Generation Interconnection System Impact Study Report

For

PJM Generation Interconnection Request Queue Position Z2-009

East Hazelton-Harwood 69kV

March 2015

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

EDF Renewable Development, Inc., the Interconnection Customer (IC), has proposed a wind generating facility located in Luzerne County, Pennsylvania. The installed facilities will have a total capability of 52.0 MW with 6.7 MW of this output being recognized by PJM as capacity. The proposed in-service date for this project is December 2016. **This study does not imply a PPL Electric Utilities (PPL EU) commitment to this in-service date.**

Point of Interconnection

Z2-094 will interconnect with the PPL EU transmission system along the East Hazelton-Harwood 69kV line.

Cost Summary

The Z2-009 project will be responsible for the following costs:

Description	Total Cost	
Attachment Facilities	$	2,480,000
Direct Connection Network Upgrades	$	0
Non Direct Connection Network Upgrades	$	150,000
Allocation for New System Upgrades	$	0
Contribution for Previously Identified Upgrades	$	0
Total Costs	**$**	**2,630,000**

Attachment Facilities

69kV Transmission Tap

PJM Network Upgrade Number n4397

The Z2-009 Project will require siting to identify a suitable route for the 100'-wide right of way needed to construct the approximately 0.1 mile 69 kV single circuit transmission line using 556 Kcmil ACSR conductors with optical ground wire (OPGW) to the dead end structure inside the customer's substation (POI). The tap line will be a 138 kV single circuit steel pole design, initially operated at single circuit 69 kV

- The tap will be designed to 138kv 845BIL standards by utilizing 556.5 ACSR power conductors and 2 – 0.567" OPGW fiber optic cables in the shield wire position
- The tap will begin from structure number 53851N30533
- The total distance of the tap will be less than one mile from this structure
- Existing wood pole 53851N30533 will be replaced with a custom steel tap pole
- Install new LD steel pole angle structure 200 feet from new tap pole.
- Install substation DE angle structure 200 feet from previous angle structure.
- 2-Molbab structures will be installed on either side of new LD steel tap pole along the White Haven Tap line, approximately 100' from the new LD tap pole.

The transmission network upgrade work includes installation of two MOLBAB (Motor Operated Load Break Air Break) switch on the PPL EU Harwood-East Hazleton #2 69 kV line on either side of the tap point to Z2-009. The switches would be installed on a custom designed steel pole with concrete foundations. See Figure 1 for the connection schematic.

PA PUC Certification of the proposed 69 kV transmission line route will be required as it will be designed for future 138 kV operation. The certification would be through the abbreviated "Letter of Notification" (LON) process since the tap is expected to be less than 2 miles long. The lead time required to prepare, file and obtain PA PUC approval and obtain property rights will be approximately 12-15 months and assumes that no litigation or condemnation is required.

Substation Work for Mini Yard

Outside the IPP customer substation, a mini yard with a motor-operated switch and 69 kV breaker will be installed in the future by PPL. A small control house will contain the circuit breaker relays and communication devices.

Cost 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
Transmission Tap work	$ 2,480,000
Total Attachment Facility Work	**$ 2,480,000**

Direct Connection Cost Estimate

There are no Direct Connection Facilities that will be constructed by the Transmission Owner.

Non-Direct Connection Cost Estimate

Substation work at Harwood 69 kV Source Substation

PJM Network Upgrade Number n4398

The protection system at the source end of the 69 kV line will be modified to support this interconnection. To accommodate Z2-009, the following upgrades are required at PPL EU's Harwood 230-69kV Substation:

- Update relay to Microprocessor based on East Hazleton #2 69kV line at Harwood
- Install 1 Relay (DTT) Cabinets at Harwood
- Install new phone based line protection equipment at Harwood
- Install Potential Transformer (PT) at Harwood necessary for sync check of East Hazleton #2 69kV transmission line
- Modify the controls of the East Hazleton #2 69kV circuit breaker at Harwood for trip and close
- Modify SCADA for new alarms
- Modify AMS (Alarm Management System)
- Perform system checks and test equipment 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
Harwood substation work	$ 150,000
Total Non-Direct Connection Facility Work	**$ 150,000**

Schedule

The estimated PPL EU elapsed time to complete the 69 kV attachment facility transmission tap and the non-direct connection substation upgrades is approximately 18 months after the receipt of a fully executed ISA/CSA.

The schedule for the 69 kV transmission and substation work to accommodate Z2-009 would depend on the project start date. The work to accommodate Z2-009 will require an outage of the Harwood-E. Hazelton #2 69 kV line. 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.

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. 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.

Assumptions and Notes

- For the custom-designed steel transmission poles, the lead-time is approximately 32 to 42 weeks. It is estimated that approximately custom designed steel poles will be needed for this project.
- 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.
- This magnitude estimate has been prepared without extensive research or field review.
- For the new 69 kV tap from Z2-009 to the Harwood-East Hazleton #2 69 kV line, it is as assumed that a new ROW and siting study would be required and the tap would be owned by PPL EU.
- No environmental, real estate, or permitting issues were reviewed for the estimate of this project.
- This estimate assumes that suitable facility outages can be schedule as required to install the new circuit breaker. 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 Z2-009 Interconnection Customer, PJM, and PPL EU before any PPL EU design and construction activities may commence.

Interconnection Customer Requirements

Queue Z2-009 Interconnection Customer will be responsible for the construction of all their generating station facilities on the Z2-009 side of the POI (Point of Interconnection).

Z2-009 Inverter and GSU modeling Data

The turbines will be modeled as one unit and will inject 52 MW into PPL EU's system.

Per the Z2-009 supplied data the following was used in modeling the generator and the GSU:

Z2-009 Generator (Alstom ECO 122):

Number of Turbines: 19
Size: 2.7 MW per turbine
MVA Base: 3.27 MVA
0.90 lead to 0.90 lag power factor at the 69 kV bus

Transformers:

GSU (Generator Step Up Transformer):

- Number of machines per GSU: 19
- MVA Base: 45 MVA
- Voltage Level: 34.5/69 kV
- Impedance: 8.0%

GSU (Wind Turbine Unit):

- MVA Base: 3.2 kV
- Voltage Level: 34.5/0.69 kV

Transmission Line:

- Voltage Level: 69 kV
- MVA Base: 100 MVA
- Length: 0.25 miles
- Positive sequence impedance: 0.00460+j0.01580
- Negative sequence impedance: 0.01380+j0.04740

Telephone Circuit Requirements

PPL EU will require communication paths between the Z2-009 customer substation and PPL EU's Harwood Substation for DTT, Voice and SCADA.

For the telephone communication path, the Interconnection Customer will be responsible to procure the following to communicate with PPL EU Harwood substation:

1. A 4-wire dedicated FDDA-type phone line for SCADA.
2. A normal dialup telephone line for voice communication.
3. A protective relay-grade telephone circuit for the DTT communication requirements, type PRDA. This phone line needs to communicate between the Interconnection Customer's control house and PPL EU's Harwood Substation.

The SCADA phone line will go to one of our Service centers, to be determined during the Facility study. The Interconnection Customer should secure the necessary phone lines as soon as possible.

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

Note that PPL EU will evaluate the need for fiber based communication in lieu of telephone line communication as telephone lines are being phased out. PPL EU may specify fiber based communication at the Facilities Study stage or at a future point in time. If PPL EU needs to upgrade to fiber-based relaying in the future, PPL EU will be responsible for the replacement cost.

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

Isolation Breaker Requirement at the Interconnection Customer's Substation

It is assumed that the customer will 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.

Z2-009 Generator Harmonic and Flicker Requirements

On the PPL EU 69 kV system, the total harmonic distortion to the fundamental voltage wave from a single customer is limited to 1.5% of nominal. In addition, no individual harmonic component can exceed 1.0% of the fundamental system voltage.

If PPL EU discovers that objectionable harmonics in excess of the stated limits are being injected into the system from Z2-009's equipment, the Queue Z2-009 Interconnection Customer will be responsible for taking corrective measures to mitigate harmonic currents.

Concerning voltage flicker, the Z2-009 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 Z2-009 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.

Z2-009 Inverter Regulation or Reactive Supply Requirements

As specified in Interconnection Service Agreement, Appendix 2, and Section 4.7.1.1 of the PJM OATT (Open Access Transmission Tariff), the Z2-009 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 to 0.95 lagging."

This indicates that the interconnection customer must maintain a composite power factor at the point of interconnection in between .95 leading or .95 lagging. If this capability cannot be met, the Z2-009 Project must provide a STATCOM or SVC device at its substation. A power factor (MW/MVAR) schedule will be provided in the Facilities Study stage.

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

PPL EU SCADA Equipment Requirements

PPL EU will require 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 status monitoring of the POC isolating circuit breaker. In addition to that, monitoring of other abnormal conditions at developer's plant will be provided where deemed necessary. This connection will be a 4-wire dedicated FDDA-type phone line. PPL EU will provide detailed specifications and design drawings for this equipment.

Revenue Metering Equipment Installation at the Point of Interconnection

Installation of revenue grade Bi-directional Metering Equipment will be required at the Queue Z2-009 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 equipment should be housed in a control cabinet or similar enclosure and must be accessible to PPL EU metering personnel.

Other Issues Impacting the Interconnection Customer

Alternate Outlet for Generation Operation during PPL EU Maintenance

No alternate outlet for the generation was requested by the Z2-009 developer. As such, Z2-009 will not be able to generate power during PPL EU line maintenance/outages.

Maintenance Considerations:

The Queue Z2-009 facility will not be able to generate into the PPL EU network during maintenance on the new 69 kV generator supply line or the Harwood-East Hazelton 69 kV line. PPL EU on-going annual and long-term planned maintenance of these circuits will require PPL EU to remove each circuit from operation one (1) time every four (4) years, for an outage period of approximately two (2) weeks. The actual duration may be shorter. During maintenance periods, the circuit may or may not be returned to service during the evening hours. That decision depends on the type of work being performed. Unexpected and unplanned maintenance outages are not included in the one-in-four number and duration time. Annual inspections that uncover damaged poles, conductors, or hardware, which require immediate repair, are scheduled as soon as practicable. These types of unplanned outages may last up to 16 hours.

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 Z2-009 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.

PPL EU phase rotation at 69 kV

PPL EU 69kV phase rotation in this region is CBA and will require connection of POC transformer high side bushings in a certain way. Please refer to the below mentioned POC document for phase rotation and transformer connection requirements.

POC Requirements:

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

Future Conversion of line to 138 kV from 69 kV

PPL EU presently has no plans to convert this 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 will not be required because the tap will be designed for 69 kV.

Intertie 69-34.5 kV Transformer Turns Ratio

PPL EU typically procures the transformers with the following high side (69 kV) taps:

70.6 kV, 68.8 kV, 67.0 kV, 65.2 kV, 63.4 kV with nominal midpoint voltage is 67 kV, this provides a range of 5% above (in two 2.5% steps) and 5% below (in two 2.5% steps) to the midpoint range of 67 kV. The PPL 69 kV system is operated at around 67.9 kV at the PPL EU Harwood substation.

Network Impacts

The Queue Project Z2-009 was studied as a 67.5 MW (Capacity 8.5 MW) injection as a tap of the Harwood – East Hazelton #2 69 kV line in the PPL area. Project Z2-009 was evaluated for compliance with applicable reliability planning criteria (PJM, NERC, NERC Regional Reliability Councils, and Transmission Owners). A Summer Peak 2018 case was used for the analysis. Project Z2-009 was studied with a commercial probability of 100%. Potential network impacts were as follows:

Contingency Descriptions

The following contingencies resulted in overloads:

Contingency Name	Description
PJM69	CONTINGENCY 'PJM69' DISCONNECT BRANCH FROM BUS 200021 TO BUS 200009 CKT 1 /* SUNBURY JUNIATA 500 500 DISCONNECT BRANCH FROM BUS 200021 TO BUS 200022 CKT 2 /* SUNBURY SUSQHANA 500 500 / CKT 1 -> 2 DISCONNECT BRANCH FROM BUS 200021 TO BUS 208109 CKT 24 /* SUNBURY SUNBURY 500 230 END

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)

See Attachment 2.

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.

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.

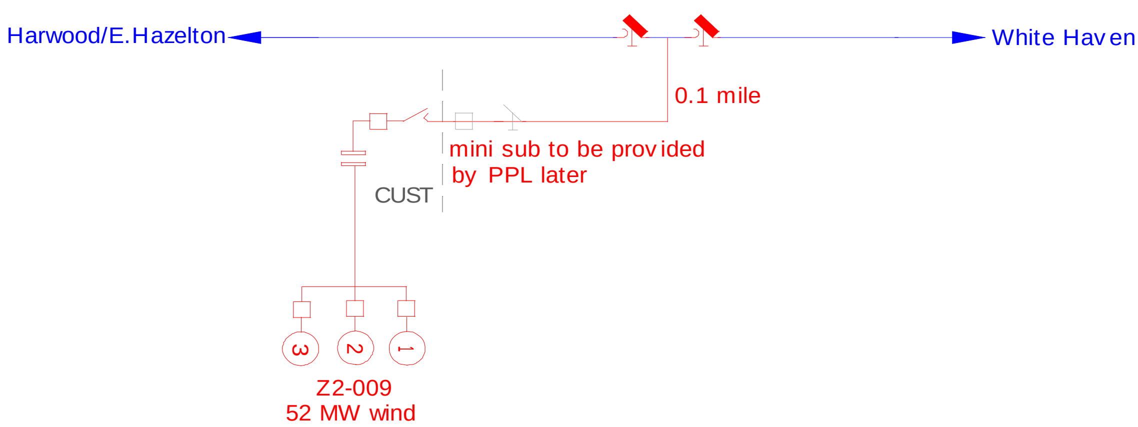
Potential Congestion due to Local Energy Deliverability

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.

	Contingency		Affected		Bus			Power	Loading %		Rating		MW	
#	Type	Name	Area	Facility Description	From	To	Circuit	Flow	Initial	Final	Type	MVA	Contribution	Ref
1	N-1	PJM69	PPL	SUSQHANA 500/230 kV transformer	208116	200022	1	AC	111.222	112.78	Er	1165	21.46	

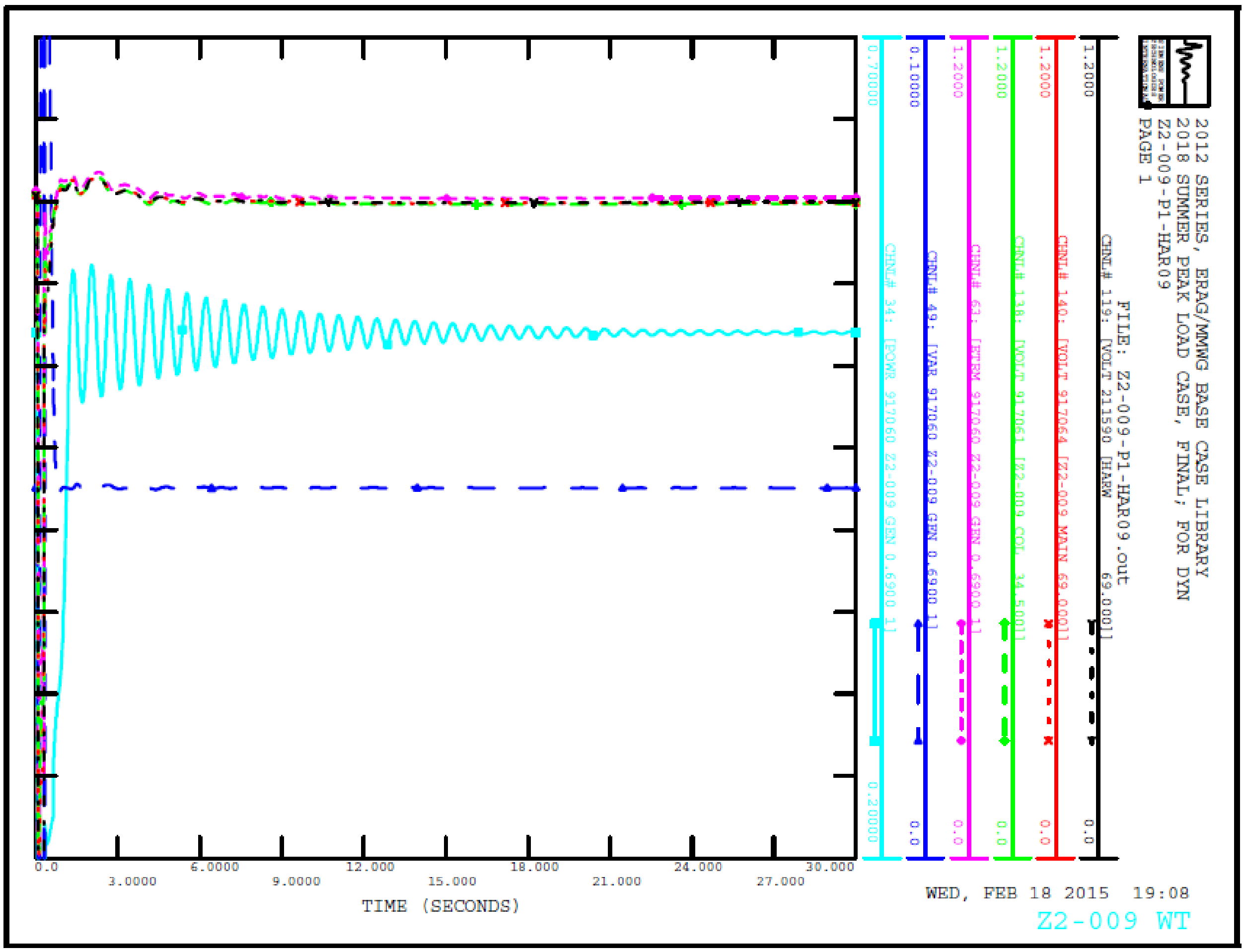
Attachment 1. Single Line Diagram



Attachment 2. Preliminary Stability Analysis

Note on the analysis:

The contingencies showed some prolonged power oscillations that decay over about 30 seconds (See plot below). Additional test were conducted to determine the cause of these oscillations and it was concluded that the oscillations are not related to the POI but are due to machine dynamic models controls. In conclusion, a further study will be required once another model is available but at this time no mitigation is required.



Executive Summary

PJM Queue project Z2-009 is a request for a 52.0 MW MFO injection to Harwood – East Hazelton 69 kV circuit # 2 of PPL 69 kV transmission system. Z2-009 project consists 26 Vestas 110 2.2 MW Wind Turbines.

This study is based on the RTEP 2018 summer peak load case and modified to include applicable queue projects. PJM queue project Z2-009 was dispatched at a maximum power transfer of 52.0 MW total and POI voltage of 66.8 kV, consistent with the default generator reference voltage specified in PJM Manual 03 Transmission Operations Section 3.3.3 for generator connections to the PJM 69.0 kV system.

Z2-009 was tested for compliance with NERC, PJM and other applicable criteria. 66 contingencies were studied, each with a 15 second simulation time period.

Based on the contingencies tested, Z2-009 meets criteria for all the contingencies tested.

Note: The contingencies results show some prolonged power oscillations that clearly decay over about 30 seconds. The impact of connection point on these oscillations were further investigated by moving the POI at 69 kV Harwood and 230 kV Harwood TS and tested 3phase fault on Harwood 69/230 kV TR4. The same type of oscillations were observed in all these investigations and testing. The same contingencies also were tested using un-stressed case with same results. It was concluded that the oscillations are not related to the POI but are due to machine dynamic models controls.

A 3 phase fault on 69/230 kV Harwood TR4 using stressed case and simulation time of 30 seconds run time showed all oscillations damped out completely. A further study will be required once another model is available but at this time no mitigation is required.

Description

This study evaluates the stability and dynamics for PJM queue project Z2-009 that is a connection at Harwood 69 kV substation in the PPL territory via Harwood – East Hazelton 69 kV circuit 2. The Z2-009 project is a wind turbine facility unit made up of 26 Vestas 110, 2.0 MW wind turbines. The wind turbines facility is modeled at 52.0 MW gross output. For this stability study, the Z2-009 project was studied as a total net injection of 51.0 MW into the 69.0 kV transmission system.

Criteria

The stability study for Z2-009 was performed on a RTEP 2018 Summer Peak load case for normal operating conditions, and modified to include applicable queue projects. 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-001faults include:

4. Three-phase (3ph) fault with normal clearing (Category P1)
5. Single-line-to-ground (slg) with delayed clearing as a result of breaker failure (Category P4)
6. Single-line-to-ground (slg) with delayed clearing as a result of protection failure (Category P5)
7. Single-line-to-ground (slg) with normal clearing for common structure (Category P7)

Note: For generator interconnection studies, Category P2, P3 and P6 faults will be studied on an as needed basis.

Other applicable criteria tested include:

1. TO specific criteria
2. Other criteria

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 to 8 buses from the generator(s) under study are dispatched at their maximum power output and set at unity power factor at the high side of the generator step up transformer. Alternatively, generators can be adjusted to hold scheduled voltages.

Specific dispatch conditions at the generator terminals for the Z2-009 generator, as obtained in the power flow solution, are illustrated below:

	26 Vestas 110 2.0 MW Wind Turbines
Gross power output (MW)	52.0
Reactive power output (MVARS)	4.5
Auxiliary Load (MW/MVARS)	0.5, 0.7
Station Service Load (MW/MVARS)	
Net real power injection (MW)	51.0
Voltage at the POI (P.U.)	0.969

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 32.0, the 2018 case with a Summer Peak 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.

LVRT: For the cases studied, the queue project rides through the faults shown in Appendix A thus meeting the LVRT test specified in FERC order 661 and 661A.

Note: The contingencies results show some prolonged power oscillations that clearly decay over about 30 seconds. The impact of connection point on these oscillations were further investigated by moving the POI at 69 kV Harwood and 230 kV Harwood TS and tested 3phase fault on Harwood 69/230 kV TR4. The same type of oscillations were observed in all these investigations and testing. The same contingencies also were tested using un-stressed case with same results. It was concluded that the oscillations are not related to the POI but are due to machine dynamic models controls.

A 3 phase fault on 69/230 kV Harwood TR4 using stressed case and simulation time of 30 seconds run time showed all oscillations damped out completely. A further study will be required once another model is available but at this time no mitigation is required.

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 Z2-009.

Mitigations:

None required.

Recommendations:

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

No.	Contingency ID	Type of Fault	Clearing time (cycles)		Results
			Normal	Delayed	
TPL 001-4_P1					
1	Z2-009-P1-HAR01	3ph fault on Harwood - Hum b#1 69 kV	12.0	N/A	Stable
2	Z2-009-P1-HAR02	3ph fault on Harwood - Hum b#2 69 kV	12.0	N/A	Stable
3	Z2-009-P1-HAR03	3ph fault on Harwood – Valmont #2 69 kV	12.0	N/A	Stable
4	Z2-009-P1-HAR04	3ph fault on Harwood – Berwick 69 kV	12.0	N/A	Stable
5	Z2-009-P1-HAR05	3ph fault on Harwood – Valmont #1 69 kV	12.0	N/A	Stable
6	Z2-009-P1-HAR06	3ph fault Harwood – JENK 69 kV	12.0	N/A	Stable
7	Z2-009-P1-HAR07	3ph fault Harwood 69/230 kV TR5	12.0	N/A	Stable
8	Z2-009-P1-HAR08	3ph fault Harwood 69/230 kV TR6	12.0	N/A	Stable
9	Z2-009-P1-HAR09	3ph fault Harwood 69/230 kV TR4	12.0	N/A	Stable
10	Z2-009-P1-HAR10	3 ph fault on Harwood – Susquehanna 230 kV ckt 1	10.0	N/A	Stable
11	Z2-009-P1-HAR11	3 ph fault on Harwood – Palmerton 230 kV	10.0	N/A	Stable
12	Z2-009-P1-HAR12	3 ph fault on Harwood – Susquehanna 230 kV ckt 2	10.0	N/A	Stable
13	Z2-009-P1-HAR13	3 ph fault on Harwood – Siiegfried 230 kV	10.0	N/A	Stable
14	Z2-009-P1-HAR14	3 ph fault on Mountain 69/230 kV TR	12.0	N/A	Stable
15	Z2-009-P1-HAR01	3ph fault on Harwood – Hazelton East#1 69 kV	12.0	N/A	Stable
TPL 001-4_P4					
16	Z2-026-NTemp-P4-01	SLG fault on Harwood 69/230 kV TR5, SB @ Harwood 69 kV, Loss of Harwood – Valmont #2 69 kV + Harwood - Hum b#2 69 kV + on Harwood – Hazelton East#1 69 kV	12.0	60.0	Stable
17	Z2-026-NTemp-P4-02	SLG fault on Harwood 69/230 kV TR6, SB @ Harwood 69 kV, Loss of Harwood - Hum b#1 69 kV, Harwood Yard Span	12.0	60.0	Stable
18	Z2-026-NTemp-P4-03	SLG fault on Harwood 69/230 kV TR4, SB @ Harwood 69 kV, Loss of Harwood S bus	12.0	60.0	Stable
19	Z2-026-NTemp-P4-04	SLG fault on Harwood – Valmont #1 69 kV, SB @ Harwood 69 kV, Loss of Harwood Yard Span	12.0	60.0	Stable
20	Z2-026-NTemp-P4-05	SLG fault on Harwood – JENK1 69 kV, SB @ Harwood 69 kV, Loss of Harwood - Hum b#2 69 kV	12.0	60.0	Stable
21	Z2-026-NTemp-P4-06	SLG fault on Harwood - Hum b#2 69 kV, SB @ Harwood 69 kV, Loss of Harwood – JENK1 69 kV	12.0	60.0	Stable
22	Z2-026-NTemp-P4-07	SLG fault on Harwood – Valmont #1 69 kV, SB @ Harwood 69 kV, Loss of Harwood Yard Span	12.0	60.0	Stable

No.	Contingency ID	Type of Fault	Clearing time (cycles)		Results
			Normal	Delayed	
22	Z2-026-NTemp-P4-08	SLG fault on Harwood - Berwick 69 kV, SB @ Harwood 69 kV, Loss of Harwood 69/230 kV TR5 + Harwood – Valmont #2 69 kV + Harwood – Hazelton East#1 69 kV	12.0	60.0	Stable
24	Z2-026-NTemp-P4-09	SLG fault on Harwood 230/69 kV TR5 + Harwood – Susquehanna 230 kV ckt 1, SB @ Harwood 230 kV, Loss of Harwood – Siiegfried 230 kV	8.0	17.0	Stable
25	Z2-026-NTemp-P4-10	SLG fault on Harwood – Siiegfried 230 kV, SB @ Harwood 230 kV, Loss of Harwood 230/69 kV TR5 + Harwood – Susquehanna 230 kV ckt 1	8.0	17.0	Stable
26	Z2-026-NTemp-P4-11	SLG fault on Harwood 230/69 kV TR4 + Harwood – Susquehanna 230 kV ckt 2, SB @ Harwood 230 kV, Loss of Harwood – Siiegfried 230 kV	8.0	17.0	Stable
27	Z2-026-NTemp-P4-12	SLG fault on Harwood – Susquehanna 230 kV ckt 1 + Harwood 230/69 kV TR5, SB @ Harwood 230 kV, Loss of Harwood 230/69 kV Tr 6 + Harwood – Palmerton 230 kV	8.0	17.0	Stable
28	Z2-026-NTemp-P4-13	SLG fault on Harwood 230/69 kV TR 6 + Harwood – Palmerton 230 kV, SB @ Harwood 230 kV, Loss of Harwood 230/69 kV TR4 + Harwood – Susquehanna 230 kV ckt 2	8.0	17.0	Stable
29	Z2-026-NTemp-P4-14	SLG fault on Harwood 230/69 kV Tr 6 + Harwood – Palmerton 230 kV, SB @ Harwood 230 kV, Loss of Harwood 230/69 kV TR5 + Harwood – Susquehanna 230 kV ckt 1	17.0		Stable

Appendix B: Project Model

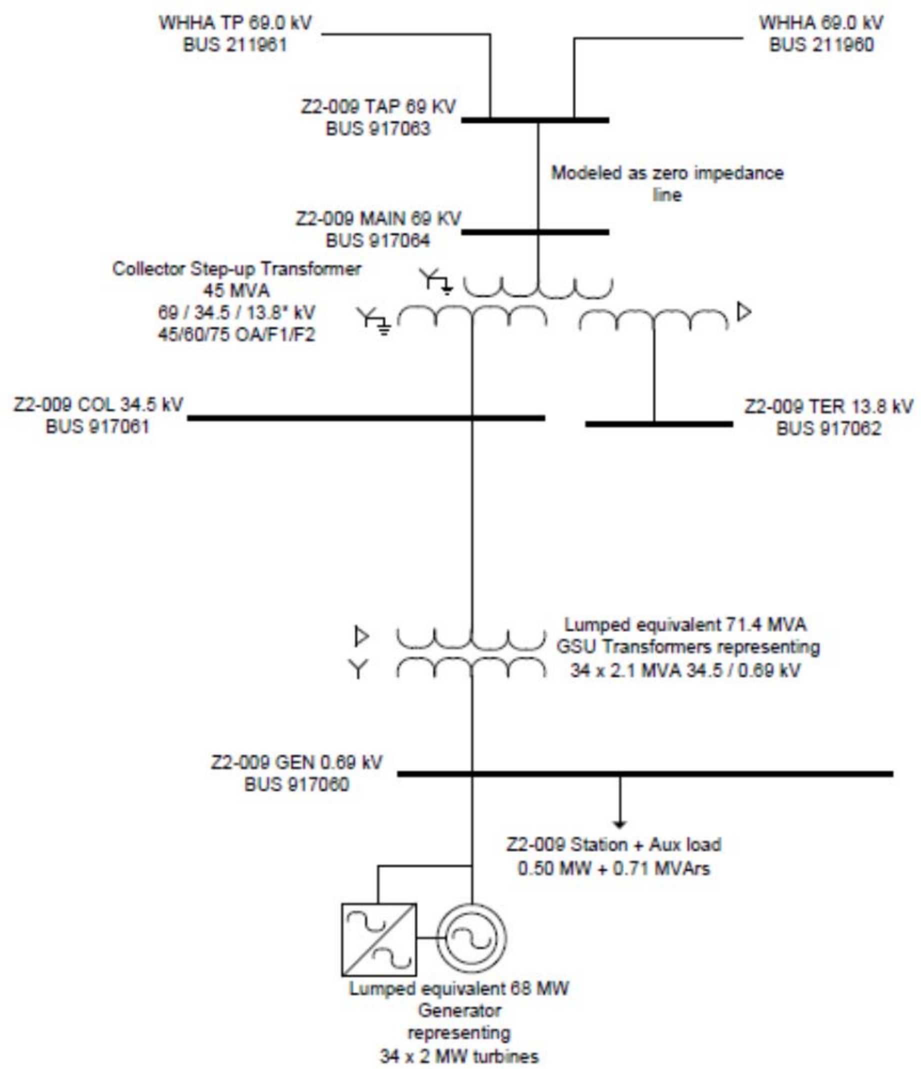


Figure 1: Z2-009 Plant Model

Figure B-1: PJM Z2-009 modeling details