Generation Interconnection System Impact Study Report

PJM Generation Interconnection Request Queue Position R-52

Mechanicsburg – Darby

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 200 MW (40 MW capacity) wind power generating facility to be located along the Urbana-Darby 138kV line in The Dayton Power and Light Company (Dayton) transmission system. The project will utilize 87 Siemens 2.3 MW wind turbines. R52 was studied as an 200 MW energy and 40 MW Capacity injection at a new 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.

<u>Point of Interconnection</u>

R52 will interconnect with the Dayton Power and Light Company (Dayton) transmission system at a new 138kV substation adjacent to the Urbana - (Givens-Mechanicsburg-Eagle Rd.) - Darby line. Along that line, the new substation will be built at a tap located between Givens and Mechanicsburg, as shown on attachment #1.

Direct Connection Requirements

Transmission Owner Scope of Direct Connection Work

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

Attachment Facilities

The new substation, to be located at a suitable site near or adjacent to the Urbana-(Givens-Mechanicsburg-Eagle Rd.) – Darby 138 kV circuit, will include three 138 kV breakers, three dead-end structures, ten 138 kV air break switches, and 138 kV interconnection metering. The estimate assumes that site preparation and site grading will be done by DP&L. The station will include a control building to house all protective relaying, metering and all communications equipment, including SCADA RTU facilities. **The estimated cost to construct this 138 kV substation is $2,400,000 in 2009 dollars**.

This estimate does not include any cost for land. The Interconnection Customer will provide the necessary land near or adjacent to the line. This estimate provides cost to terminate the existing lines one span into the substation. If transmission lines of longer distance are required, the estimated cost is $400,000/Mile in 2009 dollars. The construction of a 138kV substation requires Ohio Power Siting approval. The siting approval requires a 6 months – 1 year lead time. The lead time to complete this work is **24 months**. These estimates do not include any tax gross up cost.

DP&L (Dayton) 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: The purchase and installation of protective relaying and associated equipment at the generation site is not included in this scope of work. This work is the responsibility of the IC.

Install transfer trip receiver at Darby substation and install a transfer trip transmitter at Urbana substation. **The estimated cost for this work is $93,000 in 2009 dollars**.

Network Impacts

The Queue Project #R52 was studied as a 200 MW (40 MW Capacity) injection into the Givens – Mechanicsburg 138 kV line in the Dayton area. Project #R52 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)

1. The Johnson W – NW Urbana 69 kV line (from bus 26470 to bus 26699 ckt 1) loads from 77.2% to 100.1% (AC power flow) of its emergency rating (117 MVA) for the outage of Darby – Eagle – Mechanicsburg – R52 138 kV line and Darby – Delaware 138 kV line for a breaker failure at Darby 138 kV substation (DAY_L13811-2_R52). This project contributes approximately 25.9MW to cause this thermal violation.

2. The Urbana – Johnson WP 69 kV line (from bus 26655 to bus 26470 ckt 1) loads from 82.7% to 107.1% (AC power flow) of its emergency rating (110MVA) for the outage of Darby – Eagle – Mechanicsburg – R52 138 kV line and Darby – Delaware 138 kV line for a breaker failure at Darby 138 kV substation (DAY_L13811-2_R52). This project contributes approximately 25.9MW to cause this thermal violation.

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)

None

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 and must be replaced. 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 for replacement of these breakers is $300,000. 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 table describes the new system reinforcements/upgrades required:

Circuit	Line Length (Miles)	Upgrades Needed	New Emer Rating MVA	New Line Impedance	Costs $
Urbana-Johnson WP	2.47	Upgrade 800A Line Trap - Urbana Reconductor 636 ACSR w/ 795 ACSR	137	R = 0.6640% X = 3.709%	$900,000
Johnson WP - NW Urbana REA	1.82	Upgrade Line Drop - Urbana Reconductor 636 ACSR w/ 795 ACSR	137	R = 0.48931% X = 2.733%	$650,000

The estimated total cost for the above is $1,550,000 in 2009 dollars.

Contribution to Previously Identified System Reinforcements

(Overloads initially caused by prior Queue positions with additional contribution to overloading by this project.)

None

Steady-State Voltage Requirements

Please refer to the LVRT requirement for the turbine VAR requirement.

Stability and Reactive Power Requirements

PJM performed a study addressing the stability assessment for the PJM generator interconnection request – Queue #R52 (Mechanicsburg - Givens 138 kV Tap). The R52 project consists of a new 200 MW wind farm facility. The developer specified the use of 87 units Siemens 2.3 MW variable speed wind turbines. The objective of the study was to determine the system stability for the contingencies around the R52 project as shown in Attachment #3.

All units and their 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 light 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 turbines are required to include Voltage Control to regulate the voltage at the point of interconnection bus to 1p.u. The Reactive power limits for the machines are Max 0.95 and Min 0.85.
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.

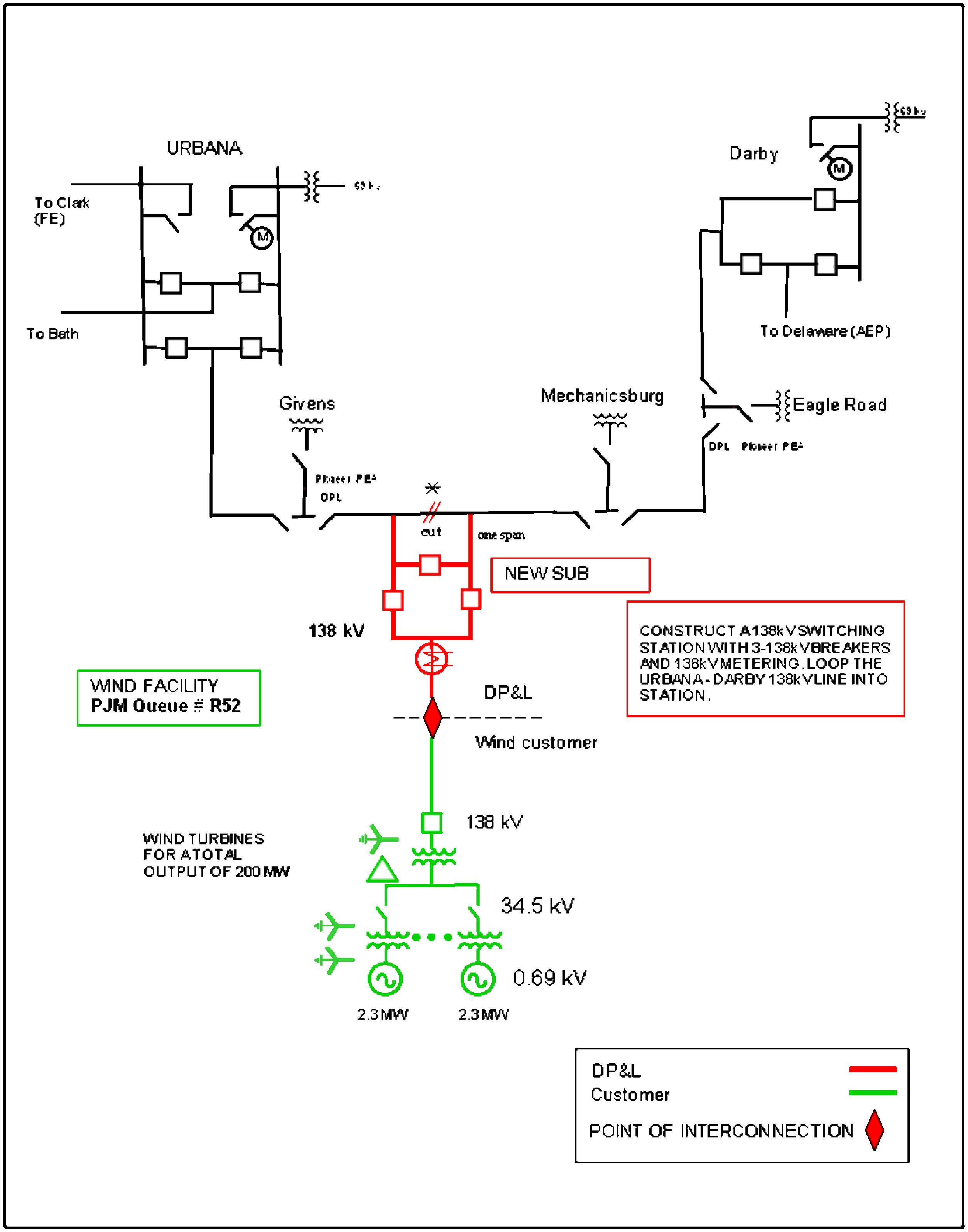
Moreover, when the proposed generating station is designed and plant specific dynamics data for the plant and its controls are available, and if it is different than the data provided for this study, a transient stability analysis at a variety of expected operating conditions using the more accurate 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.

<u>Delivery of Energy Portion of Interconnection Request</u>

PJM also studied the delivery of the energy portion of this interconnection request with all earlier queues at their energy output and the system at peak load with all transmission facilities in service. Any problems identified below may result in operational restrictions to the project under study or other PJM generation. There may also be other conditions causing congestion which were not *studied. The developer can proceed with network upgrades to eliminate the potential congestion at their discretion by submitting a Merchant Transmission Interconnection request now or in the future.*

None

Attachment # 1



Attachment #2

R52

New Over Duty Breakers

Station	Voltage (kV)	Breaker	Queue	Upgrade Cost	Upgrade Time	Upgrade Type
Urbana	69	DB-BH3E	R52	$100,000	5 days does not include lead time	Replace with 30 kA
Urbana	69	DB-BH3W	R52	$100,000	5 days does not include lead time	Replace with 30 kA
Urbana	69	DB-BH1	R52	$100,000	5 days does not include lead time	Replace with 30 kA

Attachment #3

R52

2013 Light Load 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

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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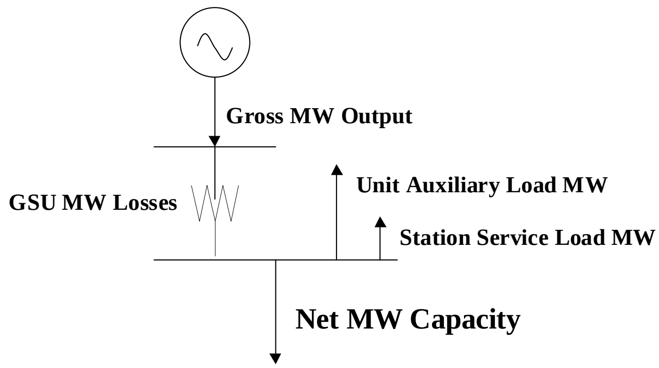
Attachment #4

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: ______________________________________ R52

Primary Fuel Type: _______________________________Wind /SIEMENS 2.3 MW

Maximum Summer (92º F ambient air temp.) Net MW Output**:____200/2.3 per turbine

Maximum Summer (92º F ambient air temp.) Gross MW Output: ____200/2.3 per turbine

Minimum Summer (92º F ambient air temp.) Gross MW Output: ________________0

Maximum Winter (30º F ambient air temp.) Gross MW Output: _____200/2.3 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 92^{o} 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: ____ R52

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: ____________________________________ R52

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: ____________________________________ R52

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