendix B. Potential solutions are supplied for information purposes only and were developed in the following order:

1. If the line is not limited by the conductor rating, then replace the terminal equipment.
2. If the line is limited by the conductor rating, then increase phase conductor clearance to the maximum operating temperature of the conductor.

3. If the maximum operating temperature of the conductor does not resolve the limit, then a line reconductor or rebuild is proposed.

Note that each solution is directly related to the individual constraint. It is possible that a separate plan may address all limits and offer secondary benefits. If the customer chooses to elect any of these upgrades in the Facility Study, then ATC will review the proposed solutions when preparing that report. Table B.1 also lists an approximate cost estimate for each identified solution. All cost estimates in Table B.1 are supplied for informational purposes only and were developed using the cost estimate reference Table 3.3 shown below.

Table 3.3: Reference Cost Estimates for typical transmission upgrades.

Facility Upgrade	Approximate Cost	
New 345 kV single circuit line	\$1,600,000	/Mile
New 345 kV double circuit line	\$1,600,000/Mile	/Mile
New 345 kV single circuit underground line (w/ terminals)	\$10,000,000	/Mile
New 138 kV or 115 kV single circuit line	\$800,000	/Mile
New 138 kV or 115 kV double circuit line	\$1,100,000	/Mile
New 138 kV or 115 kV single circuit underground line (w/ terminals)	\$3,300,000	/Mile
New 69 kV single circuit line	\$585,000	/Mile
New 69 kV double circuit line	\$770,000	/Mile
New 69 kV single circuit underground line (w/ terminals)	\$2,400,000	/Mile
Rebuild 138 kV at 138 kV (larger conductor) double circuit	\$530,000	/Mile
Rebuild 115 kV at 115 kV (larger conductor) double circuit	\$530,000	/Mile
Rebuild 69 kV to 138 kV, single circuit Mile	\$400,000	/Mile
Reconductor 138 kV or 115 kV line, single circuit	\$210,000	/Mile
Reconductor 69 kV line, single circuit	\$117,000	/Mile
345 kV substation terminal ¹	\$1,300,000	Each
138 kV or 115 kV substation terminal ¹	\$ 840,000	Each
69 kV substation terminal ¹	\$ 683,000	Each
345/138 kV transformer ²	\$3,500,000	Each
345/115 kV transformer ²	\$3,500,000	Each
138/69 kV transformer ³	\$1,800,000	Each
100 Mvar Statcom	\$10,000,000	Each

Notes:

All substation costs are inflated out one year from time of estimate.

1. Includes line breaker and maintenance switches
2. Assumes 500 MVA unit, includes high and low side breakers
3. Assumes 100 MVA unit, includes high side breaker/circuit switcher and low side breaker

3.2 Angular Stability Analysis Results

The angular stability criteria used in this study requires that all machines modeled in the system must remain stable after a three-phase or single-phase to ground fault is cleared from any transmission element under the following scenarios:

1. Three-phase fault cleared in primary time with an otherwise intact system;
2. Three-phase fault cleared in primary clearing time with a prior outage of any other transmission element;
3. Three-phase fault cleared in delayed clearing time (i.e. breaker failure condition) with an otherwise intact system;

4. Single Line to Ground (SLG) bus section fault cleared in primary clearing time with an otherwise intact system;
5. SLG internal breaker fault cleared in primary clearing time with an otherwise intact system.

In this ISIS study, potential angular stability problems were screened by studying the two scenarios that produce the most severe conditions for maintaining angular stability; that is, scenario #2 (prior outage) and scenario #3 (breaker failure). Results of the angular stability analysis are summarized in Tables C.1 and C.2 in Appendix C. Further, adequate damping of the local plant mode rotor angle oscillations was verified by running extended transient stability simulations (to 20 seconds) for selected prior outage and breaker failure cases. The two cases with smallest critical clearing time were selected from Tables C.1 and C.2 for verifying the absence of any local-plant swing mode and/or slow inter-area swing mode.

Based on the results obtained in this study and engineering judgment, it is concluded that no unacceptable angular stability conditions will arise due to faults cleared in primary breaker clearing time with an otherwise intact system (that is, scenarios 1, 4 and 5 above).

3.2.1 Results of Delayed Clearing Contingencies

The breaker failure contingencies evaluated and the study results are summarized in Table C.1 in Appendix C.

The study identified three unacceptable angular stability performance scenarios after the addition of G522. The installation of two-cycle or faster circuit breakers at the G522 interconnection substation along with SEL421 relaying eliminates one of the violations. The calculated Critical Clearing Time (CCT) has less than one cycle margin to the Maximum Expected Clearing Time (MECT) for the remaining two delayed clearing cases violations, thus not meeting the angular stability performance criteria in Section G.5 of Appendix G. Upgrading to faster acting relay equipment, such as the SEL421 relays, for two breakers at the Rocky Run 345kV substation resolves these remaining violations. No additional delayed clearing violations were identified with the study of the 345/115kV interconnection option (Figure 1b).

3.2.2 Results of Prior Outage Primary Fault Contingencies

The prior outage contingencies evaluated and the study results are summarized in Table C.2 in Appendix C. The results obtained in this analysis were not affected by the study of the 345/115kV interconnection option (Figure 1b).

The study identified no unacceptable stability performance after the addition of G522 for any of the studied prior outage primary clearing contingencies. No additional operation restrictions are necessary due to prior outage primary fault stability analysis.

3.2.3 Results of Bus Section Fault and/or Internal Breaker Fault Contingencies

No bus section fault/internal breaker fault contingencies were evaluated for Three-phase or Single-Line to Ground (SLG) faults because the breaker failure contingencies at Werner West, G522, and Rocky Run were more severe contingencies.

3.3 Short-Circuit & Breaker Duty Analysis Results

Table D.1 and D.2 in Appendix D provide the maximum short-circuit duty seen at the Point of Interconnection (POI) and the corresponding Thevenin equivalent impedances before and after G522 is interconnected.

The breaker duty analysis identified four breakers in the Rocky Run 115kV station and one breaker in the Whiting Ave 115kV station that will exceed their interruption duty with the addition of G522. As shown in the results in Table D.3 in Appendix D, all five overdutied breakers were identified as pre-existing problems and do not need upgrading due to the addition of G522. While G522 does increase the margin by which the existing duty rating is exceeded for these breakers, the new breakers will have adequate duty margin to handle the additional fault current from the operation of G522.

3.4 Deliverability Analysis Results

The MISO deliverability analysis identified 20 constraints restricting the deliverability of G522. ATC tested the impact of Table 3.1 solutions on the deliverability results. Six constraints were resolved but one new constraint was identified. Table E.1 of Appendix E provides a listing of all deliverability constraints to G522.

After adding the Table 3.1 projects, 11 constraints, representing 10 unique transmission elements, restrict deliverability to zero MW. All deliverability constraints must be resolved to achieve Network Resource Interconnection Service (NRIS) certification.

However, G522 may choose Energy Resource Interconnection Service (ERIS) without resolving the deliverability constraints, as long as all other identified Network Upgrades are constructed. Solutions for the remaining deliverability constraints have not yet been identified. If the customer elects to continue as a Network Resource, then an addendum to the ISIS report will be prepared to provide solutions and preliminary non-binding good faith estimates of cost.

Appendix A: Power Flow Analysis Results

Table A.1 – Identified Intact and N-1 Thermal Violations due to G522 Delivery to MISO

Limiting Element	MVA Rating	N-1 MVA Loading	Worst Contingency	TDF (%)	Case Description ¹	Injection Limit	Solution Proposed in TYA	Potential Solution	Good Faith Cost Estimate
None	N/A	N/A	Intact System	N/A	All Cases Tested	N/A	N/A	N/A	N/A
Rocky Run – Plover 115kV Line S-45	248	275	Rocky Run-Whiting Ave 115kV Line M-91	4.3	Summer 2011	No	No	Replace two bus jumpers at Plover to achieve 1326 Amp SE rating.	\$18 K
Rocky Run-Whiting Ave 115kV Line M-91	277	309	Rocky Run – Plover 115kV Line S-45	4.8	Summer 2011	No	No	Replace two bus jumpers at Whiting Ave to achieve 1467 Amp SE rating.	\$18 K
Caroline-Belle Plaine 115kV Line J-36	119	155	G522 – Werner West 345kV Future Line	9.3	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Whiting Ave-Hoover 115kV Line H-138	246	260	G522 – Werner West 345kV Future Line	13.4	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Whitcomb-Caroline 115kV Line J-36	119	150	G522 – Werner West 345kV Future Line	7.9	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Kelly-Whitcomb 115kV Line J-36	165	196	G522 – Werner West 345kV Future Line	8.6	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Belle Plaine-Badger 115kV Line J-36	122	149	G522 – Werner West 345kV Future Line	9.2	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Arpin-Sigel 138kV Line X-33	287	295	Coyne-Baker West 115kV Line T-72	6.0	Summer 2011	No	No	Replace CT and jumpers at Sigel and replace jumpers at Arpin to achieve 1226 Amp SE rating.	\$263 K
Werner West-Werner 138kV Future Line	287	345	Werner W.-N.Appleton 345kV Future Line	28.2	Summer 2011	Yes	Yes	Planned projects from Table 3.1	\$257.0 M
Falls-Pioneer 138kV Line 75541	382	387	Morgan-Plains 345kV Line 35321	5.2	Shoulder 2011	No	Yes	Cranberry-Conover-Plains ²	\$104.7 M
Morgan-Falls 138kV Line 35351	403	393	Morgan-Plains 345kV Line 35321	5.2	Shoulder 2011	No	Yes	Cranberry-Conover-Plains ²	\$104.7 M
Rocky Run 345/115 kV Transformer T1	192	189	Rocky Run 345/115 kV Transformer T4	3.6	Summer 2011	No	No	Replace transformer with larger unit.	\$2.8 M
Sand Lake-Port Edwards 138kV Line X-11	155	229	G522 – Werner West 345kV Future Line	11.7	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Ellington-Casaloma 138kV Line 80331	216	226	Werner W.-N.Appleton 345kV Future Line	12.9	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Coyne-Baker West 115kV Line T-72	244	243	Arpin-Sigel 138kV Line X-33	6.2	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Werner-Hintz 138kV Line HNZ-WER	287	317	Werner W.-N.Appleton 345kV Future Line	28.2	Summer 2011	Yes	Yes	Planned projects from Table 3.1	\$257.0 M
Plover-Coyne 115kV Line J-114	180	186	Rocky Run-Coyne 115kV Line N-92	3.5	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Badger 138/115kV TR 1	143	149	G522 – Werner West 345kV Future Line	9.3	Summer 2011	No	Yes	Planned projects from Table 3.1	\$257.0 M
Hintz-Ellington 138kV Line 80332	293	305	Werner W.-N.Appleton 345kV Future Line	28.2	Summer 2011	Yes	Yes	Planned projects from Table 3.1	\$257.0 M

Notes:

1. Summer 2011, Shoulder 2011, and Winter 2010/11 represent the expected summer peak and shoulder peak of 2011 and winter peak of 2010-2011, respectively, including all planned projects through 2008 and proposed projects through 2007.

G522 Interconnection System Impact Study Report

2. Construct Cranberry-Conover 115-kV line; construct 138kV bus and install 138/115kV 150 MVA and 138/69kV 60 MVA transformers at Conover; and rebuild/convert Conover-Plains 69kV line to 138 kV. These projects proposed for completion by December 2009 in the ATC TYA.

Table A.2 – N-2 Contingency¹ results for previously identified² Thermal Violations due to G522

Limiting Element ³	MVA Rating	Worst MW Loading	Double Contingency	TDF (%)	Solution Proposed in TYA
Rocky Run 345/115 kV Transformer T1	192	279	Rocky Run 345/115 kV Transformer T2 + Rocky Run 345/115 kV Transformer T4	5.4	No ⁴
Ellington-Casaloma 138kV Line 80331	216	249	Butte Des Morts – N.Appleton 138kV + N.Appleton – Apple Hills 138kV	4.1	No ⁴
Rocky Run-Whiting Ave 115kV Line M-91	277	324	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	11.7	No ⁴
Whiting Ave-Hoover 115kV Line H-138	246	255	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	13.3	No ⁵
Arpin-Sigel 138kV Line X-33	287	281	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	7.9	No ⁵
Sand Lake-Port Edwards 138kV Line X-11	155	177	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	11.7	No ⁵
Caroline-Belle Plaine 115kV Line J-36	119	125	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	9.7	No ⁵
Whitcomb-Caroline 115kV Line J-36	119	122	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	8.3	No ⁵
Kelly-Whitcomb 115kV Line J-36	165	164	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	8.8	No ⁵
Coyne-Baker West 115kV Line T-72	244	242	G522 – Werner West 345 kV + Arpin 345/138 kV Transformer T21	8.6	No ⁵
Belle Plaine-Badger 115kV Line J-36	122	118	G522 – Werner West 345 kV + Gardner Park – Central Wisconsin 345 kV	9.7	No ⁵
Falls-Pioneer 138kV Line 75541	382	371	Morgan-Plains 345kV + Kewaunee 345/138 kV Transformer 1	5.3	Yes ⁶
Plover-Coyne 115kV Line J-114	180	166	G522 – Werner West 345 kV + Arpin 345/138 kV Transformer 1	4.1	No ⁵
Werner West-Werner 138kV Future Line	287	283	North Appleton – Werner West 345kV + Morgan – Central Wisconsin 345 kV	24.5	No ⁵

Notes:

1. N-2 analysis of transmission elements in the electrical proximity of G522 performed using the Summer 2011 system peak model including the three projects listed in Table 3.1.
2. Only limiting elements that were identified in table A.1 are listed in this table. More complete N-2 analysis is provided in Appendix B.
3. Because these limiting elements were identified as a single contingency limits, only the worst double contingencies are shown for each limiting element.
4. See Table B.1 in Appendix B for potential solution to this limit.
5. Thermal overload of this limiting element under double contingency can not be resolved by the projects described in Table A.1.
6. Including the Cranberry – Conover – Plains 138kV series of projects in the model resolves this limit. These projects have been proposed for completion in December 2009 in the ATC 10-Year Assessment (TYA).

Appendix B: Summary of Operation Restrictions

Table B.1 – Summary of Identified Operation Restrictions on G522 due to N-1-1 Contingencies¹

Prior outage	Allowable MW Output	Worst Next Contingency	Most Limiting Element	MVA Rating	Potential Solution²	Generic Cost Estimate³
Amberg – Plains 138kV	0	Dead River – Plains 345kV	Plains 345/138kV Transformer T1	250	Install a second Plains 345/138 transformer	\$3.5 M
Dead River – Plains 345kV	0	Amberg – Plains 138kV	Plains 345/138kV Transformer T1	250	Install a second Plains 345/138 transformer	\$3.5 M
Falls – Pioneer 138kV	0	Dead River – Plains 345kV	Plains 345/138kV Transformer T1	250	Install a second Plains 345/138 transformer	\$3.5 M
Rocky Run 345/138 kV Transformer T2	0	Rocky Run 345/138 kV Transformer T4	Rocky Run 345/138 kV Transformer T1	192	Replace Rocky Run 345/138 T1 with larger transformer or install 345/138 transformer at G522 POI	\$3.5 M
Rocky Run 345/138 kV Transformer T4	0	Rocky Run 345/138 kV Transformer T2	Rocky Run 345/138 kV Transformer T1	192	Replace Rocky Run 345/138 T1 with larger transformer or install 345/138 transformer at G522 POI	\$3.5 M
Morgan 345/138 kV Transformer 1	0	Dead River – Plains 345kV	Plains 345/138kV Transformer T1	250	Replace Plains 345/138 T1 with larger transformer	\$3.5 M
Rocky Run 345/138 kV Transformer T1	0	Rocky Run 345/138 kV Transformer T4	Rocky Run 345/138 kV Transformer T2	210	Replace Rocky Run 345/138 T2 with larger transformer or install 345/138 transformer at G522 POI	\$3.5 M
Arpin – Sigel 138kV	0	Rocky Run 345/138 kV Transformer T4	Rocky Run 345/138 kV Transformer T1	192	Replace Rocky Run 345/138 T1 with larger transformer or install 345/138 transformer at G522 POI	\$3.5 M
Butte Des Mortes – N.Appleton 138kV	0	North Appleton – Apple Hills 138kV	Ellington – Casaloma 138kV	216	Replace line and bus-side jumpers at Ellington substation	< \$1.0 M
North Appleton – Apple Hills 138kV	0	Butte Des Mortes – N.Appleton 138kV	Ellington – Casaloma 138kV	216	Replace line and bus-side jumpers at Ellington substation	< \$1.0 M
White Lake – Waupaca 138kV	0	Rocky Run 345/138 kV Transformer T4	Rocky Run 345/138 kV Transformer T1	192	Replace Rocky Run 345/138 T1 with larger transformer or install 345/138 transformer at G522 POI	\$3.5 M
G522 – Werner West 345kV	11	Gardner Park – Central Wisconsin 345kV	Rocky Run – Whiting Ave 115kV	277	Replace line and bus-side jumpers at Whiting Ave and increase conductor clearance (2.75mi.)	< \$1.0 M
Gardner Park – Central Wisconsin 345kV	11	G522 – Werner West 345kV	Rocky Run – Whiting Ave 115kV	277	Replace line and bus-side jumpers at Whiting Ave and increase conductor clearance (2.75mi.)	< \$1.0 M
Werner West – White Lake 138kV	313	G522 – Werner West 345kV	Rocky Run – Whiting Ave 115kV	277	Replace line and bus-side jumpers at Whiting Ave and increase conductor clearance (~2.7mi.)	< \$1.0 M
Morgan – Central Wisconsin 345kV	385	North Appleton – Werner West 345kV	Werner West 345/138 kV Transformer 1	500	Replace Werner West 345/138 kV T1 with a larger transformer or install 2 nd Werner West transformer	\$5.5 M

Prior outage	Allowable MW Output	Worst Next Contingency	Most Limiting Element	MVA Rating	Potential Solution ²	Generic Cost Estimate ³
North Appleton – Werner West 345kV	385	Morgan – Central Wisconsin 345kV	Werner West 345/138 kV Transformer 1	500	Replace Werner West 345/138 kV T1 with a larger transformer or install 2 nd Werner West transformer	\$5.5 M
Arpin 345/138 kV Transformer	421	G522 – Werner West 345kV	Coyne-Baker W 115kV	244	Increase clearance on line conductor	< \$1.0 M
N.Appleton – Fitzgerald 345kV	431	Butte Des Morts – N.Appleton 138 kV	Ellington-Casaloma 138kV	216	Replace line and bus-side jumpers at Ellington substation	< \$1.0 M
Granville – Sheboygan 345kV	514	Arpin – Sigel 138kV	Coyne-Baker W 115kV	244	Increase clearance on line conductor	< \$1.0 M
Morgan – Plains 345kV	519	Kewaunee 345/138 kV Transformer	Falls-Pioneer 138kV	380	Reconductor Falls-Pioneer line (~5.0 mi.) and upgrade terminal equipment at both ends	\$2.5 M
Kewaunee 345/138kV Transformer	519	Morgan – Plains 345kV	Falls-Pioneer 138kV	380	Reconductor Falls-Pioneer line (~5.0 mi.) and upgrade terminal equipment at both ends	\$2.5 M

Notes:

1. N-1-1 contingencies were analyzed by linear transfer analysis in only the Summer 2011 model. Each prior outage is listed only once along with its most limiting second contingency.
2. Solution of the Most Limiting Element may reveal other, less limiting elements for each prior outage scenario.
3. Cost estimates are supplied for informational purposes only and were created using Table 3.3 (Cost Estimate Reference Table).

Appendix C: Angular Stability Analysis Results

Table C.1 Angular Stability Simulation Results for Breaker Failure Cases

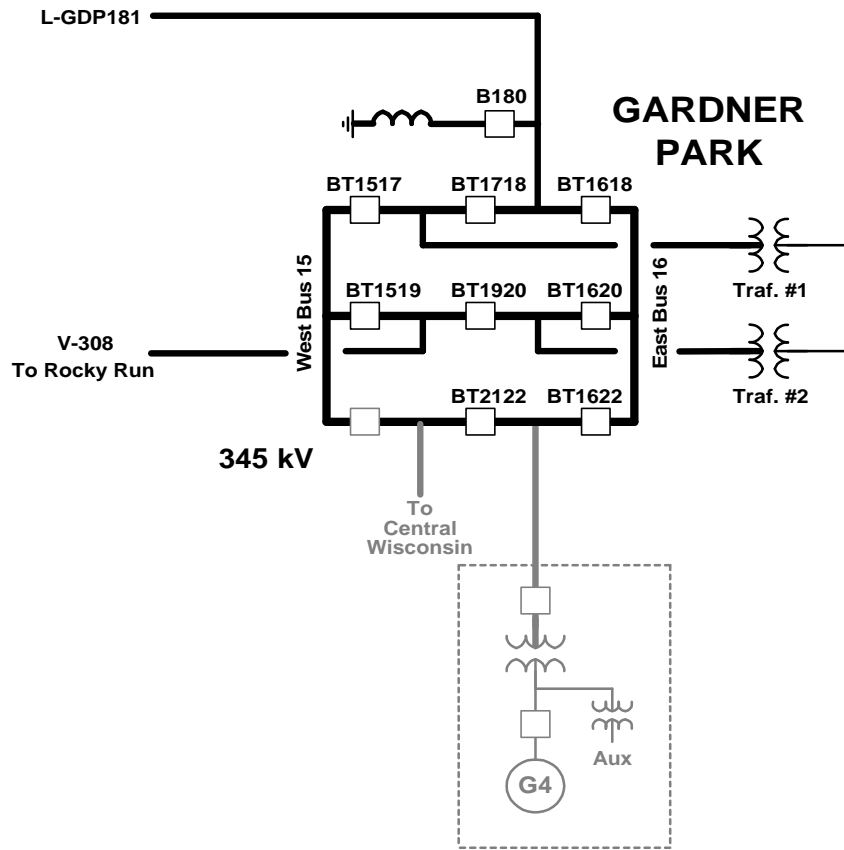
Faulted Element	Fault Location	Failed Circuit Breaker ¹	Additional Element Tripped	Circuit Breaker Type	Max Expected Clearing Time (MECT) ²	Angular Stability at MECT	Calculated Clearing Time (CCT) ³
Werner West 345kV Switchyard¹							
Werner West – North Appleton Line	Werner West End	CB 4	Werner West 345/138 kV Transformer 1	IPO	4.5/9.5	Stable	= 4.5/11.0
Werner West – North Appleton Line	Werner West End	CB 5	Werner West – G522 Line	IPO	4.5/9.5	Stable	= 4.5/11.0
Werner West 345/138kV Transformer 1	Werner West 345	CB 4	Werner West – North Appleton Line	IPO	4.5/10.0	Stable	= 4.5/11.0
Werner West 345/138kV Transformer 1	Werner West 345	CB 2	Werner West – Central Wisconsin Line	IPO	4.5/10.0	Stable	= 4.5/11.0
Werner West – Central Wisconsin Line	Werner West End	CB 2	Werner West 345/138kV Transformer 1	IPO	4.5/9.5	Stable	= 4.5/11.0
Werner West – Central Wisconsin Line	Werner West End	CB 1	Werner West – G522 Line	IPO	4.5/9.5	Stable	= 4.5/11.0
Gardner Park 345kV Switchyard⁴							
Gardner Park – Rocky Run Line	Gardner Park End	BT1920 ⁴	Gardner Park 345/115kV Transformer 2	IPO	4.5/8.0	Stable	= 4.5/10.0
Rocky Run 345kV Switchyard							
Rocky Run – Arpin Line	Rocky Run End	8-V	Rocky Run – Gardner Park Line	IPO	4.5/10.0	Stable	= 4.5/11.0
Rocky Run – Arpin Line	Rocky Run End	1-8	Rocky Run 345/138kV Transformer 1	IPO	4.5/9.8	Stable	= 4.5/11.0
Rocky Run – Gardner Park Line	Rocky Run End	8-V	Rocky Run – Arpin Line	IPO	4.5/8.8	Stable	= 4.5/11.0
Rocky Run – Gardner Park Line	Rocky Run End	V-4	Rocky Run 345/138kV Transformer 4	IPO	4.5/11.5	Stable	= 4.5/12.5
Rocky Run 345/138kV Transformer 4	Rocky Run End	V-4	Rocky Run – Gardner Park Line	IPO	4.5/11.5	Stable	= 4.5/12.5
Rocky Run 345/138kV Transformer 4	Rocky Run End	4-2	Rocky Run 345/138kV Transformer 2	IPO	4.5/11.3	Stable	= 4.5/12.5
Rocky Run 345/138kV Transformer 2	Rocky Run End	4-2	Rocky Run 345/138kV Transformer 4	IPO	4.5/12.0	Stable	= 4.5/13.0
Rocky Run 345/138kV Transformer 2	Rocky Run End	2-6	Rocky Run – G522 Line	IPO	4.5/10.3	Unstable at 4.5/11.3	4.5/11.0 ⁵

Faulted Element	Fault Location	Failed Circuit Breaker ¹	Additional Element Tripped	Circuit Breaker Type	Max Expected Clearing Time (MECT) ²	Angular Stability at MECT	Calculated Clearing Time (CCT) ³
Rocky Run 345/138kV Transformer 1	Rocky Run End	6-1	Rocky Run – G522 Line	IPO	4.5/10.3	Unstable at 4.5/11.3	4.5/11.0 ⁵
Rocky Run 345/138kV Transformer 1	Rocky Run End	1-8	Rocky Run – Arpin Line	IPO	4.5/10.3	Stable	= 4.5/12.0
G522 345kV Switchyard¹							
G522 – Rocky Run Line	G522 End	2	G522 Reserve Aux. Transformer ⁶	IPO	4.5/8.5	Unstable at 4.5/9.5	4.5/9.0 ⁵
G522 – Werner West Line	G522 End	4	G522 Reserve Aux. Transformer ⁶	IPO	4.5/8.5	Stable	= 4.5/11.0

Notes:

1. See Figure 1a or Appendix F of this report for breaker numbering diagrams. These scenarios only apply if the Reserve Aux. Transformer Option 1 from Appendix F is chosen.
2. In cycles, first number listed is remote end clearing time, second number is total breaker clearing time.
3. In cycles, an additional one-cycle margin above MECT must be attained on the total breaker failure clearing time.
4. See Figure C.1 below for breaker numbering of Gardner Park substation.
5. See Section 3.2 of this report for required network upgrades.
6. Also applies to the alternate configuration shown in Figure 1b.

Figure C.1 – Gardner Park Breaker Numbering



This diagram is for informational purposes only, breakers numbering has been arbitrarily assigned for the purposes of this study.

Table C.2 Angular Stability Simulation Results for Prior Outage Cases

Prior Outage Element	Faulted Element	Fault Location	Max. Expected Clearing Time (MECT) cycles*	Angular Stability at acceptable BCT	Critical Clearing Time (CCT) cycles*
Werner West – North Appleton 345kV line	Werner West – Central Wisconsin 345kV line	Werner West 345	4.5	Stable	= 8.0
Werner West – North Appleton 345kV line	G522 – Rocky Run 345kV line	G522 345 POI	3.5	Stable	= 7.0
Werner West – Central Wisconsin 345kV line	Werner West – North Appleton 345kV line	Werner West 345	4.0	Stable	= 8.0
Werner West – Central Wisconsin 345kV line	Werner West 345/138kV Transformer 1	Werner West 345	4.0	Stable	= 8.0
Werner West – Central Wisconsin 345kV line	G522 – Rocky Run 345kV line	G522 345 POI	3.5	Stable	= 8.0
North Appleton – Kewaunee 345kV line	North Appleton – Fox Energy 345kV line	N. Appleton 345	5.8	Stable	= 8.0
North Appleton – Kewaunee 345kV line	North Appleton – Fitzgerald 345kV line	N. Appleton 345	5.8	Stable	= 8.0
North Appleton – Kewaunee 345kV line	North Appleton – 345/138kV Transformer 1	N. Appleton 345	6.8	Stable	= 8.0
North Appleton – Kewaunee 345kV line	North Appleton – 345/138kV Transformer 2	N. Appleton 345	6.5	Stable	= 8.0
North Appleton – Kewaunee 345kV line	North Appleton – 345/138kV Transformer 3	N. Appleton 345	6.8	Stable	= 8.0
North Appleton – Kewaunee 345kV line	G522 – Rocky Run 345kV line	G522 345 POI	3.5	Stable	= 8.0
North Appleton – Fox Energy 345kV line	North Appleton – Werner West 345kV line	N. Appleton 345	5.3	Stable	= 8.0
North Appleton – Fox Energy 345kV line	Werner West – North Appleton 345kV line	Werner West 345	5.3	Stable	= 8.0
Gardner Park – Central Wisconsin 345kV line	G522 – Werner West 345kV line	G522 345 POI	3.5	Stable	= 8.0
G522 – Rocky Run 345kV line	Werner West – North Appleton 345kV line	Werner West 345	3.5	Stable	= 6.0
Eau Claire - Arpin 345kV line	Gardner Park – Stone Lake 345kV line	Gardner Park 345	3.5	Stable	= 8.0

* The Calculated CCT must exceed the MECT by at least one cycle to provide for the required margin.

Appendix D: Short Circuit / Breaker Duty Analysis Results

Table D.1 – Maximum Fault Duty at the G522 Point of Interconnection in Intact System

<i>Fault Duty Before G522</i>		<i>Fault Duty After G522</i>	
<i>Single-phase</i>	<i>Three-phase</i>	<i>Single-phase</i>	<i>Three-phase</i>
10.38 kA	12.16 kA	15.48 kA	15.09 kA

Table D.2 – Thevenin Equivalent Impedances in Ohms at the G522 Point of Interconnection in Intact System

	Pos Seq.	Neg. Seq.	Zero Seq.
<i>Before</i>	1.57497 + j16.3012	1.69086 + j16.3045	4.59445 + j24.4473
<i>After</i>	1.11282 + j13.1510	1.18800 + j13.1550	1.23162 + j12.1450

Table D.3 – Fault Duty Margins for Breakers Before and After G522 Interconnection

<i>Station</i>	Breaker ID / Name	Rating (kA)	<i>Margin Before G522</i>		<i>Margin After G522</i>	
			<i>Single-phase</i>	<i>Three-phase</i>	<i>Single-phase</i>	<i>Three-phase</i>
<i>Rocky Run 115</i>	0812 / 1151	24.0	- 17.7%	2.6%	- 31.8%	- 7.7%
<i>Rocky Run 115</i>	1926 / T-20	24.0	- 12.8%	7.2%	- 26.5%	- 2.8%
<i>Rocky Run 115</i>	0813 / 166	24.0	- 7.7%	10.9%	- 18.7%	2.7%
<i>Rocky Run 115</i>	0815 / 266	24.0	- 6.0%	11.8%	- 16.5%	3.9%
<i>Whiting Ave 115</i>	1151	14.0	4.4%	- 0.2%	0.2%	- 4.8%

Appendix E: Deliverability Analysis Results

For a full description of the Midwest ISO Generator deliverability process, follow the “Deliverability Study Whitepaper” link that can be found at:

http://www.midwestmarket.org/publish/Folder/3e2d0_106c60936d4_-76810a48324a?rev=1

Table E.1 – Deliverability Analysis Restrictions

Limiting Element	Contingency	G522 MW Deliverable	Potential Solution¹
Hoover-Armott 138kV Line I-139	G522-Werner West 345kV line	388.1	Planned projects from Table 3.1.
Butler-Granville 138kV line	Granville-Arcadian 345kV line	363.0	Further study in progress.
St. Lawrence-Arcadian 345kV line ²	Base Case	299.5	Further study in progress.
Werner West 345/138 Transformer	N.Appleton-Werner W. 345kV line	205.8	Planned projects from Table 3.1.
Pleasant Prairie-Zion 345kV line	Base Case	83.1	Further study in progress.
Kenosha-Lakeview 138kV line	Pleasant Prairie-Zion 345kV line	0	Further study in progress.
Lakeview-Zion 138kV line	Pleasant Prairie-Zion 345kV line	0	Further study in progress.
Zion-Waukegan 138kV line	Pleasant Prairie-Zion 345kV line	0	Further study in progress.
Pleasant Prairie-Zion 345kV line	Arcadian-Zion 345kV line	0	Further study in progress.
Pleasant Prairie-Zion 345kV line	Cherry Valley-Silver Lake 345kV line (ComEd)	0	Further study in progress.
Sand Lake-Port Edwards 138kV line	G522-Werner W 345kV line	0	Further study in progress.
Rocky Run-Whiting Ave 115kV line	G522-Werner W 345kV line	0	Further study in progress.
Whiting Ave-Hoover 115kV line	G522-Werner W 345kV line	0	Planned projects from Table 3.1.
Hoover 138/115kV Transformer	G522-Werner W 345kV line	0	Planned projects from Table 3.1.
Werner West-Werner 138kV line	N.Appleton-Werner W. 345kV line	0	Further study in progress.
Ellington-Casaloma 138kV line	N.Appleton-Werner W. 345kV line	0	Planned projects from Table 3.1.
G522-Werner W 345kV line	Base Case	0	Planned projects from Table 3.1.
Nelson-Electric Junction 345kV line (ComEd)	Cherry Valley-Silver Lake 345kV line (ComEd)	0	Further study in progress.
Prairie Island-Byron 345kV line (SMP/NSP)	Base Case	0	Planned projects from Table 3.1.
Cherry Valley-Silver Lake 345kV line (ComEd)	Nelson-Electric Junction 345kV line (ComEd)	0	Further study in progress.
Adams-Hazelton 345kV line (ALTW/NSP)	Base Case	0	Further study in progress.

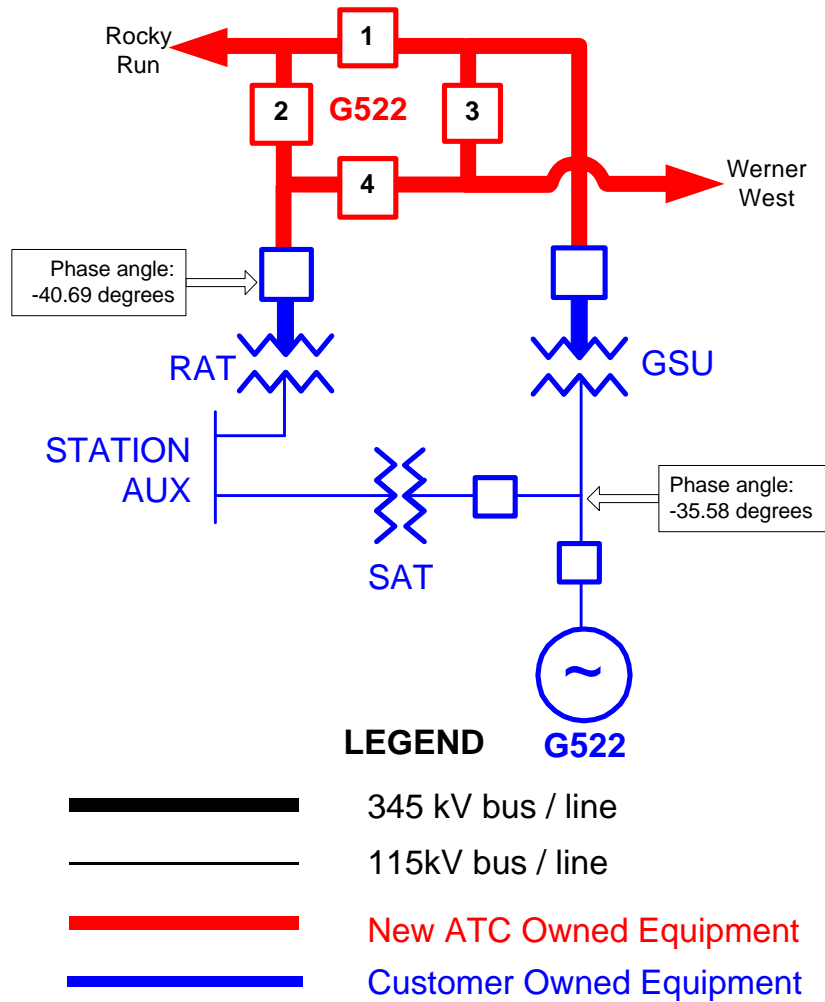
Notes:

1. ATC is actively pursuing potential solutions to deliverability constraints. If the customer decides to pursue Network Resource certification for G522 and Addendum to this report detailing potential solutions to deliverability constraints will be posted prior to the Facility Study.
2. Addition of the planned projects from Table 3.1 introduces this additional deliverability constraint.

Appendix F: Reserve Auxiliary Transformer Options

Three options have been investigated for the connection of G522 Reserve Auxiliary Transformer (RAT), as shown below in Figures F.1—F.3.

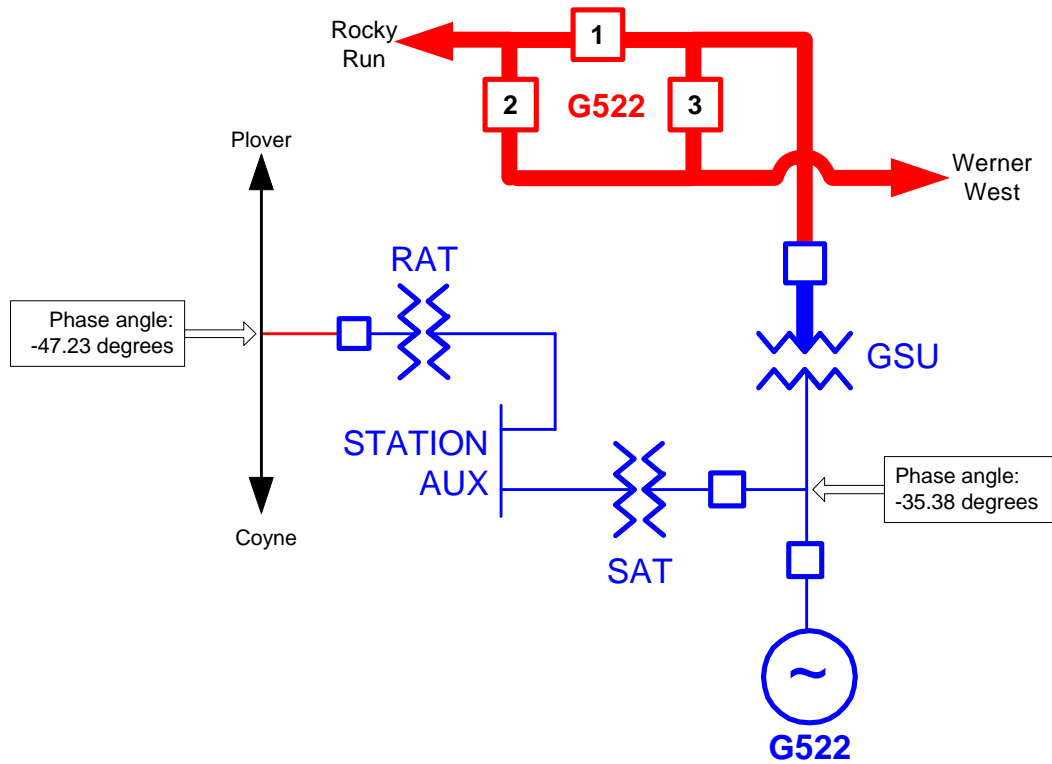
Figure F.1 – RAT Option 1



Drawing not to scale

Estimated cost of ATC facilities for Option 1:
\$6.1 M (2006 dollars)

Figure F.2 – RAT Option 2



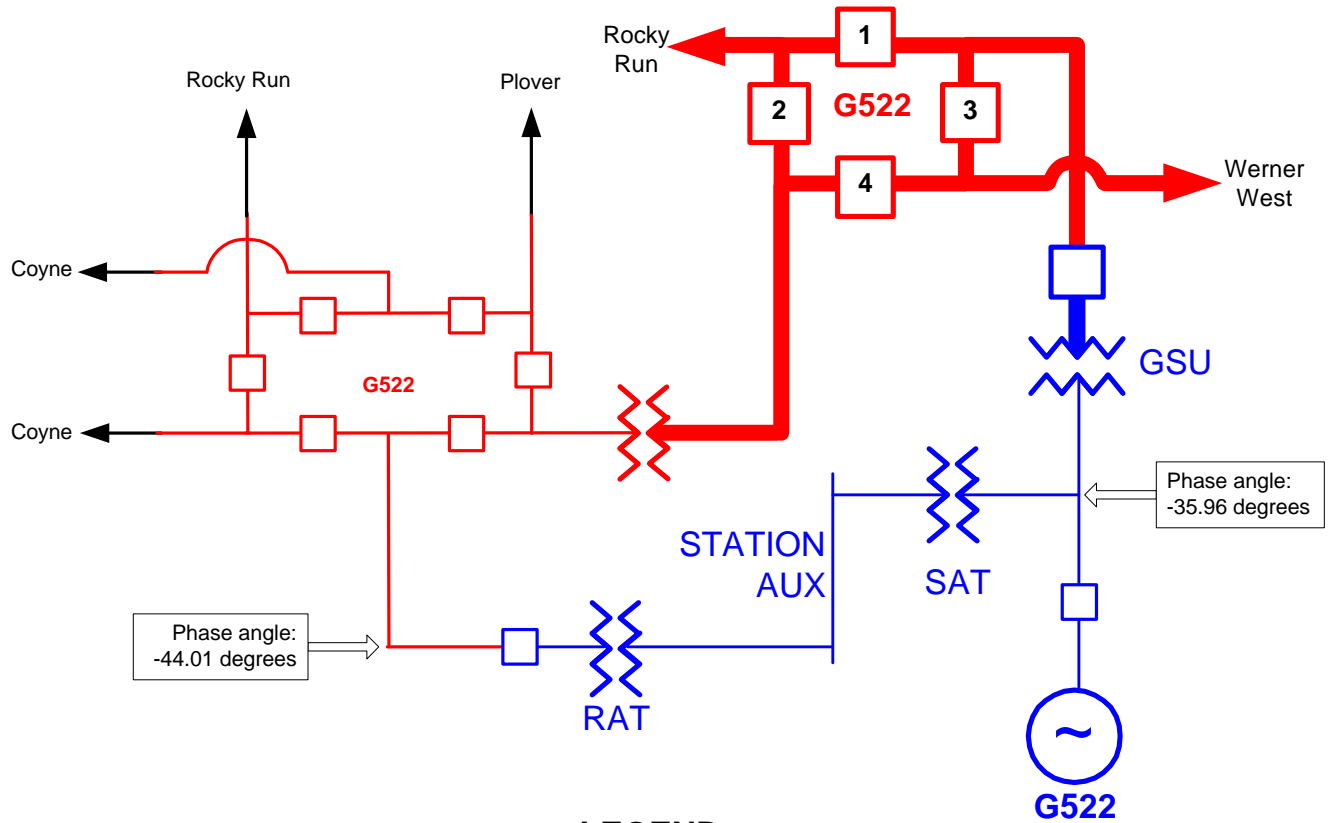
LEGEND

- 345 kV bus / line
- 115kV bus / line
- New ATC Owned Equipment
- Customer Owned Equipment

Drawing not to scale

Estimated cost of ATC facilities for Option 2:
\$5.3 M (2006 dollars)

Figure F.3 – RAT Option 3



LEGEND

- 345 kV bus / line
- 115kV bus / line
- New ATC Owned Equipment
- Customer Owned Equipment

Drawing not to scale

Estimated cost of ATC facilities for Option 3:
\$14.5 M (2006 dollars)

Table F.1 summarizes the three RAT connection options. ATC and the customer must have further discussions to determine which option to pursue in the Facility Study.

Table F.1 – Reserve Auxiliary Transformer Connection Option Comparison

	Description	ATC Cost	Phase Angle Difference*	Advantages	Drawbacks
1	Connected to 345kV G522 POI bus	\$6.1 M	5.11 degrees	Low cost, smallest phase angle difference.	Blackstart capabilities limited, station aux. power can only be fed from 345kV system.
2	Tapped into Plover-Coyne 115kV line	\$5.3 M	11.85 degrees	Lowest cost, multiple feeds for station aux. power, blackstart capabilities off 115kV system.	Large phase angle difference may complicate automatic throw-over to RAT feed from SAT.
3	Connected to 115kV portion of 345/115kV G522 POI substation	\$14.5 M	8.05 degrees	Multiple feeds for station aux. power, blackstart capabilities off 115kV system, 345/115kV transformer unloads Rocky Run transformers, relieving N-1 non-injection overloads and saving ~ \$3M in network upgrade costs.	High cost. Larger phase angle difference than option 1.

* Phase angles were measured at the high side of the RAT and at the low side of the GSU for each option. Angles were measured from Summer 2011 peak cases. The three planned projects from Table 3.1 were included in the cases. Also, G522 is on-line at 550 MW and is dispatched to ComEd (75%) and Northern States Power (25%) in the cases.

Appendix G: Study Criteria

Study Criteria

G.1 Contingencies

For stability analysis, a set of branches in the vicinity of the generator/power plant of concern is selected as contingencies, based on engineering judgment. Fault analysis is performed for the following six categories of contingency conditions:

1. Three-phase fault cleared in primary time with an otherwise intact system.
2. Three-phase fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system.
3. Three-phase fault cleared in primary clearing time with a pre-existing outage of any other transmission element.
4. Single Line Ground (SLG) bus section fault cleared in primary clearing time with an otherwise intact system.
5. SLG internal breaker fault cleared in primary clearing time with an otherwise intact system.
6. SLG fault of double circuits on common tower cleared in primary time with an otherwise intact system.

For power flow analysis, contingencies include:

1. N-1 contingencies – all lines and transformers operated at 69kV and above in the following control areas/zones: ATC Planning Zones 1-5 and ties to those zones and all branches of voltage level 69kV and above in the Dairyland Power Cooperative, Northern States Power Control Area, Commonwealth Edison, and Alliant West control areas.
2. Selected N-2 and multiple contingencies that ATC has determined to be significant.

G.2 Monitored Elements

G.2.1 Intact System, N-1, N-2, and Special Multiple Contingency Evaluation Using Linear Transfer Analysis Method

All load carrying elements operated at 69kV and above in the following control areas/zones were studied: ATC Planning Zones 1-5, ties to those zones and all branches of voltage level 69kV and above in the Dairyland Power Cooperative, Northern States Power Control Area, Commonwealth Edison, and Alliant West control areas.

A Transmission Reliability Margin (TRM) of 5% was applied to all MVA ratings of monitored elements. Violations in this report are based upon the TRM adjustment of MVA ratings.

G.3 Thermal Loading Criteria

G.3.1 Injection Violations

Generation injection violations include 1) thermal violations of the transmission elements that connect the Generator to the rest of the transmission network (outlet congestion); 2) thermal violations of the transmission elements that have TDF = 20% anywhere in the studied system.

G.3.2 Operating Restriction Calculation

$$\text{Allowable Output} = \frac{\text{Equipment Rating} - [\text{Line Flow} - (\text{Generation Output} * \text{TDF})]}{\text{TDF}}$$

G.4 Steady State Voltage Criteria

G.4.1 Intact System, N-1 and Special Multiple Contingency Evaluation Using ACCC

Under intact system conditions, the voltage magnitude of all transmission system buses with a decrease of 0.01 per unit due to the Generator must not be lower than 0.95 per unit. Under contingency conditions, the voltage magnitude of all transmission system buses with a decrease of 0.01 per unit due to the Generator must not be lower than 0.90 per unit.

G.4.2 N-2 Contingency Evaluation

Power flow solutions must converge for a selected number of N-2 contingencies in the electrical proximity of the studied Generator. Divergence of a power flow solution indicates potential voltage collapse.

G.5 Stability Criteria

Critical Clearing Time (CCT) is a period relative to the start of a fault, within which all generators in the system remain stable (synchronized). CCT is obtained from simulation. Maximum Expected Clearing Time (MECT) determines a period of time that is needed to clear a fault using the existing system facilities. MECT is dictated by the existing system facilities. In any contingency, if the computed CCT is less than the MECT plus a margin determined by ATC (1.0 cycle in this study), it is considered an unstable situation and is unacceptable. Otherwise, it is considered acceptable stability performance.

In the context of stability analysis, voltages of all transmission system buses must recover to be at least 70% of the nominal system voltages immediately after fault removal and 80% of the nominal system voltages in 0.5 second after fault removal.