**Report**

# Project G218 (MISO Queue #37356-01) Generation Interconnection Evaluation of a 750 MW Generating Power Plant at Trimble County, KY

**Prepared By**

**Engineering Department**
**Midwest ISO**
**701 City Center Dr.**
**Carmel, IN 46032**

**March 11, 2003**

**Table of Contents**

## Executive Summary

A request for a generation interconnection of a 750 MW generating power plant in Trimble County, KY (Generator) was made to Midwest ISO and was assigned Queue Number 37356-01 and Project Number G218. MISO performed generation interconnection evaluation study with assistance from the Ad Hoc Study Group consisting of members from Cinergy, LGEE and OVEC, and IMEA. The results of this study have been presented in this report.

MISO has recently completed a companion transmission service system impact study (SIS) to evaluate delivery issues as part of MISO OASIS Request Number 75052130. The delivery service SIS study has identified four facility expansion options to alleviate the thermal issues related to the delivery of power from this Generator. A list of these facility expansion options is included in Appendix G of this report.

The generation interconnection evaluation study assumed that the thermal and voltage issues associated with the interconnection of G218 have also been addressed in the system impact study. The system impact study has identified a number of system deficiencies and possible remedies to alleviate system deficiencies. These remedies will be further analyzed in detail in the Facility Study phase of the request under MISO OATT. Therefore, this study did not re-evaluate the single contingency power flow thermal and voltage issues associated with the interconnection of G218.

This study evaluated power system stability, short circuit interruption requirements and potential contingency cascading problems.

**Dynamic Stability Analysis** – The system remains stable when tested against transmission service SIS study Options 1, 3, and 4 but unstable for Option 2. For facility upgrade Option 2, the Trimble unit becomes unstable for a single pole stuck breaker close-in fault on the Trimble to Clifty 345 KV line with delayed clearing (17 cycles). The critical clearing time for this fault was determined to be 14.5 cycles. This fault condition has not been investigated any further in this evaluation study. It is recommended that this instability condition be reviewed in details in the MISO Facility Study Stage of the MISO Generation Interconnect Request process as outlined in Attachment R of the MISO OATT dated March 29, 2002 if the customer wants to pursue Option 2.

**Short Circuit Analysis** – The study finds that the addition of the Generator causes an increase in the fault currents seen by a number of breakers in the system. The increased fault currents are expected to be within the breaker current interruption capabilities. Therefore, no breaker replacements are expected to be needed due to the interconnection of this Generator to the system. However, at Clifty Creek 345 kV, duties imposed on at least two circuit breakers are shown to be approaching their nameplate capabilities. Therefore, duties at Clifty Creek will need to be confirmed as part of the facility study.

**Cascading Outage Analysis** – The study finds that the addition of the Generator did not create any new cascading outage conditions in the system.

## 1. Introduction

A request for a generation interconnection of a 750 MW generating power plant in Trimble County, KY (Generator) was made to Midwest ISO. The MISO Generation Interconnection Request Queue Number for this request is 37356-01. MISO has performed a generation interconnection evaluation study. The results of this study are presented in this report.

The proposed Generator will be connected to the 345 KV bus at the Trimble substation with an in-service date of January 1, 2007. This generator has requested designation of the generator as network resource. In the Generation Interconnection Evaluation Study Agreement dated June 20, 2002, the request was to "analyze as a 750 MW network resource sinking 1) 100% as LG&E network load or 2) 75% to LG&E network load and 25% to partners outside LG&E control area 12.8% to IMPA and 12.2 % to IMEA". The issue was discussed with the Generator in a meeting on January 8, 2003. It was decided that this study would conform with the assumptions that were made in the system impact study of delivering 100% of the generator output to LG&E control area (MISO OASIS request number 75052130). Therefore this study did not evaluate the second option as indicated in the aforesaid study agreement. Potential system facility upgrades, if any, associated with delivering "75% to LG&E network load and 25% to partners outside LG&E control area 12.8% to IMPA and 12.2 % to IMEA" will be addressed in the Facility Study if desired by the customer to the extent applicable for an interconnection study or as part of the transmission service request when submitted to the MISO OASIS. This study does not address delivery issues and focuses on the issues related to the interconnection of the Generator to the system.

MISO has recently completed a companion transmission service system impact study (SIS) to evaluate delivery issues as part of MISO OASIS Request Number 75052130. The delivery service SIS study has identified four facility expansion options to alleviate the thermal issues related to the delivery of power from this Generator. A list of these facility expansion options is included in Appendix G of this report.

The generation interconnection evaluation study assumed that the thermal and voltage issues associated with the interconnection of G218 have also been addressed in the system impact study. The system impact study has identified a number of system deficiencies and possible remedies to alleviate system deficiencies. These remedies will be further analyzed in detail in the Facility Study phase of the request under MISO OATT. Therefore, this study did not re-evaluate the single contingency power flow thermal and voltage issues associated with the interconnection of G218.

This study evaluated power system stability, short circuit interruption requirements and potential contingency cascading problems. The scope of the study has been defined in the next section.

## 2. Project Scope

### Dynamic Stability Analysis

The purpose of dynamic stability analysis was to assess the ability of the new Generator to remain in synchronism following a system disturbance; assess the adequacy of generator oscillations damping; evaluate the impact of this generator on the dynamic stability of the other generators in the system.

### Short Circuit Analysis

The purpose of the short circuit analysis was to assess the ability of the existing circuit beakers to interrupt the new level of fault currents in the system due to the addition Generator.

### Cascading Outage Analysis

The purpose of the cascading outage analysis was to identify any new outages that may potentially become a cascading outage for the system.

## 3. Methodology

**Dynamics Stability Analysis** – PTI PSSE was used to simulate power system dynamics. The model development for PTI PSSE has been described in the next section. In this study the base system (without the Generator) dynamic performance was compared with the changed system (with the Generator) dynamic performance. The differences in the results were identified and analyzed.

**Short Circuit Analysis** – PTI PSSE was used to simulate the fault currents at the substations. The model development for PTI PSSE has been described in the next section. The base system (without the Generator) short circuit currents were compared with the changed system (with the Generator) short circuit currents to determine the affect of the new Generator on the fault current. The differences in the results were identified and analyzed.

**Cascading Outage Analysis** - PTI PSSE was used to identify outages that may potentially lead to cascading outages. The model development for PTI PSSE has been described in the next section. The base system (without the Generator) overloads were compared with the changed system (with the Generator) overloads. The differences in the results were identified and analyzed.

In this analysis, the focus was on identifying the double contingencies that lead to excessive overloading of the transmission facilities.

## 4. Data Preparation

### Dynamic Stability Models

ECAR 2001 series stability model for the 2007 summer peak load was used for this study. The model was updated by including the following items –

- Generators With Signed Interconnection Agreements - Include the generators and their associated facility addition in APPENDIX F. These are the generators in the MISO Interconnection Request Queue that have either a signed Interconnection and Operating Agreement or they did not require an Interconnection and Operating Agreement with the transmission owners to interconnect to the system.
- Generators Higher In MISO Generation Interconnection Request Queue - Include generators that are higher in MISO Interconnection Request Queue. A list of the generators in the queue that is higher in queue than the generator under study has been included in APPENDIX F. In consultation with the affected transmission owners, it was decided that generator at Pike County (Queue number 36441-01) and the 750 MW Thoroughbred generator (Queue number 37077-01) networked into 345 KV and 161 KV systems in LGEE, BREC and TVA area were included in this study. The upgrades associated with Thoroughbred project are listed in APPENDIX F and have been included in the model.
- Updated Line Rating – APPENDIX F lists new line ratings of the existing facilities and have been included in the model.
- Generator Interconnection Options – System Impact Study for MISO Request #75052130 has identified four facility addition options to alleviate any system problems related to the transmission service requests of this Generator. APPENDIX G lists the facility additions associated with each of these four facility addition options. Four models were created to study each one of these four options.

### Fault Scenarios

Various faults scenarios were simulated in this study and the affect of these faults on the power system stability was analyzed. A list of all the fault scenarios that were studied is included in APPENDIX B.

### Monitored Elements

All the generators and voltages in the Cinergy, LGEE, OVEC, BREC, and EKPC area were monitored. A list of generator angles and voltages that were monitored in this study has been included in APPENDIX H.

### Reliability Criteria

The reliability criteria used in the analysis has been included in APPENDIX I.

## Positive Sequence Equivalent Fault Admittance Data

Positive sequence equivalent fault admittance data used for simulating single line to ground faults in PSSE application has been included in APPENDIX E.

## Short Circuit Model

The short circuit model for this study was created from the ECAR 2000 series short circuit model. This ECAR model was further enhanced by including the following details –

- ECAR model is a year 2000 vintage. This model did not include many generating units in AEP and CIN area that have a signed interconnection agreement. All the generators identified in APPENDIX J were included in the model.
- Add Foster – Bath 345 tie between CIN and DPL
- Delete IPP generators in the ECAR model because they have been either cancelled, withdrawn or delayed – 05Cassad 345 KV; 05Desoto 138 KV; 05Keystn 345 KV units 5-8; machine at buses 1105, 1106
- Add IPP at Hanging Rock
- Add generators identified in "Dynamic Stability Models" section

In the absence of good sequence data for the transmission elements, we have assumed that the positive, negative and zero sequence data of a transformer are same. Also, we have assumed that the zero sequence impedance of a transmission line is 3.5 times greater than the positive sequence impedance. These assumptions are based on industry literature and will be modified as better sequence data become available.

## Cascading Outage Analysis

For evaluation of the cascading outage, we have used the load flow part of the models described under section "Dynamic Stability Models".

## 5. Results and Analysis

MISO has recently completed a companion transmission service system impact study (SIS) to evaluate delivery issues as part of MISO OASIS Request Number 75052130. The delivery service SIS study has identified four facility expansion options to alleviate the thermal issues related to the delivery of power from this Generator. A list of these facility expansion options is included in Appendix G of this report.

The generation interconnection evaluation study assumed that the thermal and voltage issues associated with the interconnection of G218 have also been addressed in the system impact study. The system impact study has identified a number of system deficiencies and possible remedies to alleviate system deficiencies. These remedies will be further analyzed in detail in the Facility Study phase of the request under MISO OATT. Therefore, this study did not re-evaluate the single contingency power flow thermal and voltage issues associated with the interconnection of G218.

This study evaluated power system stability, short circuit interruption requirements and potential contingency cascading problems.

### Dynamic Stability Analysis

Results of the dynamic stability simulations have been included in APPENDIX A. The table has been organized by substations. Three phase faults with normal clearing (4 cycles) and single pole stuck breaker faults with delayed clearing (17 cycles) were simulated for this study.

**Dynamic Stability Analysis** – The system remains stable when tested against transmission service SIS study Options 1, 3, and 4 but unstable for Option 2. For facility upgrade Option 2, the Trimble unit becomes unstable for a single pole stuck breaker close-in fault on the Trimble to Clifty 345 KV line with delayed clearing (17 cycles). The critical clearing time for this fault was determined to be 14.5 cycles. This fault condition has not been investigated any further in this evaluation study. It is recommended that this instability condition be reviewed in details in the MISO Facility Study Stage of the MISO Generation Interconnect Request process as outlined in Attachment R of the MISO OATT dated March 29, 2002 if the customer wants to pursue Option 2.

### Short Circuit Analysis

APPENDIX B contains new short circuit fault currents for the four facility addition options identified in the system impact study of this Generator as part of the MISO OASIS Request # 75052130. For each option, there are two tables - one each for a three-phase fault, and a single phase to ground fault. Each table lists the fault currents in the base case and the changed case. The ad hoc group reviewed the increase in the fault current at the stations due to the addition of the Generator and determined that except at Clifty where duties imposed on at least two circuit breakers are shown to be approaching their nameplate capabilities, the increased level of fault currents are still within the existing breaker fault current interruption capability. Breaker duties at Clifty will need to be confirmed at the facility study.

**Cascading Outage Analysis**

A summary of the results of the cascading outage analysis has been included in APPENDIX C. There are a total of 7 contingencies in the base case (without Generator) that lead to violations in the system. A violation was defined as an overload that met the following criteria –

- Greater than 130% overload on a transmission line or a transformer; emergency rating was considered for the contingency case
- Change in flow of 20 MW or more between the base case and the contingency case
- Contingency Elements - double contingencies of all transmission lines and transformers 230 KV and above in CIN, LGEE, and OVEC, EKPC, BREC control areas
- Monitored Elements – Monitor all branches 230 KV and above in CIN, LGEE, and OVEC, EKPC, BREC control areas

The changed case (with Generator) for Option 1, Option 2, Option 3, Option 4 gave rise to an additional 2, 0, 3, 2 contingencies respectively that lead to thermal overloading. Since we are interested in the affect of the new generators on the cascading outages, we did not analyze the base case contingencies that gave rise to overloads. This study has focused on the incremental changes due to the new Generator. The new overloads are in the Kokomo, and Lafayette area in Indiana. These areas are electrically separated from Trimble area in Kentucky where the proposed generation has been added and could not possibly be affected by the addition of the new Generator. Further investigation into these overloads show that in the base case (without the new Generator) the overloading in the Kokomo and Lafayette area was marginal with respect to the 130% overload cutoff limit, and therefore, these overloads did not make the list of overloading facilities. However, due to the topology changes with the addition of the Generator, there was an increase of one-megawatt flow on the elements in the Kokomo and Lafayette area that caused these contingencies to make the list of overloads. The purpose of this effort was to identify contingencies leading to excessive overload that may potentially lead to cascading outages. The overloads identified in the Kokomo and Lafayette area are not considered excessive overloads due to the Generator, and therefore, does not warrant further investigations. Therefore, the study concludes that no new cascading outages have been created due to the addition of the Generator.
As part of this study, we have also investigated simultaneous outage of a generator and a transmission line in the LGEE area. The assumptions were made for this analysis –

- Monitored Elements – Monitor all branches 230 KV and above in CIN, LGEE, and OVEC, EKPC, BREC control areas
- Contingency Elements- single contingencies of all transmission lines and transformers 230 KV and above in LGEE control area
- Violation – overload of greater than100% of the emergency rating
- PTI MUST was used for this analysis; the loss of generation was picked up by the rest of the generators in the CIN, LGEE and OVEC, EKPC, BREC control areas

A summary of the results has been included in APPENDIX D. The first column of this table lists the location of the generator in the LGEE area. The next 5 columns include the maximum MW generation loss for which no thermal overload was found for the loss of a transmission line or a transformer in the contingency list. The entry of "No Problem" indicates that the loss of the biggest generator at each location considered in combination with a single contingency did not cause any violations in the system. The study finds that at Mill Creek generating station, only a loss of 250 MW of generation could be sustained without overloading 345 KV transmission line from Middletown to Buckner and Middletown to Trimble. Once this limitation has been eliminated, the system will be able to sustain the loss of the biggest generating plant at Mill Creek in combination with the critical contingency without any violation.

## 6. Conclusions

**Dynamic Stability Analysis** – The system remains stable when tested against transmission service SIS study Options 1, 3, and 4 but unstable for Option 2. For facility upgrade Option 2, the Trimble unit becomes unstable for a single pole stuck breaker close-in fault on the Trimble to Clifty 345 KV line with delayed clearing (17 cycles). The critical clearing time for this fault was determined to be 14.5 cycles. This fault condition has not been investigated any further in this evaluation study. It is recommended that this instability condition be reviewed in details in the MISO Facility Study Stage of the MISO Generation Interconnect Request process as outlined in Attachment R of the MISO OATT dated March 29, 2002 if the customer wants to pursue Option 2.

**Short Circuit Analysis** – The study finds that the addition of the Generator causes an increase in the fault currents seen by a number of breakers in the system. The increased fault currents are expected to be within the breaker current interruption capabilities. Therefore, no breaker replacements are expected to be needed due to the interconnection of this Generator to the system. However, at Clifty Creek 345 kV, duties imposed on at least two circuit breakers are shown to be approaching their nameplate capabilities. Therefore, duties at Clifty Creek will need to be confirmed as part of the facility study.

**Cascading Outage Analysis** – The study finds that the addition of the Generator did not create any new cascading outages in the system.

## Glossary of Terms

**Generator** – 750 MW generating power plant in Trimble County