System Impact Study Report

Generator Interconnection Request GIC044
(MISO #G144/#37187-01)

500 MW Coal Generation Facility

in Marathon County, Wisconsin

December 30, 2002

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Executive Summary

This report contains the System Impact Study (SIS) for Generation Interconnection Request (GIR) #GIC044 [MISO #G144/#37187-01]. The purpose of this study is to evaluate the impact of connecting a 504 MW coal fired generation facility to the Weston Substation 345 kV bus that is owned by the American Transmission Company (ATC). The generation facility is to be located in Marathon County, Wisconsin. The generation will normally be in a base load mode of operation. The requested in-service date is June 2008.

This study is to identify whether any stability, short circuit, or power flow limits may be violated by the addition of GIC044. If any stability, short circuit, or power flow problems are found, then possible solutions that might address these problems are suggested.

The resolution of possible thermal loadability problems is not required for interconnection service, since thermal loadability impacts may be significantly affected by the specific power delivery requests from the facility. A customer can only identify whether any specific power delivery can be accomplished without causing thermal loadability problems or whether specific system modifications will be required via a valid Transmission Service Request (TSR) submitted on the MISO OASIS.

ATC determined in its sole judgment that two Generator Interconnection Requests (GIRs) with an earlier queue position may impact the GIC044 study results. These requests are GIC011 and GIC014. This study included these facilities and any required system modifications identified in these requests. If any of these requests are not actualized as planned, the GIC044 study results may change and this Request may be subject to restudy at the Generator's expense. Subsequently, the Generator's obligations that are identified in this report may change depending on the results of any restudy.

This study also includes authorized ATC transmission system projects that are planned to be in service by June 2008. In addition, the impacts were examined with and without the addition of the planned Arrowhead-Weston 345 kV line (see Figure 3 for connection information).

The results of this study may be subject to change. The results are based on data provided by the Generator and other ATC system information that was available at the time the study was performed. If there are any significant changes in the Generator data, in earlier queue GIRs, in related TSRs, or subsequent ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this request may be subject to restudy. The Generator is responsible for communicating any significant generation facility data changes in a timely fashion to ATC prior to commercial operation.

Interconnection Facilities For GIC044

The analysis was performed with the GIC044 generation facility connected to the Weston Substation 345 kV bus in a three-breaker ring bus configuration. This substation is owned by ATC. The generating facility will have one 560 MVA generating unit connected through a 345-

22 kV, 650 MVA generation setup (GSU) transformer and 345 kV synchronizing breaker. Refer to Figure 2 for a one-line diagram of the connection facilities.

System Impacts Before the Addition of GIC044

The stability, short circuit, and power flow system impacts were investigated for system that is presently expected to exist in June 2008, before the addition of GIC044. Refer to Figure 1 for a one-line diagram of the system in the vicinity of GIC044. It was required that the expected system include the GIC011 and the GIC014 projects, but not the Arrowhead-Weston 345 kV line. However, some stability sensitivity analyses were performed for scenarios that excluded GIC011 or GIC014, but included the Arrowhead-Weston line.

The problems that were identified are to be resolved before the commercial operation of GIC044. Any necessary transmission or distribution system upgrades and the associated cost of these upgrades would be the responsibility of the corresponding owner (e.g. ATC, NSP, WPS).

Stability

Eight system contingencies were identified that cause unacceptable system stability. These impacts are expected to occur with or without the addition of the Arrowhead-Weston 345 kV line, the GIC011 generation, or the GIC014 generation.

The stability impacts might be addressed by one of the following system upgrades.

1. Replace all the Weston 115 kV breakers with 2 cycle breakers and replace the existing breaker failure protection relays with new relays that provide the fastest available clearing times.
2. Develop a double breaker configuration on each of the Weston 115 kV lines with five new 115 kV breakers.
3. With the addition Arrowhead-Weston 345 kV line, develop a Weston breaker-and-a-half 115 kV bus configuration for the Black Brook line, Kelly line, Rocky Run line, and Unit #3.

Short Circuit

Two 138 kV ATC breakers and eleven 115 kV ATC breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability. Six 115 kV WPS breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability.

Power Flow

The key power flow impacts were identified in the Transmission Service Request (TSR) #75000492, which is based on specific, approved, power deliveries. Although the TSR analysis did not specifically address thermal loadability issues before the addition GIC044, it did highlight nine of the potentially overloaded transmission elements for which ATC has previously identified projects (or their equivalents) that may address the power flow problems. These

overloaded elements and the prospective projects to relieve the overload conditions are listed in Table C.1 in the Appendix.

System Impacts After the Addition of GIC044

The stability, short circuit, and power flow system impacts were also investigated for the system that is presently expected to exist in June 2008, after the addition of GIC044. Again, the expected system included the GIC011 and the GIC014 projects, but not the Arrowhead-Weston 345 kV line. However, some sensitivity analyses were performed for scenarios that excluded GIC011 or GIC014, but included the Arrowhead-Weston line.

The problems that were identified are to be resolved before the commercial operation of GIC044. Any necessary transmission or distribution system upgrades would be the responsibility of the corresponding owner (e.g. ATC, NSP, MP, WPS). The financing costs associated with any ATC stability or short circuit related upgrades would be the responsibility of the Generator. The costs associated with any ATC power flow related upgrades might be borne by the Generator and reimbursed through transmission service credits. The handling of cost associated with any upgrades of 3rd party equipment would be worked out with the corresponding owner (e.g. NSP, MP, WPS).

Stability

Based on the analysis in this report, there are major system stability issues with the addition of GIC044. All of the Weston generating units (G1, G2, G3, G4, G31, and G32) become unstable for a three-phase fault on the Weston-Rocky Run 345 kV line or a three-phase fault near the Weston 115 kV bus with a prior outage of the Weston-Rocky Run 345 kV line. The primary fault clearing times are less than 3 cycles, which cannot be achieved by simply using the fastest available (2-cycle) breakers. These impacts are expected to occur with or without the addition of the Arrowhead-Weston 345 kV line, the GIC011 generation, or the GIC014 generation.

Major transmission system upgrades will be required to address the system stability issues. Preliminary consideration was given to 27 possible system upgrade alternatives, which are listed in Table A.3 and Table A.4 in the Appendix. Significant deficiencies were found with all but seven of the prospective system upgrades. The seven promising options all have the following features in common:

1. Develop a Weston 345 kV breaker-and-a-half bus configuration with 2-cycle, independent pole, 345 kV breakers
2. Build a Weston-Arpin 345 kV line
3. Develop a Weston 115 kV breaker-and-a-half bus configuration with 3-cycle, ganged pole, 115 kV breakers
4. Replace the existing Weston 345-115 kV 350 MVA transformer with two Weston, 345-115 kV, 500 MVA transformers.

Short Circuit

One 115 kV ATC breaker was found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability. Two 115 kV WPS breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability.

Power Flow

The key power flow impacts were identified in the Transmission Service Request (TSR) #75000492, which is based on specific, approved, power deliveries. The TSR analysis found numerous limiting facilities for the delivery of the full GIC044 output to Wisconsin Public Service (WPS) network load. The most limiting facility was identified as the Port Edwards-Sand Lake 138kV line for the loss of Plover-North Appleton 345kV.

Major transmission system upgrades will be needed to address the power flow issues. Seven different transmission line options were given preliminary consideration.

1. Build a new Weston-Venus 345 kV line
2. Build a new Weston-Venus-Plains 345 kV line
3. Build a new Morgan-Werner West 345 kV line
4. Build a new Weston-Badger 345 kV line
5. Build a new Weston-Badger-Morgan-Werner West 345 kV line
6. Build a new Plover-Fitzgerald 345 kV line.
7. Replace the single 345-115 kV, 350 MVA transformer with two 345-115 kV, 500 MVA transformers.

Further Study

The next step in the Generation Interconnection Request process is for the Generator to decide whether to proceed with a Facility Study. A Facility Study would investigate whether the selected System Upgrades will address all of the identified System Impact Study issues. The Facility Study will also include a budgetary cost estimate and schedule for any ATC system modifications that are required to resolve the identified impact problems.

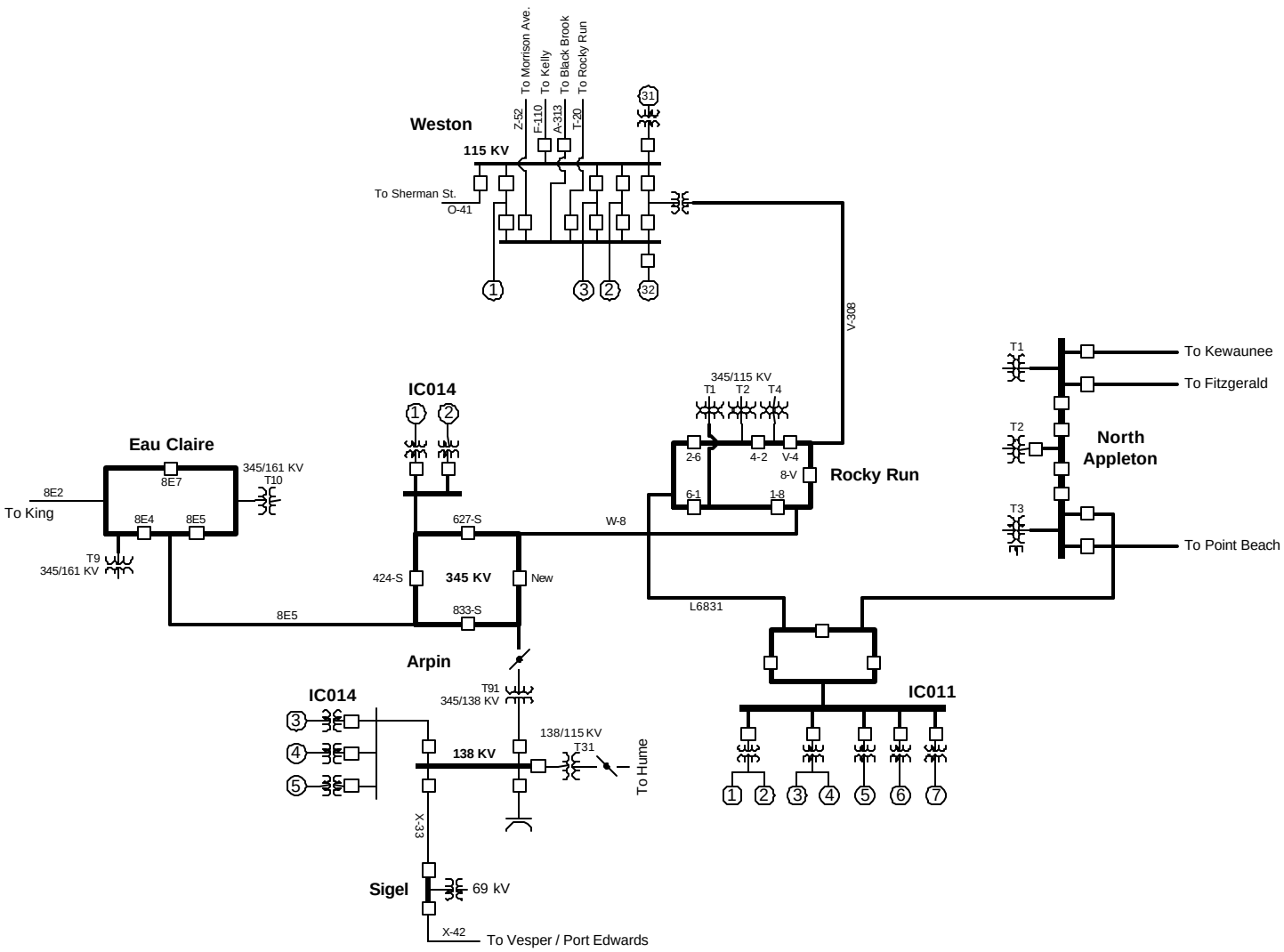

Figure 1: One-Line Diagram of the Expected System on June 2008 Without GIC044

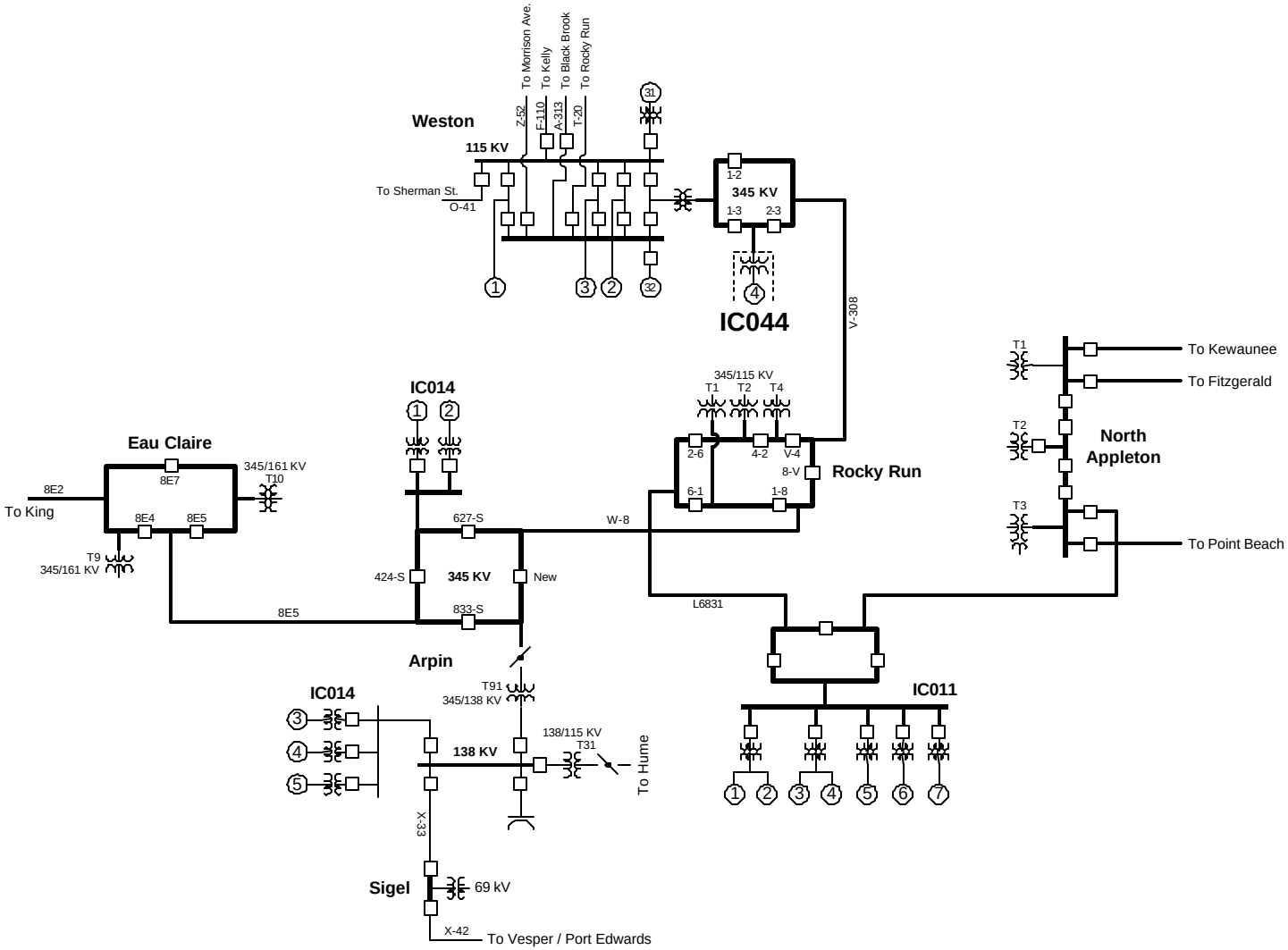

Figure 2: One-Line Diagram of the Expected System on June 2008 With GIC044

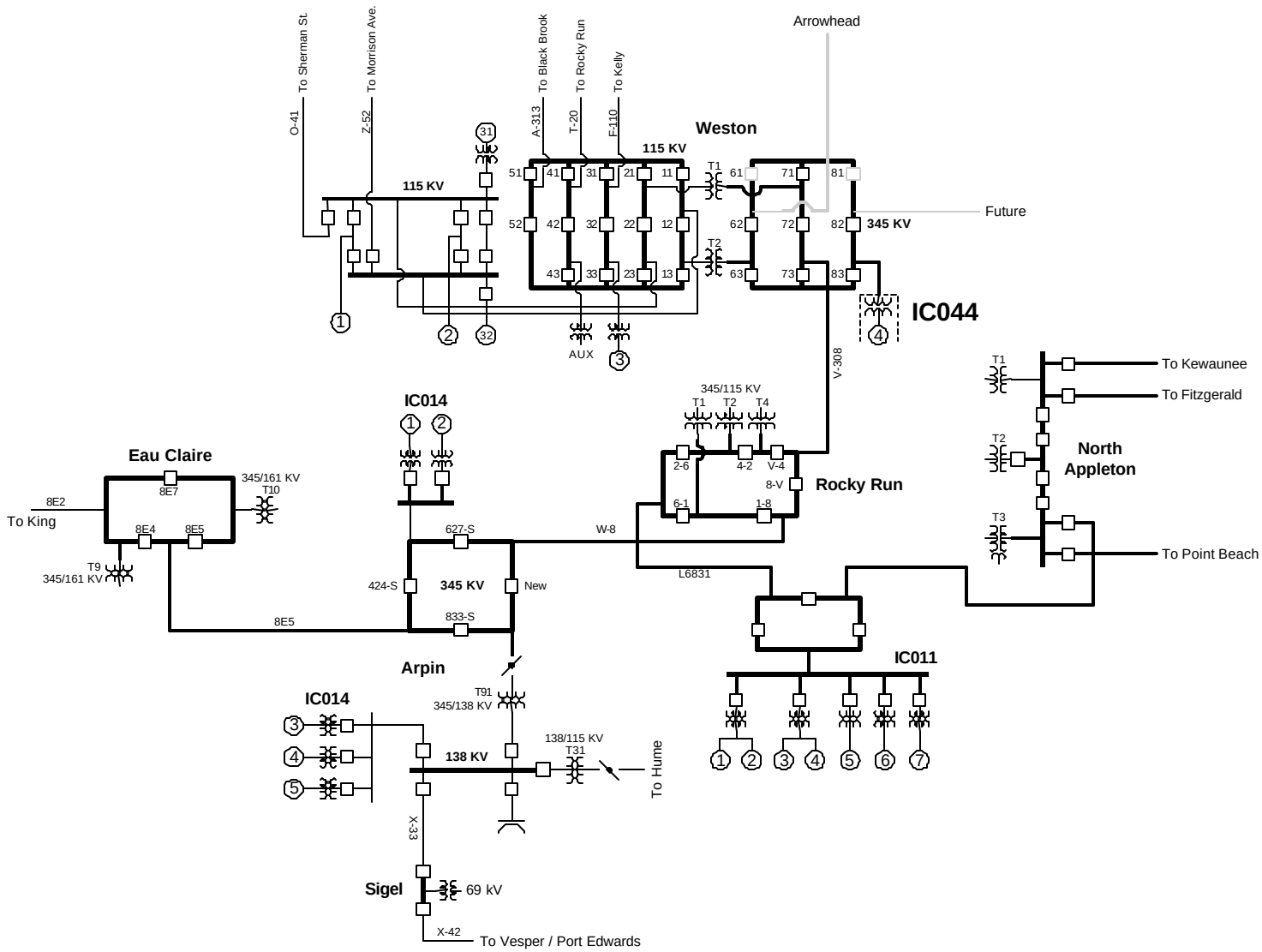

Figure 3: One-Line Diagram of the Expected System on June 2008 With the Addition of GIC044 and the Arrowhead-Weston 345 kV Line

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1. Introduction

This report contains the System Impact Study (SIS) for Generation Interconnection Request (GIR) #GIC044 [MISO #G144/#37187-01]. The purpose of this study is to evaluate the impact of connecting a 504 MW coal generation facility to the Weston Substation 345 kV bus that is owned by the American Transmission Company (ATC). The generation facility is to be located in Marathon County, Wisconsin. The generation will normally be in a base load mode of operation. The requested in-service date is June 2008.

This study is to identify whether any stability, short circuit, or power flow limits may be violated by the addition of GIC044. If any stability, short circuit, or power flow problems are found, then possible solutions that might address these problems are suggested.

The resolution of possible thermal loadability problems is not required for interconnection service, since thermal loadability impacts may be significantly affected by the specific power delivery requests from the facility. A customer can only identify whether any specific power delivery can be accomplished without causing thermal loadability problems or whether specific system modifications will be required via a valid Transmission Service Request (TSR) submitted on the MISO OASIS.

ATC determined in its sole judgment that two Generator Interconnection Requests with an earlier queue position may impact the GIC044 study results. These requests are GIC011 and GIC014. This study included these facilities and any required system modifications identified in these requests. If any of these requests are not actualized as planned, the GIC044 study results may change and this Request may be subject to restudy at the Generator's expense. Subsequently, the Generator's obligations that are identified in this report may change depending on the results of any restudy.

Public information related to GIC011 (MISO #G049/#36705-01), GIC014 (MISO #G062/ #36811-01), and GIC044 **(**MISO #G144/#37187-01) can be found via the MISO web site at **http://oasis.midwestiso.org/documents/ATC/queue.html**

The study also gave consideration to the addition of the Arrowhead-Weston 345 kV line.

The results of this study may be subject to change. The results are based on data provided by the Generator and other ATC system information that was available at the time the study was performed. If there are any significant changes in the Generator data, in earlier queue GIRs, in related Transmission Service Requests (TSRs), or subsequent ATC transmission system development plans, then the results of this study may also change significantly. Therefore, this request may be subject to restudy. Generator is responsible for communicating any significant generation facility data changes in a timely fashion to ATC prior to commercial operation.

2. Project Description

Generator Interconnection Request (GIR) GIC044 is a request to connect a 504 MW coal fired generation facility to the Weston Substation 345 kV bus that is owned by the American Transmission Company (ATC). The generation facility is to be located in Marathon County, Wisconsin. The generation will normally be in a base load mode of operation.

Interconnection Facilities For GIC044

The analysis was performed with the GIC044 generation facility connected to the Weston Substation 345 kV bus in a three-breaker ring bus configuration. This substation is owned by ATC. The 345 kV breakers will be at least 3000 A., 3-cycle, 40 kA, independent pole type. This substation will be owned by ATC. Refer to Figure 2 for a one-line diagram of the connection facilities.

The generating facility will have one 560 MVA generating unit with a 345/22 kV, 650 MVA generation setup (GSU) transformer and 345 kV synchronizing breaker. The 345 kV synchronizing breaker will be at least 3000 A., 3-cycle, 40 kA, independent pole type.

3. Criteria, Methodology, and Assumptions

3.1 Study Criteria

3.1.1 Contingency Criteria

All of the MISO-adopted NERC Reliability Criteria and the ATC contingency criteria are to be met for both the stability analysis, as well as the power flow (thermal loadability and voltage level) analysis

For the stability analysis, a set of contingencies are selected to address the MISO and ATC concerns with particular attention to contingency conditions:

1. Fault cleared in primary time with an otherwise intact system.
2. Fault cleared in delayed clearing time (i.e. breaker failure conditions) with an otherwise intact system.
3. Fault cleared in primary clearing time with a pre-existing outage of any other transmission element.

For the power flow analysis, the contingencies included the normal (intact) system configuration, all of the standard N-1 contingencies and a set of about N-2 contingencies that ATC has determined to be significant.

3.1.2 Affected Element Criteria

A load-carrying system element is considered to be affected by GIC044, if at least 3% of the GIC044 generation flows in the element with the GIC044 generator exporting the maximum amount of power.

3.1.3 Thermal Loadability Criteria

For normal (intact) system conditions, the loading of all transmission system elements significantly affected by GIC044 must not exceed 100% of the summer normal loadability rating (Rate A). For contingency system conditions (selected N-1 and N-2 contingencies), the loading of all transmission system elements significantly affected by GIC044 must not exceed 100% of the summer emergency loadability rating (Rate B).

Equipment thermal loadability limit violations do not need to be addressed to enter into an interconnection agreement. Nevertheless, the thermal loadability limit violations are a reasonable indication of what facilities might need upgrading when power delivery service is requested. Delivery service can only be reserved through a confirmed, valid Transmission Service Request submitted on the MISO OASIS. It is important to note that generic assumptions are made in this analysis regarding the delivery of power from the proposed plant and may not accurately reflect the specific delivery service that is requested for the initial in service date.

3.1.4 Voltage Level Criteria

For normal (intact) system conditions, the voltage level of all busses significantly affected by GIC044 must be in the range of 95% to 105% of the nominal system voltage. For contingency system conditions (selected N-1 and N-2 contingencies), the voltage level of all busses significantly affected by GIC044 must be in the range of 90% to 105% of the nominal system voltage.

3.1.5 Stability Criteria

Transient stability simulations were performed to determine if the critical clearing times (CCT) for all pertinent criteria contingencies were less than the maximum expected clearing times in this area. Any critical clearing times that were less than the maximum expected clearing times would, therefore, be considered unacceptable. The CCT is the clearing time for which any generation unit becomes unstable (i.e. continually slips poles). The clearing time values are measured to the nearest 1/2 (0.5) cycle.

3.2 Study Methodology

3.2.1 Before and After Comparison

To identify what impacts should be attributed to the GIC044, two system conditions are examined, "Before" and "After" the addition of the proposed generation. The "Before" base case is to identify the expected system without the addition of GIC044. The "After" base case is to represent the expected system with GIC044 in service. Any "Before" problems are to be resolved by ATC or 3rd party prior to GIC044 being placed in service. Any "After" problems are to be attributed to the addition of GIC044 and resolved prior to commercial operation of the facility.

3.2.2 Base Case Development

A. General

The Summer 2004 Peak base case from the Multi-Regional Modeling Working Group (MMWG) 1999 series was used as the starting point for the development of the various power flow analysis and stability analysis base cases. The 1999 series was used because the 2000 series posed a number of stability simulation problems.

The power flow analysis was performed using the full 100% peak load base case because this should yield the most conservative results.

The stability analysis was performed using the above base case, which was then modified to represent a light load (50% of peak load) condition. Simulations were performed at the light-load (50%) system load level. The stability performance in this area during light-load conditions is worse than at higher load levels. This is expected due to the different system conditions the generators see at light load, specifically the longer electrical path from source to load. Therefore, the light-load studies were performed to identify the more conservative stability performance in this area, and to identify required upgrades that will protect the transmission system and generation in this area for year round conditions.

The 2004 MMWG stability base case contains dynamic model information for generators throughout MAIN, as well as a significant portion of the continental United States. The original case and model database were *not* modified to include other proposed generation interconnection customers.

B. Generation Interconnection Requests with Earlier Queue Position

Proposed GIRs with earlier queue positions than GIC044 that may affect GIC044 study results were included in the appropriate study base case. Two (2) earlier GIRs were to be included in this analysis because they were judged by ATC to have the potential to significantly affect the GIC044 SIS results.

These GIRs are:

- GIC011 (MISO #G049/#36705-01) 950 MW, 345 kV, in Portage County, June 2005
- GIC014 (MISO #G062/#36811-01) 755 MW, 345 kV, in Wood County, June 2003

C. Planned Transmission System Projects

The effects of the planned Arrowhead-Weston 345 kV line were considered in sensitivity analysis. However, since it presently needs to receive further approval from the Public Service Commission of Wisconsin and all right-of-way has not been acquired, it is not included in the "baseline" analysis.

Other planned ATC transmission projects included in the base case are the following:

1. Conversion of the Pine-Eastom 46 kV to 115 kV and addition of a second circuit from Skanawan to Highway 8
2. Rebuild of Weston-Kelly (F-110) 115 kV line
3. Rebuild of the Weston-Sherman St. (O-41) 115 kV line
4. Conversion of the West Shawano-East Shawano 34.5 kV line to 138 kV
5. Conversion of the Maplewood-Badger 115 kV line to 138 kV
6. Installation of a 138/115 kV transformer at Badger and the retirement of the 138/115 kV transformer at Maplewood

D. Generation Dispatch

The GIC044 generator unit power was exported in the following manner - 75% south to Commonwealth Edison network load and 25% west to Northern States Power network load. The output of any generating units associated with the GIR with an earlier queue position that did not have an approved TSR was also exported in a like manner.

The dispatch of the remaining generator units in the base case remained the same as the MMWG base case for power flow analysis (100% of peak load) bases cases. For stability analysis (50% of peak load condition), the dispatch of generating units in and around ATC were reduced to the 50% levels, except the generating units in the vicinity of GIC044, which were dispatched at the 100% levels. This approach assures conservative stability performance results.

D. Voltage Regulation

The scheduled voltage levels at all buses in the MAIN base case were unchanged. For the power flow analysis (100% of peak load condition), the scheduled voltage at the Weston 345 kV bus was selected to cause the generator to operate at .98 lagging power factor for the normal (intact) system configuration. For the stability analysis (50% of peak load condition), the scheduled voltage at the Weston 345 kV bus was selected to cause the generator to operate at 1.00 (unity) power factor. The unity power factor condition is a conservative state.

E. Interface Exchange Considerations

The power flow analysis and stability analysis were performed at one interface exchange pattern. This interface exchange is used by ATC to produce relatively conservative results.

3.2.3 Monitored Elements

All of the load carrying elements that are included in the base case and assigned to the ATC control area were monitored for the thermal loadability analysis. In general, any network Load-serving Distribution Company (LDC) elements that are modeled in the base case were monitored. In general, radial LDC elements are not modeled or monitored.

No ATC or LDC system bus voltages were judged by ATC to be significantly affected by GIC044. So, they were not monitored.

3.2.4 Software Analysis Tools

The stability analysis was performed using the Dynamics Simulation and Power Flow modules of the Power System Simulation/Engineering-26 (PSS/E, Version 26) program from Power Technologies, Inc (PTI). This program is accepted industry-wide for dynamic stability analysis.

The short circuit analysis was performed using the Computer Assisted Protection Engineering (CAPE) program (Build Date May 6, 2002). This program is accepted industry-wide for short circuit analysis.

The system power flow analysis was performed using the Power Technologies, Inc. (PTI) Power System Simulator for Engineering (PSS/E) power flow software package (Version 26.2.3) and the PTI Managing and Utilizing System Transmission (MUST) software package (Version 4.0). These programs are accepted industry-wide for power flow analysis. MUST efficiently calculates the impact of transactions on key network elements, identifies the most limiting contingencies and constraints, calculates the First Contingency Incremental Transfer Capability (FCITC) and calculates FCITC sensitivity to transactions and generation dispatch changes.

3.2.5 Critical Clearing Times

Three-phase faults were applied at the faulted bus and cleared in progressively longer times to determine the critical clearing time (CCT) to avoid any generating unit becoming unstable after clearing the fault. For example, a CCT of 10 cycles means that one or more generating units became unstable at 10.5 cycles, while all units remained stable at 10 cycles. CCT is the longest time that fault conditions can be applied at the described location before being removed by protective equipment for which the units on the system will remain stable.

3.3 Assumptions

3.3.1 Generation Facility Model Data

The latest power flow and dynamic model information for the GIC044 generator, exciter, and governor, as provided by the Generator, was used in the study. The information was incorporated into the dynamic study database. Response tests of the exciter and governor were

completed, and steady-state and step response tests of the entire system were performed to ensure an acceptable dynamics model. It is noted here that the governor submitted by the Generator does not meet ATC's normal criteria for this type of equipment. So, no governor model was included at this time.

The GIC044 generation was modeled based on information provided by the customer as follows:

560 MVA, 0.85 pf, 22 kV
Auxiliary load = ***

The GSU (generator step-up transformer) model data included:
650 MVA, Z = 13.1 % on 650 MVA base, X/R ratio = 50

*** This study did not included modeling of any auxiliary load associated with GIC044. The impact this auxiliary load would have on the post-GIC044 stability results would be minimal. In addition, load modeled near the generator could only improve the GIC044 stability response, so the results in this report represent a worst-case scenario.

4. Analysis Results

The system impacts of GIC044 on system thermal loadability, voltage level, and stability limit violations were examined for two GIRs with earlier queue position GIC011 and GIC014 which are to be in service before the addition of GIC044 in June 2008.

Although the power flow analysis for this study includes these generator interconnection requests, it does not incorporate requests for delivery service already in the TSR queue that are currently in the "study" mode. Therefore, this analysis may not identify the same transmission facilities problems that would be found by a TSR evaluation for GIC044.

It should be noted that this GIR study, which uses assumed energy transfers, does not determine required power flow related system upgrades. Required power flow related system upgrades are determined by the TSR studies, which will model actual contracted energy transfers, once they are known. The TSR study results may differ significantly from the GIR power flow analysis results.

4.1 June 2008 – Without the Addition of GIC044, the "Before" State

The stability, short circuit, and power flow system impacts were investigated for the system that is presently expected to exist in June 2008, before the addition of GIC044. It was required that the expected system include the GIC011 and the GIC014 projects, but not the Arrowhead-Weston 345 kV line. However, some sensitivity analyses were performed for scenarios that excluded GIC011 or GIC014, but included the Arrowhead-Weston line.

The problems that were identified are to be resolved before the commercial operation of GIC044. Any necessary transmission or distribution system upgrades and the associated cost of these upgrades would be the responsibility of the corresponding owner (e.g. ATC, NSP, WPS).

Stability Analysis

Twelve system contingencies were simulated to assess whether there are system stability issues related to the Weston 115 kV generating units prior to the addition of GIC044. Five three-phase faults with prior outage contingencies and seven three-phase faults with breaker failure contingencies were simulated. Eight system contingencies were identified that cause unacceptable system stability. These eight contingencies are listed in Table 4.1.1 below.

Based on the results of other simulations performed for this study, the impacts listed in Table 4.1.1 are expected to occur with or without the addition of the Arrowhead-Weston 345 kV line, the GIC011 generation, or the GIC014 generation.

The stability impacts in Table 4.1.1 might be addressed by one of the following system upgrades.

1. Replace all the Weston 115 kV breakers with 2 cycle breakers and replace the existing breaker failure protection relays with new relays that provide the fastest available clearing times.
2. Develop a double breaker configuration on each of the Weston 115 kV lines with five new 115 kV breakers.
3. For the addition Arrowhead-Weston 345 kV line, develop a Weston breaker-and-a-half 115 kV bus configuration for the Black Brook line, Kelly line, Rocky Run, and Weston Unit #G3.

Table 4.1.1 - Contingencies Expected to Cause System Instability in June 2008 Without the Addition of GIC044

ID	Fault	Conditions	MECT	CCT	Comments
F1	3 phase fault on Black Brook 115 kV line near Weston 115 kV bus	Failure of A-313 115kV breaker	11.0	9.5	Weston G1, G2, G3, G31 units become unstable at 10.0 cycles. Weston G32 unit is tripped.
F2	3 phase fault on Kelly 115 kV line near Weston 115 kV bus	Failure of F-110 115kV breaker	11.0	9.5	Weston G1, G2, G3, G32 units become unstable at 10.0 cycles. Weston G31 unit is tripped.
F3	3 phase fault on Sherman St. 115 kV line near Weston 115 kV bus	Failure of O-41 115kV breaker	11.0	9.5	Weston G1, G2, G3, G32 units become unstable at 10.0 cycles. Weston G31 unit is tripped.
F4	3 phase fault on Rocky Run 115 kV line near Weston 115 kV bus	Failure of T-20 115kV breaker	11.0	9.5	Weston G1, G2, G3, G31 units become unstable at 10.0 cycles. Weston G32 unit is tripped.
F5	3 phase fault on Morrison Ave. 115 kV line near Weston 115 kV bus	Failure of Z-52 115kV breaker	11.0	9.5	Weston G1, G2, G3, G31 units become unstable at 10.0 cycles. Weston G32 unit is tripped.
F6	3 phase fault on Weston transformer 115 kV terminal or winding	Failure of 1266E 115kV breaker	11.0	7.5	Weston G1, G2, G3, G32 units become unstable at 8.0 cycles. Weston G31 unit is tripped.
F7	3 phase fault on Weston transformer 115 kV terminal or winding	Failure of 1266W 115kV breaker	11.0	6.5	Weston G1, G2, G3, G31 units become unstable at 7.0 cycles. Weston G32 unit is tripped.
F11	3 phase fault on Rocky Run 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	4.5	Weston G1, G2, G3, G31, and G32 units become unstable at 5.0 cycles.

MECT = Maximum expected clearing time, CCT = Critical clearing time

Short Circuit Analysis

Three phase fault simulations were performed for all of the 345 kV, 138 kV, and 115 kV breakers in the vicinity of the Weston substation. A total of nineteen breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability prior to the addition of GIC044. Two 138 kV ATC breakers and eleven 115 kV ATC breakers could be overdutied. These thirteen breakers are listed in Table 4.1.2 below.

Table 4.1.2 – ATC Breakers Expected to be Overdutied in June 2008 Without the Addition of GIC044

					Existing	Existing	New
Breaker	From	To	Ckt	kV	Rating	Derated I	Derated I
F-110	WESTON	KELLY	1	115	23857	37658	40735
0-41	WESTON	SHRMN ST	1	115	23857	38147	41229
T-20	WESTON	DEWEY_TP	1	115	23857	36618	39332
A313	WESTON	BLACK BK	1	115	23857	38171	41261
T-20	ROCKY RN	NORTHPT	1	115	23857	27949	30554
N-92	ROCKY RN	COYNE	1	115	23857	29041	31854
166	ROCKY RN	RCKY RN BK1T	1	115	23857	24847	27078
266	ROCKY RN	RCKY RN BK2T	2	115	23857	24264	26452
1151	WHITG AV	WHITG AV	1	115	13936	16764	17906
H-138	WHITG AV	HOOVER	1	115	13940	15446	16352
6863	NAP	LOST DAU	1	138	42000	44345	45073
6853	NAP	BDM	1	138	42000	44360	45085
6862	NAP	APPLE HILLS	1	138	42000	46116	46856

Six 115 kV WPS breakers could be overdutied. These breakers are listed in Table 4.1.3 below.

Table 4.1.3 – WPS Breakers Expected to be Overdutied in June 2008 Without the Addition of GIC044

					Existing	Existing	New
Breaker	From	To	Ckt	kV	Rating	Derated I	Derated I
G1W	WESTON	WES G1	1	115	23857	34955	38045
G1E	WESTON	WES G1	1	115	23857	34955	38045
G2W	WESTON	WES G2	1	115	23857	34917	38007
G2E	WESTON	WES G2	1	115	23857	34917	38007
3299	WESTON	WES G32	1	115	Unknown	>23000	>25000
1099	WESTON	WESTON BK10T	1	115	Unknown	>24000	>26000

Power Flow Analysis

The key power flow impacts were identified in the Transmission Service Request (TSR) #75000492, which is based on specific, approved, power deliveries. Although the TSR analysis did not specifically address thermal loadability issues before the addition GIC044, it did highlight nine of the potentially overloaded transmission elements for which ATC has previously identified projects (or their equivalents) that may address the power flow problems. These overloaded elements and the prospective projects to relieve the overload conditions are listed in Table C.1 in the Appendix.

4.2 June 2008 – With the Addition of GIC044, the "After" State

The stability, short circuit, and power flow system impacts were also investigated for the system that is presently expected to exist in June 2008, after the addition of GIC044. Again, the expected system included the GIC011 and the GIC014 projects, but not the Arrowhead-Weston 345 kV line. However, some sensitivity analyses were performed for scenarios that excluded GIC011 or GIC014, but included the Arrowhead-Weston line.

The problems that were identified are to be resolved before the commercial operation of GIC044. Any necessary transmission or distribution system upgrades would be the responsibility of the corresponding owner (e.g. ATC, NSP, MP, WPS). The financing costs associated with any ATC stability or short circuit related upgrades would be the responsibility of the Generator. The costs associated with any ATC power flow related upgrades might be borne by the Generator and reimbursed through transmission service credits. The handling of cost associated with any upgrades of 3rd party equipment would be worked out with the corresponding owner (e.g. NSP, MP, WPS).

Stability Analysis

These impacts are expected to occur with or without the addition of the Arrowhead-Weston 345 kV line, the GIC011 generation, or the GIC014 generation.

Six system contingencies were simulated to assess the effect of the addition of GIC044 on the transmission system stability margin. As noted in Table 4.2.1 below, all of the Weston generating units (G1, G2, G3, G4, G31, and G32) become unstable for a three-phase fault on the Weston-Rocky Run 345 kV line or a three-phase fault near the Weston 115 kV bus with a prior outage of the Weston-Rocky Run 345 kV line. The primary fault clearing times are less than 3 cycles, which cannot be achieved by simply using the fastest available (2-cycle) breakers.

Based on the results of other simulations performed for this study, the impacts listed in Table 4.2.1 are expected to occur with or without the addition of the Arrowhead-Weston 345 kV line, the GIC011 generation, or the GIC014 generation.

Major transmission system upgrades will be required to address the system stability issues. Preliminary consideration was given to 27 possible system upgrade options, which are given in

Table A.3 and Table A.4 in the Appendix. Significant deficiencies were found with all but seven of the 27 prospective system upgrades. The seven promising options all have the following features in common:

1. Develop a Weston 345 kV breaker-and-a-half bus configuration with 2-cycle, independent pole, 345 kV breakers
2. Build a Weston-Arpin 345 kV line.
3. Develop a Weston 115 kV breaker-and-a-half bus configuration with 3-cycle, ganged pole, 115 kV breakers
4. Replace the existing Weston 345-115 kV 350 MVA transformer with two Weston, 345/115 kV, 500 MVA transformers.

Table 4.2.1 - Contingencies Expected to Cause System Instability in June 2008 With the Addition of GIC044

ID	Fault	Conditions	MECT	CCT	Comments
F13	3 phase fault on Black Brook 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31 and G32units become unstable in <3.0 cycles.
F14	3 phase fault on Kelly 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32 units become unstable in <3.0 cycles.
F15	3 phase fault on Sherman St. 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32 units become unstable in <3.0 cycles.
F16	3 phase fault on Rocky Run 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32 units become unstable in <3.0 cycles.
F17	3 phase fault on Morrison Ave. 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32 units become unstable in <3.0 cycles.
F18	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	No prior outages	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32 units become unstable in <3.0 cycles.

MECT = Maximum expected clearing time, CCT = Critical clearing time

Short Circuit Analysis

Three phase fault simulations were performed for all of the 345 kV, 138 kV, and 115 kV breakers in the vicinity of the Weston substation with the addition of GIC044. Three more 115 kV breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability. One 115 kV ATC breaker could be overdutied. This breaker is listed in Table 4.2.2 below.

Table 4.2.2 – ATC Breaker Expected to be Overdutied in June 2008 Without the Addition of GIC044

						Existing	New
Breaker	From	To	Ckt	kV	Rating	Derated	Derated
1151	SHRMN ST	SHRMN ST	1	115	16700	16028	16795

Two 115 kV WPS breakers could be overdutied. These breakers are listed in Table 4.2.3 below.

Table 4.2.3 – WPS Breakers Expected to be Overdutied in June 2008 Without the Addition of GIC044

						Existing	New
Breaker	From	To	Ckt	kV	Rating	Derated	Derated
G3W	WESTON	WES G3	1	115	23857	22095	24821
G3E	WESTON	WES G3	1	115	23857	22095	24821

Power Flow Analysis

The key power flow impacts were identified in the Transmission Service Request (TSR) #75000492, which is based on specific, approved, power deliveries. The TSR analysis found numerous limiting facilities for the delivery of the full GIC044 output to Wisconsin Public Service (WPS) network load. The most limiting facility was identified as the Port Edwards-Sand Lake 138kV line for the loss of Plover-North Appleton 345kV.

For nine of the potentially overloaded transmission elements, ATC has previously identified projects (or their equivalents) that may address the identified power flow problems. These overloaded elements and the prospective projects to relieve the overload conditions are listed in Table C.1 in the Appendix.

Another thirteen transmission elements were identified that may be overloaded, but which do not have planned projects to relieve the power flow problems. These overloaded elements are listed in Table C.2 in the Appendix and which will need to be addressed in a Facility Study.

Major transmission system upgrades will be needed to address the power flow issues. Seven different transmission line options were given preliminary consideration.

1. Build a new Weston-Venus 345 kV line
2. Build a new Weston-Venus-Plains 345 kV line
3. Build a new Morgan-Werner West 345 kV line
4. Build a new Weston-Badger 345 kV line
5. Build a new Weston-Badger-Morgan-Werner West 345 kV line
6. Build a new Plover-Fitzgerald 345 kV line.
7. Replace the single 345-115 kV, 350 MVA transformer with two 345-115 kV, 500 MVA transformers.

5. Conclusions

Interconnection Facilities For GIC044

The GIC044 generation facility will be connected to the Weston Substation 345 kV bus with a three-breaker ring bus configuration. This substation will be owned by ATC.

The generating facility will have one 504 MW coal fired generating unit each with its own 345/22 kV, 650 MVA generation setup (GSU) transformer and 345 kV synchronizing breaker.

System Impacts Before the Addition of GIC044

The stability, short circuit, and power flow system impacts were investigated for system that is presently expected to exist in June 2008, before the addition of GIC044. It was required that the expected system include the GIC011 and the GIC014 projects, but not the Arrowhead-Weston 345 kV line. However, some sensitivity analyses were performed for scenarios that excluded GIC011 or GIC014, but included the Arrowhead-Weston line.

The problems that were identified are to be resolved before the commercial operation of GIC044. Any necessary transmission or distribution system upgrades and the associated cost of these upgrades would be the responsibility of the corresponding owner (e.g. ATC, NSP, WPS).

Stability

Eight system contingencies were identified that cause unacceptable system stability. These impacts are expected to occur with or without the addition of the Arrowhead-Weston 345 kV line, the GIC011 generation, or the GIC014 generation.

The stability impacts might be addressed by one of the following system upgrades:

1. Replace all the Weston 115 kV breakers with 2 cycle breakers and replace the existing breaker failure protection relays with new relays that provide the fastest available clearing times.
2. Develop a double breaker configuration on each of the Weston 115 kV lines with five new 115 kV breakers.

3. With the addition Arrowhead-Weston 345 kV line, develop a Weston breaker-and-a-half 115 kV bus configuration for the Black Brook line, Kelly line, Rocky Run line, and Unit #3.

Short Circuit

Two 138 kV ATC breakers and eleven 115 kV ATC breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability. Six 115 kV WPS breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability.

Power Flow Analysis

The key power flow impacts were identified in the Transmission Service Request (TSR) #75000492, which is based on specific, approved, power deliveries. Although the TSR analysis did not specifically address thermal loadability issues before the addition GIC044, it did highlight nine of the potentially overloaded transmission elements for which ATC has previously identified projects (or their equivalents) that may address the power flow problems. These overloaded elements and the prospective projects to relieve the overload conditions are listed in Table C.1 in the Appendix.

System Impacts After the Addition of GIC044

The stability, short circuit, and power flow system impacts were also investigated for the system that is presently expected to exist in June 2008, after the addition of GIC044. Again, the expected system included the GIC011 and the GIC014 projects, but not the Arrowhead-Weston 345 kV line. However, some sensitivity analyses were performed for scenarios that excluded GIC011 or GIC014, but included the Arrowhead-Weston line.

The problems that were identified are to be resolved before the commercial operation of GIC044. Any necessary transmission or distribution system upgrades would be the responsibility of the corresponding owner (e.g. ATC, NSP, MP, WPS). The financing costs associated with any ATC stability or short circuit related upgrades would be the responsibility of the Generator. The costs associated with any ATC power flow related upgrades might be borne by the Generator and reimbursed through transmission service credits. The handling of cost associated with any upgrades of 3rd party equipment would be worked out with the corresponding owner (e.g. NSP, MP, WPS).

Stability

Major transmission system upgrades will be required to address the system stability issues. Based on the results in Table 4.2.1, the primary fault clearing times are less than 3 cycles, which cannot be achieved by simply using the fastest available (2-cycle) breakers. Preliminary consideration was given to 27 possible system upgrade alternatives, which are given in Table A.3 and Table A.4 in the Appendix. Significant deficiencies were found with all but seven of the 27

prospective system upgrades. The seven promising options all have the following features in common:

1. Develop a Weston 345 kV breaker-and-a-half bus configuration with 2-cycle, independent pole, 345 kV breakers
2. Build a Weston-Arpin 345 kV line.
3. Develop a Weston 115 kV breaker-and-a-half bus configuration with 3-cycle, ganged pole, 115 kV breakers
4. Replace the existing Weston 345-115 kV 350 MVA transformer with two Weston, 345-115 kV, 500 MVA transformers.

Short Circuit Analysis

One 115 kV ATC breaker was found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability. Two 115 kV WPS breakers were found that could be overdutied and would need to be replaced with breakers that have a higher interrupting capability.

Power Flow Analysis

Major transmission system upgrades will be needed to address the power flow issues. Seven different transmission line options were given preliminary consideration.

1. Build a new Weston-Venus 345 kV line
2. Build a new Weston-Venus-Plains 345 kV line
3. Build a new Morgan-Werner West 345 kV line
4. Build a new Weston-Badger 345 kV line
5. Build a new Weston-Badger-Morgan-Werner West 345 kV line
6. Build a new Plover-Fitzgerald 345 kV line.
7. Replace the single 345-115 kV, 300 MVA transformer with two 345-115 kV, 500 MVA transformers.

Further Study

The next step in the Generation Interconnection Request process is for the Generator to decide whether to proceed with a Facility Study. A Facility Study would investigate whether the selected System Upgrades will address all of the identified System Impact Study issues. The Facility Study will also include a budgetary cost estimate and schedule for any ATC system modifications that are required to resolve the identified impact problems.

Appendix A

Stability Analysis

TableA.1 - Contingencies Expected to Cause System Instability in June 2008 Without the Addition of GIC044

ID	Fault	Conditions	MECT	CCT	Comments
F1	3 phase fault on Black Brook 115 kV line near Weston 115 kV bus	Failure of A-313 115kV breaker	11.0	9.5	Weston G1, G2, G3, G31 units become unstable at 10 cycles. G32 unit is tripped.
F2	3 phase fault on Kelly 115 kV line near Weston 115 kV bus	Failure of F-110 115kV breaker	11.0	9.5	Weston G1, G2, G3, G32 units become unstable at 10 cycles. G31 unit is tripped.
F3	3 phase fault on Sherman St. 115 kV line near Weston 115 kV bus	Failure of O-41 115kV breaker	11.0	9.5	Weston G1, G2, G3, G32 units become unstable at 10 cycles. G31 unit is tripped.
F4	3 phase fault on Rocky Run 115 kV line near Weston 115 kV bus	Failure of T-20 115kV breaker	11.0	9.5	Weston G1, G2, G3, G31 units become unstable at 10 cycles. G32 unit is tripped.
F5	3 phase fault on Morrison Ave. 115 kV line near Weston 115 kV	Failure of Z-52 115kV breaker	11.0	9.5	Weston G1, G2, G3, G31 units become unstable at 10 cycles. G32 unit is tripped.
F6	3 phase fault on Weston transf. 115 kV terminal or winding	Failure of 1266E 115kV breaker	11.0	7.5	Weston G1, G2, G3, G32 units become unstable at 8.0 cycles. G31 unit is tripped.
F7	3 phase fault on Weston transf. 115 kV terminal or winding	Failure of 1266W 115kV breaker	11.0	6.5	Weston G1, G2, G3, G31 units become unstable at 7.0 cycles. G32 unit is tripped.
F8	3 phase fault on Black Brook 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	6.5	All ATC system units are stable.
F9	3 phase fault on Kelly 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	6.5	All ATC system units are stable.
F10	3 phase fault on Sherman St. 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	6.5	All ATC system units are stable.
F11	3 phase fault on Rocky Run 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	4.5	Weston G1, G2, G3, G31 and G32 units become unstable at 5.0 cycles.
F12	3 phase fault on Morrison Ave. 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	6.5	All ATC system units are stable.

MECT = Maximum expected clearing time, CCT = Critical clearing time

Table A.2 - Contingencies Expected to Cause System Instability in June 2008 With the Addition of GIC044

ID	Fault	Conditions	MECT	CCT	Comments
F13	3 phase fault on Black Brook 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
F14	3 phase fault on Kelly 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
F15	3 phase fault on Sherman St. 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
F16	3 phase fault on Rocky Run 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
F17	3 phase fault on Morrison Ave. 115 kV line near Weston 115 kV bus	Prior outage of Weston-Rocky Run 345 kV line	5.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
F18	3 phase fault on Weston-Rocky Run 345 kV line	No prior outages	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.

MECT = Maximum expected clearing time (cycles), CCT = Critical clearing time (cycles)

Table A.3 Possible Solutions to Address System Stability Problems in June 2008 With the Addition of GIC044

ID	Possible Solution	Fault	MECT	CCT	Comments
S1	Two Weston 345/115 kV transformers	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S2	Arrowhead-Weston 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S3	Weston-Venus 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S4	Weston-Venus-Plains 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S5	Weston-Arpin 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S6	Weston-Badger-Morgan 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S7	Weston-Badger-Werner West 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S8	Weston-Badger-Morgan-Werner West 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.
S9	Plover-Fitzgerald 345 kV line *	3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus	4.0	<3.0	Weston G1, G2, G3, G4, G31, and G32, units are unstable at less than 3 cycles.

MECT = Maximum expected clearing time (cycles), CCT = Critical clearing time (cycles)

* Two Weston 345/115 kV transformers

Table A.4 Possible Solutions to Address System Stability Problems in June 2008 With the Addition of GIC044

Test Contingency = 3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus with breaker failure

ID	First Line	Additional Line(s)	MECT	CCT	Comments
S10	Arrowhead-Weston 345 kV line *	Weston-Venus 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S11	Arrowhead-Weston 345 kV line *	Weston-Venus-Plains 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S12	Arrowhead-Weston 345 kV line *	Weston-Arpin 345 kV line	9.0	9.5	All units are stable.
S13	Arrowhead-Weston 345 kV line *	Weston-Badger-Morgan 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S14	Arrowhead-Weston 345 kV line *	Weston-Badger-Werner West 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S15	Arrowhead-Weston 345 kV line *	Weston-Badger-Morgan-Werner West 345 kV line	9.0	8.5	Weston G4 unit is unstable at 9.0 cycles.
S16	Weston-Venus 345 kV line *	Weston-Arpin 345 kV line	9.0	9.0	All units are stable.
S17	Weston-Venus 345 kV line *	Weston-Badger-Morgan 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S18	Weston-Venus 345 kV line *	Weston-Badger-Werner West 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S19	Weston-Venus 345 kV line *	Weston-Badger-Morgan-Werner West 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.

MECT = Maximum expected clearing time (cycles), CCT = Critical clearing time (cycles)

* Two Weston 345/115 kV transformers

Table A.4 (Continued) Possible Solutions to Address System Stability Problems in June 2008 With the Addition of GIC044

Test Contingency = 3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus with breaker failure

ID	First Line	Additional Line(s)	MECT	CCT	Comments
S20	Weston-Venus-Plains 345 kV line *	Weston-Arpin 345 kV line	9.0	9.0	All units are stable.
S21	Weston-Venus-Plains 345 kV line *	Weston-Badger-Morgan 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S22	Weston-Venus-Plains 345 kV line *	Weston-Badger-Werner West 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S23	Weston-Venus-Plains 345 kV line *	Weston-Badger-Morgan-Werner West 345 kV line	9.0	8.0	Weston G4 unit is unstable at 8.5 cycles.
S24	Weston-Arpin 345 kV line *	Weston-Badger-Morgan 345 kV line	9.0	9.5	All units are stable.
S25	Weston-Arpin 345 kV line *	Weston-Badger-Werner West 345 kV line	9.0	9.5	All units are stable.
S26	Weston-Arpin 345 kV line *	Weston-Badger-Morgan-Werner West 345 kV line	9.0	9.5	All units are stable.
S27	Weston-Arpin 345 kV line *	Arrowhead-Weston 345 kV line and Weston-Badger-Morgan-Werner West 345 kV line	9.0	10.0	All units are stable.

MECT = Maximum expected clearing time (cycles), CCT = Critical clearing time (cycles)

* Two Weston 345/115 kV transformers

Table A.5 Weston-Arpin 345 kV Line Solutions in June 2008 With the Addition of GIC044, but Without GIC011 and GIC014

Test Contingency = 3 phase fault on Rocky Run 345 kV line near Weston 345 kV bus with breaker failure

ID	First Line	Additional Line(s)	MECT	CCT	Comments
S12	Weston-Arpin 345 kV line *	Arrowhead-Weston 345 kV line	9.0	9.5	Change of 0.0 cycles
S16	Weston-Arpin 345 kV line *	Weston-Venus 345 kV line	9.0	8.5	Change of –0.5 cycles
S20	Weston-Arpin 345 kV line *	Weston-Venus-Plains 345 kV line	9.0	9.5	Change of 0.5 cycles
S24	Weston-Arpin 345 kV line *	Weston-Badger-Morgan 345 kV line	9.0	9.5	Change of 0.0 cycles
S25	Weston-Arpin 345 kV line *	Weston-Badger-Werner West 345 kV line	9.0	9.5	Change of 0.0 cycles
S26	Weston-Arpin 345 kV line *	Weston-Badger-Morgan-Werner West 345 kV line	9.0	9.5	Change of 0.0 cycles

MECT = Maximum expected clearing time (cycles), CCT = Critical clearing time (cycles)

* Two Weston 345/115 kV transformer

Appendix B

Short Circuit Analysis

Table B.1 – Short Circuit Simulation Results

Weston 4 before and After Questionable Short Circuit Currents (V > 46 kV, I > 10 kA)

							Before				After				Imax							Existing	New
ID	From		To			kV	TPH	SLG	XR3	XR1	TPH	SLG	XR3	XR1	Before	After	Chng	Rating	Problem	Sym/Tot	Part	Factor	Derated	Derated
G1W / G1E	167	WESTON	169	WES G1	1	115	17629	22552	66	69	19167	24545	67	72	22552	24545	8.8%	23857	Existing	Total	3/2	1.55	34955	38045
G2W / G2E	167	WESTON	170	WES G2	1	115	17673	22527	63	66	19210	24521	64	69	22527	24521	8.8%	23857	Existing	Total	3/2	1.55	34917	38007
F-110	167	WESTON	174	KELLY	1	115	18515	24295	67	70	20044	26281	68	73	24295	26281	8.2%	23857	Existing	Total	3/2	1.55	37658	40735
0-41	167	WESTON	176	SHRMN ST	1	115	18745	24611	66	69	20277	26599	67	73	24611	26599	8.1%	23857	Existing	Total	3/2	1.55	38147	41229
T-20	167	WESTON	191	DEWEY_TP	1	115	17821	23625	70	73	19137	25376	72	77	23625	25376	7.4%	23857	Existing	Total	3/2	1.55	36618	39332
A313	167	WESTON	202	BLACK BK	1	115	18772	24627	66	69	20309	26620	67	72	24627	26620	8.1%	23857	Existing	Total	3/2	1.55	38171	41261
T-20	252	ROCKY RN	260	NORTHPT	1	115	16535	19963	30	37	18242	21824	31	37	19963	21824	9.3%	23857	Existing	Total	3/2	1.4	27949	30554
N-92	252	ROCKY RN	261	COYNE	1	115	17329	20743	27	34	19211	22753	28	34	20743	22753	9.7%	23857	Existing	Total	3/2	1.4	29041	31854
166	252	ROCKY RN	5021	RCKY RN BK1T	1	115	14709	17748	28	35	16195	19341	29	35	17748	19341	9.0%	23857	Existing	Total	3/2	1.4	24847	27078
266	252	ROCKY RN	5022	RCKY RN BK2T	2	115	14599	17331	28	35	16070	18894	29	35	17331	18894	9.0%	23857	Existing	Total	3/2	1.4	24264	26452
1151	253	WHITG AV	254	WHITG AV	1	115	13868	13970	19	27	14922	14742	18	26	13970	14922	6.8%	13936	Existing	Total	5/3	1.2	16764	17906
H-138	253	WHITG AV	257	HOOVER	1	115	12608	12872	20	29	13627	13617	19	28	12872	13627	5.9%	13940	Existing	Total	5/3	1.2	15446	16352
6863	641	NAP	13	LOST DAU	1	138	32848	31424	20	32	33388	31759	20	31	32848	33388	1.6%	42000	Existing	Total	3/2	1.35	44345	45073
6853	641	NAP	643	BDM	1	138	32860	31548	20	30	33396	31881	19	30	32860	33396	1.6%	42000	Existing	Total	3/2	1.35	44360	45085
6862	641	NAP	3015	APPLE HILLS	1	138	34160	32461	19	30	34708	32795	19	30	34160	34708	1.6%	42000	Existing	Total	3/2	1.35	46116	46856
3299	167	WESTON	173	WES G32	1	115	18094	23332	65	68	19632	25326	66	71	23332	25326	8.5%		Existing				0	0
1099	167	WESTON	5036	WESTON BK10T	1	115	18356	23985	66	69	19893	25980	67	72	23985	25980	8.3%		Existing				0	0
G3W / G3E	167	WESTON	171	WES G3	1	115	13675	15782	32	34	15210	17729	36	37	15782	17729	12.3%	23857	New	Total	3/2	1.4	22095	24821
1151	176	SHRMN ST	177	SHRMN ST	1	115	12720	10213	13	23	13330	10480	12	22	12720	13330	4.8%	16700	New	Total	3/2	1.26	16028	16795
Z-52	167	WESTON	197	MORRISON	1	115	18748	24614	66	69	20280	26603	67	73	24614	26603	8.1%	40000	OK	Sym/Tot	2/1.5	1.23	30276	32721
Z-52	176	SHRMN ST	197	MORRISON	1	115	10272	8658	10	17	10637	8834	9	17	10272	10637	3.6%	16700	OK	Total	3/2	1.19	12223	12658
W-23	176	SHRMN ST	3017	Sunny Vale	1	115	11312	9225	14	25	11851	9465	13	24	11312	11851	4.8%	16700	OK	Total	3/2	1.18	13348	13985
M-91	252	ROCKY RN	253	WHITG AV	1	115	17340	20535	26	33	19228	22532	27	33	20535	22532	9.7%	31500	OK	Sym	3/2	1.18	24232	26588
S-45	252	ROCKY RN	263	PLOVER	1	115	17517	20970	27	34	19409	22991	28	34	20970	22991	9.6%	31500	OK	Sym	3/2	1.18	24744	27129
B-106	253	WHITG AV	263	PLOVER	1	115	12997	13201	18	26	13914	13858	17	25	13201	13914	5.4%	16700	OK	Total	5/3	1.2	15842	16697
6841	641	NAP	21	MASON ST	1	138	33975	32458	20	31	34521	32796	20	31	33975	34521	1.6%	55000	OK	Sym	3/2	1.15	39071	39699
6842	641	NAP	612	KM_NORTH	1	138	34044	32469	20	31	34590	32805	19	31	34044	34590	1.6%	55000	OK	Sym	3/2	1.15	39150	39779
6854	641	NAP	1642	NAP BK2	1	138	32514	30563	20	8	32939	30816	20	8	32514	32939	1.3%	41800	OK	Total	3/2	1.24	40317	40844
6851	641	NAP	3012	PARK LAWN	1	138	34104	32610	19	30	34656	32951	19	30	34104	34656	1.6%	55000	OK	Sym	3/2	1.15	39219	39854
1266E / 1266 W	167	WESTON	168	WESTON	1	115	18677	24259	65	68	20214	26254	66	71	24259	26254	8.2%	40000	OK	Sym	3/2	1.3	31537	34131

Appendix C

Power Flow Analysis

Table C.1 Projects Identified by ATC That May Address Power Flow Analysis Problems (From TSR #75000492 SIS)

1. **Port Edwards-Sand Lake 138kV.** The present rating is 154 MVA. This line is scheduled to be upgraded in 2005/06.
2. **Kelly-Whitcomb 115kV Rebuild.** This is scheduled in 2005/06.
3. **Weston-Sherman Street 115kV.** This line is planned to be upgraded from its' present rating of 215 MVA in 2007.
4. **East Shawano-West Shawano 138kV.** This new line is planned for 2003.
5. **Arrowhead-Weston 345kV.** This new line project would include two 345-115kv, 500 MVA transformers at Weston. This is currently scheduled for 2005. This would alleviate the Weston 345-115kV limit.
6. **Weston-Morrison-Sherman Street 115kV Upgrade.** The present ratings are 220 MVA for Sherman Street-Morrison and 239 MVA for Morrison-Weston. This is planned for 2007.
7. **Kelly-Bunkerhill 115kV Upgrade.** The present rating is 145/169 MVA. This is planned for 2005.
8. **Weston-North Point-Rocky Run 115kV.** The present ratings are 93 MVA for Weston-North Point and 120 MVA for North Point-Rocky Run. A project to increase the rating of this circuit is presently scheduled in 2006.
9. **Stratford-McMillan 115kV.** The rating for this line is presently 92 MVA. This line is scheduled to be reconductored in 2005.

Table C.2 Transmission Elements That May Be Overloaded and Require System Upgrades (From TSR #75000492 SIS)

1. **Hoover-Whiting 115kV**. There is presently no project to address this limit.
2. **Whitcomb-Caroline-Badger 115kV**. There is presently no project to upgrade this line.
3. **Hoover 138-115kV**. There is no project to address this transformer limit.
4. **North Appleton-Plover 345kV**. There is presently is no project to rebuild this line.
5. **Badger 138-115kV**. There is no project to address this transformer limit.
6. **Weston-Kelly 115kV**. This line will be upgraded from its present rating of 210 MVA to 271 MVA in 2005. This line still shows up as a limit with the 271 MVA rating.
7. **Sand Lake-Wautoma 138kV**. There is presently is no project to rebuild this line.
8. **Plover-Whiting 138kV**. There is presently no project to rebuild this line.
9. **Baker-Saratoga 115kV**. There is presently no project to rebuild this line.
10. **Arpin-Sigel 138kV**. There is presently is no project to rebuild this line.
11. **Hilltop-Sherman Street 115kV**. The present rating is 239 MVA. There is a project to increase this rating in 2008, but the scope of work is yet to be determined.
12. **Rocky Run 345-115kV**. There is no project to address this transformer limit.
13. **Sigel-Lakehead Vesper 138kV**. There is no project to address this limit.