

**Generator Interconnection Study**  
**System Impact Report For GIC027**  
**(MISO #G093 / #37004-01)**  
**Revision 1**

**December 6, 2002**

**American Transmission Company, LLC**

**Robert L. Krueger**

This page intentionally left blank.

## I. Executive Summary

### Purpose

This report contains a revision to the final stability, short circuit and thermal analysis for ATCLLC (“ATC”) Generator Interconnection Request #GIC027 (MISO #G093 / #37004-01) dated August 12, 2002. This report will outline an alternate connection configuration for the proposed generators. The information presented in this report will highlight the impacts of the proposed connection and will not contain budgetary estimates nor will it contain solutions to problems found in this study. The revision to the original study is the result of data not previously submitted to ATC engineering for review and implementation. For purposes of this study, the results of the previous interconnection will be labeled and referred to as “Original Connection” and the revisions to the results of the original study will be labeled and referred to as “Alternate Connection”

ATC determined, in its sole judgment, that Generation Interconnection Request #GIC010 (MISO #G048/#36749-01) is the only competing request for the purpose of this study. GIC027 is for a new 1200 MW combined cycle generation facility located in Ozaukee County, WI. Public information related to GIC027 and GIC010 can be found via the MISO web site at <http://www.MidwestISO.org>

The existing generation facilities at the Port Washington 138 kV substation will be retired prior to commencement of GIC027. The plant modeling for both studies include a reconfiguration of the 138 kV bus at the Port Washington substation. The GIC027 facility includes four gas turbine and two steam turbine generation units that are interconnected to the Port Washington substation with six separate step-up transformers. Two separate blocks of generation are planned to be installed at the Port Washington substation. The first 600 MW block of generation is planned to be in service in June of 2005. The second 600 MW block of generation is planned to be in service in June of 2008. The GIC027 study is a net increase of 200 MW for the GIC002 (MISO #G014 / #36465-01) study, which was originally evaluated at a net output of 1000 MW. GIC027, which includes modified parameters for all generators involved, is studied with a net output of 1200 MW.

The Original Connection showed a configuration where two generators were connected to bus sections 4, 5 and 6 respectively. The Alternate Connection will show one generator connected to bus section 4, three generators connected to bus section 5 and two generators connected to bus section 6.

It should be noted that the plant data used to perform the study, as well as configuration information, might change as the design process goes forward. If any significant design change occurs with the proposed GIC027 plant, additional studies may need to be performed to ensure that these design changes do not degrade system performance. The results are based on data provided by the Generator Customer 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 Generation Interconnection Requests (GIRs), in related Transmission Service Requests (TSRs), or subsequent ATC transmission system development plans, then the results of this study may also change significantly. It is the responsibility of the customer to communicate

any design modifications to ATC as soon as these modifications become available. ATC reserves the right to re-evaluate the study as required if any portion of the modeling data changes.

This executive summary provides a listing of the Required System Upgrades and the Optional System Upgrades associated with GIC027.

### **System Upgrades Due to Pre-Existing Issues (Original Connection and Alternate Connection)**

These upgrades will need to be performed whether or not the proposed GIC027 generation is installed. However, these upgrades will need to be completed prior to the commercial operation of the unit. These upgrades are listed in Table I.1 and shown in Figure I.1.

The total cost estimate of all Required System Upgrades due is \$TBD. This financial cost is the responsibility of the distribution company, We Energies, since these upgrades are required regardless of GIC027 being placed in service.

### **Required System Upgrades (Original Connection)**

Required System Upgrades will need to be constructed prior to commercial operation of the unit and are due to either stability or short circuit analysis results. These upgrades are listed in Table I.2 and shown in Figure I.2.

With the addition of the proposed generation at the Port Washington substation, the Port Washington substation will need to be reconfigured to accommodate the interconnection. This reconfiguration is shown in Figure I.2.

The total cost estimate of all Required System Upgrades due is \$TBD. This financial cost is the responsibility of GIC027 since these upgrades are due to the proposed generation addition.

### **Required System Upgrades (Alternate Connection)**

Required System Upgrades will need to be constructed prior to commercial operation of the unit and are due to either stability or short circuit analysis results. These upgrades are listed in Table I.3 and shown in Figure I.3.

With the addition of the proposed generation at the Port Washington substation, the Port Washington substation will need to be reconfigured to accommodate the interconnection. This reconfiguration is shown in Figure I.3.

The total cost estimate of all Required System Upgrades due is \$TBD. This financial cost is the responsibility of GIC027 since these upgrades are due to the proposed generation addition.

### **Optional System Upgrades**

Optional System Upgrades are not required for interconnection service. Therefore, these facilities do not have to be implemented prior to the commercial operation of the proposed facility.

## Section I. Executive Summary

The customer waived the typical thermal analysis because Transmission Service Requests had already been submitted on the MISO OASIS and a Facility Study has been completed as of 11/15/2001. The Transmission Service Requests associated with this proposed facility are MISO OASIS #72856710, 72856700, 72807215 and #72807208. Since no thermal analysis was performed, no Optional System Upgrades will be presented in this report. Discussion about possible operating restrictions for both connection options will be discussed further in the Thermal section of this report.

**Table I.1: Required Upgrades, Pre-Existing System, Without GIC027.**

Equipment (CB) Number	Equipment Replacements/Changes				Cost Estimates
	Circuit Breaker		Relaying	Communication	
	Type	Rating			
<b>Port Washington</b>					
T7 Circuit Switcher	138 kV	2 cycle, 63kA	None		\$TBD
T8 Circuit Switcher	138 KV	2 cycle, 63kA	None		\$TBD
<b>Total Cost</b>					<b>\$TBD</b>

Section I. Executive Summary

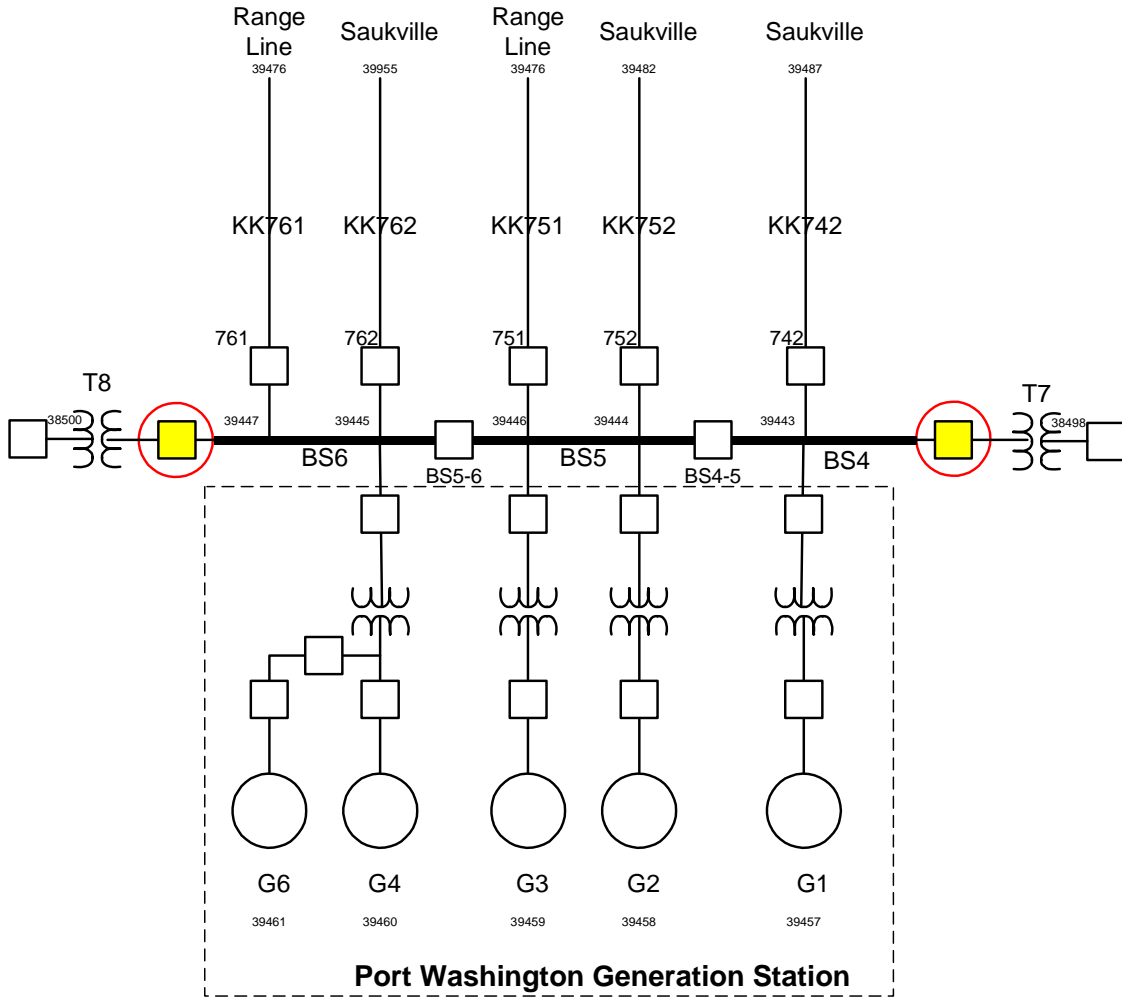


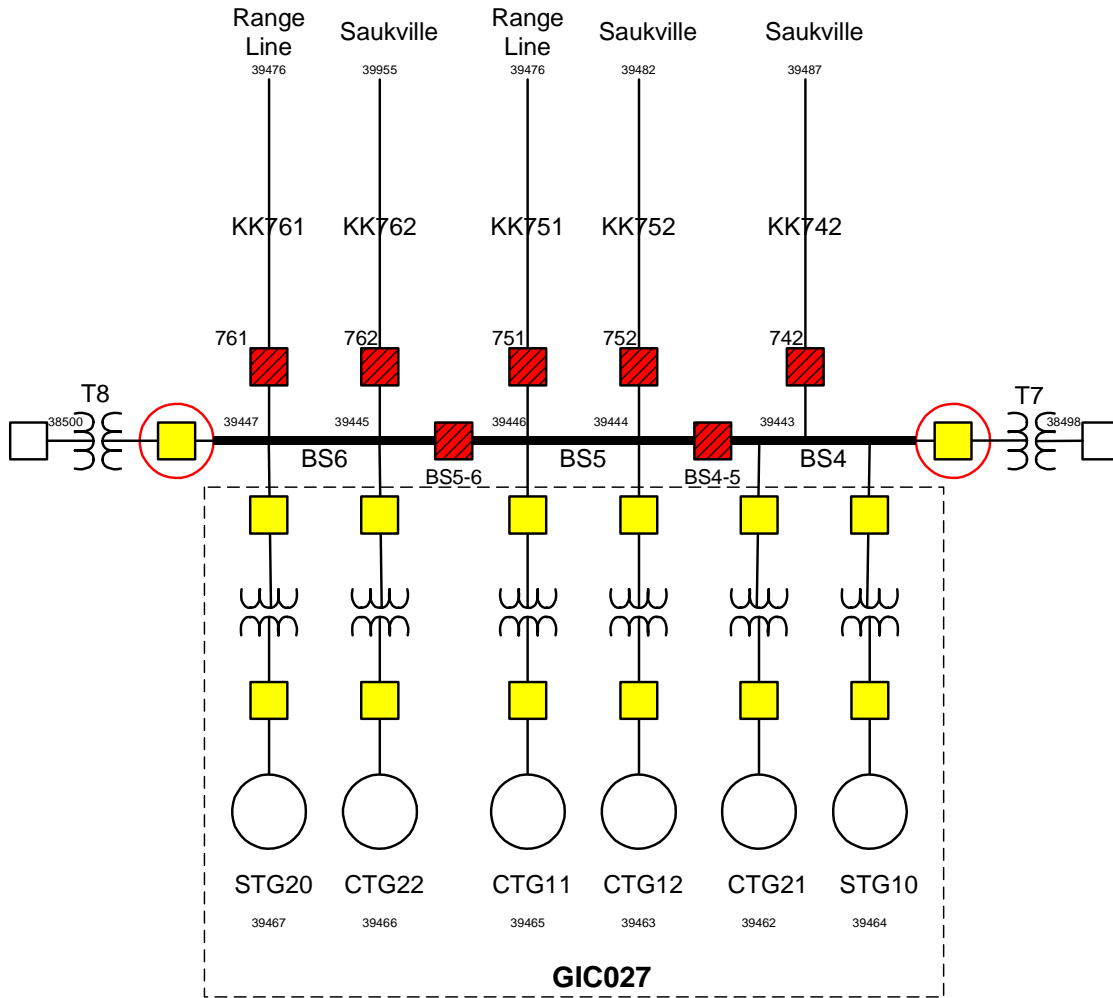
Figure I.1: Required System Upgrades Before GIC027.



**Table I.2: Required System Upgrades due to GIC027 (Original Connection).**

Equipment (CB) Number	Equipment Replacements/Changes				Cost Estimates
	Circuit Breaker		Relaying	Communication	
	Type	Rating			
<b>Port Washington</b>					
KK742	138 kV	2 cycle, 63kA	None		\$TBD
KK751	138 KV	2 cycle, 63kA	None		\$TBD
KK752	138 kV	2 cycle, 63kA	None		\$TBD
KK761	138 kV	2 cycle, 63kA	None		\$TBD
KK762	138 kV	2 cycle, 63kA	None		\$TBD
BS45	138 kV	2 cycle, 63kA	None		\$TBD
BS56	138 kV	2 cycle, 63kA	None		\$TBD
<b>Total Cost</b>					<b>\$TBD</b>

Section I. Executive Summary



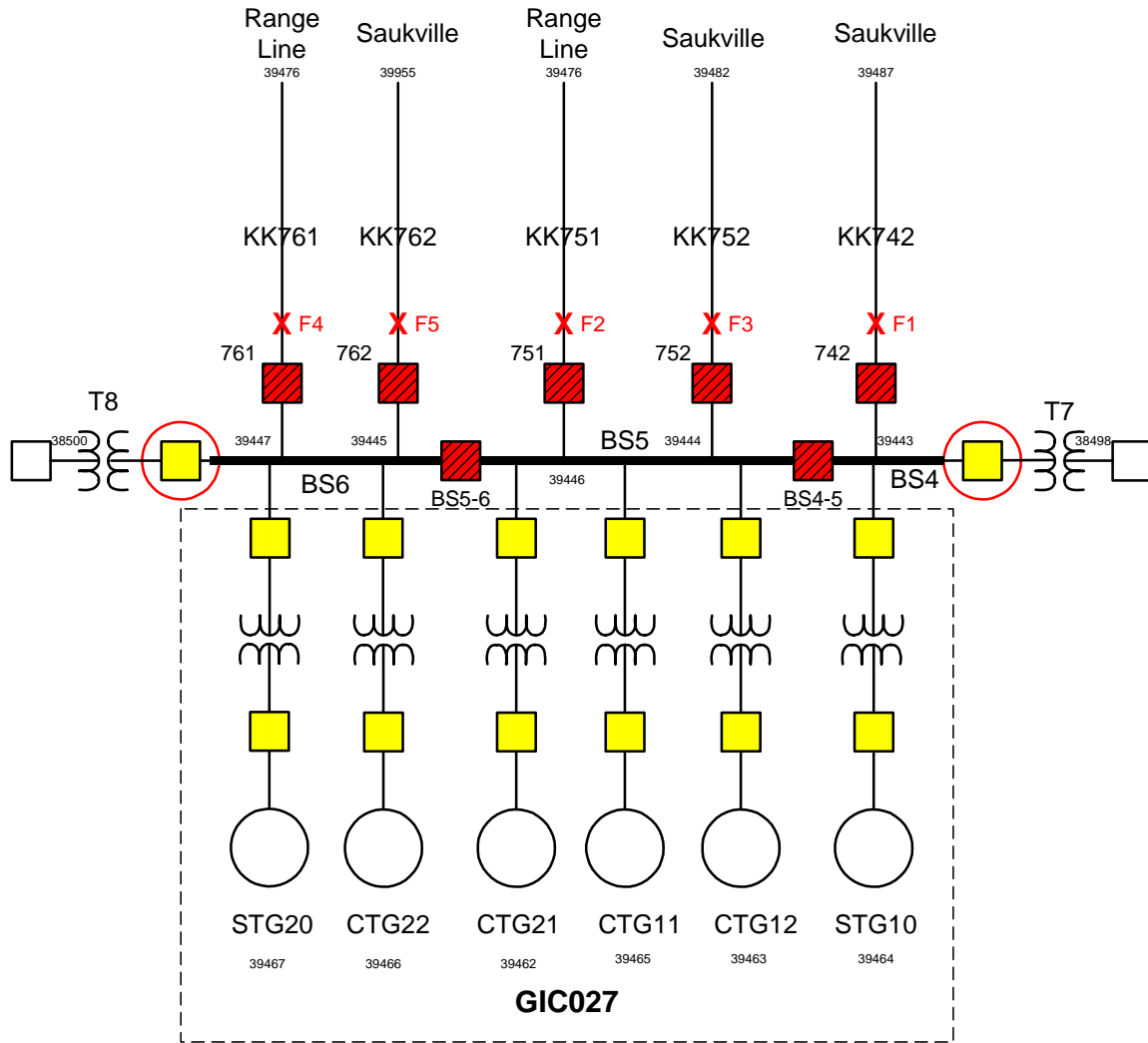
**Figure I.2: Required System Upgrades Due to GIC027.  
(Original Connection)**

- Breaker replacement only
- Breaker & High Speed Relaying
- New Equipment
- Breaker requiring improved relaying and/or communication
- Communications Only
- We Energies Owned Equipment

**Table I.3: Required System Upgrades due to GIC027 (Alternate Connection).**

Equipment (CB) Number	Equipment Replacements/Changes				Cost Estimates
	Circuit Breaker		Relaying	Communication	
	Type	Rating			
<b>Port Washington</b>					
KK742	138 kV	2 cycle, 63kA	None		\$TBD
KK751	138 KV	2 cycle, 63kA	None		\$TBD
KK752	138 kV	2 cycle, 63kA	None		\$TBD
KK761	138 kV	2 cycle, 63kA	None		\$TBD
KK762	138 kV	2 cycle, 63kA	None		\$TBD
BS45	138 kV	2 cycle, 63kA	None		\$TBD
BS56	138 kV	2 cycle, 63kA	None		\$TBD
<b>Total Cost</b>					<b>\$TBD</b>

Section I. Executive Summary



**Figure I.3: Required System Upgrades Due to GIC027. (Alternate Connection)**

- Breaker replacement only
- Breaker & High Speed Relaying
- New Equipment
- Breaker requiring improved relaying and/or communication
- Communications Only
- We Energies Owned Equipment



## Section II. Stability Analysis

STG10: 188/251/314 MVA  $Z = 10\%$  on 170 MVA base  
 $Z = 0.0015 + j0.0588$  on a 100MVA base  
STG20: 188/251/314 MVA  $Z = 10\%$  on 170 MVA base  
 $Z = 0.0015 + j0.0588$  on a 100MVA base

Additional studies will be required at the expense of the customer if the study data changes significantly. The new data could worsen or better the results presented in this report.

### *Study Criteria*

The stability criteria used in this study is the same criteria used for all generation impact studies. All machines modeled in the system must remain stable after a three-phase fault is cleared from any transmission element under the following conditions:

- 1) Fault cleared in primary time with an otherwise intact system (Including internal SLG faults for selected breakers).
- 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.

Transient stability studies were performed to determine if the critical clearing times for all pertinent contingencies were less than the maximum expected breaker failure clearing times in this area. Any critical clearing times that were less than the actual breaker failure clearing times would, therefore, be considered unacceptable.

It should be noted that extensive simulations for criteria #2 and #3 were performed for GIC027. Criteria #1 simulations were limited to a few fault scenarios because both criteria #1 and #3 included faults cleared in primary clearing time. Criteria #3 simulations involve a pre-existing outage with a faulted element cleared in primary time, which is actually a more severe case.

The stability simulation results presented in this section are based on the stability criteria stated above. 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 worst-case stability performance in this area, and to identify required upgrades that will protect the transmission system and generation in this area at various load levels.

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.

## **Summary of Stability Results (Original Connection)**

### ***Stability Study Scenario – Expected System Before GIC027***

A stability analysis was not performed on the proposed system to identify the stability performance and any required protection upgrades due to the existing Port Washington substation. All existing generators will be retired prior to commissioning the new substation. The substation will be built to standards as indicated in the analysis for Port Washington substation with the addition of IC027. ATC System Protection has identified that the circuit switchers located on the high side of the distribution transformers at the Port Washington substation will have to be replaced with circuit breakers regardless if GIC027 is placed in service. The circuit switchers do not meet ATC guidelines for protection and will have to be replaced with 2 cycle circuit breakers. These cost of these circuit breakers are the responsibility of the local distribution company, We Energies.

### ***Stability Study Scenario – Expected System After GIC027***

A stability analysis was performed on the proposed system to identify the stability performance and any required protection upgrades due to the addition of GIC027. Figure A1 in Appendix A shows the one-line diagram of the area transmission system after the addition of GIC027. Note the reconfiguration of Port Washington substation to accommodate the GIC027 generation.

### ***Stability Criteria #1 – Intact System, Fault Cleared in Breaker failure Clearing Time (Tie Breaker SLG Internal Faults)***

Table A1 in Appendix A presents the results for the existing transmission system with the criteria #1 contingencies studied. The table shows that the existing primary clearing times are sufficient to meet the required clearing times for all scenarios. No upgrades are identified at this time to obtain acceptable critical clearing times for stability criteria #1 contingencies.

### ***Stability Criteria #2 – Intact System, Fault Cleared in Breaker failure Clearing Time***

Table A2 in Appendix A presents the results for the transmission system after the addition of GIC027 with the criteria #2 contingencies examined. The table shows that all contingency scenarios with the exception of contingency #F6 resulted in having a critical clearing times that were less than the actual clearing times of the protection equipment in this area.

The critical clearing times in Table A2 vary from 10.5 cycles to 11.5 cycles at the Port Washington substation. The actual clearing times are determined by the speed of the protection equipment that protects the faulted element(s). The existing breakers and relays at the Port Washington substation has the capability of clearing a fault in breaker failure time in 12.5 cycles. For the existing 3-cycle breakers and the addition of high-speed relaying, the fastest possible clearing time possible is 12.0 cycles. The actual clearing times of the equipment is shown in the column “Breakers Cleared In BF Time (cycles)”.

Contingencies F2 and F3 all have critical clearing times of 10.5 cycles. These contingencies require the 3-cycle 138 kV circuit breakers KK751, KK752, BS4-5 and BS5-6 to be replaced with 2-cycle SF6 breakers. Relays at the substation will have to be verified for the needed specifications and may require replacement.

Contingencies F1, F4, and F5 all have critical clearing times of 11.5 cycles. These contingencies require the 3-cycle 138 kV circuit breakers KK742, KK761, and KK762 to be replaced with 2-cycle SF6 breakers as well. Relays at the substation will have to be verified for the needed specifications and may require replacement.

All GIC027 studies performed included modeling the generator terminal voltage at near 1.0 per unit. This voltage level resulted in a total GIC027 reactive power output of 0.84 MVAR (producing). The stability response of the generator typically improves as the power factor increases toward lagging (producing reactive power).

A list of the equipment upgrades that are needed to operate adequately for these contingencies is shown below in Table II.1.

*Stability Criteria #3 – Pre-existing Outage, Fault Cleared in Primary Clearing Time*

Table A3 in Appendix A presents the results for the existing transmission system with the criteria #3 contingencies studied. The table shows that the existing primary clearing times are sufficient to meet the required clearing times for all scenarios. No upgrades are identified at this time to obtain acceptable critical clearing times for stability criteria #3 contingencies. However, the damping for contingency #F5a is considered to be unacceptable and additional study work will be required for this contingency (See discussion in next paragraph). Use of power system stabilizers, possible generator reductions, bus reconfigurations, and additional transmission support may be necessary to obtain acceptable generator damping for this contingency.

Element	Present Requirement	Action Necessary
KK742	PW BF time (10.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK751	PW BF time (10.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK752	PW BF time (10.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK761	PW BF time (11.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK762	PW BF time (11.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
BS4-5	PW BF time (10.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
BS5-6	PW BF time (10.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.

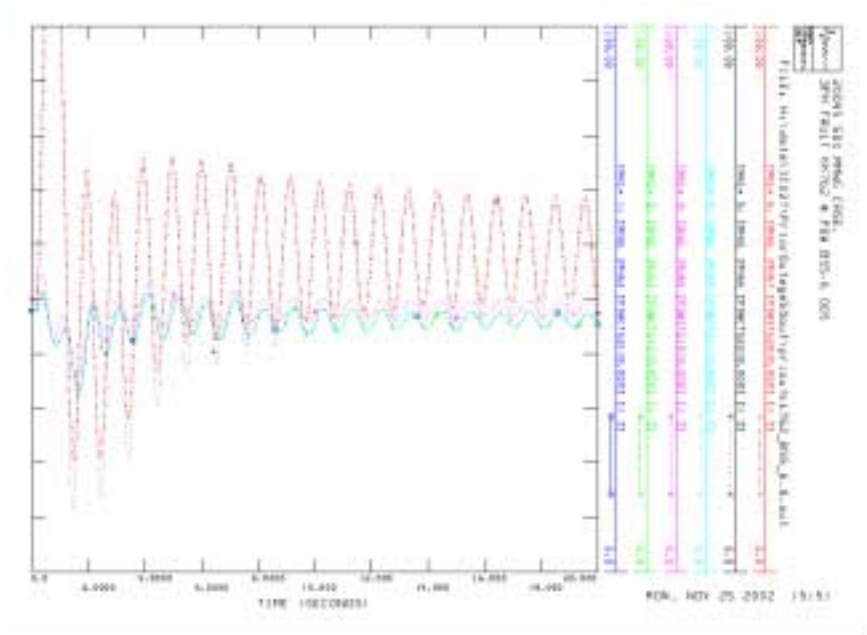
\* BF = breaker failure

**Table II.1: Required Upgrades – Existing System With GIC027 (Original Connection)**

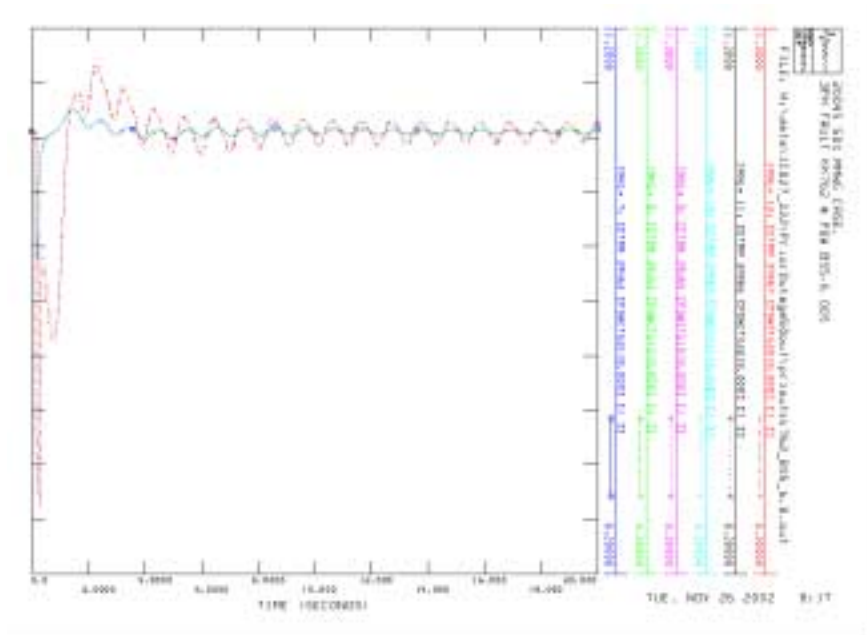
*Damping*

Once critical clearing times were found, additional simulations were performed to identify any possible damping concerns with the proposed generators. Each contingency was performed and the disturbance was removed at the found critical time. The behavior of the generators was then monitored to 20 seconds to verify that all oscillations damp out and the system returns to normal. All generators showed acceptable damping after the disturbance is removed from the system, with the exception of prior outage contingency #F5a (Figure II.1). Damping for this contingency is considered to be unacceptable and additional study work will be required for this contingency. Use of power system stabilizers, possible generator reductions, bus reconfigurations, and additional transmission support may be necessary to obtain acceptable generator damping for this contingency.

Section II. Stability Analysis



(Angle)



(Voltage)

Figure II.1 Damping for Contingency F5a (Original Connection)

*Stability Study Summary – After GIC027*

The critical clearing times calculated for five of the breaker failure scenarios are shorter than what is possible for the existing equipment to operate and clear the faults reliability. The clearing times for the existing equipment are 12.5 cycles for breaker failure scenarios. Seven breakers are required to be replaced with 2 cycle breakers (SF6). The existing BE1-50BF relays at the substation need to be verified to have post 1994 CT subsidence design capability and may also need to be replaced depending on the outcome of the testing. The breaker replacements and potential relay replacements are a Required System Upgrade for the interconnection of the proposed GIC027 generation. This protection upgrade needed to operate adequately for this contingency is shown above in Table II.1. Note that these upgrades are Required System Upgrades for the interconnection of the proposed GIC027 generation and are the responsibility of the customer.

The critical clearing times calculated for all of the primary clearing with prior outage scenarios are long enough to allow proper operation of the existing equipment operate and clear the faults reliability. The damping associated with one of the fault scenarios is unacceptable and additional study work will be required to minimize rotor swings. Use of power system stabilizers, possible generator reductions, bus reconfigurations, and additional transmission support may be necessary to obtain acceptable generator damping for this contingency.

**Conclusions (Original Connection)**

*Proposed System With GIC027*

Five contingencies (Table A2) were found for which the existing protection equipment in the area is not expected to provide acceptable stability response for the generators. Therefore, certain Required System Upgrades are needed to accommodate the addition of the proposed GIC027 generation.

Seven of the existing, 3-cycle 138 kV, breakers at the Port Washington 138 kV substation need to be replaced with 2-cycle breakers. These breakers are specifically listed in Table II.1. In addition to the replacement of these breakers, the Port Washington 138 kV protective relays will need to be tested for integrity and replaced as necessary.

Additional study work will be required to address damping issues associated with a prior outage scenario. The prior outage scenarios studied represent outages (planned and unplanned) for key elements while faults on the system are incurred. Potential solutions for stability problems include and are not limited to use of power system stabilizers, generator reductions for certain outages, installation of a bus tie breaker between bus sections 5 and 6, and additional transmission line connected to bus section 6.

The circuit switchers located on the high side of the distribution transformers at the Port Washington substation will have to be replaced with circuit breakers. The circuit switchers do not meet ATC guidelines for protection and will have to be replaced with 2 cycle circuit breakers. These are pre-existing issues and the costs of these circuit breakers are the responsibility of the local distribution customer, We Energies.

Finally, all of the breakers connecting GIC027 generator step up transformers to the Port Washington substation, must be 2 cycle breakers. These breakers will be owned by GIC027.

### **Summary of Stability Results (Alternate Connection)**

#### ***Stability Study Scenario – Expected System Before GIC027***

A stability analysis was not performed on the proposed system to identify the stability performance and any required protection upgrades due to the existing Port Washington substation. All existing generators will be retired prior to commissioning the new substation. The substation will be built to standards as indicated in the analysis for Port Washington substation with the addition of IC027. ATC System Protection has identified that the circuit switchers located on the high side of the distribution transformers at the Port Washington substation will have to be replaced with circuit breakers regardless if GIC027 is placed in service. The circuit switchers do not meet ATC guidelines for protection and will have to be replaced with 2 cycle circuit breakers. These cost of these circuit breakers are the responsibility of the local distribution company, We Energies.

#### ***Stability Study Scenario – Expected System After GIC027***

A stability analysis was performed on the proposed system to identify the stability performance and any required protection upgrades due to the addition of GIC027. Figure A2 in Appendix A shows the one-line diagram of the area transmission system after the addition of GIC027. Note the reconfiguration of Port Washington substation to accommodate the GIC027 generation.

#### ***Stability Criteria #1 – Intact System, Fault Cleared in Breaker failure Clearing Time (Tie Breaker SLG Internal Faults)***

Table A4 in Appendix A presents the results for the existing transmission system with the criteria #1 contingencies studied. The table shows that the existing primary clearing times are sufficient to meet the required clearing times for all scenarios. No upgrades are identified at this time to obtain acceptable critical clearing times for stability criteria #1 contingencies.

#### ***Stability Criteria #2 – Intact System, Fault Cleared in Breaker failure Clearing Time***

Table A5 in Appendix A presents the results for the transmission system after the addition of GIC027 with the criteria #2 contingencies examined. The table shows that all contingency scenarios with the exception of contingency #F6 resulted in having a critical clearing times that were less than the actual clearing times of the protection equipment in this area.

The critical clearing times in Table A5 vary from 11.0 cycles to 11.5 cycles at the Port Washington substation. The actual clearing times are determined by the speed of the protection equipment that protects the faulted element(s). The existing breakers and relays at the Port Washington substation has the capability of clearing a fault in breaker failure time in 12.5 cycles. For the existing 3-cycle breakers and the addition of high-speed relaying, the fastest possible clearing time possible is 12.0 cycles. The actual clearing times of the equipment is shown in the column “Breakers Cleared In BF Time (cycles)”.

Contingencies F2 and F3 all have critical clearing times of 11.0 cycles. These contingencies require the 3-cycle 138 kV circuit breakers KK751, KK752, BS4-5 and BS5-6 to be replaced

with 2-cycle SF6 breakers. Relays at the substation will have to be verified for the needed specifications and may require replacement.

Contingencies F1, F4, and F5 all have critical clearing times of 11.5 cycles. These contingencies require the 3-cycle 138 kV circuit breakers KK742, KK761, and KK762 to be replaced with 2-cycle SF6 breakers as well. Relays at the substation will have to be verified for the needed specifications and may require replacement.

All GIC027 studies performed included modeling the generator terminal voltage at near 1.0 per unit. This voltage level resulted in a total GIC027 reactive power output of 0.84 MVAR (producing). The stability response of the generator typically improves as the power factor increases toward lagging (producing reactive power).

A list of the equipment upgrades that are needed to operate adequately for these contingencies is shown below in Table II.2.

*Stability Criteria #3 – Pre-existing Outage, Fault Cleared in Primary Clearing Time*

Table A6 in Appendix A presents the results for the existing transmission system with the criteria #3 contingencies studied. The table shows that the existing primary clearing times are sufficient to meet the required clearing times for all scenarios. No upgrades are identified at this time to obtain acceptable critical clearing times for stability criteria #3 contingencies. However, the damping for contingency #F5a is considered to be unacceptable and additional study work will be required for this contingency (See discussion in next paragraph). Use of power system stabilizers, possible generator reductions, bus reconfigurations, and additional transmission support may be necessary to obtain acceptable generator damping for this contingency.

Element	Present Requirement	Action Necessary
KK742	PW BF time (11.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK751	PW BF time (11.0) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK752	PW BF time (11.0) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK761	PW BF time (11.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
KK762	PW BF time (11.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
BS4-5	PW BF time (10.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.
BS5-6	PW BF time (10.5) <12.5 cycle	Replace existing 3 cycle breaker with a 2 cycle breaker. Existing relays need to be tested for integrity. Replace as necessary.

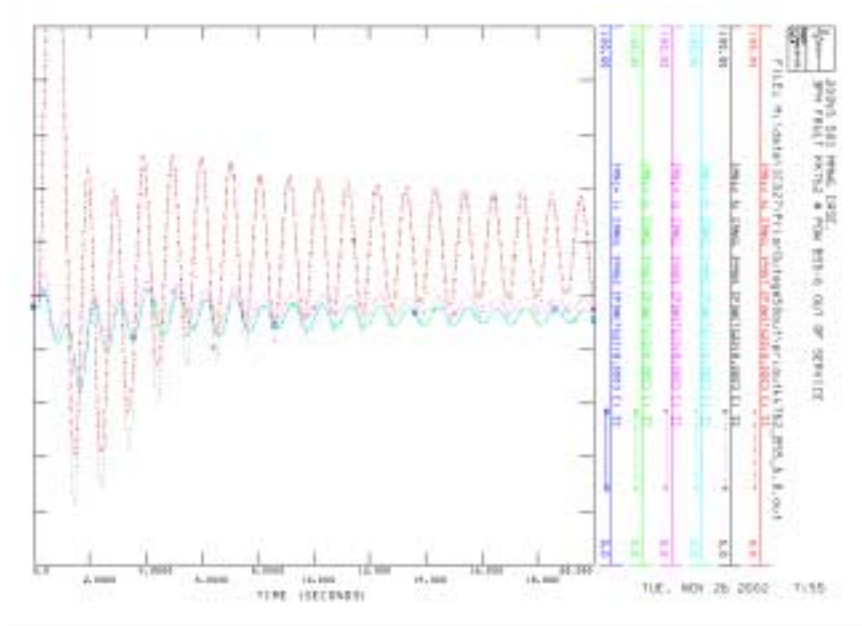
\* BF = breaker failure

**Table II.2: Required Upgrades – Existing System With GIC027 (Alternate Connection)**

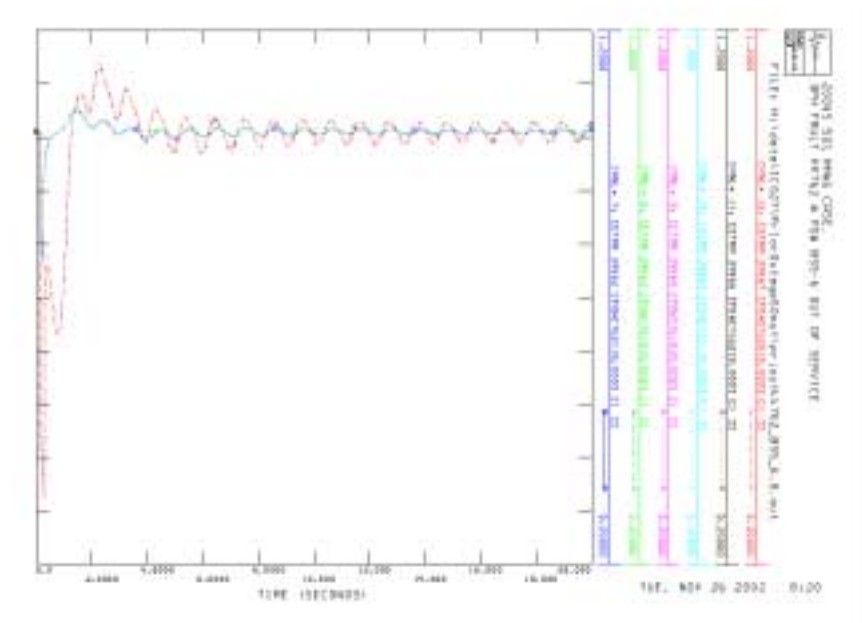
## Section II. Stability Analysis

### *Damping*

Once critical clearing times were found, additional simulations were performed to identify any possible damping concerns with the proposed generators. Each contingency was performed and the disturbance was removed at the found critical time. The behavior of the generators was then monitored to 20 seconds to verify that all oscillations damp out and the system returns to normal.



(Angle)



(Voltage)

**Figure II.2 Damping for Contingency F5a (Alternate Connection)**

All generators showed acceptable damping after the disturbance is removed from the system, therefore, with the exception of prior outage contingency #F5a (Figure II.2). Damping for this contingency is considered to be unacceptable and additional study work will be required for this contingency. Use of power system stabilizers, possible generator reductions, bus reconfigurations, and additional transmission support may be necessary to obtain acceptable generator damping for this contingency.

*Stability Study Summary – After GIC027*

The critical clearing times calculated for five of the breaker failure scenarios are shorter than what is possible for the existing equipment to operate and clear the faults reliability. The clearing times for the existing equipment are 12.5 cycles for breaker failure scenarios. Seven breakers are required to be replaced with 2 cycle breakers (SF6). The existing BE1-50BF relays at the substation need to be verified to have post 1994 CT subsidence design capability and may also need to be replaced depending on the outcome of the testing. The breaker replacements and potential relay replacements are a Required System Upgrade for the interconnection of the proposed GIC027 generation. This protection upgrade needed to operate adequately for this contingency is shown above in Table II.2. Note that these upgrades are Required System Upgrades for the interconnection of the proposed GIC027 generation and are the responsibility of the customer.

The critical clearing times calculated for all of the primary clearing with prior outage scenarios are long enough to allow proper operation of the existing equipment operate and clear the faults reliability. The damping associated with one of the fault scenarios is unacceptable and additional study work will be required to minimize rotor swings. Use of power system stabilizers, possible generator reductions, bus reconfigurations, and additional transmission support may be necessary to obtain acceptable generator damping for this contingency.

**Conclusions (Alternate Connection)**

*Proposed System With GIC027*

Five contingencies (Table A5) were found for which the existing protection equipment in the area is not expected to provide acceptable stability response for the generators. Therefore, certain Required System Upgrades are needed to accommodate the addition of the proposed GIC027 generation.

Seven of the existing, 3-cycle 138 kV, breakers at the Port Washington 138 kV substation need to be replaced with 2-cycle breakers. These breakers are specifically listed in Table II.2. In addition to the replacement of these breakers, the Port Washington 138 kV protective relays will need to be tested for integrity and replaced as necessary.

Additional study work will be required to address damping issues associated with a prior outage scenario. The prior outage scenarios studied represent outages (planned and unplanned) for key elements while faults on the system are incurred. Potential solutions for stability problems include and are not limited to use of power system stabilizers, generator reductions for certain outages, installation of a bus tie breaker between bus sections 5 and 6, and additional transmission line connected to bus section 6.

## Section II. Stability Analysis

The circuit switchers located on the high side of the distribution transformers at the Port Washington substation will have to be replaced with circuit breakers. The circuit switchers do not meet ATC guidelines for protection and will have to be replaced with 2 cycle circuit breakers regardless if GIC027 is placed in service. The cost of these circuit breakers are the responsibility of the local distribution customer, We Energies.

Finally, all of the breakers connecting GIC027 generator step up transformers to the Port Washington substation, must be 2 cycle breakers. These breakers will be owned by GIC027.

### **III. Short Circuit Analysis (Original and Alternate Connection)**

#### **Study Methodology**

##### *Study Criteria*

This section of the report will identify any circuit breaker replacements that will be required due to the increased fault duty provided by the proposed generation, as well as breakers over-dutied under existing system conditions.

The fault duty study for GIC027 consists of evaluating the short circuit interrupting capability of the protection devices in the area of the proposed generation. Three-phase and single-phase-to-ground faults were calculated at GIC027, as well as at multiple sites relevant to this study. The interrupting rating of all circuit breakers at the ATC-owned substations were then reviewed to determine if any circuit breakers became over-dutied due to the proposed generation. The total interrupting requirement of a circuit breaker was determined by the calculated fault current and the corresponding bus X/R ratio. The larger of either the 3-phase or 1-phase faults was used to identify the maximum short-circuit duty for each circuit breaker.

##### *Base Case Assumptions*

The protection model base case used to perform the study includes detailed modeling of all transmission elements and generation in the area, including positive-, negative-, and zero-sequence impedances to allow calculation of both three-phase and single-phase-to-ground faults.

##### *Scenarios Examined*

Generation customer, GIC010, was determined to be the only competing generator for this request. Then the system was evaluated with and without the competing generation added to the system. This study methodology will identify system upgrades required to address fault duty concerns for before and after the addition of GIC027 as well as any additional upgrades due to the increased fault current with the addition of competing generation. Figure A1 in Appendix A shows the configuration of Port Washington with the addition of GIC027 generation.

Four short circuit scenarios were evaluated for this study.

1. The existing system (existing generators at the Port Washington substation) without any modifications to the Port Washington substation. No competing generators included.
2. The existing system with the original Port Washington generators removed and the GIC027 generators added at the Port Washington substation. No competing generators.
3. The existing system (existing generators at the Port Washington substation) without any modifications to the Port Washington substation. GIC010 added as competing generation.
4. The existing system with the original Port Washington generators removed and the GIC027 generators added at the Port Washington substation. GIC010 added as competing generation.

The first comparison includes evaluating the existing system with the original Port Washington Generators (scenario 1) against the system with the new GIC027 generators connected to the Port Washington substation and the existing Port Washington generators removed (scenario 2). No competing generators were added in this portion of the evaluation.

The second comparison includes evaluating the existing system modified to include GIC010 as competing generation (scenario 3) against the system with the new GIC027 generators connected to the Port Washington substation (existing Port Washington generators removed) and IC010 added as competing generation (scenario 4).

These comparisons are used to determine the impact that each generator has on the ATC transmission system.

#### *Study Assumptions*

Two assumptions had to be made when analyzing the circuit breaker data. First, all circuit breakers are assumed to have a contact parting time of 1 cycle less than the operating time, unless specifically stated in the engineering documentation. Second, all breakers were assumed to be rated on a symmetrical current basis, unless they were manufactured prior to 1964 or they are specifically stated as being total current basis rated.

#### **Summary of Short Circuit Results**

##### ***First Short Circuit Comparison - Expected System, Without Competing Generation added.***

No circuit breakers were found to have fault interrupting capabilities less than the adjusted fault current under existing system conditions.

##### ***Second Short Circuit Comparison - Expected System, With Competing Generation added***

No circuit breakers were found to have fault interrupting capabilities less than the adjusted fault current due to the addition of GIC027 generation.

All of the 138 kV breakers at the Port Washington will be required to be replaced due to stability concerns. The new breakers will be required to have a minimum rating of 63 kA to accommodate the fault current at this substation. The breakers connecting GIC027 generator step up transformers to the ATC system will also be required to have a rating of 63 kA.

#### **Conclusions**

No breakers were identified to be replaced due to fault duty with and without the addition of GIC027.

All ATC 138 kV breakers that will be required to be replaced due to stability concerns at the Port Washington substation will be required to have a minimum fault duty of 63 kA. The breakers owned by customer GIC027, connecting the generator step up transformers to the 138 kV system at the Port Washington substation, should have a fault interrupting capability of at least 63 kA. Even though the existing breakers at the Port Washington substation have 63 kA capacities, additional engineering studies will be required to ensure that all elements (e.g. buss work) of the

### Section III. Short Circuit Analysis

substation have adequate capacities. The outcome of this evaluation and the additional costs associated with this evaluation will be shared with the customer as it becomes available.

ATC System Protection has identified that the circuit switchers located on the high side of the distribution transformers at the Port Washington substation will have to be replaced with circuit breakers. The circuit switchers do not meet ATC guidelines for protection and will have to be replaced with 2 cycle 63 kA circuit breakers regardless if GIC027 is placed in service. These cost of these circuit breakers are the responsibility of the local distribution company, We Energies.

## IV. Thermal Analysis

The customer waived the typical thermal analysis because Transmission Service Requests had already been submitted on the MISO OASIS and a Facility Study has been completed as of 11/15/2001. The Transmission Service Requests associated with this proposed facility are MISO OASIS #72856710, 72856700, 72807215 and #72807208. Since no thermal analysis was performed, no Optional System Upgrades will be presented in this report. However, a basic substation analysis was completed to illustrate the constraints seen at the Port Washington substation with the addition of the two connection configurations. Since the Port Washington substation is largely an exporting substation, the use of a light load (50%) case is acceptable for the purposes of this study.

This analysis will point out possible operating restrictions as well as possible overloads at the substation and the lines connected to the substation. This analysis will be used to support possible operating restrictions and the need for additional projects to support full capacity of the plant. The Transmission Service Request study reports produced by ATC indicated the need for a rebuild of all lines connected to the Port Washington plant as well as the bus structure within the plant switch yard. The new ratings of the lines and the bus work were implemented in the study and the overloads seen in this analysis are compared against those ratings. Single and double contingencies were evaluated in this analysis.

### ***Thermal Study Scenario – Expected System After GIC027 (Original and Alternate Connection Configurations)***

A thermal analysis was performed on the proposed system to identify potential operating restrictions and thermal violations at the substation. The two possible connection configurations for GIC027 are shown in Figures A1 and A2 in Appendix A. Note the reconfiguration of Port Washington substation to accommodate the GIC027 generation for both options.

### ***Thermal Study Summary – After GIC027 (Original Connection Configuration)***

Table C1 in Appendix C shows four elements overloaded for double contingency scenarios. A generation operating guide would be required by GIC027 for the outage of either one of the double contingency elements in anticipation of the second element being removed from service. In the event that both elements would be tripped, it is desirable to prevent the overload of additional elements.

### ***Thermal Study Summary – After GIC027 (Alternate Connection Configuration)***

Table C2 in Appendix C shows four elements overloaded for double contingency scenarios. A generation operating guide would be required by GIC027 for the outage of either one of the double contingency elements in anticipation of the second element being removed from service. In the event that both elements would be tripped, it is desirable to prevent the overload of additional elements.

**Conclusions (Original Connection and Alternate Connection)**

No elements were identified at Port Washington as possibly being overloaded for single contingencies.

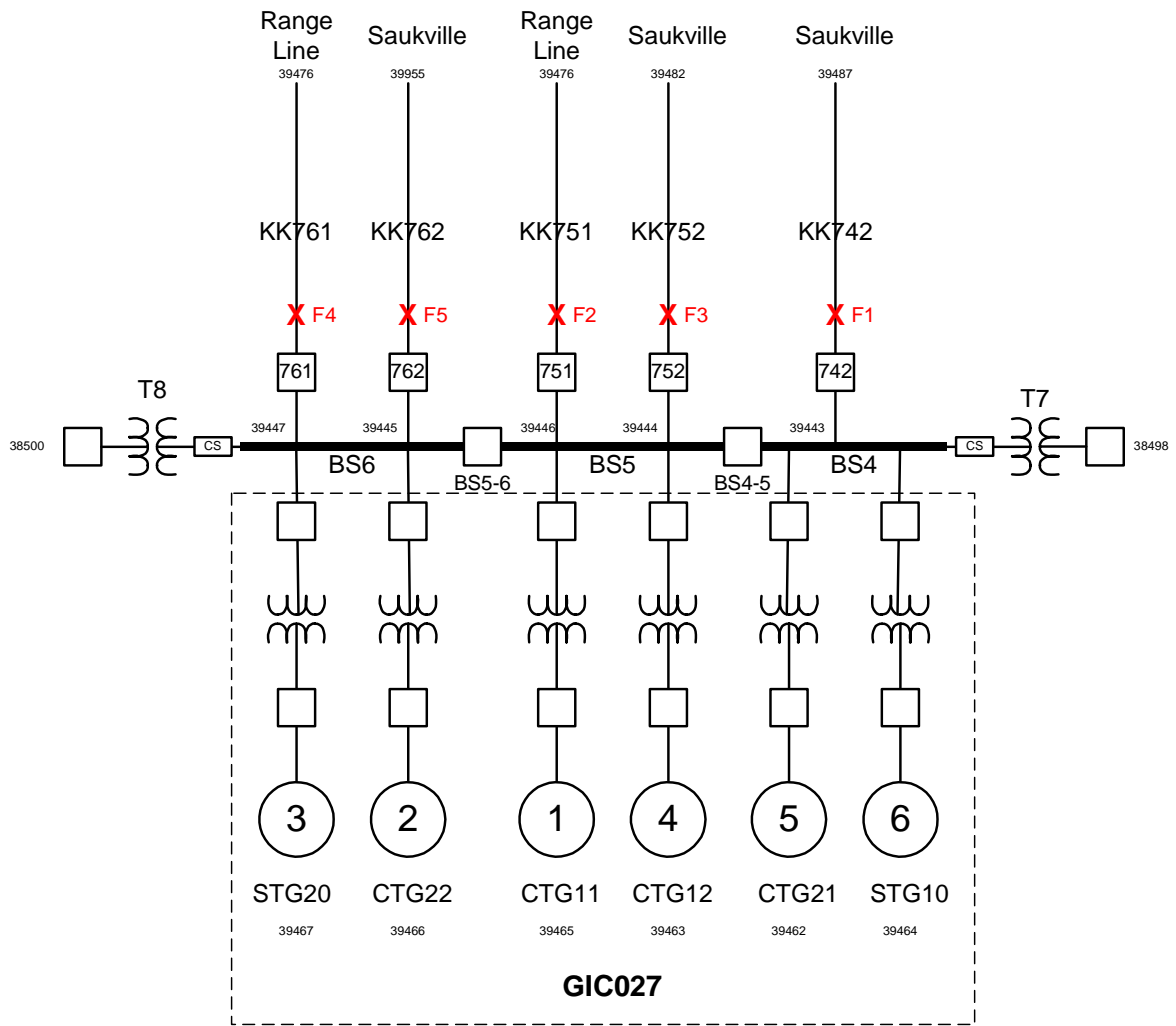
Four elements were identified as possibly being overloaded for double contingency scenarios. While it is desirable to plan for most contingencies, it is noted that double contingencies are severe in nature and generation operating guides are sometimes necessary for survival of the system. Additional projects are being reviewed to relieve the overloads in the event of double contingencies. Potential solutions for thermal limitations include and are not limited to generator reductions for certain outages, installation of a bus tie breaker between bus sections 5 and 6, and additional transmission line connected to bus section 6.

This thermal evaluation was done in support of the stability study and is in no way a replacement of the Transmission Service Request that was placed by the customer. This is only an indication of possible operating restrictions for specific contingencies.

**APPENDIX A**

**STABILITY RESULTS**  
**WITH ADDITION OF GIC027**

Appendix A. Stability Analysis With GIC027 Results



**Figure A1: Port Washington Area Transmission System One-Line With GIC027 (Original Configuration)**

Appendix A. Stability Analysis With GIC027 Results

Fault Scenario	Faulted Element	Breakers Cleared in Primary Time (Cycles)	Clearing Times		Comments
			Critical (Cycles)	Actual (Cycles)	
BS4-5	BS4-5 Breaker @ Port Washington	KK742, KK752, KK751, BS5-6 CTG21, CTG11, CTG12, STG10, T7 @ Port Washington	≥ 5	4.5	CTG21, CTG11, CTG12, STG10 tripped in Primary Time
BS5-6	BS5-6 Breaker @ Port Washington	KK752, KK751, BS4-5 CTG21, CTG11, CTG22, STG20, T8 @ Port Washington	≥ 5	4.5	CTG21, CTG11, CTG12, CTG22, STG20 tripped in Primary Time

- 1 Table abbreviations: STG10, STG20 – Steam Generator, CTG11, CTG21, CTG12, CTG22 – Combustion Turbine.
- 2 The fault is applied at terminal of the faulted element indicated by @.
- 3 CCT = Critical Clearing Time.
- 4 Highlighted cells indicate critical clearing times shorter than the actual clearing times of the protection equipment.
- 5 All Faults are single line to ground faults internal to the faulted element.
- 6 Damping of units is considered acceptable unless otherwise noted.

**Table A1: Critical Clearing Times, 2004 MMWG Light-Load (50%) Stability Base Case. Intact System, Primary Clearing Time. (Original Configuration)**

Appendix A. Stability Analysis With GIC027 Results

Fault Scenario	Faulted Element	Failed Breaker	Breakers Cleared in BF Time (Cycles)	Clearing Times		Comments
				Critical (Cycles)	Actual (Cycles)	
F1	Line KK742 @ Port Washington	KK 742	BS4-5, STG10, CTG21 At Port Washington	11.5	12.5	STG20 Unstable @ 12.0 cycles CTG21 and STG10 tripped in BF Time
F2	Line KK752 @ Port Washington	KK 752	BS4-5, BS5-6, KK751, CTG12, CTG11 At Port Washington	10.5	12.5	STG10 Unstable @ 11.0 cycles CTG12 and CTG11 tripped in BF Time
F3	Line KK751 @ Port Washington	KK 751	BS4-5, BS5-6, KK752, CTG12, CTG11 At Port Washington	10.5	12.5	STG10 Unstable @ 11.0 cycles CTG12 and CTG11 tripped in BF Time
F4	Line KK761 @ Port Washington	KK 761	BS5-6, KK762, STG20, CTG22 At Port Washington	11.5	12.5	STG10 Unstable @ 12.0 cycles STG20 and CTG22 tripped in BF Time
F5	Line KK762 @ Port Washington	KK 762	BS5-6, KK761, STG20, CTG22 At Port Washington	11.5	12.5	STG10 Unstable @ 12.0 cycles STG20 and CTG22 tripped in BF Time
F6	Line KK762 @ Saukville	KK 762	Random Lake 8241, Maple 2642 at Saukville	13.5	12.5	STG10 & STG20 Unstable @ 14.0 cycles

- 1 Table abbreviations: STG10, STG20 – Steam Generator, CTG11, CTG21, CTG12, CTG22 – Combustion Turbine.
- 2 The fault is applied at terminal of the faulted element indicated by @.
- 3 CCT = Critical Clearing Time.
- 4 Highlighted cells indicate critical clearing times shorter than the actual clearing times of the protection equipment.
- 5 All Faults are three-phase faults close in.
- 6 Damping of units is considered acceptable unless otherwise noted.

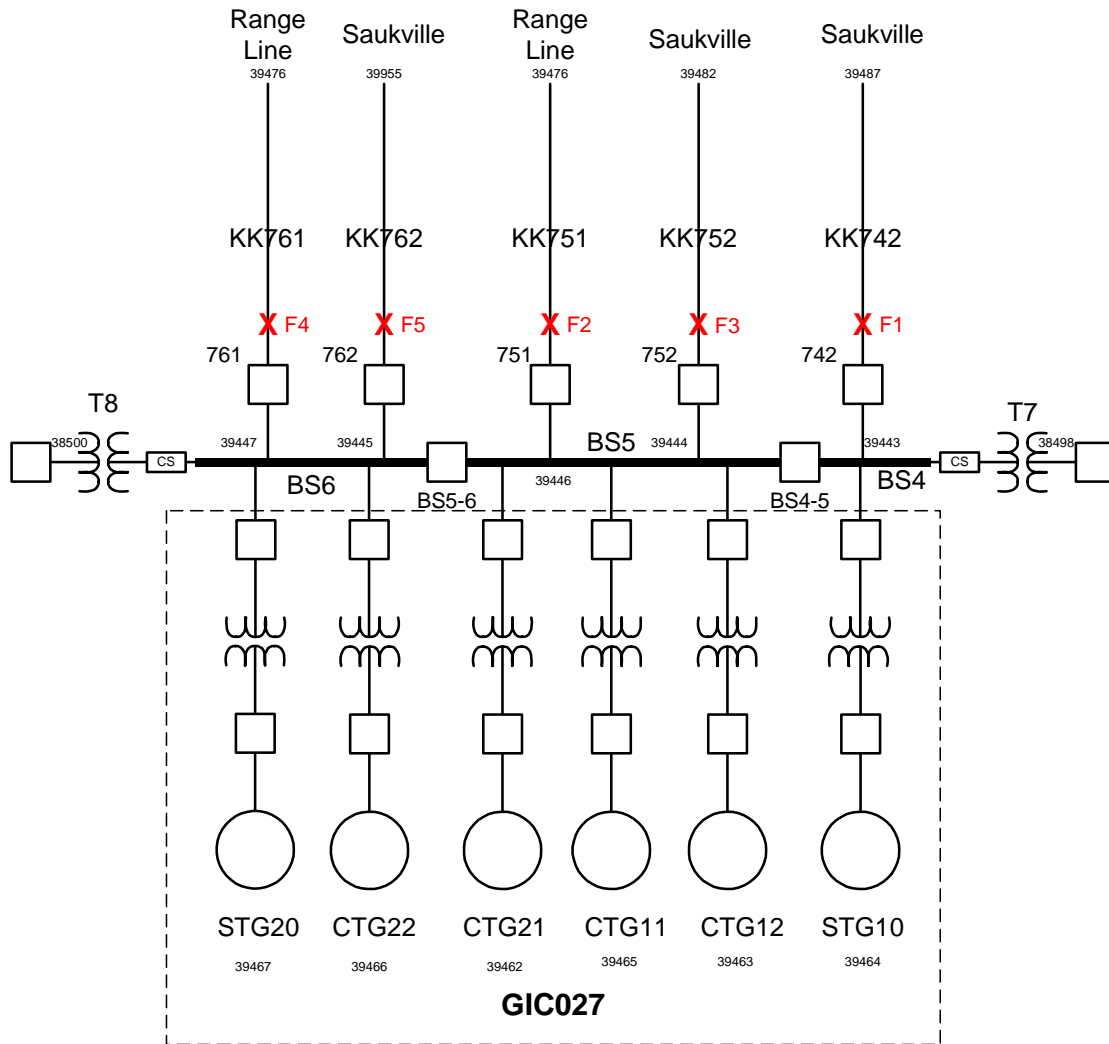
**Table A2: Critical Clearing Times, 2004 MMWG Light-Load (50%) Stability Base Case.  
Intact System, Breaker Failure Clearing Time.  
(Original Configuration)**

Appendix A. Stability Analysis With GIC027 Results

Fault Scenario	Pre-Existing Outage	Faulted Facilities and Fault Location	Breaker Operation (Primary Time)	Clearing Times		Comments
				Critical (Cycles)	Actual (Cycles)	
F3a	KK-742, Port Washington to Saukville	KK752 @ Port Washington	KK752 at Port Washington	9.5	4.5	All Units Stable @ 9.5 cycles
						STG1 and STG20 Unstable @ 10.0 cycles
F3b	KK-751, Port Washington to Range Line	KK752 @ Port Washington	KK752 at Port Washington	10.0	4.5	All Units Stable @ 10.0 cycles
						All Units Unstable at 10.5 cycles
F1a	KK-742, Port Washington to Saukville	KK761 @ Port Washington	KK761 at Port Washington	10.0	4.5	All Units Stable @ 10.0 cycles
						STG10 and STG20 Unstable @ 10.0 cycles
F1b	KK-751, Port Washington to Range Line	KK761 @ Port Washington	KK761 at Port Washington	10.0	4.5	All Units Stable @ 10.0 cycles
						All Units Unstable at 10.5 cycles
F5a	Bus Breaker BS5-6	KK762 @ Port Washington	KK762 at Port Washington	8.0	4.5	All Units Stable @ 8.0 cycles
						STG20 and CTG22 Unstable at 8.5 cycles <b>Unacceptable Damping</b>
F3c	Bus Breaker BS4-5	KK752 @ Port Washington	KK752 at Port Washington	12.0	4.5	All Units Stable @ 12.0 cycles
						STG20 Unstable at 12.5 cycles

- 1 Table abbreviations: STG10, STG20 – Steam Generator, CTG11, CTG21, CTG12, CTG22 – Combustion Turbine.
- 2 The fault is applied at terminal of the faulted element indicated by @.
- 3 CCT = Critical Clearing Time.
- 4 Highlighted cells indicate critical clearing times shorter than the actual clearing times of the protection equipment.
- 5 All Faults are three-phase faults close in.
- 6 Damping of units is considered acceptable unless otherwise noted.

**Table A3: Critical Clearing Times, 2004 MMWG Light-Load (50%) Stability Base Case. Line Out, Primary Clearing Time. (Original Configuration)**



**Figure A2: Port Washington Area Transmission System One-Line With GIC027 (Alternate Configuration)**

Appendix A. Stability Analysis With GIC027 Results

Fault Scenario	Faulted Element	Breakers Cleared in Primary Time (Cycles)	Clearing Times		Comments
			Critical (Cycles)	Actual (Cycles)	
BS4-5	BS4-5 Breaker @ Port Washington	KK742, KK752, KK751, BS5-6 CTG21, CTG11, CTG12, STG10, T7 @ Port Washington	≥ 5	4.5	CTG21, CTG11, CTG12, STG10 tripped in Primary Time
BS5-6	BS5-6 Breaker @ Port Washington	KK752, KK751, BS4-5 CTG11, CTG22, STG20, T8 @ Port Washington	≥ 5	4.5	CTG11, CTG12, CTG22, STG20 tripped in Primary Time

- 7 Table abbreviations: STG10, STG20 – Steam Generator, CTG11, CTG21, CTG12, CTG22 – Combustion Turbine.
- 8 The fault is applied at terminal of the faulted element indicated by @.
- 9 CCT = Critical Clearing Time.
- 10 Highlighted cells indicate critical clearing times shorter than the actual clearing times of the protection equipment.
- 11 All Faults are single line to ground faults internal to the faulted element.
- 12 Damping of units is considered acceptable unless otherwise noted.

**Table A4: Critical Clearing Times, 2004 MMWG Light-Load (50%) Stability Base Case. Intact System, Primary Clearing Time. (Alternate Configuration)**

Appendix A. Stability Analysis With GIC027 Results

Fault Scenario	Faulted Element	Failed Breaker	Breakers Cleared in BF Time (Cycles)	Clearing Times		Comments
				Critical (Cycles)	Actual (Cycles)	
F1	Line KK742 @ Port Washington	KK 742	BS4-5, STG10 At Port Washington	11.5	12.5	STG20 Unstable at 12.0 cycles (STG10 tripped in BF Time)
F2	Line KK752 @ Port Washington	KK 752	BS4-5, BS5-6, KK751, CTG12, CTG11, CTG21 At Port Washington	11.0	12.5	STG10 and STG20 Unstable at 11.5 cycles (CTG21, CTG12 and CTG11 tripped in BF Time)
F3	Line KK751 @ Port Washington	KK 751	BS4-5, BS5-6, KK752, CTG12, CTG11, CTG21 At Port Washington	11.0	12.5	STG10 and STG20 Unstable at 11.5 cycles (CTG21, CTG12 and CTG11 tripped in BF Time)
F4	Line KK761 @ Port Washington	KK 761	BS5-6, KK762, STG20, CTG22 At Port Washington	11.5	12.5	STG10 Unstable (12.0 cycles) (STG20 and CTG22 tripped in BF Time)
F5	Line KK762 @ Port Washington	KK 762	BS5-6, KK761, STG20, CTG22 At Port Washington	11.5	12.5	STG10 Unstable at 12.0 cycles (STG20 and CTG22 tripped in BF Time)
F6	Line KK762 @ Saukville	KK 762	Random Lake 8241, Maple 2642 at Saukville	13.5	12.5	STG10 & STG20 Unstable at 14.0 cycles

- 1 Table abbreviations: STG10, STG20 – Steam Generator, CTG11, CTG21, CTG12, CTG22 – Combustion Turbine.
- 2 The fault is applied at terminal of the faulted element indicated by @.
- 3 CCT = Critical Clearing Time.
- 4 Highlighted cells indicate critical clearing times shorter than the actual clearing times of the protection equipment.
- 5 All Faults are three-phase faults close in.
- 6 Damping of units is considered acceptable unless otherwise noted.

**Table A5: Critical Clearing Times, 2004 MMWG Light-Load (50%) Stability Base Case.  
Intact System, Breaker Failure Clearing Time.  
(Alternate Configuration)**

Appendix A. Stability Analysis With GIC027 Results

Fault Scenario	Pre-Existing Outage	Faulted Facilities and Fault Location	Breaker Operation (Primary Time)	Clearing Times		Comments
				Critical (Cycles)	Actual (Cycles)	
F3a	KK-742, Port Washington to Saukville	KK752 @ Port Washington	KK752 at Port Washington	9.5	4.5	All Units Stable @ 9.5 cycles
						STG1 and STG20 Unstable @ 10.0 cycles
F3b	KK-751, Port Washington to Range Line	KK752 @ Port Washington	KK752 at Port Washington	10.0	4.5	All Units Stable @ 10.0 cycles
						All Units Unstable at 10.5 cycles
F1a	KK-742, Port Washington to Saukville	KK761 @ Port Washington	KK761 at Port Washington	10.0	4.5	All Units Stable @ 10.0 cycles
						STG10 and STG20 Unstable @ 10.0 cycles
F1b	KK-751, Port Washington to Range Line	KK761 @ Port Washington	KK761 at Port Washington	10.0	4.5	All Units Stable @ 10.0 cycles
						All Units Unstable at 10.5 cycles
F5a	Bus Breaker BS5-6	KK762 @ Port Washington	KK762 at Port Washington	8.0	4.5	All Units Stable @ 8.5 cycles
						STG20 and CTG22 Unstable at 10.5 cycles
						<b>Unacceptable Damping</b>
F3c	Bus Breaker BS4-5	KK752 @ Port Washington	KK752 at Port Washington	11.0	4.5	All Units Stable @ 11.0 cycles
						STG20 Unstable at 11.5 cycles

- 1 Table abbreviations: STG10, STG20 – Steam Generator, CTG11, CTG21, CTG12, CTG22 – Combustion Turbine.
- 2 The fault is applied at terminal of the faulted element indicated by @.
- 3 CCT = Critical Clearing Time.
- 4 Highlighted cells indicate critical clearing times shorter than the actual clearing times of the protection equipment.
- 5 All Faults are three-phase faults close in.
- 6 Damping of units is considered acceptable unless otherwise noted.

**Table A6: Critical Clearing Times, 2004 MMWG Light-Load (50%) Stability Base Case. Line Out, Primary Clearing Time. (Alternate Configuration)**

## **APPENDIX B**

### **SHORT CIRCUIT RESULTS**

*No Breakers were Found to be Over-dutied in this Study*

**APPENDIX C**

**THERMAL ANALYSIS RESULTS**

Appendix C. Thermal Analysis Results

Contingency	Element and Rating (Emergency)				
	KK742 (455MVA)	KK752 (455MVA)	KK751 (386MVA)	KK762 (455MVA)	KK761 (386MVA)
	Flow on Element				
BS4-5	425	208	174	209	173
BS5-6	287	286	187	178	250
KK762 & BS5-6	308	308	144		425
KK752 & BS4-5	425		198	367	197
KK752 & KK742			248	689	247
KK751 & KK752	468			465	251
KK742 & KK761		467	252	465	
KK761 & KK751	394	394		396	
KK742		394	202	390	201
KK761	321	319	226	320	

**Table C1: Thermal Overloads at Port Washington (50%) Case.  
(Original Configuration)**

Contingency	Element and Rating (Emergency)				
	KK742 (455MVA)	KK752 (455MVA)	KK751 (386MVA)	KK762 (455MVA)	KK761 (386MVA)
	Flow on Element				
BS4-5	258	280	185	281	184
BS5-6	286	286	187	250	178
KK762 & BS5-6	306	308	145		424
KK752 & BS4-5	258		217	494	217
KK752 & KK742			248	688	246
KK751 & KK752	466			466	251
KK742 & KK761		466	252	465	
KK761 & KK751	393	394		398	
KK742		393	202	390	201
KK761	319	319	226	322	

**Table C2: Thermal Overloads at Port Washington (50%) Case.  
(Alternate Configuration)**