Generation Interconnection System Impact Study Report

for

PJM Generation Interconnection Request Queue Position AB1-182

Bear Creek

January 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 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

Leeward Member LLC, the Interconnection Customer (IC), has proposed a battery storage facility located in Luzerne County, Pennsylvania. The installed facilities will have a total capability of 20 MW with 0 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project, as stated in the Attachment N, is April 2016. **This study does not imply a PPL Electric Utilities Corporation (PPL EU) commitment to this in-service date.**

Point of Interconnection

In order to interconnect with the PPL EU transmission system, PPL EU will tap the Bear Creek Tap off of the Harwood Jenkins #1 69 kV line. The Point of Interconnection will be the first deadend structure inside the IC substation fence. Refer to Attachment 1.

Cost Summary

The AB1-182 project will be responsible for the following costs:

Description	Total Cost
Attachment Facilities	$ 754,000
Direct Connection Network Upgrades	$ 0
Non Direct Connection Network Upgrades	$ 250,000
Allocation for New System Upgrades	$ 0
Contribution for Previously Identified Upgrades	$ 0
Total Costs	**$ 1,004,000**

The 69 kV connection estimate is based on the assumptions stated in the following Transmission Attachment Facilities and Non-Direct Connection Work sections. This estimate may vary depending upon the Queue AB1-182 substation location and orientation.

The transmission and substation costs given above exclude any applicable state or federal taxes. If at a future date Federal CIAC (cost in aid of construction) taxes are deemed necessary by the IRS for this project, both PJM and PPL EU shall be reimbursed by the Interconnection Customer for such taxes.

Note: Before the Facilities Study stage, the exact location and orientation of the Interconnection Substation must be identified by the AB1-182 IC in order to refine the cost estimate.

The estimated time frame to complete the facility addition for direct connection is approximately 14 months after the PJM three-party Interconnection Service Agreement (ISA) and Construction Service Agreement (CSA) are signed. PPL EU will commence siting, engineering design, material purchase and construction of the facilities identified above after receiving written authorization by PJM to begin work. This time frame is contingent upon the acquisition of all rights of way in the stated time frame before the start of construction and detailed design.

Attachment Facilities

New 69kV transmission tap

PJM Network Upgrade Number n5133

A new connection from the existing Bear Creek 69kV Tap will be needed to establish a new 20MW battery storage facility at coordinate location 41.2313898°N, 75.781667°W. This location is approximately 90ft from the existing Bear Creek Wind Farm. In order to make the connection, an existing dead-end guyed structure will be converted into a tap pole at grid location 54149n39403 and a new dead-end guyed heavy angle structure will be installed before slack spanning into the new battery storage facility. Additionally, a new MOLBAB structure will have to be installed between the Bear Creek 69kV Tap and the Bear Creek Wind Farm.

It is assumed that the developer will purchase the property needed for PPL EU's facilities and transfer the rights to PPL EU.

Project Details:

Design & Location Details:
This work will include installation or modification of three (3) structures. The first structure involves converting an existing dead-end structure into a tap structure at grid location 54149n39403. The second structure involves the installation of a new dead-end guyed heavy angle structure approximately 150ft away from the Bear Creek 69kV Line Tap. The final structure involves the installation of a new MOLBAB between the existing tap structure at grid location 54138n39394 and the converted dead-end structure at grid location 54149n39403. These structures will be designed for 138kV future operation.

Steel Poles:
There will be a total of three (3) structures included in this scope of work. After the line taps off of the Bear Creek 69kV Tap at grid location 54138n39394, a new 85ft tall MOLBAB will be installed. The existing 75ft tall dead-end structure will be converted into a tap structure at grid location 54149n39403. The line will continue approximately 90ft northeast to a new 75ft dead end guyed heavy angle structure before going into the new battery storage facility. All structures will be direct embedded except for the MOLBAB structure which will be on a caisson foundation.

Conductor and Overhead Shield Wire (OHSW):
Conductor

- Total Length: 1,100 ft. (for all three phases)
- 60' average span length for 556.5 kcmil base 24/7 ACSR (conductor length at 60 deg F for all phases)

OHSW

- Total Length: 375 ft. (for single circuit section)
- 60' average span length for 0.567" 48 count SFPOC Fiber (single OPGW length at 60 deg F)

- Splice box with mounting hardware and storage rack

Guy Wire

- Total Length: 1,200 ft. (for both the converted tap structure and dead-end structure)
- Assumed for 45 deg slope

Siting/PUC Letter of Notification required:
The current Harwood-Jenkins #1 69 kV line is designed and certified as a 138 kV line. This project will require PA PUC Letter of Notification for the new tap to the POI. The lead time required from filing preparation to PA PUC approval is approximately 8 months. The approved filing is needed before construction can start. PPL EU will determine environmental impacts and mitigation strategies of the facilities being certified (i.e. - the transmission lines). These costs to address environmental impacts are not included in this estimate.

The total preliminary cost estimate for the Attachment work is given in the table below. These costs do not include CIAC Tax Gross-up.

Description	Total Cost
New 69kV Transmission Line Tap PJM Network Upgrade Number n5133	$ 754,000
Total Attachment Cost Estimate	**$ 754,000**

Direct Connection Cost Estimate

There are no Direct Connection Facilities required to support the connection of this request.

Non-Direct Connection Cost Estimate

Protection and Communications work for Jenkins-Harwood 69kV

PJM Network Upgrade Number n5134

Below mentioned work needs to be done at Jenkins and Harwood (or Palooka) substations to accommodate the proposed IPP in PPL EU's network.

- A new telephone circuit and termination box will be extended to Jenkins telephone panel (by Telephone Company).
- Install new Positron 7501-53 transformer on Jenkins telephone panel and extend wire from the new telephone termination box to it.
- Install Direct Transfer Trip (DTT) relay equipment at Jenkins with control switches, status indication lights and one (1) telephone based RFL 9745 relay. Tie DTT scheme into Harwood-Jenkins 69kV line #1 breaker control scheme.

- Install DTT relay equipment at Harwood (or Palooka) with control switches, status indication lights and one (1) fiber based SEL 2411 relay. Tie DTT scheme into Harwood-Jenkins 69kV line #1 breaker control schemes.
- Install one (1) fiber optic duplex patch cord from SEL 2411 to fiber optic entry cabinet.
- Modify SCADA for new alarms (program new alarms in SCADA for IPP).
- Modify Alarm Management system (program new alarms in AMS for IPP).
- Perform system checks and test equipment at Jenkins, Harwood (or Palooka) and the IPP site before placing in service.

Below mentioned work needs to be done at Bear Creek Battery substation to accommodate the proposed IPP in PPL EU's network.

- The IPP will need to install at their substation a matching RFL 9745 relay for Jenkins and a matching SEL-2411 relay for Harwood (or Palooka).
- Review and acceptance of IPP's Intertie Protective Relaying (IPR) and Point of Contact (POC) design of their facility.
- Perform system checks and test equipment at Jenkins, Harwood (or Palooka) and the IPP site before placing in service.

The total preliminary cost estimate for the Non-Direct Connection work is given in the table below. These costs do not include CIAC Tax Gross-up.

Description	Total Cost
Protection and Communications work for Jenkins-Harwood 69kV PJM Network Upgrade Number n5134	$ 250,000
Total Non-Direct Facilities Cost Estimate	**$ 250,000**

Schedule

The estimated PPL EU elapsed time to complete the 69 kV transmission line Attachment Facilities and Direct Connection substation work is approximately 14 months after the receipt of a fully executed ISA/CSA. The transmission and substation work can be completed concurrently. PPL EU will commence siting, engineering design, material purchase and construction of the facilities identified in this study after receiving written authorization by PJM to begin work.

The work to accommodate AB1-182 will require an outage of the Bear Creek 69 kV tap. PPL EU's outage windows for construction are typically available in the spring and fall of the year. Missing an outage window could result in project delays.

Transmission Owner Assumptions in Developing the Cost Estimates

- During construction, if extreme weather conditions or other system safety concerns arise, field construction may need to be rescheduled, which could possibly delay the schedule.
- It is assumed that outages required to construct the new tap off of the Bear Creek 69 kV Tap will be coordinated with the Bear Creek Wind Farm.

- This magnitude estimate has been prepared without extensive research or field review.
- For the new 69 kV tap line from the generation facility to the POI, it is as assumed that the IC will provide sufficient ROW and the line would be owned by PPL EU. It is also assumed that the IC is the landowner.
- No environmental, real estate, or permitting issues were reviewed for the estimate of this project.
- It is assumed that the developer will purchase the property needed for PPL EU's facilities and transfer the rights to PPL EU.
- This estimate assumes that suitable facility outages can be scheduled as required to install the new switchyard. Failure to meet a scheduled facility outage may result in project delays.
- Excepting any operational, governmental, and/or environmental regulatory delays, the use of additional resources, such as overtime, premiums for expedited material, and/or contractor labor, may enable PPL EU to decrease this construction period but no guarantees can be made. It is also assumed that all rights-of-way and easements are secured by the anticipated construction start dates.
- PPL EU recommends that an Interim ISA be completed during the Facilities Study stage to address critical path items, such as long lead-time purchases and any other compressed project schedule issues.
- The ISA/CSA or an Interim Interconnection Service Agreement (IISA) must be signed by the AB1-182 Interconnection Customer, PJM, and PPL EU before any PPL EU design and construction activities may commence.

Generator, GSU, and Line Modeling

The Generator interconnect consists of 5 battery storage containers; each container producing 4MW. The total is about 20 MW.

The Battery storage was modeled and injects approximately 20 MW into PPL EU's system.

Per the AB1-182 supplied data, the following was used in modeling the battery storage:

AB1-182: Battery Storage Generation

Battery Storage Generator:

- Number of Containers Per Transformer: 5
- Size: 20 MW

Transformers:

GSU (Generator Step Up Transformer):

- Number of machines per GSU: 1
- Voltage Levels: 34.5/69 kV

Transmission Tap Line:

- Voltage Level: 69 kV

- MVA Base: 100 MVA
- Length: approximately 200 feet

Telephone / Communication Circuit Requirements (At the IPP)

PPL EU will require a communication path for SCADA and voice circuits. It is assumed that this IPP will tie into the existing SCADA and voice circuits at Bear Creek. If not, then the IC's new substation will need its own independent RTU, SCADA circuit, and voice circuit. In this case, PPL EU anticipates that either telephone circuits or IP will be required to establish these paths. The Interconnection Customer would be responsible to procure the following:

- SCADA – either a 4-wire dedicated FDDA-type phone line or DNP over IP. It is at PPL's discretion as to which SCADA (4 wire or DNP/IP) is required to be provided.
- A normal dialup telephone line for voice communication.

Phone lines tend to be long lead-time items and must be in place and operational for equipment testing. The Interconnection Customer should investigate with the local phone company the possibility of obtaining this type of service at their facility.

All installation, maintenance, and monthly lease or billing charges for communications facilities are the responsibility of the Interconnection Customer.

Intertie and POC Protective Relaying Equipment

The Interconnection Customer will need to install suitable protection and control equipment at its facilities based on PPL EU parallel generation requirements. This includes both Intertie Protective Relaying (IPR) and Point of Contact (POC) relaying. Please refer to the PPL EU web site for the IPR and POC requirements. The website addresses are shown below:

IPR Requirements:
https://www.pplelectric.com/at-your-service/electric-rates-and-rules/customer-owned-generation.aspx

POC Requirements:
https://www.pplelectric.com/at-your-service/electric-rates-and-rules/point-of-contact-requirements-for-high-voltage-facilities.aspx

DTT Equipment Requirements

It is assumed that the IC will tie into the existing Direct Transfer Trip circuit at the Bear Creek Facility. If this is not the case, the IC should inform PPL at the next study phase so it can be incorporated into future study cost estimates.

Isolation Breaker Requirement at the Interconnection Customer's Substation

Per the customer's preliminary sketches, the customer is planning to provide a high side circuit breaker at 69 kV with a manually operated 69 kV disconnect switch on the PPL EU line side of this breaker. Unless otherwise indicated, it is assumed that this be will be the "Isolation Circuit Breaker" and will be operated by the IPR relay and the DTT signal. It is requested that the customer confirm this or provide alternate isolation breaker.

Generator Harmonic and Flicker Requirements

On the 69 kV system, the total harmonic distortion to the fundamental voltage wave is limited to 1.5% of nominal. In addition, no individual harmonic can exceed 1.0% of the fundamental. If PPL EU discovers that objectionable harmonics in excess of the stated limits are being injected into the system from AB1-182's equipment, the Queue AB1-182 Interconnection Customer will be responsible for taking corrective measures to mitigate harmonic currents.

Concerning voltage flicker, the AA2-182 Project must limit the severity of their voltage variation to within a level which will not cause objectionable flickers to other customers. A voltage drop greater than 5% at the point of interconnection is generally not acceptable. The frequency and severity of the voltage variation will be considered when determining whether a customer's equipment is violating PPL EU flicker guidelines. PPL EU uses the General Electric flicker irritation curves as a guideline to determine if the system is operating within acceptable limits. PPL EU will require corrective actions by the AB1-182 customer if their operation causes flickers that exceed PPL EU guidelines. One such correction could be the installation of static var compensators (SVC) to hold a constant voltage.

Generator Regulation or Reactive Support Requirements

As specified in Section 4.7.1.1 of the PJM OATT (Open Access Transmission Tariff), the AB1 182 Project shall design its Facility to meet the following power factor requirement:

"For all new wind-powered and other non-synchronous generation facilities, if determined in the system Feasibility study to be required for the safety or reliability of the Transmission System, the Generation Interconnection Customer shall design its Customer Facility with the ability to maintain a composite power delivery at continuous rated power output at a power factor of at least 0.95 leading (absorbing vars) to 0.95 lagging (supplying vars)."

The PPL EU preliminary load flow studies have indicated that the AB1-182 generator will maintain the required voltage regulation within required regulations. A MW/MVAR schedule will be provided to the developer at the Facilities Study Stage.

Distribution Service Requirements

The Interconnection Customer must submit a request for electric service through PPL EU's Industrial and Commercial Services (ICS) group if the queue AB1-182 requires back-up electric

service at a voltage less than 69 kV. The ICS Help Desk can be reached at 1-888-220-9991. Cost for distribution electric service is NOT included in the PPL scope of work transmission or substation estimates.

Future Conversion of line to 138 kV from 69 kV

PPL EU presently has no plans to convert the Harwood-Jenkins #1 69 kV line to 138 kV in the next 15-20 years. If the transmission system in this area is converted to 138 kV in the future, the Interconnection Customer would be responsible for conversion of its substation to 138kV at that time.

PA PUC Certification & Environmental Issues

All required land and right of way will be made available to PPL EU at no cost from the Interconnection Customer developer. It is assumed here that the transmission tap would be owned by PPL EU.

PA PUC certification in the form of a Letter of Notification (LON) will be required because the new 69 kV tap is tapping a circuit designed for 138 kV.

To avoid duplication of costs and efforts, PPL EU recommends that the Interconnection Customer obtain all environmental approvals required for construction of the generating station and share pertinent details with PPL EU prior to PPL EU beginning work on the line.

Revenue Metering and SCADA Requirements

PJM Requirements

The Interconnection Customer will be required to install equipment necessary to provide Revenue Metering (KWH, KVARH) and real time data (KW, KVAR) for IC's generating Resource. See PJM Manuals M-01 and M-14D, and PJM Tariff Sections 24.1 and 24.2.

PPL EU Requirements

SCADA Requirements

PPL EU will require the installation of PPL EU approved SCADA equipment that will connect to its existing SCADA system to provide real time values of kW, kVAR, and kV metering data at the POC. SCADA equipment will also provide capability to trip and the monitoring of the POC isolating circuit breaker. PPL EU will provide detailed specifications and design drawings for this equipment should the IC proceed to an ISA/ICSA.

Metering Equipment Installation at the POI (Point of Interconnection)

Installation of revenue grade Bi-directional Metering Equipment will be required at the Queue AA2-182 Point of Interconnection (POI) to measure KWh and KVARh. PPL EU will design and

supply the required metering equipment, but all the installation cost would be borne by the developer including CT/PTs. All metering equipment must meet applicable PPL EU tariff requirements as well as being compliant with all applicable requirements of the PJM agreements. The equipment must provide bi-directional revenue metering (KWH and KVARH) and real-time data (KW, KVAR, circuit breaker status, and generator bus voltages) for the developer's generating resource. The metering equipment should be housed in a control cabinet or similar enclosure and must be accessible to PPL EU metering personnel.

The developer is also required to provide revenue metering (KWH and KVARH) and real-time telemetry data (KW, KVAR, and KV) to PJM in compliance with the requirements listed in PJM Manuals M-01 and M-14. Any data from the PPL EU revenue meters can be transferred by fiber optic link to the PJM RTU located at the IPP facility.

Network Impacts

The Queue Project AB1-182 was evaluated as a 20.0 MW (Capacity 0.0 MW) injection at the Bear Creek 69kV substation in the PPL area. Project AB1-182 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). Project AB1-182 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Base Case Used

Summer Peak Analysis – 2019 Case

Generator Deliverability

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

None.

Light Load Analysis

Light Load Studies to be conducted during later study phases (applicable to wind, coal, nuclear, and pumped storage projects).

None.

Multiple Facility Contingency

(Double Circuit Tower Line contingencies were studied for the full energy output. The contingencies of Line with Failed Breaker and Bus Fault will be performed for the Impact Study.)

None.

Short Circuit

(Summary of impacted circuit breakers)

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.

Steady-State Voltage Requirements

(Summary of the VAR requirements based upon the results of the steady-state voltage studies)

None.

Stability and Reactive Power Requirement for Low Voltage Ride Through

(Summary of the VAR requirements based upon the results of the dynamic studies)

See Attachment 2.

Potential Congestion due to Local Energy Deliverability

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 Request, a subsequent analysis will be performed which shall study all overload conditions associated with the overloaded element(s) identified.

None.

New System Reinforcements

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

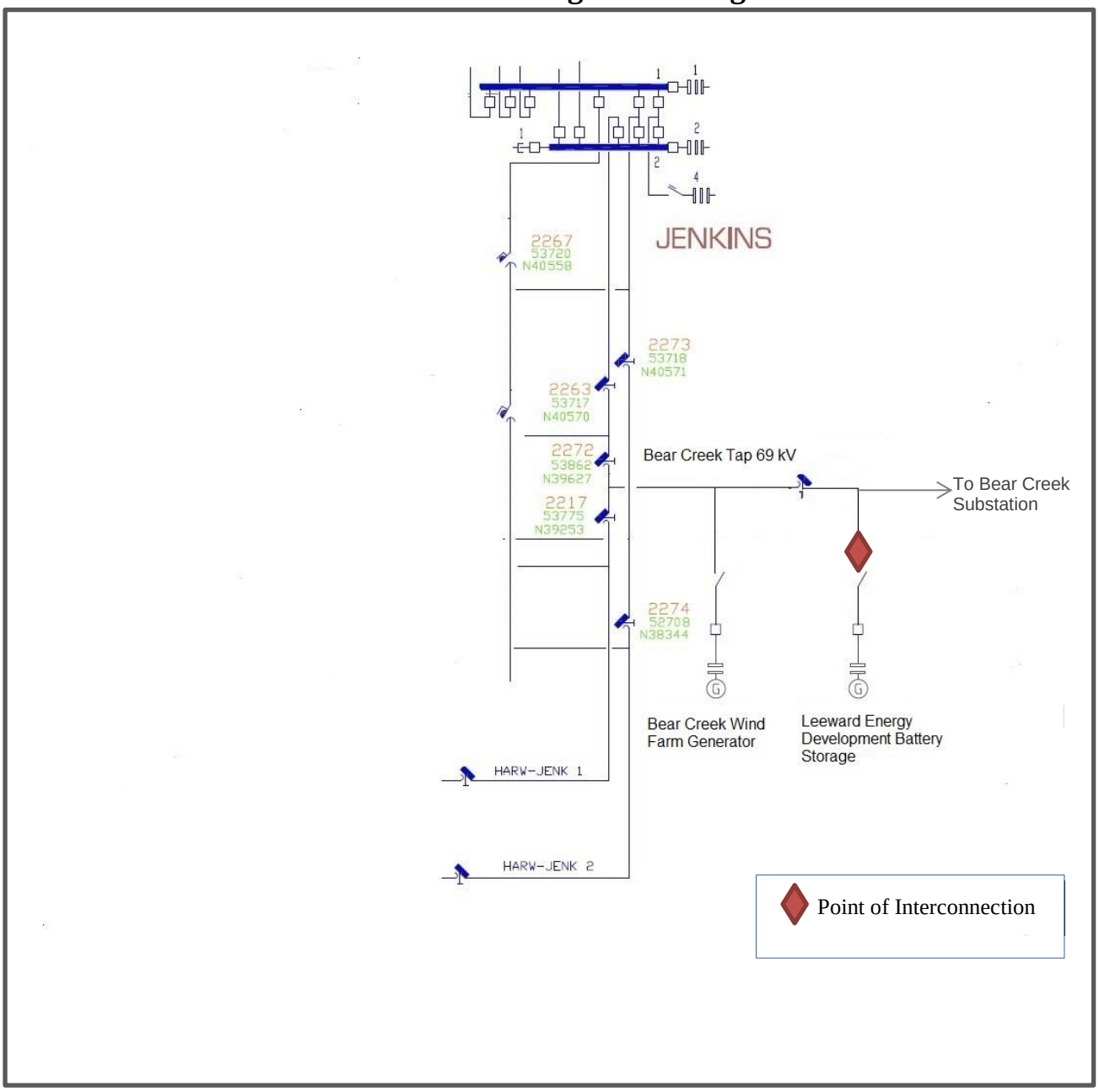
None.

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.

Attachment 1. Single Line Diagram



Attachment 2. Stability Study Report

Executive Summary

Generator Interconnection Request AB1-182 is a request for a 20.0 MW Maximum Facility Output (MFO) battery storage facility. AB1-182 consists of 20x1 MW Kokam LSEP-10000G1-(US) inverters with a Point of Interconnection (POI) at Bear Creek 34.5 kV substation in the PPL transmission system (JENK-HARW1 69 kV), Luzerne County, PA.

This study is based on the RTEP 2019 light load case and modified to include applicable queue projects. PJM queue project AB1-182 was dispatched at a maximum power transfer of 20.0 MW total and POI voltage of 68.0 kV (0.986 p.u.), consistent with the default generator reference voltage specified in PJM Manual 03 Transmission Operations Section 3.3.3 for generator connections to the PJM system.

AB1-182 was tested for compliance with NERC, PJM and other applicable criteria. 32 contingencies were studied, each with a 15 second simulation time period.

Based on the contingencies tested, AB1-182 meets criteria for all other contingencies tested.

Description

This study evaluates the stability and dynamics for PJM queue project AB1-182. The POI is a at Bear Creek 34.5 kV substation off a JENK-HARW1 69 kV circuit in PPL EU area. The AB1-182 project is comprised of 20 MW battery storage and inverters. For this stability study, the AB1-182 project was studied as a total net injection of 19.9 MW into PPL EU 69 kV transmission system.

Criteria

The stability study for AB1-182 was performed on a RTEP 2019_BaseCases_AB1 light load-case for normal operating conditions, and modified to include applicable queue projects. The base case was also adjusted for the voltage profile provided by the TO. The range of contingencies evaluated was limited to those necessary to assess compliance with NERC, PJM and other applicable criteria. Simulation time was 15 seconds for all faults.

Simulated NERC Standard TPL-001 faults include:

1. Three-phase (3ph) fault with normal clearing (Category P1)
2. Single-line-to-ground (slg) with normal clearing for bus faults (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)

Note: For generator interconnection studies, Category P3 and P6 faults will be studied on an as needed basis.

The system was tested for an all lines in service condition and the faults listed above. Specific fault descriptions and breaker clearing times used for this study are provided in Appendix A.

All generators were monitored to assess transient stability and satisfactory post-contingency conditions.

Case Setup

Generators within 5 buses from the generator(s) under study are dispatched at their maximum power output and were set to hold scheduled voltages.

Studies were completed using RTEP 2019_BaseCases_AB1 light load case including applicable queue projects, and as per TO requirements and suggestions some voltages were adjusted in order to bring the required voltage levels.

Specific dispatch conditions at the generator terminals for the AB1-182 generators, as obtained in the power flow solution, are illustrated below:

	Gen / Battery Storage
Gross power output (MW)	20.0
Reactive power output (MVARS)	0.0
Auxiliary Load (MW/MVARS)	0.1,0.1
Net real power injection (MW) @ 34.5 kV Bus	19.9
Voltage at the POI (P.U.)	0.986

Results

Simulation Initialization

The case was initialized successfully. No errors were reported.

20 second no fault test (Steady State evaluation)

The system successfully met the 20 second run test without any significant deviations in system states.

Simulation Results

Dynamics and stability was tested using Siemens/PTI PSS/E Version 32, the RTEP 2019_BaseCases_B1case with a Light Load condition and the data supplied by the developer.

Transient Stability: For all cases studied, transient stability is maintained, with all oscillations stabilized in less than 15 seconds. Also, the voltage levels returned to acceptable levels for all cases following the fault clearance. Hence, no transient stability issues were identified.

Small Signal (if applicable): N/A

SPS: N/A

Maintenance outage: No maintenance outage conditions were evaluated.

Conclusion

No issues were identified for the stability study performed for PJM queue project AB1-182.

Mitigations:

None required.

Recommendations:

1) Installation of out-of-step protection is recommended: This study was made using a certain set of operating conditions. There may be other operating conditions, although less probable, that can create stability problems. It is the Customer's responsibility to protect their own equipment from damage due to disturbances on the transmission system by installing out-of-step protection on their generators.

Note: While the stability analysis has been performed at 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 may 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 dynamic data for the plant and its controls are available, it must be forwarded to PJM. 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. Note that any and all changes to the generation equipment's dynamic data, including the GSU data, must be submitted to PJM for evaluation.

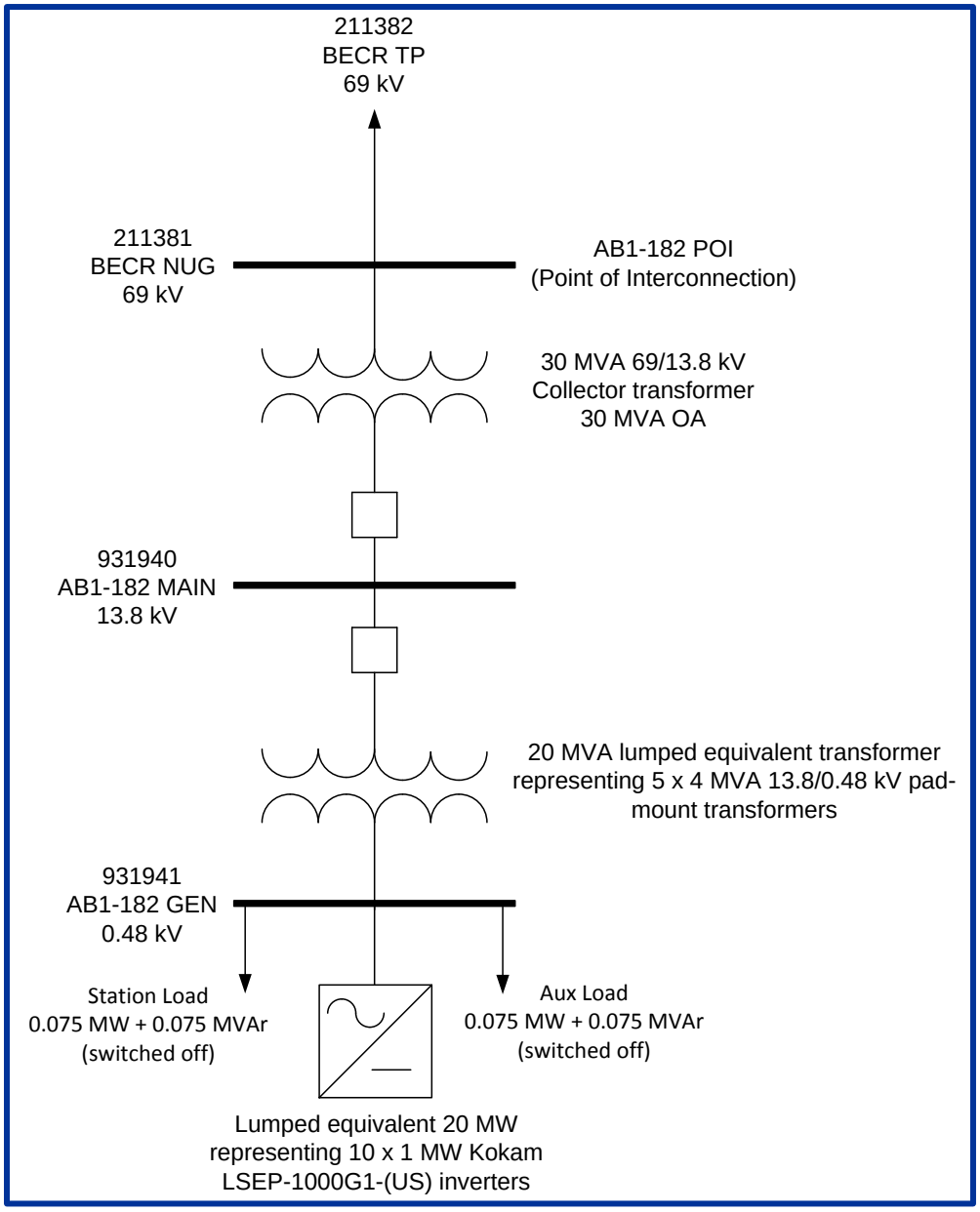
Appendix A: Fault Table

The following contingencies were tested

No.	Contingency ID	Type of Fault	Clearing time (cycles)		Results
			Normal	Delayed	
Criteria = TPL 001-4_P1					
01	AB1-182-JENK-P1-01	3 ph fault on JENK CT 69 kV	7.5	NA	Stable
02	AB1-182-JENK-P1-02	3 ph fault on JENK- RIVE2 69 kV	7.5	NA	Stable
03	AB1-182-JENK-P1-03	3 ph fault on JENK – SCRA2 69kV	7.5	NA	Stable
04	AB1-182-JENK-P1-04	3 ph fault on JENK – PLYM 69 kV	7.5	NA	Stable
05	AB1-182-JENK-P1-05	3 ph fault on JENK 69/230 kV TF1	7.5	NA	Stable
06	AB1-182-JENK-P1-06	3 ph fault on JENK – RIVE1 69kV	7.5	NA	Stable
07	AB1-182-JENK-P1-07	3 ph fault on JENK – SCRA1 69 kV	7.5	NA	Stable
08	AB1-182-JENK-P1-08	3 ph fault on JENK 69/230 kV TF2	7.5	NA	Stable
09	AB1-182-JENK-P1-09	3 ph fault on JENK 69/230 kV TF4	7.5	NA	Stable
10	AB1-182-JENK-P1-10	3 ph fault on HARW– JENK1 69kV	7.5	NA	Stable
11	AB1-182-JENK-P1-11	3 ph fault on HARW– JENK2 69kV	7.5	NA	Stable
12	AB1-182-JENK-P1-12	3 ph fault on JENK – STAN1 230 kV	5.0	NA	Stable
13	AB1-182-JENK-P1-13	3 ph fault on JENK – STAN2 230 kV	5.0	NA	Stable
14	AB1-182-JENK-P1-14	3 ph fault on JENK - SUSQ 230 kV	5.0	NA	Stable
15	AB1-182-JENK-P1-15	3 ph fault on JENK – ACAH 230 kV	5.0	NA	Stable
16	AB1-182-JENK-P1-16	3 ph fault on JENK 230/69 kV TF1	5.0	NA	Stable
17	AB1-182-JENK-P1-17	3 ph fault on JENK 230/69 kV TF4	5.0	NA	Stable
Criteria = TPL 001-4_P2					
18	AB1-182-JENK-P2-01	SLG fault on JENK 69 kV Bus 1, Loss of JENK CT 69 kV + JENK- RIVE2 69 kV+ JENK – SCRA2 69kV + JENK – PLYM 69 kV + JENK 69/230 kV TF1	7.5	NA	Stable
19	AB1-182-JENK-P2-02	SLG fault on JENK 69kV Bus 2, Loss of JENK-RIVE1 69Kv + JENK-SCRA1 + HARW-JENK1 + JENK 69/230 kV TF2	7.5	NA	Stable
20	AB1-182-JENK-P2-03	SLG fault on JENK 230 kV 'W' Bus, Loss of JENK230/69 kV TF1	5.0	NA	Stable
21	AB1-182-JENK-P2-04	SLG fault on JENK 230 kV 'E' Bus, Loss of JENK69/230 kV TF4	5.0	NA	Stable
Criteria = TPL 001-4_P4					
22	AB1-182-JENK-P4-01	SLG fault on JENK 69/230 kV TF4, SB @ JENK 69 kV, Loss of JENK69 kV Bus1	7.5	38.0	Stable
23	AB1-182-JENK-P4-02	SLG fault on JENK 69/230 kV TF4, SB @ JENK 69 kV, Loss of JENK 69 kV Bus 2	7.5	38.0	Stable
243	AB1-182-JENK-P4-03	SLG fault on JENK – ACAH 230 kV, SB JENK 230 kV 'E' Bus, Loss of JENK 230/69 kV TF4	5.0	17.0	Stable

No.	Contingency ID	Type of Fault	Clearing time (cycles)		Results
			Normal	Delayed	
25	AB1-182-JENK-P4-04	SLG fault on JENK 230/69 kV TF4, SB JENK 230 kV 'E' Bus, Loss of JENK – ACAH 230 kV	5.0	17.0	Stable
26	AB1-182-JENK-P4-05	SLG fault on JENK – STAN1 230 kV, SB JENK 230 kV 'W' Bus, Loss of JENK 230/69 kV TF1	5.0	17.0	Stable
27	AB1-182-JENK-P4-06	SLG fault on JENK 230/69 kV TF1, SB JENK 230 kV 'W' Bus, Loss of JENK – STAN1 230 kV	5.0	17.0	Stable
28	AB1-182-JENK-P4-07	SLG fault on JENK 230/69 kV TF4, SB JENK 230 kV 'E' Bus, Loss of JENK – SUSQ 230 kV + JENK 230/69 kV TF2	5.0	17.0	Stable
29	AB1-182-JENK-P4-08	SLG fault on JENK – SUSQ 230 kV / JENK 230/69 kV TF2, SB JENK 230 kV 'E' Bus, Loss of JENK 230/69 kV TF4	5.0	17.0	Stable
Criteria = TPL 001-4_P5					
30	AB1-182-JENK-P5-01	SLG fault 80% on JENK – STAN2 230 kV	5.0	35.0	Stable
31	AB1-182-JENK-P5-02	SLG fault 80% on JENK – ACAH 230 kV	5.0	35.0	Stable
32	AB1-182-JENK-P5-03	SLG fault 80% on JENK – SUSQ 230 kV	5.0	35.0	Stable

Appendix B: Breaker Diagram



Appendix C: Power Flow and Dynamic Models

C.1) PSS/E Models

PSS/E Model for AB1-182 Generator

Generator model: CBEST

C.2) Power Flow Model Data

```
Version 32
RDCH
1
931940,'AB1-182 MAIN',  13.8000,1, 229, 239,   1,0.98355,  -8.0432
931941,'AB1-182 GEN ',   0.4400,2, 229, 239,   1,1.02635,  -4.3266
0 / END OF BUS DATA, BEGIN LOAD DATA
931941,'1 ',0,   1,   1,     0.075,     0.075,     0.000,     0.000,     0.000,     0.000,   1,1
0 / END OF LOAD DATA, BEGIN FIXED SHUNT DATA
0 / END OF FIXED SHUNT DATA, BEGIN GENERATOR DATA
931941,'1 ',   20.000,     0.000,     0.000,     0.000,1.00000,     0,    20.000, 0.00000E+0, 9.99900E+3, 0.00000E+0, 0.00000E+0,1.00000,1,
100.0,    20.000,     0.000,   1,1.0000
0 / END OF GENERATOR DATA, BEGIN BRANCH DATA
0 / END OF BRANCH DATA, BEGIN TRANSFORMER DATA
211381,931940,     0,'1 ',3,2,1, 0.00000E+0, 0.00000E+0,2,'           ',1,   1,1.0000
 3.99500E-3, 7.99000E-2,    30.00
1.00000,   0.000,   0.000,    30.00,     0.00,     0.00, 0,      0, 1.05000, 0.95000, 1.05000, 0.95000,   5, 0, 0.00000, 0.00000,  0.000
1.00000,   0.000
931940,931941,     0,'1 ',3,2,1, 0.00000E+0, 0.00000E+0,2,'           ',1,   1,1.0000
 5.72100E-3, 5.71250E-2,    20.00
1.05000,  13.800,   0.000,    20.00,     0.00,     0.00, 0,      0, 1.05000, 0.95000, 1.05000, 0.95000,   5, 0, 0.00000, 0.00000,  0.000
1.00000,   0.480
0 / END OF TRANSFORMER DATA, BEGIN AREA DATA
 229,     0,     0.000,     0.000,'PL          '
0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA
0 / END OF VSC DC LINE DATA, BEGIN IMPEDANCE CORRECTION DATA
0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-TERMINAL DC DATA
0 / END OF MULTI-TERMINAL DC DATA, BEGIN MULTI-SECTION LINE DATA
0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA
   1,'CHICAGO     '
 239,'CENTRAL     '
0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA
0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA
   1,'CENT HUD    '
0 / END OF OWNER DATA, BEGIN FACTS DEVICE DATA
0 / END OF FACTS DEVICE DATA, BEGIN SWITCHED SHUNT DATA
0 / END OF SWITCHED SHUNT DATA, BEGIN GNE DATA
0 / END OF GNE DATA
Q
```

C.3) Dynamic Data

```
      /*****************************************
/***    PSSE Version 32                    ***
/***    AB1-182 - 20 MW Battery Storage    ***
/*****************************************

 931941 'CBEST'  1     1.0000       1.1000   0.9000
0.9900
         1000          0.0050       0.0050      0.0050
```

C.4) PSS/E Single Line Diagram

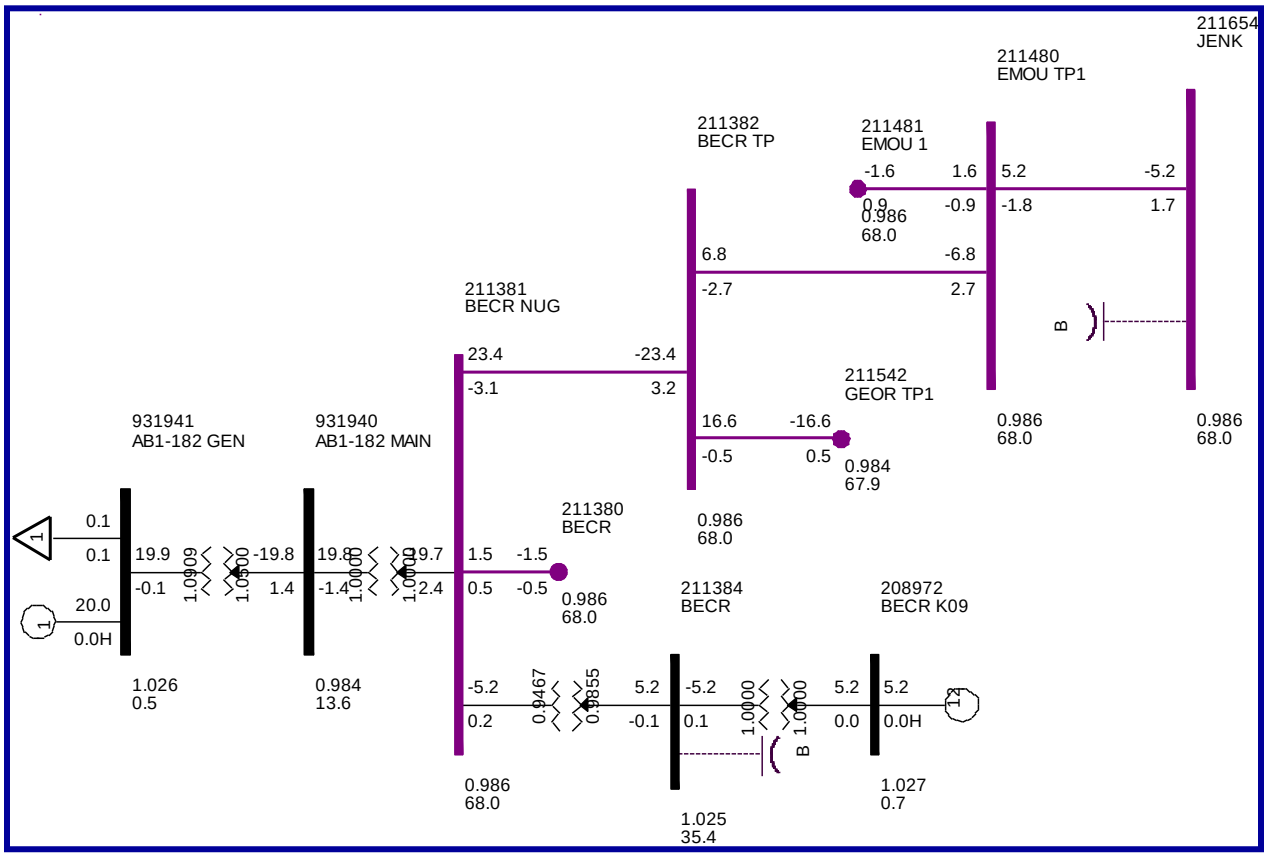


Figure C-1: Single-line diagram for AB1-182 (LL case) (Breaker information not shown)

C.5) Voltage Schedules and Generation

Machines data

Bus Number	Bus Name	Id	Code	VSched (pu)	Remote Bus Number	In Service	Pgen (MW)	Pmax (MW)	Pmin (MW)	Qgen (Mvar)	Qmax (Mvar)	Qmin (Mvar)
200038	SUSQ 2 24.000	1	-2	1.07	200022	1	1302	1302	1096	488.7	488.7	-258
208911	MONT G1 24.000	1	2	1.026	208040	1	745	758.5	403	136.8	228	0
208912	MONT G2 24.000	1	-2	1.026	208040	1	743	756.9	403	208	208	0
208912	MONT G2 24.000	2	-2	1.026	208040	0	11.192	11.4	0	0	0	0
208918	SUSQ 1 24.000	1	-2	1.0304	208113	1	1302	1340	1096	190	190	0
208942	HARR CT 12.470	1	-2	1	0	1	56	56	48.72	0	0	0
208943	HARW CT 12.470	1	-2	1	0	1	28	28	24.36	0	0	0
208944	JENK CT 12.470	1	-2	1	0	1	28	28	24.36	0	0	0
208972	BECR K09 0.6900	1 2	-2	1	0	1	5.2	5.2	0	0	0	0
209018	SUNBIPCT 12.470	1	-2	1	0	1	36	36	31.32	0	0	0
212449	SUNB CT 69.000	1	-2	1	0	0	6	6	0	0	0	0
889013	U2_015_GEN 0.6900	1	-2	1.0217	292934	1	98.9	98.9	0	0	0	0
912292	Y2-089-CT1 23.500	1	2	1	0	1	467.7	467.7	0	36.08	226.5	-153.7
912293	Y2-089-CT2 23.500	1	2	1	0	1	467.7	467.7	0	36.08	226.5	-153.7
912294	Y2-089-CT3 23.500	1	2	1	0	1	467.7	467.7	0	36.08	226.5	-153.7
917353	Z2-046_CT1 23.500	1	2	1.05	917352	1	529	529	0	-51.54	265	-198
917354	Z2-046_CT2 23.500	1	2	1.05	917352	1	529	529	0	-51.54	265	-198
919510	AA2-008 G1 23.000	1	2	1.0217	212397	1	462	462	92	13.02	245	-200
919511	AA2-008 G2 23.000	1	2	1.0217	212397	1	462	462	92	13.02	245	-200
920651	AA2-171 CT1 18.000	1	2	1.05	200021	1	243	243.7	0	97.37	120	-96
920652	AA2-171 CT2 18.000	1	2	1.05	200021	1	243	243.7	0	97.37	120	-96
920653	AA2-171 CT3 18.000	1	2	1.05	200021	1	243	243.7	0	97.37	120	-96
920654	AA2-171 ST 22.000	1	2	1.05	200021	1	350	421	0	97.37	259	-220
920717	AA2-182 GEN124.000	1	2	1.05	200021	1	300	525	0	97.37	275	-200
920718	AA2-182 GEN224.000	1	2	1.05	200021	1	300	525	0	97.37	275	-200
930641	AB1-108 GEN 23.500	1	-2	1.0217	208009	1	508	508	0	310	310	-205
931941	AB1-182 GEN 0.4400	1	-2	1	0	1	20	20	0	0	0	0

Plants data

Bus Number	Bus Name	Code	PGen	QGen	QMax	QMin	VSched (pu)	Remote Bus Number	Remote Bus Name	Voltage (pu)	RMPCT
200038	SUSQ 2 24.000	-2	1302	488.7	488.7	-258	1.07	200022	SUSQHANA 500.00	1.0519	100
208911	MONT G1 24.000	2	745	136.8	228	0	1.026	208040	MONT 230.00	1.026	50
208912	MONT G2 24.000	-2	743	208	208	0	1.026	208040	MONT 230.00	1.026	100
208918	SUSQ 1 24.000	-2	1302	190	190	0	1.0304	208113	SUSQ 230.00	1.0114	100
208942	HARR CT 12.470	-2	56	0	0	0	1	0		0.9709	100
208943	HARW CT 12.470	-2	28	0	0	0	1	0		0.9705	100
208944	JENK CT 12.470	-2	28	0	0	0	1	0		0.9863	100
208972	BECR K09 0.6900	-2	5.2	0	0	0	1	0		1.0269	100
209018	SUNBIPCT 12.470	-2	36	0	0	0	1	0		0.9833	100
212449	SUNB CT 69.000	-2	0	0	0	0	1	0		0.9912	100
889013	U2_015_GEN 0.6900	-2	98.9	0	0	0	1.0217	292934	U2-015 230.00	1.0004	100
912292	Y2-089-CT1 23.500	2	467.7	36.1	226.5	-153.7	1	0		1	100
912293	Y2-089-CT2 23.500	2	467.7	36.1	226.5	-153.7	1	0		1	100
912294	Y2-089-CT3 23.500	2	467.7	36.1	226.5	-153.7	1	0		1	100
917353	Z2-046_CT1 23.500	2	529	-51.5	265	-198	1.05	917352	Z2-046_MAIN 500.00	1.05	100
917354	Z2-046_CT2 23.500	2	529	-51.5	265	-198	1.05	917352	Z2-046_MAIN 500.00	1.05	100
919510	AA2-008 G1 23.000	2	462	13	245	-200	1.0217	212397	SAEG 230.00	1.0217	8
919511	AA2-008 G2 23.000	2	462	13	245	-200	1.0217	212397	SAEG 230.00	1.0217	8
920651	AA2-171 CT1 18.000	2	243	97.4	120	-96	1.05	200021	SUNBURY 500.00	1.05	100
920652	AA2-171 CT2 18.000	2	243	97.4	120	-96	1.05	200021	SUNBURY 500.00	1.05	100
920653	AA2-171 CT3 18.000	2	243	97.4	120	-96	1.05	200021	SUNBURY 500.00	1.05	100
920654	AA2-171 ST 22.000	2	350	97.4	259	-220	1.05	200021	SUNBURY 500.00	1.05	100
920717	AA2-182 GEN124.000	2	300	97.4	275	-200	1.05	200021	SUNBURY 500.00	1.05	100
920718	AA2-182 GEN224.000	2	300	97.4	275	-200	1.05	200021	SUNBURY 500.00	1.05	100
930641	AB1-108 GEN 23.500	-2	508	310	310	-205	1.0217	208009	LACK 230.00	0.9953	100
931941	AB1-182 GEN 0.4400	-2	20	0	0	0	1	0		1.0261	100