



Interconnection Feasibility Study Report
550 MW Coal Fired Generation
Columbia, Wisconsin

G528
MISO Queue #38512-02

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American Transmission Company, LLC

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System Planning

1. Summary

This report contains the Feasibility Study Report for the Generation Interconnection Request Midwest Independent System Operator (“MISO”) project #G528, MISO Queue #38512-02. The purpose of this study is to identify steady state thermal and voltage violations caused by the proposed interconnection. The requested back feed date for this project is November 1, 2010 and the requested in-service date is October 1, 2011.

The G528 generation is proposed to connect to the Columbia substation at 345 kV. Figure 1 shows the existing transmission system including the proposed G528 point of interconnection (“POI”). The proposed interconnection **does not** show the ultimate expected substation layout. The final interconnection will depend on the thermal, voltage, and stability analysis performed in the Feasibility Study and the Interconnection System Impact Study (“ISIS”) in addition to operational issues and physical space for the new equipment required to support the interconnection.

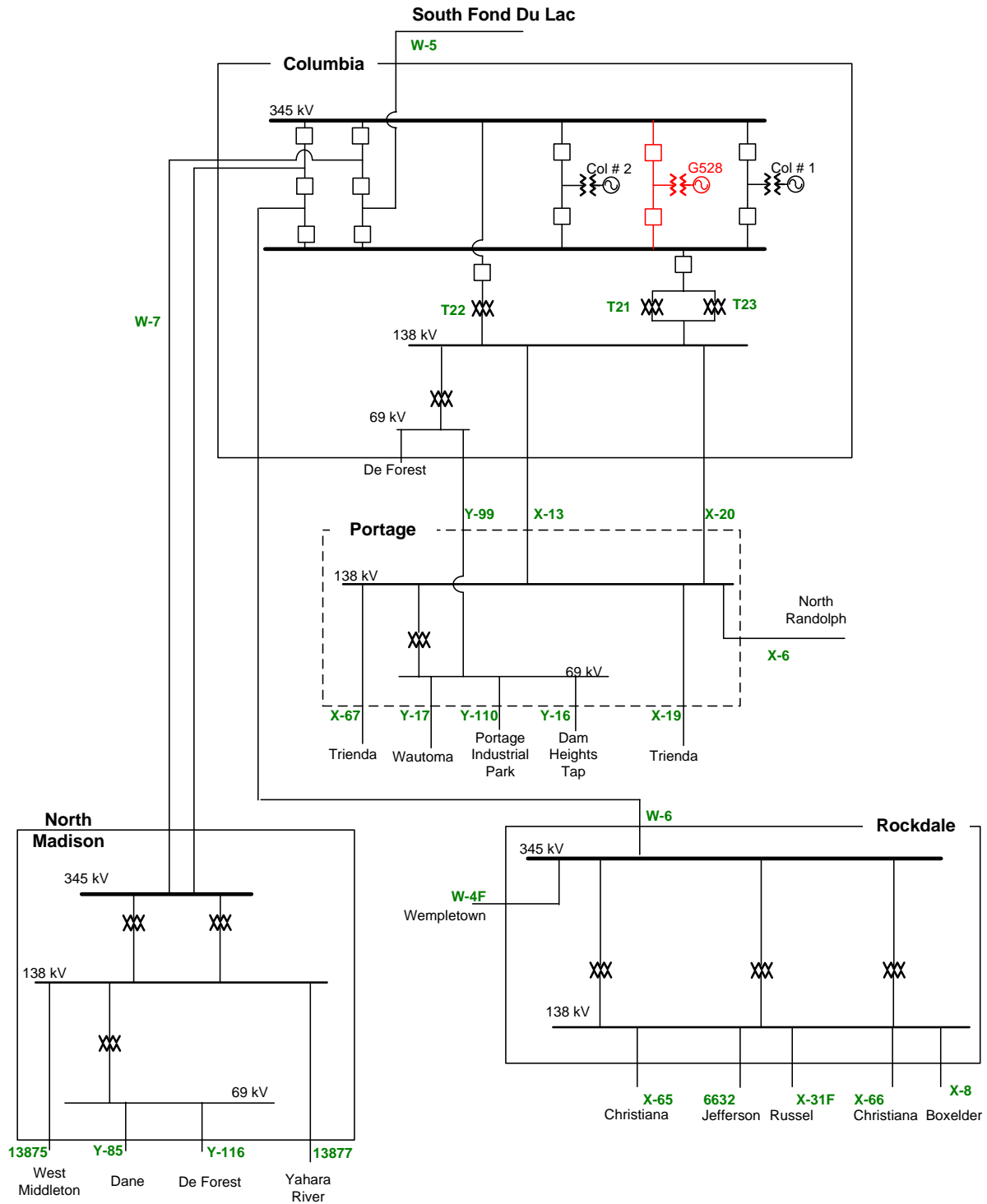


Figure 1: Equivalent modeling of G528 interconnected at the Columbia substation. Breaker configuration is shown **only** for the Columbia 345 kV bus.

An injection analysis study was performed by sourcing 550 MW from G528 and delivering to the MISO footprint. The study identified a total of ten steady-state NERC Category B event

thermal violations as shown in Table A.1. Five of which will require mitigation to acquire energy resource status. These five limits are:

1. X-13 Columbia - Portage 138 kV
2. X-20 Columbia - Portage 138 kV
3. T22 Columbia 345/138 kV Transformer
4. T21 Columbia 345/138 kV Transformer
5. T23 Columbia 345/138 kV Transformer

The maximum allowable generation without mitigating the above five injection limits was found to be 100 MW as given in Table A.2. The plant output may be limited to zero MW when considering all the identified constraints. The injection study also identified thirteen double contingency violations requiring potential operating restrictions as shown in Table A.3.

An additional transfer sensitivity study was performed by sourcing 550 MW from G528 and delivering 275 MW to the Wisconsin Public Service (“WPS”) control area and 275 MW to the Alliant East (“ALTE”) control area. The transfer sensitivity did not identify any new limits compared to the thermal injection analysis.

Voltage analysis determined that the voltage magnitude of all system busses whose magnitude decreases at least 0.01 p.u. after adding G528 remain above 0.95 pu for the intact system and remain above 0.9 p.u. for the single contingency condition. Hence, the study did not identify any voltage limit violation or need for reactive power capability enhancement specifically due to the addition of G528.

Further Study

The next step in the Generator Interconnection Request process is for the Generator customer to decide whether to proceed with an ISIS. The ISIS will determine the system upgrades required to resolve all injection limits identified in this report and will include short circuit, transient and dynamic stability, and deliverability studies, as applicable. Limits identified in the ISIS will also need to be resolved to obtain interconnection service. The ISIS will also determine the final interconnection configuration at the Columbia substation.

Required Interconnection Facilities

To be determined in the ISIS.

Network Upgrades

To be determined in the ISIS.

Special Facility Requirements

To be determined in the ISIS.

Operation Restrictions

The double contingency analysis identified fourteen operating restrictions on G528 due to thermal constraints. A summary of the operation restrictions on G528 under prior outage conditions is provided in Table B.1 in Appendix B.

2. Criteria, Methodology and Assumptions

2.1 Study Criteria

All relevant MISO-adopted NERC Reliability Criteria and the American Transmission Company (“ATC”) contingency criteria are to be met for both the thermal and voltage analysis. Details of the analysis criteria applied in this study can be found in the Appendix C.

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, in earlier queue Generator Interconnection Requests, in 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 determined in its sole judgment that four Generator Interconnection Requests with an earlier queue position will impact the G528 study results. G144, G366, and G477 are considered competing requests for the interconnection of this generator. G144 is a 550 MW coal fired generating facility located in Marathon County, WI. G366 is an 80 MW wind unit connected to Friesland 138 kV substation. G477 is a 531 MW integrated gasification combined cycle generating facility located in Minnesota.

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 (i.e. 0% 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-6.03 (MUST, Version 6.03) 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 and voltage analysis for this study were developed based upon the ATC summer peak 2005 model and the July 2005 build of MISO seasonal cases (accessible through the MISO Extranet). Three cases were developed to model the winter peak of 2010/11, a shoulder peak of 2011, and the summer peak of 2011.

The ATC system was modified by updating all loads to the expected coincident peak value and including all proposed projects through 2007 and all planned projects through 2008 as listed in the ATC Ten Year Assessment.

2.2.3.2 Deliverability analysis

Deliverability analysis, required for G528 to attain Network Resource status, was not performed for this study. This will be performed in the ISIS.

2.3 Assumptions

2.3.1 Generation Facility Modeling

The G528 generation was modeled at 550 MW of real power output connected to the Columbia 345 kV substation via a single 18/345 kV generator step-up transformer. The low side of the step up transformer was regulated to 1.03 pu for the power flow analysis, unless specified otherwise. Physical ratings of the Columbia bus sections will be reviewed in the ISIS when the final interconnection configuration at the Columbia substation is determined.

3. Analysis Results

3.1 Power Flow Analysis Results

3.1.1 Voltage Analysis & Reactive Capability

Voltage analysis determined that the voltage magnitude of all system busses whose magnitude decreases at least 0.01 p.u. after adding G528 remain above 0.95 pu for the intact system and remain above 0.9 p.u. for the single contingency condition. Hence, the study did not identify any voltage limit violations or need for reactive power capability enhancement specifically due to the addition of G528.

3.1.2 Results of Single Contingencies (N-1)

Study of the 550 MW injection from G528 identified no steady-state thermal violations for NERC Category A events. Ten transmission element violations for NERC Category B events were identified. Of these ten violations, five transmission elements have been identified as injection limits as given in Table A.1. A transfer sensitivity study was also performed delivering 50% of the G528 output to WPS and 50% of the output to ALTE. This transfer sensitivity did not identify any additional limits.

The maximum allowable real power output without system upgrades was determined by reducing G528 generation until all steady-state thermal violations due to G528 were resolved. The maximum allowable generation without mitigating the above five injection limits was found to be 100 MW. The plant output may be limited to zero MW when considering all the identified constraints. Results of the maximum allowable generation analysis can be found in Table A.2 in Appendix A.

For each of the five injection limits identified in the N-1 analysis, a solution of limited scope is proposed in the footnotes of Table A.1 in Appendix A. These potential solutions are reproduced in Table 3.1 below. Additionally, there are no planned or proposed projects in the ATC 10 Year Assessment report that would mitigate these injection overloads. These solutions, 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 3.1: Transmission Projects relieving G528 injection limits

Limiting Element	Potential Solution
Portage-Columbia 138kV Line X-13 and X-20	New line paralleling existing lines or rebuild/reconductor existing lines with high temperature, low sag ACSS conductor
Columbia 345/138 kV Transformer T21 and T23	Replace paralleled pair with one larger (500 MVA summer normal/625 MVA summer emergency) 345/138 kV transformer
Columbia 345/138 kV Transformer T22	Replace with one larger (500 MVA summer normal/625 MVA summer emergency) 345/138 kV transformer

The viability of each proposed solution cannot be assessed in the Feasibility Study. It may be possible that a solution is not physically or financially reasonable or that new injection limits might appear once the original injection limit is mitigated due to the lower impedance of a proposed solution. Also, each solution is directly related to the individual constraint, it is possible that a separate plan may address all limits and offer secondary benefits, such as relieving N-2 constraints. Solutions of this nature will be developed and examined in the ISIS.

3.1.3 Results of Double Contingencies (N-2)

Thermal and voltage violations were evaluated for NERC Category C events (N-2 contingencies) in the electrical proximity of G528. 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 on the summer peak model.

The double contingency constraints are not required to be resolved for the generator to attain either Energy Resource or Network Resource status. All identified operating restrictions will be reviewed in the ISIS as solutions are developed for NERC Category A and B violations.

3.1.3.1 Thermal analysis

Thermal N-2 analysis was performed using the Summer 2011 model. The study identified numerous thermal violations as a result of local contingencies. Injection limits identified in Table A.1 have been excluded from the double contingency analysis because physical upgrades will be required for all injection limits. The violations are listed in Table A.3 in Appendix A. In particular, the study identified two double contingencies for which the load flow study could not find an acceptable steady state solution. These two double contingencies are 1) losing both of the 345 kV lines from Columbia to North Madison and 2) losing all three 345/138 kV Columbia transformers.

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. These restrictions will be reviewed in the ISIS and a complete description of all N-2 limits and operating restrictions will be developed once the required solutions for N-1 limits are identified.

Appendix A

Power Flow Analysis Results

Table A.1 – Identified Thermal Violations due to G528 Delivery to MISO for N-1 Contingencies¹

Limiting Element	Existing MVA Rating	Worst MVA G528 = 0 MW	Worst MVA G528 = 550 MW	Worst Contingency	TDF (%)	G528 Outlet	Case Description	Injection Limit	Solution Planned for Limiting Element
63151 Bain – Kenosha 138 kV	287	345	364	Pleasant Prairie – Zion 345 kV	3.6	No	Summer 2011	No	No
T31 North Madison 138/69 kV XFMR	224	204	228	North Madison - Yahara River 138 kV	4.3	No	Summer 2011	No	Yes ²
X-13 Columbia - Portage 138 kV	403	387	450	X-20 Columbia - Portage 138 kV	12.9	Yes ³	Summer 2011	Yes	No ⁴
X-20 Columbia - Portage 138 kV	403	387	450	X-13 Columbia - Portage 138 kV	12.9	Yes ³	Summer 2011	Yes	No ⁴
T22 Columbia 345/138 kV XFMR	478	441	506	T21 and T23 Columbia 345/138 kV XFMRs	13.6	Yes	Summer 2011	Yes	No ⁵
X-6 Friesland - North Randolph 138 kV	240	154	245	Columbia – South Fond du Lac 345 kV	15.0	No	Summer 2011	No	No
T21 Columbia 345/138 kV XFMR	250	219	252	T22 Columbia 345/138 kV XFMR	6.8	Yes	Summer 2011	Yes	No ⁶
T23 Columbia 345/138 kV XFMR	250	219	252	T22 Columbia 345/138 kV XFMR	6.8	Yes	Summer 2011	Yes	No ⁶
X -19 Portage - Trienda 138 kV	240	274	316	Portage - Trienda 138 kV	6.4	No	Summer 2011	No	No
X -67 Portage - Trienda 138 kV	287	272	314	Portage - Trienda 138 kV	6.4	No	Summer 2011	No	No

Notes:

1. An additional transfer sensitivity study was performed by sourcing 550 MW from G528 and delivering 275 MW to the Wisconsin Public Service (“WPS”) control area and 275 MW to the Alliant East (“ALTE”) control area. The transfer sensitivity did not identify any new limits compared to the thermal injection analysis.
2. North Madison T31 138/69 kV Transformer will be mitigated with the construction of the proposed North Madison - Waunakee - Blount 138 kV line with Projected 2008 in service date.
3. Substation outlet on the 138 kV side.
4. Limited by line conductor (795.0 kcmil ACSR 26/7 Drake, 200°F Norm, 300°F Emergency). Therefore, a new line or a rebuild or reconductor of the existing line may be required to mitigate the overload.
5. T21 and T23 are connected via a single breaker (3014-S) to the Columbia 138 kV bus. Hence losing both transformers is considered as single contingency. T22 is a 400 MVA 345/138 kV transformer. Replacement of this transformer with a higher rating is needed.
6. T21 and T23 are both 200MVA, 345/138/13.8 kV transformers. Replacement of these transformers with a higher rating is needed.

Table A.2 – Maximum Allowable Generation Without System Upgrades¹

Limiting Element	G528 Maximum MW	Worst Contingency	Worst Season/Model Description
X-13 or X-20 Columbia - Portage 138 kV	100	X-20 or X-13 Columbia - Portage 138 kV	Summer 2011
T22 Columbia 345/138 kV XFMR	300	T21 & T23 Columbia 345/138 kV XFMR	Summer 2011
T21 or T23 Columbia 345/138 kV XFMR	500	T22 Columbia 345/138 kV XFMR	Summer 2011

Notes:

1. Only steady state thermal and voltage analysis was considered, stability limitations will be considered in the ISIS.

Table A.3 – Identified Thermal Violations due to G528 under N-2 Contingencies

Limiting Element	Existing MVA Rating	Worst MVA Loading	Double Contingency	TDF (%)	Solution Planned for Limiting Element
Load flow did not converge	N/A	N/A	Columbia – North Madison 345 kV circuit # 1 Columbia – North Madison 345 kV circuit # 2	N/A	No
Load flow did not converge	N/A	N/A	T22 Columbia 345/138 kV transformer T21 and T23 Columbia 345/138 kV transformers	N/A	No
T31 North Madison 138/69 kV XFMR	224	298	North Madison - Yahara River 138 kV North Madison – West Middleton 138 kV	6.3	Yes ¹
13877 North Madison – Yahara River – American –Sycamore 138 kV	316	375	North Madison – West Middleton 138 kV North Madison 138/69 kV Transformer	9.7	Yes ¹
13877 North Madison – Yahara River – American –Sycamore 138 kV	316	340	North Madison – West Middleton 138 kV Columbia – South Fond du Lac 345 kV	12.8	Yes ¹
X-6 Friesland – North Randolph 138 kV	240	274	Cambridge SW STR – Rockdale 138 kV Rockdale – Lakehead Cambridge Tap- 138 kV	8.3	No
X-6 Friesland – North Randolph 138 kV	240	278	Cambridge SW STR – Rockdale 138 kV Columbia – South Fond du Lac 345 kV	15.8	No
13875 North Madison – West Middleton 138 kV	306	314	North Madison - Yahara River 138 kV North Madison 138/69 kV Transformer	8.3	Yes ¹
X -19 Portage - Trienda 138 kV	240	306	Portage 138/69 kV transformer X -67 Portage – Trienda 138 kV	6.5	No
X -19 Portage - Trienda 138 kV	240	309	North Madison 138/69 kV transformer X -67 Portage – Trienda 138 kV	6.6	No
X -67 Portage - Trienda 138 kV	287	324	Columbia – South Fond du Lac 345 kV X -19 Portage – Trienda 138 kV	9.4	No
X -67 Portage - Trienda 138 kV	287	308	North Madison 138/69 kv transformer X -19 Portage – Trienda 138 kV	6.6	No
6632 Rockdale – Lakehead Cambridge Tap- Jefferson 138 kV	403	406	Columbia – South Fond du Lac 345 kV Cambridge SW STR – Rockdale 138 kV	9.3	No

Notes:

1. North Madison T31 138/69 kV Transformer will be mitigated with the construction of the proposed North Madison - Waunakee - Blount 138 kV line with Projected 2008 in service date

Appendix B

Summary of Operation Restrictions

Table B.1 – Identified Operation Restrictions on the G528 due to Thermal Constraints¹

Prior outage	Allowable MW Output	Worst Next Contingency	Most Limiting Element	MVA Rating
Columbia – North Madison 345 kV circuit # 1	0	Columbia – North Madison 345 kV circuit # 2	Load flow does not converge	N/A
Columbia – North Madison 345 kV circuit # 2	0	Columbia – North Madison 345 kV circuit # 1	Load flow does not converge	N/A
T22 Columbia 345/138 kV transformer	0	T21 and T23 Columbia 345/138 kV transformers	Load flow does not converge	N/A
T21 and T23 Columbia 345/138 kV transformers	0	T22 Columbia 345/138 kV transformer	Load flow does not converge	N/A
Columbia – South Fond du Lac 345 kV	0	Cambridge SW STR – Rockdale 138 kV	X-6 Friesland – North Randolph 138 kV	240
North Madison - Yahara River 138 kV	0	North Madison – West Middleton 138 kV	13877 North Madison – Yahara River – American –Sycamore 138 kV	316
North Madison – West Middleton 138 kV	0	North Madison - Yahara River 138 kV	13877 North Madison – Yahara River – American –Sycamore 138 kV	316
North Madison 138/69 kV Transformer	0	North Madison – West Middleton 138 kV	13877 North Madison – Yahara River – American –Sycamore 138 kV	316
Cambridge SW STR – Rockdale 138 kV	135	Rockdale – Lakehead Cambridge Tap 138 kV	X-6 Friesland – North Randolph 138 kV	240
Rockdale – Lakehead Cambridge Tap 138 kV	135	Cambridge SW STR – Rockdale 138 kV	X-6 Friesland – North Randolph 138 kV	240
Portage 138/69 kV transformer	0	X -67 Portage – Trienda 138 kV	X -19 Portage – Trienda 138 kV	240
X -67 Portage – Trienda 138 kV	0	Portage 138/69 kV transformer	X -19 Portage – Trienda 138 kV	240
X -19 Portage – Trienda 138 kV	136	Columbia – South Fond du Lac 345 kV	X -67 Portage – Trienda 138 kV	287
Cambridge SW STR – Rockdale 138 kV	360	Columbia – South Fond du Lac 345 kV	6632 Rockdale – Lakehead Cambridge Tap- Jefferson 138 kV	403

Notes:

1. Additional operating restrictions may be identified in the ISIS due to stability analysis

Appendix C

Study Criteria

Study Criteria

C.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.

C.2 Monitored Elements

C.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.

C.3 Thermal Loading Criteria

C.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 $\geq 20\%$ anywhere in the studied system.

C.3.2 Operating Restriction Calculation

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

C.4 Steady State Voltage Criteria

C.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.

C.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.

C.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.