Generation Interconnection Revised System Impact Study Report

For

PJM Generation Interconnection Request Queue Position AB2-135

"Church-Kent 69 kV"

Revised: February 2021
May 2017

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 Interconnection Customer 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

The Interconnection Customer (IC), has proposed a 64 MW (29.9 MWC) solar generating facility to be located in Millington, Queen Anne’s County, Maryland. PJM studied AB2-135 as a 64 MW injection into the Delmarva Power and Light Company (DPL) system at a tap of the Church-New Meredith 69 kV circuit and evaluated it for compliance with reliability criteria for summer peak conditions in 2020. The planned in-service date, as requested by the IC during the project kick-off call, was September 30, 2018. This date was not attainable due to additional required PJM studies and the Transmission Owner’s construction schedule.

Point of Interconnection

The Interconnection Customer requested a transmission level interconnection. As a result, AB2-135 will interconnect with the DPL transmission system at a new three breaker ring bus 69 kV substation to be constructed adjacent to the Church-New Meredith 69 kV circuit (see Attachment 1).

Transmission Owner Scope of Direct Connection Work

Substation Interconnection Estimate

Scope: Build a new 69 kV substation with a 3 position ring bus. Two of the positions on the ring bus will be transmission line terminals for the tie-in of Line 6704 to the substation. The other position will be a terminal configured for the interconnection of a generator.

Estimate: $3,967,000
Construction Time: 24 months

Major Equipment Included in Estimate:

• Control Enclosure, 20' x 15'	Qty. 1
• Power Circuit Breaker, 69 kV, 2000A, 40kA, 3 cycle	Qty. 3
• Disconnect Switch, 69 kV, 2000A, Manual Wormgear, Arcing Horns	Qty. 9
• CT/VT Combination Units, 69 kV	Qty. 3
• CVT, 69 kV	Qty. 6
• Disconnect Switch Stand, High, 69 kV, Steel	Qty. 5
• Disconnect Switch Stand, Low, 69 kV, Steel	Qty. 4
• CT/VT Stand, Single Phase, Low, 69 kV, Steel	Qty. 3
• CVT Stand, Single Phase, Low, 69 kV, Steel	Qty. 6
• SSVT, 69 kV/240-120 V	Qty. 1
• Relay Panel, Transmission Line, FL/BU (20")	Qty. 3
• Control Panel, 69 kV Circuit Breaker (10")	Qty. 3
• Take-off structure, 69 kV	Qty. 2
• Bus Support Structure, 3 phase, 69 kV, Steel	Qty. 8

Estimate Assumptions:

- Land purchase for the substation is not included.
- A 2.5 acre, relatively square lot is available for use.
- Site clearing and grading performed by Developer.
- Lightning protection (lightning masts) are not required.

Required Relaying and Communications

An SEL-487 will be required for primary protection and an SEL-387 will be required for back-up protection. One 20" relay panel for each line terminal will be required for front line and back-up protection.

New protection relays are required for the new line terminals. An SEL-421 will be required for primary protection and an SEL-311C will be required for back-up protection. A 20" relay panel will be required for each transmission line (2 total).

An SEL-451 relay on a 20" breaker control panel will be required for the control and operation of each new 138 kV circuit breaker.

The project will require re-wiring and adjustment of existing relay schemes to accommodate the new 69 kV substation.

The cost of the required relay and communications listed above is included in the Substation Interconnection Estimate.

In addition protective relays at the new substation, relay upgrades will need to be performed on the remote ends at Church and Kent substations. An SEL-421 will be required for primary protection and an SEL-311C will be required for back-up protection at each remote end. The estimate to perform this work is **$300,000** and will take **24 months** to complete.

To accommodate the line protection schemes and relay equipment, fiber communications will need to be added to Circuit 6704 from Church Substation to Kent Substation. The estimate to perform this work is **$3,150,000** and will take **36 months** to complete. (Note: the overall cost of the fiber communications installation may be less if the system reinforcement work to rebuild Circuit 6704 from AB2-135 to New Meredith Substation is required. The cost will be reassessed in the Impact Study and Facilities Study.)

Metering

Three phase 69 kV revenue metering points will need to be established. DPL will purchase and install all metering instrument transformers as well as construct a metering structure. The secondary wiring connections at the instrument transformers will be completed by DPL's metering technicians. The metering control cable and meter cabinets will be supplied and installed by DPL. DPL will install conduit for the control cable between the instrument transformers and the metering enclosure. The location of the metering enclosure will be determined in the construction phase. DPL will provide both the Primary and the Backup meters. DPL's meter technicians will program and install the Primary & Backup solid state multi-function meters for each new metering position. Each meter will be equipped with load profile, telemetry, and DNP outputs. The IC will be provided with one meter DNP output for each meter. DPL will own the metering equipment for the interconnection point, unless the IC asserts its right to install, own, and operate the metering system.

The Interconnection Customer will be required to make provisions for a voice quality phone line within approximately 3 feet of each Company metering position to facilitate remote interrogation and data collection.

It is the IC's responsibility to send the data that PJM and DPL requires directly to PJM. The IC will grant permission for PJM to send DPL the following telemetry that the IC sends to PJM: real time MW, MVAR, volts, amperes, generator status, and interval MWH and MVARH. The estimate for DPL to design, purchase, and install metering as specified in the aforementioned scope for metering is included in the Substation Interconnection Estimate.

Interconnection Customer Scope of Work

The Interconnection Customer is responsible for all design and construction related to activities on their side of the Point of Interconnection. Site preparation, including grading and an access road, as necessary, is assumed to be by the IC. Route selection, line design, and right-of-way acquisition of the direct connect facilities is not included in this report, and is the responsibility of the IC. The IC is also required to provide revenue metering and real-time telemetering data to PJM in conformance with the requirements contained in PJM Manuals M-01 and M-14 and the PJM Tariff.

DPL Interconnection Customer Scope of Direct Connection Work Requirements

- DPL requires that an IC circuit breaker is located within 500 feet of the new substation to facilitate the relay protection scheme between DPL and the IC at the Point of Interconnection (POI).

Special Operating Requirements

1. DPL will require the capability to remotely disconnect the generator from the grid by communication from its System Operations facility. Such disconnection may be facilitated by a generator breaker, or other method depending upon the specific circumstances and the evaluation by DPL.

2. DPL reserves the right to charge the Interconnection Customer operation and maintenance expenses to maintain the Interconnection Customer attachment facilities, including metering and telecommunications facilities, owned by DPL.

Summer Peak Analysis - 2020

Transmission Network Impacts

Potential transmission network impacts are 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, Fault with a Stuck 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)

None

Summer Peak Load Flow Analysis Reinforcements

New System Reinforcements

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

None

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 Impact Study)

None

Stability Analysis

No issues identified. See Attachment 2 for full report.

Short Circuit

No issues identified.

Affected System Analysis and Mitigation

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.

Only the most severely overloaded conditions are listed. 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 Request, a subsequent analysis will be performed, which will study all overload conditions associated with the overloaded element(s) identified.

None

Light Load Analysis - 2020

Light Load Analysis is not required for AB2-135.

Summary Peak Load Flow Analysis Reinforcements

New System Reinforcements

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

None

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 Impact Study)
(Summary form of Cost allocation for transmission lines and transformers will be inserted here if any)

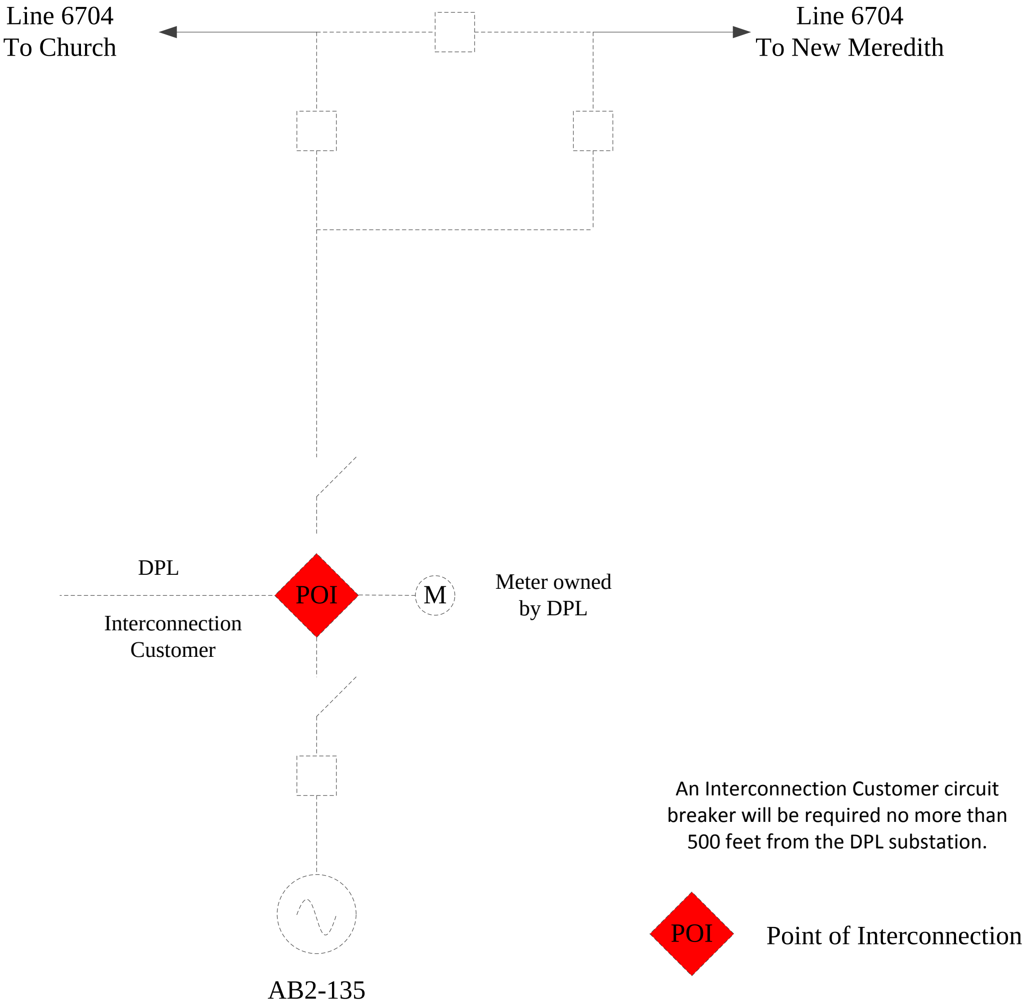
None

Delmarva Power and Light Costs

Cost estimates will further be refined as a part of the Facilities Study for this project. The Interconnection Customer will be responsible for all costs incurred by DPL in connection with the AB2-135 project. DPL reserves the right to reassess issues presented in this document and, upon appropriate justification, submit additional costs related to the AB2-135 project.

Attachment 1

AB2-135
Church - Kent 69 kV
New 69 kV Substation



An Interconnection Customer circuit breaker will be required no more than 500 feet from the DPL substation.

Attachment 2

AB2-135

System Impact Study

Dynamic Simulation Analysis

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Executive Summary

Generator Interconnection Request AB2-135 is for a 64 MW Maximum Facility Output (MFO) solar generation plant. AB2-135 consists of 26x2.7 MVA (2x2.7MW+24x2.5MW) TMEIC Samurai, PVH-L2700GR inverters with a Point of Interconnection (POI) tapped into Church – New Meredith – Kent 69kV line in the DPL transmission system, Queen Anne's county, MD.

This report describes a dynamic simulation analysis of AB2-135 as part of the overall system impact study.

The load flow scenario for the analysis was based on the RTEP 2020 Summer Peak case, modified to include applicable queue projects. AB2-135 has been dispatched online at maximum power output, with approximately unity power factor at the POI.

The AB2-135 queue project was tested for compliance with NERC, PJM and other applicable criteria. The range of contingencies evaluated was limited to that necessary to assess compliance and each was limited to a 20-second simulation time period.

Simulated NERC Standard TPL-001faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Operating of a line section w/o a fault, Single-line-to-ground (slg) on Bus Section and Breaker. (Category P2)
3. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
4. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5)
5. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P3 and P6 faults will be studied on an as needed basis. In this study, P2 contingencies are not applicable.

Other applicable criteria tested include:

1. Transmission Owner (TO) specific criteria
2. Other criteria

The system was tested for a system intact condition and the fault types listed above. Specific fault descriptions and breaker clearing times used for this study are provided in the result table.

No relevant High Speed Reclosing (HSR) contingencies were identified.

For all simulations, the queue project under study along with the rest of the PJM system were required to maintain synchronism and with all states returning to an acceptable new condition following the disturbance.

For the remaining fault contingencies tested on the 2020 Summer Peak case:

a) Post-contingency oscillations were positively damped with a damping margin of at least 4% for local modes and 3% for inter-area modes.

b) The AB2-135 generator was able to ride through all faults (except for faults where protective action trips a generator(s)).

c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

No mitigations were found to be required.

1. Introduction

Generator Interconnection Request AB2-135 is for a 64 MW Maximum Facility Output (MFO) solar generation plant. AB2-135 consists of 26x2.7 MVA (2x2.7MW+24x2.5MW) TMEIC Samurai, PVH-L2700GR inverters with a Point of Interconnection (POI) tapped into Church – New Meredith – Kent 69kV line in the DPL transmission system, Queen Anne's county, MD.

This analysis is effectively a screening study to determine whether the addition of AB2-135 will meet the dynamic requirements of the NERC, PJM and Transmission Owner reliability standards.

In this report the AB2-135 project and how it is proposed to be connected to the grid are first described, followed by a description of how the project is modeled in this study. The fault cases are then described and analyzed, and lastly a discussion of the results is provided.

2. Description of Project

Generator Interconnection Request AB2-135 is for a 64 MW Maximum Facility Output (MFO) solar generation plant. AB2-135 consists of 26x2.7 MVA (2x2.7MW+24x2.5MW) TMEIC Samurai, PVH-L2700GR inverters with a Point of Interconnection (POI) tapped into Church – New Meredith – Kent 69kV line in the DPL transmission system, Queen Anne's county, MD. The AB2-135 Point of Interconnection (POI) is as shown in Figure 1.

Table 1 lists the parameters given in the impact study data and the corresponding parameters of the AB2-135 loadflow models.
The dynamic model for the AB2-135 plant is based on the model data supplied by the Developer.

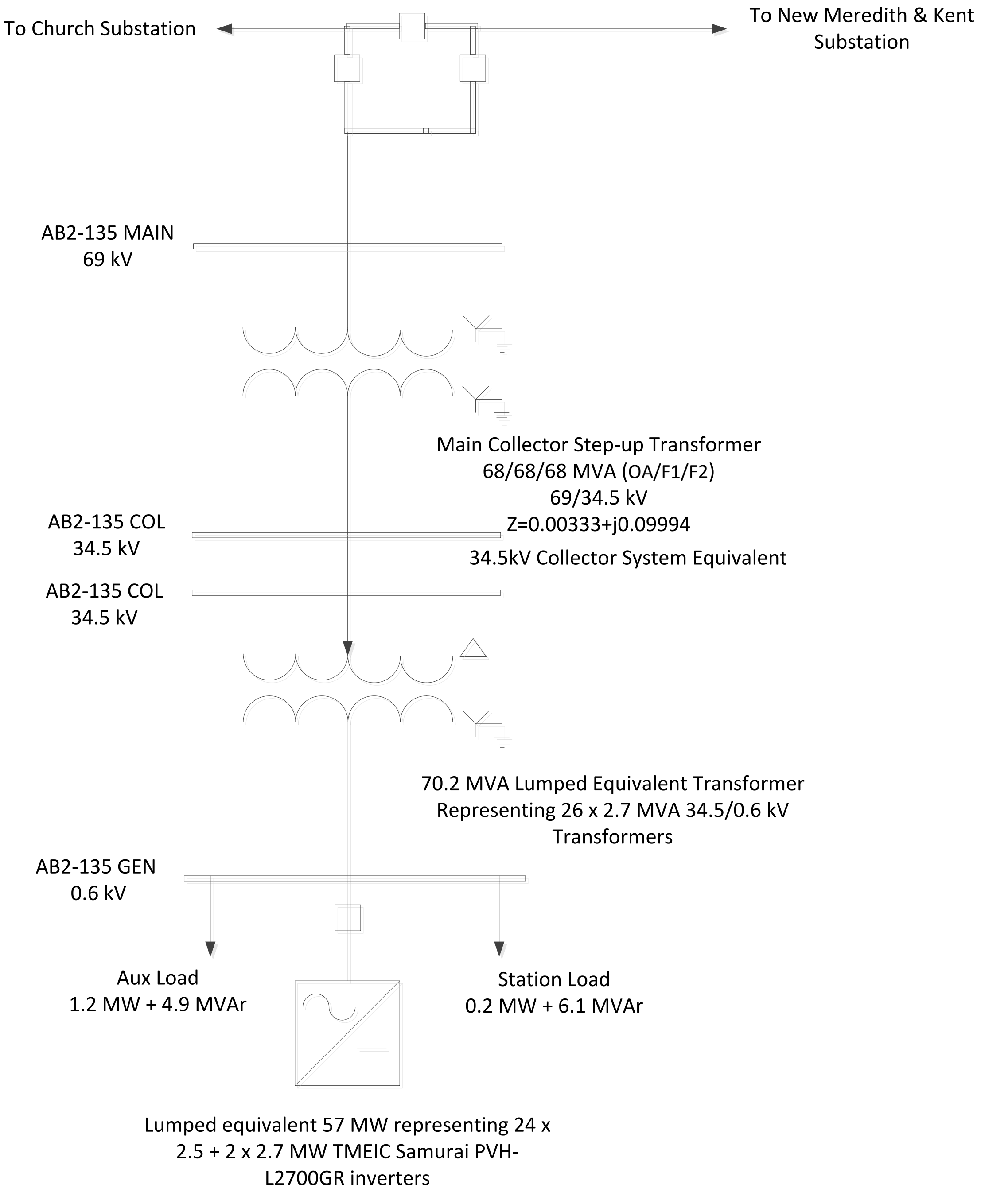

Figure 1: AB2-135 Plant Model

Table 1: AB2-135 Plant Model

	Impact Study Data	Model
Inverters	26 x TMEIC Samurai PVH-L2700GR 2.7MVA inverters (2x2.7MW and 24x2.5MW) MVA base = 2.7 MVA Vt = 0.6 kV Unsaturated sub-transient reactance = j1.000 pu @ MVA base	Lumped equivalent representing 26 x TMEIC Samurai PVH-L2700GR 2.7 MVA inverters (2x2.7MW and 24x2.5MW) Pgen 65.4 MW Pmax 65.4 MW Pmin 0 MW Qmax 21.5 MVAr Qmin -21.5 MVAr Mbase 70.2 MVA Zsorce j1.000 pu @ Mbase
Inverter Transformers	26 x 34.5/0.6 kV two winding transformers Rating = 2.7 MVA (OA) Transformer base = 2.7 MVA Impedance = 0.0071 + j0.057 @ MVA Base Number of taps = N/A Tap step size = N/A	Lumped equivalent representing 26 x 34.5/0.6 kV two winding transformers Rating = 70.2 MVA Transformer base = 70.2 MVA Impedance = 0.0071 + j0.057 @ MVA Base Number of taps = 5 Tap step size = 2.5 %
Collector System Equivalent	R = 0.0018 X = 0.0010 B = 0.0036 @100MVA	R = 0.0018 X = 0.0010 B = 0.0036 @100MVA
Collector transformer	69/34.5 kV two winding transformer Rating = 68/68/68 MVA Transformer base = 68 MVA Impedances: High – Low = 0.0033 + j0.09994 @ MVA base Number of taps = 5 Tap step size = 2.5 Nominal Tap = 2.5	69/34.5 kV two winding transformer Rating = 68/68/68 MVA (OA/F1/F2) Transformer base = 68 MVA Impedances: High – Low = 0.0033 + j0.09994 @ MVA base Number of taps = 5 Tap step size = 2.5 Nominal Tap = 2.5
Auxiliary load	1.2 MW + 4.9 MVAR	1.2 MW + 4.9 MVAr at low voltage side of GSU transformer

Station load	0.2 MW + 6.1 MVAR	0.2 MW + 6.1 MVAR at low voltage side of GSU transformer (turned off)
Transmission line	R = 0.00036 X = 0.00138 B = 0.00003 @100MVA	R = 0.00036 X = 0.00138 B = 0.00003 @100MVA

3. Loadflow and Dynamics Case Setup

The dynamics simulation analysis was carried out using PSS/E Version 33.7.
The load flow scenario and fault cases for this study are based on PJM's Regional Transmission Planning Process[1].
The selected load flow scenario is the RTEP 2020 Summer Peak case with the following modifications:

a) Addition of all applicable queue projects prior to AB2-135.

b) Addition of AB2-135 queue project.

c) Removal of withdrawn and subsequent queue projects in the vicinity of AB2-135.

d) Dispatch of units in the PJM system to maintain slack generators within limits.

The AB2-135 initial conditions are listed in Table 2, indicating maximum power output, with AB2-135 regulating to unity power factor at the generator bus.

Table 2: AB2-135 machine initial conditions

Bus	**Name**	**Unit**	**PGEN (MW)**	**QGEN (MVAR)**	**ETERM (p.u.)**	**POI Voltage (p.u.)**
924824	AB2-135 GEN 0.6000	1	65.4	1.4	0.96	1.0145

Generation within the vicinity of AB2-135 has been dispatched online at maximum output (PMAX). The dispatch of generation in the vicinity of AB2-135 is given in Attachment 3.

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[1] Manual 14B: PJM Region Transmission Planning Process, Rev 33, May 5 2016, Attachment G : PJM Stability, Short Circuit, and Special RTEP Practices and Procedures.

4. Fault Cases

Tables 3 listed the contingencies and results that were studied, with representative worst case total clearing times provided by PJM. Each contingency was studied over a 20 second simulation time interval.
Simulated NERC Standard TPL-001faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Operating of a line section w/o a fault, Single-line-to-ground (slg) on Bus Section and Breaker. (Category P2)
3. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
4. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5)
5. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P3 and P6 faults will be studied on an as needed basis. In this study, P2 contingencies are not applicable.

Other applicable criteria tested include:

1. Transmission Owner (TO) specific criteria
2. Other criteria

The system was tested for a system intact condition and the fault types listed above. No relevant High Speed Reclosing (HSR) contingencies were studied.

5. Evaluation Criteria

This study is focused on AB2-135, along with the rest of the PJM system, maintaining synchronism and having all states return to an acceptable new condition following the disturbance. The recovery criteria applicable to this study are as per PJM’s Regional Transmission Planning Process and Transmission Owner criteria:

a) The system with AB2-135 included is transiently stable and post-contingency oscillations should be positively damped with a damping margin of at least 4% for local modes and 3% for inter-area modes.

b) The AB2-135 is able to ride through faults (except for faults where protective action trips AB2-135).

c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

6. Summary of Results

Plots from the dynamic simulations are summarized in Table 3.
Due to the frequency protection was disabled due to the PSSE deficiency in calculating frequencies.

For the fault contingencies tested in this study:

a) Post-contingency oscillations were positively damped with a damping margin of at least 4% for local modes and 3% for inter-area modes.

b) The AB2-135 generator was able to withstand all contingencies.

c) Following fault clearing, all bus voltages recover to a minimum of 0.7 per unit after 2.5 seconds (except where protective action isolates that bus).

d) No transmission element trips, other than those either directly connected or designed to trip as a consequence of that fault.

7. Mitigations

No Mitigations were found to be required.

Table 3: Fault list

P0: Steady State

Fault ID	Duration
P0.00	Steady State 20 sec run

P1: Three Phase Faults with normal clearing

Fault ID	Fault description	Clearing Time Normal (Cycles)	Results
P1.00	3ph @ AB2-135 POI – Chestertown 69kV line, normal clear	9	Stable
P1.01	3ph @ Chestertown – McCleans – Lynch – Kennedyville – Massey – Church 69kV line, normal clear loss of AA1-110	9	Stable
P1.02	3ph @ Chestertown – Clough – Church 69kV line, normal clear	9	Stable
P1.03	3ph @ AB2-036 – Oil City – Steele 138kV line, normal clear	9	Stable
P1.04	3ph @ Church 69/138kV Tx #1, normal clear	9	Stable
P1.05	3ph @ Church 69/138kV Tx #2, normal clear	9	Stable
P1.06	3ph @ Church – AB2-135 POI, normal clear	9	Stable
P1.07	3ph @ Church – I.B. Corners – Price 69kV line, normal clear	9	Stable
P1.08	3ph @ Centerville – Wye Mills 69kV line, normal clear	9	Stable
P1.09	3ph @ AB2-135 POI – New Meredith – Kent 69kV line, normal clear	9	Stable
P1.10	3ph @ Kent – Cheswold 69kV line, normal clear	9	Stable
P1.11	3ph @ Kent – NRG Dover 69kV line, normal clear loss of NRG G1 and G2	9	Stable
P1.12	3ph @ Kent – Vaughn – Harrington 69kV line, normal clear loss of Vaughn unit	9	Stable

P4: SLG Stuck Breaker (SB) Faults at Backup Clearing

Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results

Fault ID	**Fault description**	**Clearing Time Normal/Delayed (Cycles)**	**Results**
P4.01	SLG @ Chestertown 69/25kV Tx #1, SB @ Chestertown, delayed clear loss of Chestertown – McCleans – Lynch – Kennedeyville – Massey – Church 69kV line, AA1-110	9 / 22	Stable
P4.02	SLG @ Chestertown – McCleans – Lynch – Kennedeyville – Massey – Church 69kV line, normal clear loss of AA1-110, SB @ Chestertown, delayed clear loss of AB2-133	9 / 22	Stable
P4.03	SLG @ Chestertown 69/25kV Tx #2, SB @ Chestertown, delayed clear loss of Chestertown – Clough – Church 69kV line	9 / 22	Stable
P4.04	SLG @ Chestertown – Clough – Church 69kV line, SB @ Chestertown, delayed clear loss of AB2-133	9 / 22	Stable
P4.05	SLG @ Chestertown 69/25 kV Tx #1, SB @ Chestertown, delayed clear loss of Chestertown 69/25kV Tx #2	9 / 22	Stable
P4.06	SLG @ Church – AB2-036 138kV line, SB @ Church, delayed clear loss of Church – AB1-141 138kV line.	9 / 21	Stable
P4.07	SLG at Church 69 kV on Massey – Kennedeyville – Lynch – McCleans – Chestertown circuit 6727 nomal clear loss of AA1-110. Breaker 7210 stuck. Fault cleared with loss of Church 69 kV / 138 kV transformer AT2.	9 / 22	Stable
P4.08	SLG at Church 69 kV on Massey – Kennedeyville – Lynch – McCleans – Chestertown circuit 6727, nomal clear loss of AA1-110. Breaker 7290 stuck. Fault cleared with loss of Church – AB2-135 POI circuit 6704.	9 / 22	Stable
P4.09	SLG at Church 69 kV on Clough – Chestertown circuit 6773. Breaker 7240 stuck. Fault cleared with loss of I.B. Corners – Price circuit 6710.	9 / 22	Stable
P4.10	SLG at Church 69 kV on Clough – Chestertown circuit 6773. Breaker 7260 stuck. Fault cleared with loss of Church 69 kV / 138 kV Transformer AT1.	9 / 22	Stable
P4.11	SLG at Church 69 kV on AB2-135 POI circuit 6704. Breaker 7290 stuck. Fault cleared with loss of Church 69 kV on Massey – Kennedeyville – Lynch – McCleans – Chestertown circuit 6727, loss AA1-110.	9 / 22	Stable
P4.12	SLG at Church 69 kV on AB2-135 POI circuit 6704. Breaker 7220 stuck. Fault cleared with loss of Church 69 kV / 25 kV Transformer T3 and Church 69 kV / 25 kV Transformer T4, Z1-081.	9 / 22	Stable
P4.13	SLG at Church 69 kV on I.B. Corners – Price circuit 6710. Breaker 7250 stuck. Fault cleared with loss of Church 69 kV / 25 kV Transformer T3 and Church 69 kV / 25 kV Transformer T4, Z1-081.	9 / 22	Stable

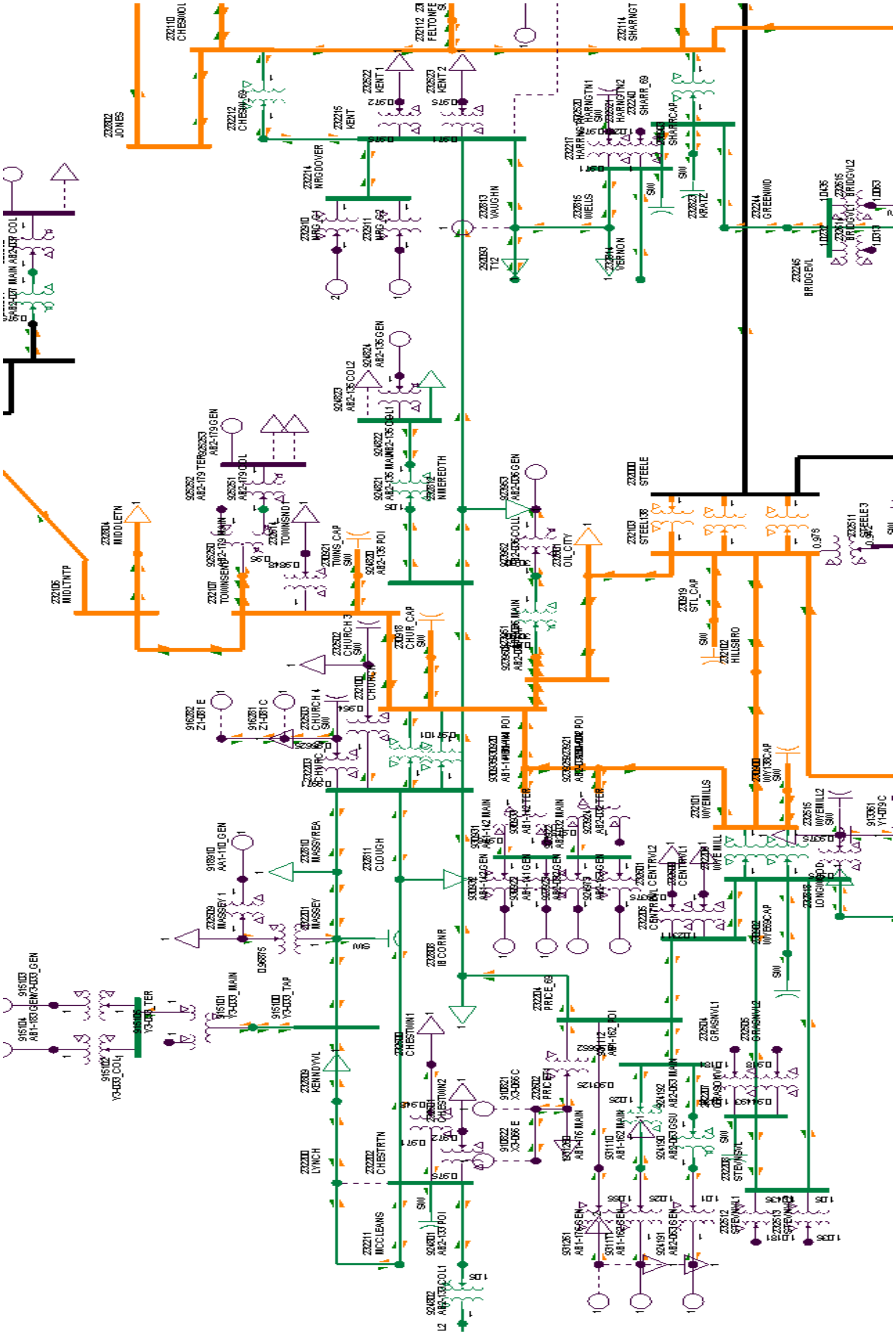
Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
P4.14	SLG at Church 69 kV on I.B. Corners – Price circuit 6710. Breaker 7240 stuck. Fault cleared with loss of Clough – Chestertown circuit 6773.	9 / 22	Stable
P4.15	SLG at Church 69 kV on 69 kV / 138 kV transformer AT1. Breaker 60 stuck. Fault cleared with loss of Church 69 kV / 138 kV Transformer AT2.	9 / 22	Stable
P4.16	SLG at Church 69 kV on 69 kV / 138 kV transformer AT1. Breaker 7260 stuck. Fault cleared with loss of Clough – Chestertown circuit 6773.	9 / 22	Stable
P4.17	SLG at Church 69 kV on 69 kV / 138 kV transformer AT2. Breaker 60 stuck. Fault cleared with loss of Church 69 kV / 138 kV Transformer AT1.	9 / 22	Stable
P4.18	SLG at Church 69 kV on 69 kV / 138 kV transformer AT2. Breaker 7210 stuck. Fault cleared with loss of Church 69 kV on Massey – Kennedeyville – Lynch – McCleans – Chestertown circuit 6727. Trips AA1-110.	9 / 22	Stable
P4.19	SLG @ Kent – Cheswold 69kV line, Stuck Breaker @ Kent, delayed clear loss of Kent – New Meredith – AB2-135 POI 69kV line	9 / 22	Stable
P4.20	SLG @ Kent – NRG Dover 69kV line, normal clear loss of NRG Dover units, Stuck Breaker @ Kent, delayed clear loss of Kent – New Meredith – AB2-135 POI 69kV line	9 / 22	Stable
P4.21	SLG @ Kent – Cheswold 69kV line, Stuck Breaker @ Kent, delayed clear loss of Kent – Scuse (Not Modeled)	9 / 22	Stable
P4.22	SLG @ Kent 69/25kV Tx T2, Stuck Breaker @ Kent 69kV, delayed clear loss of NRG Dover units	9 / 22	Stable
P4.23	SLG @ Kent 69/25kV Tx T2, Stuck Breaker @ Kent 69kV, delayed clear loss of Kent – Vaughn – Harrington 69kV line, Vaughn unit.	9 / 22	Stable

P5: SLG Fault with Delayed (Zone 2) Clearing

Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
P5.01	SLG at 80% of 138kV line from AB2-036 to Oil City – Steele, delayed clear.	9 / 37	Stable
P5.02	SLG at 80% of 69 kV line from Chestertown to Clough – Church circuit 6773. Delayed clearing at Chestertown.	9 / 42	Stable

Fault ID	Fault description	Clearing Time Normal/Delayed (Cycles)	Results
P5.03	SLG at 80% of 69 kV line from Church to Massey – Kennedyville – Lynch – Chestertown circuit 6727. Delayed clearing at Church, loss of AA1-110.	9 / 42	Stable
P5.04	SLG at 80% of 69 kV line from Church to Clough – Chestertown circuit 6773. Delayed clearing at Church.	9 / 42	Stable
P5.05	SLG at 80% of 69 kV line from Church on AB2-135 POI circuit 6704. Delayed clearing at Church.	9 / 42	Stable
P5.06	SLG at 80% of 69 kV line from Church on I.B. Corners – Price circuit 6710. Delayed clearing at Church.	9 / 42	Stable
P5.07	SLG at 80% of 69kV line from Chestertown – Lynch – Kennedyville – Massey – Church, Delayed clearing at Chestertown, loss of AA1-110.	9/42	Stable
P5.08	SLG at Church 69/138kV transformer AT1, Delayed clearing	/42	Stable
P5.09	SLG at 80% of 69 kV line from AB2-135 POI on Church circuit 6704. Delayed clearing at AB2-135 POI.	9 / 42	Stable
P5.10	SLG at 80% of 69 kV line from AB2-135 POI on New Meredith - Kent circuit 6704. Delayed clearing at AB2-135 POI.	9 / 42	Stable
P5.11	SLG at 80% of 69 kV line from Kent on New Meredith - AB2-135 POI circuit 6704. Delayed clearing at Kent.	9 / 42	Stable
P5.12	SLG @ 80% of 69kV line from Kent on Cheswold, delayed clearing at Kent	9 / 42	Stable
P5.13	SLG @ 80% of 69kV line from Kent on Vaughn – Harrington, delayed clearing at Kent, loss of Vaughn unit	9 / 42	Stable
P5.14	SLG @ 80% of 69kV line from Kent on NRG Dover, delayed clearing at Kent, loss of NRG Dover units.	9 / 42	Stable

Attachment 1. PSS/E Model One Line Diagram



Attachment 2. AB2-135 PSS/E Dynamic Model

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924824,'USRMDL', 1, 'REGCAU1', 101, 1, 1, 14, 3, 4, 1, 0.2, 10.0, 0.75,-10.0, 0.23, 2.0, 0.1, 0.0, -
0.377, 0.02, 0.0, 10.0, -10.0, 0.0/
924824,'USRMDL', 1, 'REECBU1', 102, 0, 5, 25, 6, 4, 0, 0, 0, 0, 0, 0.0, 2.0, 0.0, -0.1, 0.1, 0.0, 0.377,
-0.377, 0.0, 0.05, 0.377, -0.377, 1.1, 0.9, 0.0, 0.0, 0.0, 0.0, 0.02, 2.0, -2.0, 0.932, 0.0, 1.00, 0.02/
924824,'USRMDL', 1, 'REPCAU1', 107, 0, 7, 27, 7, 9, 924820, 0, 0, 0, 0, 1, 0, 0.02, 18, 5, 0, 0.15, -1,
0, 0, 0, 999, -999,-0.02, 0.02, 0.377, -0.377, 10, 1, 0.02, -99.0, 99.0, 999, -999, 0.932, 0, 20, 20, 20/
9248241, 'VTGTPAT', 924820, 924824, 1, -1, 1.200, 0, 0.0/
9248242, 'VTGTPAT', 924820, 924824, 1, -1, 1.175, 0.2, 0.0/
9248243, 'VTGTPAT', 924820, 924824, 1, -1, 1.15, 0.5, 0.0/
9248244, 'VTGTPAT', 924820, 924824, 1, -1, 1.10, 1.0, 0.0/
9248245, 'VTGTPAT', 924820, 924824, 1, 0.45, 5, 0.20, 0.0/
9248246, 'VTGTPAT', 924820, 924824, 1, 0.65, 5, 0.80, 0.0/
9248247, 'VTGTPAT', 924820, 924824, 1, 0.75, 5, 2, 0.0/
9248248, 'VTGTPAT', 924820, 924824, 1, 0.90, 5, 3, 0.0/
/9248249, 'FRQTPAT', 924820, 924824, 1, -100, 61.8, 0, 0.0/
/92482410, 'FRQTPAT', 924820, 924824, 1, -100, 60.5, 600.66, 0.0/
/92482412, 'FRQTPAT', 924820, 924824, 1, 57.8, 100, 0, 0.0/
/92482413, 'FRQTPAT', 924820, 924824, 1, 59.5, 100, 1792.049, 0.0/
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Attachment 3. AB2-135 PSS/E Case Dispatch

Bus Number	Bus Name	Id	In Service	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)
200052	ROCKSP 1 18.000	1	1	164	164	20	67.3	67.3	-50
200053	ROCKSP 2 18.000	1	1	164	164	20	67.3	67.3	-50
200054	ROCKSP 3 18.000	1	1	165	165	20	75	75	-50
200055	ROCKSP 4 18.000	1	1	165	165	20	75	75	-50
230927	CDRCRK_REAC 230.00	1	1	0	0	0	-20	0	-20
231118	NEWCASTL 138.00	1	1	0	0	0	-60	0	-60
231131	BLOOM ENRGY 138.00	1	1	27	27	0	0	0	0
231505	HR4 18.000	4	1	185	185	0	23.3	23.3	-23
231900	EM5 23.000	5	1	450	450	0	0	0	0
231902	DC CT7 13.800	1	1	62.1	62.1	0	-3.1	65.1	-3.1
231903	GEN4 13.800	4	1	72	72	0	0	0	0
231904	DC1 NUG 13.800	1	1	0	0	0	0	0	0
231905	DC2 NUG 13.800	1	1	0	0	0	0	0	0
231907	DC10 13.800	1	1	17.8	17.8	0	12.1	12.1	-5
231911	HR5 13.800	5	1	125	125	0	10	10	-10
231912	HR6 13.800	6	1	125	125	0	10	10	-10
231913	HR7 13.800	7	1	125	125	0	10	10	-10
231914	HR8 18.000	8	1	190	190	0	18.6	18.6	-9.3
231915	DC CT6 13.800	1	1	55	55	0	-17	15	-17
232227	EASTN_69 69.000	1	1	0	0	0	-30	0	-30
232616	GEN FOOD 13.200	1	1	15.2	15.2	0	0	1	0
232632	IR SVC 16.000	1	1	0	0	0	147	150	-150
232813	VAUGHN 69.000	1	1	3	3	0	0	0	0
232901	NORTHST 69.000	1	1	45	45	5	0	15.6	0
232902	EASTMUNI 69.000	1	1	69	69	0	34.6	34.6	0
232904	IR4 26.000	4	1	414	414	0	4.9	4.9	-2.9
232907	VN8 18.000	8	1	153	153	0	-15	28	-15
232910	NRG_G1 13.800	2	1	44	44	0	5.91	27	-20
232911	NRG_G2 13.800	1	1	44	44	0	5.91	27	-20
232922	MR3 13.000	3	1	102	102	35	0	35	0
232923	MR1 12.500	1	1	17	17	6	0	12	0
232924	MR2 12.500	2	1	17	17	6	0	12	0
293251	N-034 13.800	1	1	0	0	0	0	0	0
901171	SMYRNA 2 13.800	1	1	53	53	30	-3.9	28	-18
901172	SMYRNA 1 13.800	1	1	48	48	30	1.06	25	0
903342	W3-032A-CTG118.000	1	1	211	211	0	28.6	100	-60
903343	W3-032A-STG113.800	1	1	127	127	0	28.6	50	-40
907291	X1-074 CT 20.000	1	1	201	201	92	52.3	120	-85

907292	X1-074 ST 13.800	1	1	99.5	99.5	92	34	34	-34
910821	X3-066 C 12.500	1	1	2.28	2.28	0	0	0	0
910822	X3-066 E 12.500	1	1	3.72	3.72	0	0	0	0
913361	Y1-079 C 24.900	1	1	3.8	3.8	0	0	0	0
913362	Y1-079 E 24.900	1	1	6.2	6.2	0	0	0	0
913400	Y3-102-STG 23.500	1	1	499	499	0	110	499	-183
913401	Y3-102-CTG1 21.000	1	1	290	290	100	110	290	-114
913402	Y3-102-CTG2 21.000	1	1	290	290	100	110	290	-114
916281	Z1-081 C 24.900	1	1	2.28	2.28	0	0	0	0
916282	Z1-081 E 24.900	1	1	3.72	3.72	0	0	0	0
918910	AA1-110_GEN 0.8000	1	1	6	6	0	0.09	2.75	-2.8
919831	AA2-069 CT 18.000	CT	1	245	245	0	28.6	130	-90
919832	AA2-069 ST 18.000	ST	1	217	217	0	28.6	170	-120
923923	AB2-032 GEN 0.6000	1	1	20	20	0	3.01	6.58	-6.6
923953	AB2-036 GEN 0.3850	1	1	102	102	0	-19	33.7	-34
923963	AB2-037 GEN 0.3850	1	1	213	213	0	23.1	69.8	-70
924191	AB2-063 GEN 0.4180	1	1	20	20	0	-6.6	6.57	-6.6
924804	AB2-133 GEN 0.6000	1	1	57	57	0	12.1	18.8	-19
924824	AB2-135 GEN 0.6000	1	1	65.4	65.4	0	1.42	21.5	-22
924881	AB2-142 C 24.900	1	0	5.1	5.1	0	0	0	0
924882	AB2-142 E 24.900	1	0	8.3	8.3	0	0	0	0
924973	AB2-153 GEN 0.6000	1	0	20	20	0	0.1	6.58	-6.6
925111	AB2-168 C 34.500	1	0	3.8	3.8	0	0	0	0
925112	AB2-168 E 34.500	1	0	5.2	5.2	0	0	0	0
925253	AB2-179 GEN 0.3850	1	0	50	50	0	-17	16.5	-17
925271	AB2-185 C OP24.900	1	0	14	14	0	0	0	0
925272	AB2-185 E OP24.900	1	0	6	6	0	0	0	0
930922	AB1-141 GEN 0.5500	1	1	20	20	0	2.69	6.58	-6.6
930932	AB1-142 GEN 0.5500	1	1	20	20	0	2.69	6.58	-6.6
931111	AB1-162 GEN 0.4180	1	1	16.7	16.7	0	4.42	5.48	-5.5
931261	AB1-176 GEN 0.4800	1	1	9	9	0	0	0	0