# *Generation Interconnection System Impact Study Report*

# *PJM Generation Interconnection Request Queue Position R-52A*

# *Kings Creek 69kV*

**February 2009**

# Preface

The intent of the System Impact Study is to determine a plan, with approximate cost and construction time estimates, to connect the subject generation interconnection project to the PJM network at a location specified by the Interconnection Customer. As a requirement for interconnection, the Interconnection Customer may be responsible for the cost of constructing: Network Upgrades, which are facility additions, or upgrades to existing facilities, that are needed to maintain the reliability of the PJM system. All facilities required for interconnection of a generation interconnection project must be designed to meet the technical specifications (on PJM web site) for the appropriate transmission owner.

In some instances an Interconnection Customer may not be responsible for 100% of the identified network upgrade cost because other transmission network uses, e.g. another generation interconnection or merchant transmission upgrade, may also contribute to the need for the same network reinforcement. The possibility of sharing the reinforcement costs with other projects may be identified in the Feasibility Study, but the actual allocation will be deferred until the System Impact Study is performed.

The System Impact Study estimates do not include the feasibility, cost, or time required to obtain property rights and permits for construction of the required facilities. The project developer is responsible for the right of way, real estate, and construction permit issues. For properties currently owned by Transmission Owners, the costs may be included in the study.

# General

EverPower Ohio, L.L.C., the Interconnection Customer (IC), has proposed a 100 MW (20 MW capacity) wind power generating facility to connect into The Dayton Power and Light Company (Dayton) transmission system. It is identified as Kings Creek 69kV – Project queue number R52A. The project will utilize 44 Siemens 2.3 MW wind turbines. R52A was studied as an 100 MW energy and 20 MW Capacity injection at the Kings Creek substation on the Dayton system. It was evaluated for compliance with reliability criteria for summer peak conditions in 2012. The planned in service date, as stated in the Generation Interconnection Feasibility Study Agreement, is October 1, 2008. That date was not met and a new in-service date has not yet been provided by the IC.

## Point of Interconnection

R52A will interconnect with the Dayton Power and Light Company (Dayton) transmission system at the Kings Creek 69kV substation. A new line and associated reliability and protection equipment will be installed to facilitate that connection.

## Direct Connection Requirements

### Transmission Owner Scope of Direct Connection Work

The Transmission Owner's (Dayton) scope of work includes:

Attachment Facilities

At Kings Creek substation, add one 69kV breaker, relaying, disconnect switches and metering. The estimate assumes that site preparation and site grading will be done by DP&L. The estimated cost to construct the additional 69kV line termination at Kings Creek substation is **$790,000 in 2009 dollars.**

This estimate assumes the Interconnection Customer (IC) will build the transmission line to the DP&L take-off structure at Kings Creek substation. The lead time to complete this work is 9 months. These estimates do not include any tax gross up cost.

DP&L has responsibility for providing specifications for the relaying protection package to be employed on the interconnection breaker terminal at the generation site to assure that the protective relaying equipment will be compatible with that installed on the interconnection breaker terminal at the new switching station. The relaying package will likely include both primary and backup protection. DP&L is also responsible for testing and calibrating all relays protecting the interconnect line and performing all tests to assure that this relaying is properly installed and functional. The estimated total cost of this engineering and field test effort is **$3,000 in 2009 dollars**.

*Note: Purchase and installation of protective relaying and associated equipment at the generation site is not included in this scope of work. This phase of work is the responsibility of the customer.*

## Network Impacts

The Queue Project #R52A was studied as a(n) 100 MW(Capacity=20 MW) injection into KingsCreek 69 kV substation in the Dayton area. Project #R52A was evaluated for compliance with reliability criteria for summer peak conditions in 2012. Potential network impacts were as follows:

### Generator Deliverability

*(Single or N-1 contingencies for the **Capacity** portion only of the interconnection)*

None

## Multiple Facility Contingency

*(Double Circuit Tower Line, Line with Failed Breaker and Bus Fault contingencies for the full energy output)*

None

## Contribution to Previously Identified Overloads

*(This project contributes to the following contingency overloads, i.e. "Network Impacts", identified for earlier generation or transmission interconnection projects in the PJM Queue)*

The Kingscreek – Logan 69 kV line (from bus 26610 to bus 26612 ckt 1) loads from 76.8% to 126.6% (AC power flow) of its emergency rating (72MVA) for the outage of Shelby – Miami 345 kV line and Shelby – W Lima 345 kV line for a breaker failure at Shelby 345 kV substation (DAY_L34528-2). This project contributes approximately 34.6MW to cause this thermal violation.

## Short Circuit

A Short Circuit analysis was performed using a 2012 baseline case. The results were that three breakers were affected by the addition of this generation. These breakers are listed below.

| Urbana | Breaker | kV | Rating 2012 |
|---|---|---|---|
| 1 | DB-BH3E | 69 | 12551.1 |
| 2 | DB-BH3W | 69 | 12551.1 |
| 3 | DB-BH1 | 69 | 12551.1 |

The breakers to be replaced are all solenoid operating oil circuit breakers ranging in age from 56 to 61 years old, single trip coil design with opening times of 5 to 8 cycles. Upgrading is not practical. All overdutied breakers would be replaced with 3-cycle, 30 kA redundant trip coil gas circuit breakers. Each breaker would take five work days to replace once they are delivered to the site.

A set of transformer fuses and holders on BK-1 at the Logan Substation would also be above their short circuit interrupting rating and need to be replaced.

**The total estimated cost allocation for replacement of these breakers is $227091.63**. More detailed information on each of these breakers, as well as the upgrade costs and timing is provided in Attachment No 2.

## New System Reinforcements

*(Upgrades required to mitigate reliability criteria violations, i.e. "Network Impacts," initially caused by the addition of this project's generation)*

The following upgrades are required to address overloads found in the Multiple Facility Contingency section above:

| Queue Project R52A: Upgrades Needed | | | | | |
|---|---|---|---|---|---|
| Circuit | Line Length (Miles) | Upgrades Needed | New Emer Rating MVA | New Line Impedance | Costs $ |
| Kingscreek-Logan | 10.8 | Upgrade 600A Breaker/CT - Logan<br>Upgrade 600A Switch - Logan | 98 | N/A | $200,000 (2009 dollars) |

## Contribution to Previously Identified System Reinforcements

*(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project. This project may have a % allocation cost responsibility which will be calculated and reported for the System Impact Study)*

## Steady-State Voltage Requirements

None Required.

## Stability and Reactive Power Requirements

This study concerns the stability assessment for the PJM generator interconnection request – Queue #R52A (Kings Creek 69 kV). The R52A project consists on a new 100 MW wind farm facility. The developer specified the use of 44 units Siemens 2.3 MW variable speed wind turbine.

The objective of the study was to determine the system stability for the contingencies around the R52A project as shown in Attachment #3.

All units and its control systems were updated according to the developer's specification; these updates are shown in Attachment #4.

### Stability (ECAR Stability Criteria)

Stability analysis was performed at 2013 summer peak load condition. The maximum generation output is considered. The range of contingencies evaluated was limited to that necessary to assess expected compliance with ECAR criteria.
This study includes 38 contingencies condition that includes 3-phase faults for normal clearing time contingencies and single line to ground for delayed clearing time due to stuck breaker condition and single line to ground for delayed clearing time due to loss of communication.

**Result and Analysis**

The network bridge of the turbines was studied operating in a fixed reactive current control mode.

No stability problem was identified. The swing angles do not exceed the transient stability criteria and the transient voltage criteria were also satisfactory for all contingencies scenarios.

Table-1 in Attachment #1 tabulates the clearing times for the some specific contingencies scenarios, also a brief description of the scenario is provided.

Note: While the stability analysis has been performed at expected extreme system conditions, there is a potential that evaluation at a different level of generator MW and/or MVAR output at different system load levels and operating conditions would disclose unforeseen stability problems. The regional reliability analysis routinely performed to test all system changes will include one such evaluation. Any problems uncovered in that or other operating or planning studies will need to be resolved.

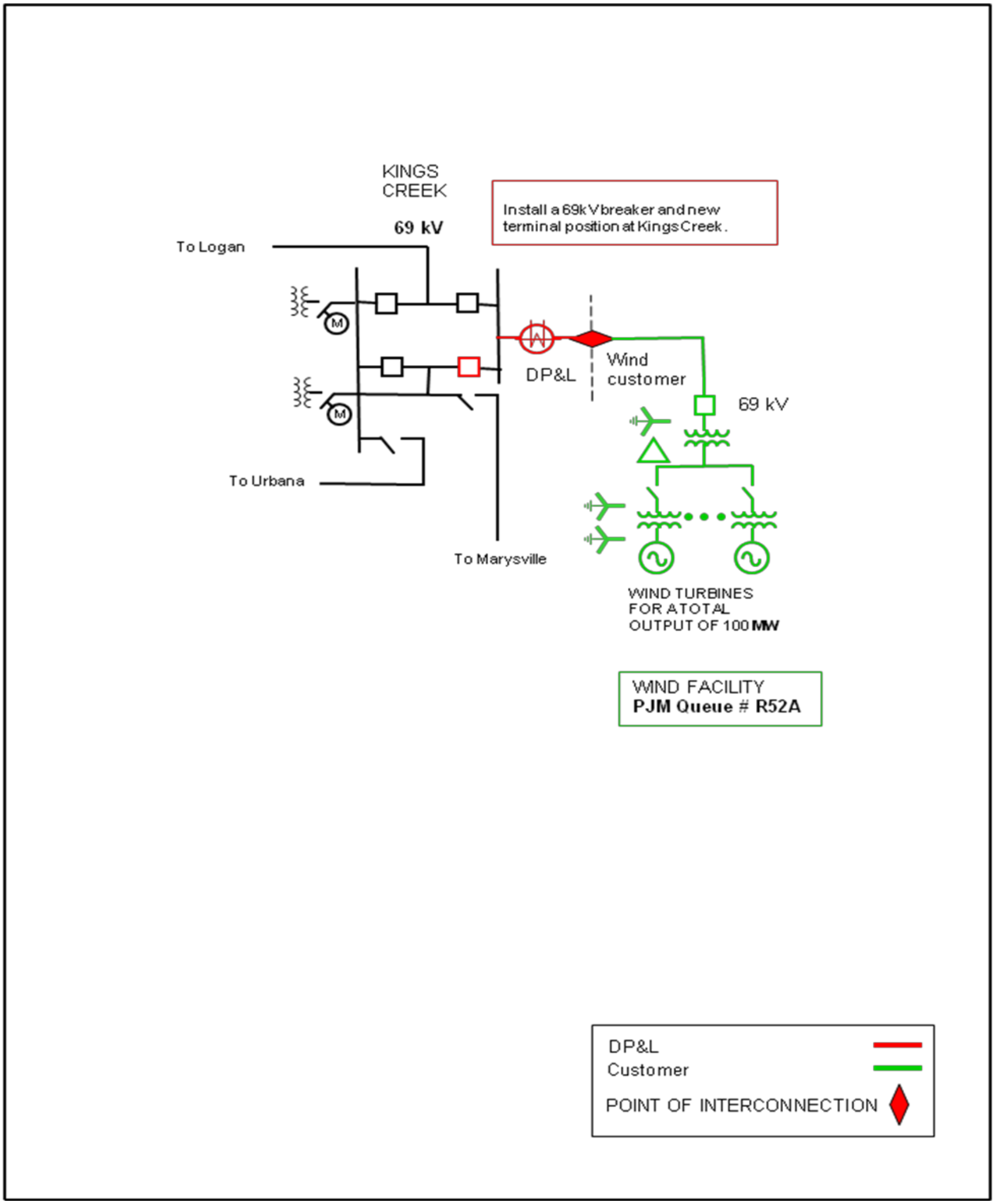
Moreover, when the proposed generating station is designed and plant specific dynamics data for the plant and its controls are available, and if it is different than the data provided for this study, a transient stability analysis at a variety of expected operating conditions using the more accurate data shall be performed to verify impact on the dynamic performance of the system. As more accurate or unit specific dynamics data for the proposed facility, as well as Plant layout become available, it must be forwarded to PJM.

## Delivery of Energy Portion of Interconnection Request

PJM also studied the delivery of the energy portion of this interconnection request. Any problems identified below are likely to result in operational restrictions to the project under study. The developer can proceed with network upgrades to eliminate the operational restriction at their discretion by submitting a Merchant Transmission Interconnection request.
Note: Only the most severely overloaded conditions are listed below. There is no guarantee of full delivery of energy for this project by fixing only the conditions listed in this section. With a Transmission Interconnection the conditions listed in this section. With a Transmission Interconnection Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified.

None

Attachment 1



# Attachment #2

**R52A**

| Newly Over Dutied - Pre-Existing Over-Duty Breakers | | | | | | |
|---|---|---|---|---|---|---|
| **Station** | **Voltage** | **Breaker** | **Cost Alloc % R52** | **Cost Alloc % R52A** | **Upgrade Cost R52** | **Upgrade Cost R52A** |
| Urbana | 69 | DB-BH3E | 24.30% | 75.70% | $24,302.79 | $75,697.21 |
| Urbana | 69 | DB-BH3W | 24.30% | 75.70% | $24,302.79 | $75,697.21 |
| Urbana | 69 | DB-BH1 | 24.30% | 75.70% | $24,302.79 | $75,697.21 |

## Attachment #3

**R52A**
2013 Summer Peak Stability Faults

**BREAKER CLEARING TIMES (CYCLES)**

| Station | Primary (3ph/slg) | Stuck Breaker (total) | Zone 2 (total) |
|---|---|---|---|
| 138kV | 7 | 19.5 | 37 |
| 69kV | 10 | 25.5 | 70 |
| | | | |
| | | | |

**Table-1: Summary of the recommended maximum clearing time for the different case scenarios.**

**All cases stable**

1a. 3ph @ Kings Creek – Logan 69 kV line
1c. slg @ Kings Creek – Logan 69 kV line, 80% from Kings Creek, Zone 2 clearing

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2a. 3ph @ Kings Creek – Urbana 69 kV line
2c. slg @ Kings Creek – Urbana 69 kV line, 80% from Kings Creek, Zone 2 clearing

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3a. 3ph @ Kings Creek – Marysville 69 kV line
3c. slg @ Kings Creek – Marysville 69 kV line, 80% from Kings Creek, Zone 2 clearing

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4a. 3ph @ Logan – Blue Jacket 69 kV line
4c. slg @ Logan – Blue Jacket 69 kV line, 80% from Logan, Zone 2 clearing

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5a. 3ph @ Logan – Shelby 138 kV line
5c. slg @ Logan – Shelby 138 kV line, 80% from Logan, Zone 2 clearing

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6a. 3ph @ Urbana – Bath 138 kV Line
$6b_{1.}$ slg @ Urbana – Bath 138 kV line, BF @ Urbana
Description: BF-(B) Loss of Urbana Transformer 138/69 kV
$6b_{2.}$ slg @ Urbana – Bath 138 kV line, BF @ Urbana
Description: BF-(D) Loss of Urbana – Clark 138 kV Line
6c. slg @ Urbana – Bath 138 kV line, 80% from Urbana, Zone 2 clearing

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7a. 3ph @ Urbana – Clark 138 kV Line

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8a. 3ph @ Urbana – R52A 138 kV Line
$8b_{1.}$ slg @ Urbana – R52A 138 kV line, BF @ Urbana
Description: BF-(A) Loss of Urbana Transformer 138/69 kV
$8b_{2.}$ slg @ Urbana – R52A 138 kV line, BF @ Urbana
Description: BF-(C) Urbana – Clark 138 kV Line

8c. slg @ Urbana – R52A 138 kV line, 80% from Urbana, Zone 2 clearing

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9a. 3ph @ Darby – R52A 138 kV Line
9b$_{1}$. slg @ Darby – R52A 138 kV line, BF @ Darby
Description: BF-(B) Loss of Darby Transformer 138/69 kV
9b$_{2}$. slg @ Darby – R52A 138 kV line, BF @ Darby
Description: BF-(F) Loss of Darby – Delaware 138 kV line
9c. slg @ Darby – R52A 138 kV line, 80% from Darby, Zone 2 clearing

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10a. 3ph @ Darby – Delaware 138 kV line
10c. slg @ Darby – Delaware 138 kV line, 80% from Darby, Zone 2 clearing

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11a. 3ph @ R52A– Darby 138 kV line
11c. slg @ R52A– Darby 138 kV line, 80% from R52A, Zone 2 clearing

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12a. 3ph @ R52A– Urbana 138 kV line
12c. slg @ R52A– Urbana 138 kV line, 80% from R52A, Zone 2 clearing

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13a. 3ph @ Logan – Bellefontaine 69 kV line
13c. slg @ Logan – Bellefontaine 69 kV line, 80% from Logan, Zone 2 clearing

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14a. 3ph @ Urbana – Kings Creek 69 kV line
14b. 3ph @ Urbana – Kings Creek 69 kV line, BF @ Urbana
14c. slg @ Urbana – Kings Creek 69 kV line, 80% Urbana, Zone 2 clearing

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15a. 3ph @ Darby – Honda 69 kV Line
15c. slg @ Darby – Honda 69 kV Line, 80% from Darby, Zone 2 clearing

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16a. 3ph @ Darby – Marysville 69 kV line
16c. slg @ Darby – Marysville 69 kV line, 80% from Darby, Zone 2 clearing

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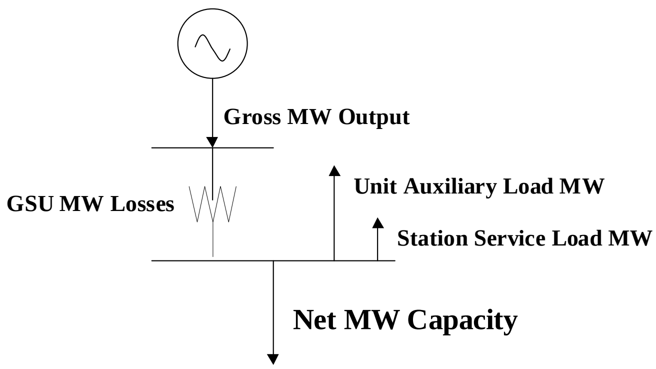
## Attachment #4

## Unit Capability Data




Net MW Capacity = (Gross MW Output - GSU MW Losses* – Unit Auxiliary Load MW - Station Service Load MW)

Queue Letter/Position/Unit ID: ________________________________________ R52A

Primary Fuel Type: _________________________________ Wind /SIEMENS 2.3 MW

Maximum Summer (92º F ambient air temp.) Net MW Output**: ___ 100/2.3 per turbine

Maximum Summer (92º F ambient air temp.) Gross MW Output: ___ 100/2.3 per turbine

Minimum Summer (92º F ambient air temp.) Gross MW Output:___________________0

Maximum Winter (30º F ambient air temp.) Gross MW Output:_____ 100/2.3 per turbine

Minimum Winter (30º F ambient air temp.) Gross MW Output: ___________________0

Gross Reactive Power Capability at Maximum Gross MW Output – Please include Reactive Capability Curve (Leading and Lagging):________________________________ N/A

Individual Unit Auxiliary Load at Maximum Summer MW Output (MW/MVAR): _ N/A

Individual Unit Auxiliary Load at Minimum Summer MW Output (MW/MVAR): _ N/A

Individual Unit Auxiliary Load at Maximum Winter MW Output (MW/MVAR): __ N/A

Individual Unit Auxiliary Load at Minimum Winter MW Output (MW/MVAR): __ N/A

Station Service Load (MW/MVAR): _____________________________________ N/A

* GSU losses are expected to be minimal.
** Your project's declared MW, as first submitted in Attachment N, and later confirmed or modified by the Impact Study Agreement, should be based on either the 92º F Ambient Air Temperature rating of the unit(s) or, if less, the declared Capacity rating of your project.

## Unit Generator Dynamics Data

Queue Letter/Position/Unit ID: ________________________________________ R52A

MVA Base (upon which all reactances, resistance and inertia are calculated): ______ 2.3

Nominal Power Factor: ________________________________________________ 1.0

Terminal Voltage (kV): _______________________________________________ 0.69

Unsaturated Reactances **(on MVA Base)**

Direct Axis Synchronous Reactance, $X_{d(i)}$ : _____________________________ N/A

Direct Axis Transient Reactance, X’d(i):________________________________ N/A

Direct Axis Sub-transient Reactance, X”d(i): ____________________________ N/A

Quadrature Axis Synchronous Reactance, Xq(i): __________________________ N/A

Quadrature Axis Transient Reactance, X’q(i):____________________________ N/A

Quadrature Axis Sub-transient Reactance, X”q(i): ________________________ N/A

Stator Leakage Reactance, Xl:________________________________________ N/A

Negative Sequence Reactance, X2(i): __________________________________ N/A

Zero Sequence Reactance, X0: _______________________________________ N/A

Saturated Sub-transient Reactance, X”d(v) (on MVA Base):____________________ N/A

Armature Resistance, Ra (on MVA Base): ____________________________________ N/A

**Time Constants (seconds)**

Direct Axis Transient Open Circuit, $T'_{do}$: ____________________________ N/A

Direct Axis Sub-transient Open Circuit, $T''_{do}$:_ ______________________ N/A

Quadrature Axis Transient Open Circuit, $T'_{qo}$:_ _______________________ N/A

Quadrature Axis Sub-transient Open Circuit, $T''_{qo}$: ____________________ N/A

Inertia, H (kW-sec/kVA, on KVA Base): ______________________________ 1.0927

Speed Damping, D: ____________________________________________________ N/A

Saturation Values at Per-Unit Voltage [S(1.0), S(1.2)]: __________________________ N/A

*Units utilize a Generator model*

## Unit GSU Data

Queue Letter/Position/Unit ID:_________________________________________R52A

Generator Step-up Transformer MVA Base: ________________________________ 2.3

Generator Step-up Transformer Impedance (R+jX, or %, on transformer MVA Base): __ j0.063

Generator Step-up Transformer Reactance-to-Resistance Ration (X/R):___________ N/A

Generator Step-up Transformer Rating (MVA):______________________________ 2.3

Generator Step-up Transformer Low-side Voltage (kV):______________________ 0.69

Generator Step-up Transformer High-side Voltage (kV): ______________________ 34.5

Generator Step-up Transformer Off-nominal Turns Ratio: _____________________ N/A

Generator Step-up Transformer Number of Taps and Step Size: ________________ N/A

## Main Transformer Data

Queue Letter/Position/Unit ID:_________________________________________R52A

Generator Step-up Transformer MVA Base: _______________________________ 138

Generator Step-up Transformer Impedance (R+jX, or %, on transformer MVA Base): ___ j0.15

Generator Step-up Transformer Reactance-to-Resistance Ration (X/R):___________ N/A

Generator Step-up Transformer Rating (MVA):__________________________ 34.5/69

Generator Step-up Transformer H-side Voltage (kV): _________________________ 138

Generator Step-up Transformer X-side Voltage (kV): _________________________ 34.5

Generator Step-up Transformer Off-nominal Turns Ratio: _____________________ N/A

Generator Step-up Transformer Number of Taps and Step Size: ________________ N/A