MARYLAND PUBLIC SERVICE COMMISSION
OFFSHORE WIND ANALYSES AND REVIEW II

SECTION 2.3.1

Generation Interconnection System Impact Study Report

Prepared for

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TABLE OF CONTENTS

Maryland PSC Offshore Wind Analyses and Review II – 2.3.1

System Impact Study Report

I. Preface

On October 18, 2019, the Maryland Public Service Commission ("Commission") issued a Request for Proposal ("RFP")[1] in compliance with the Clean Energy Jobs Act, Senate Bill 516.[2] The Act required the Commission to provide certain additional application periods for consideration of Round 2 offshore wind projects and to establish certain criteria for the Commission to consider with respect to approval of an application for a Round 2 offshore wind project. The Commission has engaged two consultants for assistance in the following two categories: (1) estimating the need for transmission upgrades and associated costs (RFP Section 2.3.1); and (2) evaluating potential applications for proposed offshore wind projects (RFP Section 2.3.2),

This report focuses solely on the scope of Section 2.3.1 of the RFP, that is assessing the need and costs of transmission upgrades that could be used by applicants in the Round 2 application processes. The purpose of this assessment was to identify any Direct and Non-Direct Connection Network Upgrades as well as Attachment Facilities to accommodate the

[1] Offshore Wind Analyses and Application Review II, PSC #07.15.19, State of Maryland, Public Service Commission.

[2] Senate Bill 516, Md. Clean Energy Jobs Act passed during the 2019 Session of the Maryland General Assembly. The Act includes certain goals and mandates including consideration of Round 2 offshore wind projects. "Round 2 Offshore Wind Project" means a Qualified Offshore Wind Project that: (1) is not less than 10 miles off the coast of the State; and (2) the Commission approves under § 7–704.1 of this subtitle on or after July 1, 2017.

The Act, subsequently codified in the Public Utilities Article ("PUA"), directed the Commission to contract for the services of independent consultants and experts. *See Public Utilities Article (PUA) § 7-704.1(D)(2).*

interconnection of a Qualified Offshore Wind Project(s) [3] and to provide cost estimates. Section 2.3.1 states that the Qualified Offshore Wind Project will be required to secure Capacity Resource status[4], and will be located on the outer continental shelf of the Atlantic Ocean between 10 to 80 miles off the coast of Maryland. The Qualified Offshore Wind Project must be interconnected to the PJM Interconnection system at a point located on the Delmarva Peninsula.

The transmission assessment was performed to identify attachment facilities and network upgrades to interconnect potential Maryland offshore wind ("OSW") project(s) to the PJM grid on the Delmarva Peninsula. Specifically, system impact analyses were conducted for interconnecting a potential offshore wind generation connecting at a point on the Delmarva Peninsula. The analyses were conducted for: (1) a potential OSW project with a 400 megawatts ("MW") nameplate rating and (2) a potential OSW project with an 800 MW nameplate rating. The estimated costs associated with any network upgrades are made available herein on behalf of the Commission for use by potential applicants in the submission of a proposed offshore wind project application.

The Maryland OSW system impact study process mirrored the PJM generation interconnection study procedures as described in PJM Manuals, specifically:

- Manual 14A - Generation and Transmission Interconnection Process; and

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[3] "Qualified Offshore Wind Project" is defined by the authorizing statute, PUA § 7-701 (k), as follows: "Qualified offshore wind project" means a wind turbine electricity generation facility, including the associated transmission–related interconnection facilities and equipment, that: (1) is located on the outer continental shelf of the Atlantic Ocean in an area that the United States Department of the Interior designates for leasing after coordination and consultation with the State in accordance with § 388(a) of the Energy Policy Act of 2005; and (2) interconnects to the PJM Interconnection grid at a point located on the Delmarva Peninsula. *See PUA §7-701.*

[4] "Capacity Resource status is based on providing sufficient transmission capability to ensure deliverability of generator output to aggregate network load and to satisfy various contingency criteria established by the particular regional reliability council (e.g. ReliabilityFirst or SERC) in which the generator is located." *See PJM Manual 14A. Also See PJM Governing Documents and Manuals.*

- Manual 14B - PJM Region Transmission Planning Process.

In addition, the study utilized the most current PJM base case (2019 Queue AF1 – Generation Base Case)[5] for generation interconnection. Power flow analysis was performed using Siemens PTI PSS/E program and short circuit analysis was performed using ASPEN One-Liner program. Stemming from these analyses, this study identifies the network impacts and upgrades, along with associated estimated costs, to connect potential offshore wind projects at a point on the Delmarva Peninsula. The planning-level estimates of network upgrade costs included in this report are based on PJM and other industry information available at the time of the study.

In accordance with PJM requirements, an interconnection requester will have the responsibility of the necessary attachment facility costs and network upgrade costs. The network upgrades costs are "but for" costs for facility additions or upgrades to existing facilities that are needed to maintain the reliability of the PJM system. Cost responsibility for the various network upgrades discussed in this report was determined in accordance with the PJM Manual 14A.

This system impact study report represents the Commission's estimated cost of transmission upgrades associated with two increments of capacity for a potential MD OSW project. In accordance with Commission regulations, an application shall include a proposed offshore wind renewable energy credit ("OREC") price schedule for the proposed offshore wind project that consists of either a one-part OREC price or a two-part OREC price.[6] In submitting a two-part OREC price, the first component is expressed as a firm price while the second price component is subject to a true-up based upon any change between

[5] Per PJM, AF1 was the most recent base cases available for conducting AC power flow analysis at the start of this study. AF2 base cases were only available for DC power flows studies used in the feasibility analyses phase for a cursory review of network impacts.

[6] *See* COMAR 20.61.06.02(M)(1).

the Commission's estimated cost of transmission upgrades and PJM's actual upgrade costs as specified in the executed Interconnection Service Agreement,[7] for a total OREC price up to and not exceeding $190 per megawatt hour (levelized in 2012 dollars).[8]

[7] The network upgrade estimates represented in this report are point in time estimates. A future study, most importantly, a PJM Queue Process study for a proposed or qualified MD OSW project expected to be conducted at a future date could produce different results due to changes in generation retirement and/or changes in the status of prior queue projects (e.g., project withdrawals).

[8] The true-up is also subject to the projected net rate impact caps for residential and nonresidential customers, as described in PUA § 7-704.1(e)(1)(iii).

II. General

For purposes of this study, the location of the MD OSW project(s) is expected to be approximately 20 miles offshore in the Atlantic Ocean. The interconnection analyses were performed for two project sizes: 400 MW and 800 MW nameplate ratings.

Based on current PJM rules, Capacity Interconnection Rights (CIRs) for wind and solar resources are based on the respective summer peak hour capacity factor of each resource.[9] The capacity value for an intermittent capacity resource, such as offshore wind, represents that amount of generating capacity that can reliably be contributed during summer peak hours and which can be offered as unforced capacity (UCAP) into PJM's capacity markets. A 30% capacity factor was applied to calculate the resulting capacity values for the MD OSW projects: 120 MWC and 240 MWC, respectively.

Currently, PJM's effective class average capacity factor based on onshore wind resources is 14.7% in mountainous terrain and 17.6% in open flat terrain[10] [11]. Offshore wind resources and other wind resources located in other than these two locations can request an

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[9] The initial CIR is typically granted with the execution of an Interconnection Service Agreement (ISA) after completion of all applicable interconnection studies and identification of network upgrades that are necessary to ensure deliverability of the generation resources during peak hours. CIRs are retained when a wind or solar unit's highest summer capacity factor of the most recent three summer periods meets or exceeds the capacity factor associated with its CIRs. *See PJM Manual 21, Rules and Procedures for Determination of Generating Capability, §1.1.7.*

[10] In PJM, the determination of a capacity factor for an intermittent resource is based on historical operating data and/or the Class Average Capacity Factors (CACF). The capacity factor for mature resources, defined by PJM as resources with three or more years of historical operational data, is determined by calculating the mean of the single year capacity factors for the three summers prior to the delivery year. CACF is used only in the calculations of capacity values for immature intermittent capacity resources. PJM periodically updates CACFs based upon review of operating data for similar units and/or engineering studies for future installations. *See PJM Manual 21, Appendix B.*

[11] See "Class Average Capacity Factors Wind and Solar Resources", PJM, June 1, 2017.

alternative capacity factors for planned facilities with proper documentation. Offshore wind developer(s) would have to meet PJM regulations if it plans to undertake the alternative class average capacity factor process.[12] Documentation for justifying an alternative capacity factor could include manufacturer specifications, resource diagnostics, and engineering analysis supporting the ability to reach increased production levels. While there are currently no offshore wind resources operating within the PJM footprint, 25-30% capacity factors are potentially achievable for offshore wind resources.[13] [14]

PJM is currently considering a new method for determining capacity values for intermittent resources based on an effective load carrying capability (ELCC) approach.[15] This approach is intended to capture the interaction of intermittent generation and load especially with a changing resource mix and integration of significantly higher penetration of intermittent resources into the grid.

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[12] The study assumes that considerations of alternative capacity factor would include an evaluation of expected benefits (i.e., revenues) versus expected costs (i.e., costs/penalties).

[13] Based on over 25 offshore wind projects that are active in the PJM queue process, the capacity factors range between 18-30% with an average value of 25% and a median of 27%.
Also See NY ISO Installed Capacity Manual (Manual 4) issued June 2020 in which unforced capacity percentage for offshore wind during the summer is listed as 38%.

[14] *The Potential Impact of Offshore Wind Energy on a Future Power System in the U.S. Northeast, NREL/TP-5000-74191, January 2020.* < https://www.nrel.gov/wind/publications.html/pdfs/74191.pdf>; 2019 PJM State of the Market Report, Section 8. <http://www.monitoringanalytics.com/reports/PJM_State_of_the_Market/2019/2019-som-pjm-sec8.pdf>; 2018 Renewable Energy Grid Integration Data Book, DOE-EERE, <https://www.energy.gov/eere/analysis/downloads/2018-renewable-energy-grid-integration-data-book>

[15] PJM. Agenda. Capacity Capability Senior Task Force (CCSTF) (August 7, 2020). https://www.pjm.com/committees-and-groups/task-forces/ccstf.aspx

III. Point of Interconnection

A number of potential interconnection sites/substations, that is, Delmarva Power & Light Company ("DPL") substations in the Lower Peninsula, were considered as a potential point of interconnection for the MD OSW project. There are limited number of interconnection points on the current Delmarva transmission system that are suitable for interconnecting 400-800 MW size generation. The analysis used a high-level qualitative comparison of the options based on electrical, constructability and economic factors. A number of these substations along the Atlantic Coast were deemed unacceptable for the proposed level of generation injection.[16] The DPL Indian River 230kV Substation offered the best option for a point of interconnection.[17]

IV. Connection Requirements

A. Attachment Facilities

Indian River substation provides a viable 230kV interconnection to potential OSW projects with closer proximity to the coast of Maryland. Accordingly, this aspect could result in the need of a major substation expansion to accommodate multiple OSW interconnections. The study assumes the OSW project will be interconnected at the Indian River 230 kV North substation. The interconnection will require expanding the substation located on the west side of the transmission right-of-way corridor

[16] The primary reasons for this finding include physical space limitation to accommodate a 138 kV or a 230kV interconnection, expected level of local reinforcements and limited power transfer capability for the proposed level of generation injection.

[17] The interconnection customer entering the PJM Queue process at a future date may designate an alternative point of interconnection after consultation with the MD PSC for the qualified MD OSW project. Per the Commission's regulations, any material change to the qualified offshore wind project shall be reported to the Commission within 30 days of the date of that decision.

(with lines going north of Indian River) to establish a 230kV terminal on a new bay. While any OSW generation will likely approach the substation from the east, requiring a crossing of the transmission right-of-way corridor to the north to connect to the section of the 230 kV substation with planned expansions.

The substation expansion and reinforcement to interconnect the potential OSW project will include the following:

- (2) 245kV breakers (50kA, 3000A)
- (5) 245KV disconnect switches
- (2) 230KV pole & flexible conductor
- (15) 230KV bus support & associated rigid bus
- 230 KV dead-end structure
- (1) 230KV CVT (set of 3)
- (3) 230KV metering unit
- (3) 230KV surge arrester
- Static masts
- Ground grid
- Fencing
- Cable & Conduit
- Cable trench
- Revenue metering, relay/control panel, DC panel, fiber communication

In addition, a 230kV line which will span approximately 500 feet from the Delmarva substation will include the following:

- Tangent structures
- Dead-end structures
- Conductor & OPGW

See Attachment 1A and 1B for simplified diagrams and illustration of the interconnection facilities.

B. Customer Interconnection Facilities – Generation Side

The generator will be responsible for the construction of all generating station facilities on the generator's side of the point of interconnection. Protective relaying and metering design and installation must comply with Delmarva's applicable standards. The interconnection generator 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.

V. Network Impacts

The analysis used a 2023 PJM Base Case. For the generation deliverability analyses the case included all active PJM queue projects up to AF1 queue. The analysis was initially conducted with all of these queue projects using the 2023 PJM Base Case. The analyses were updated to reflect queue withdrawals through July 10, 2020.

Any generator requesting interconnection to the PJM system must be deliverable in order to be a PJM capacity resource. The generation deliverability test determines the ability of an electrical area to export generation sources to the remainder of the PJM system. This test is applied to ensure that generation is not bottled from a reliability perspective and that there is sufficient transmission capability from the generation resources to deliver energy to the load. The method tests the project at the MW capacity level for single contingency conditions and at the full output MW level for common mode outages. These common mode outages include double circuit tower line, line with failed breaker and bus fault contingencies. If violations are determined under the single or common mode contingencies, the interconnection generator is responsible for the costs associated with network enhancement to mitigate the overloading conditions. This section provides the results of the single contingencies. Common mode outage results are discussed under the multiple facility contingency section.

The following summarize the results of the generation deliverability analyses.

A. Generator Deliverability

Single contingency results for the capacity portion of the interconnection:

There were no single contingency violations for the capacity portion (120 MW & 240 MW) of the MD OSW project.[18]

B. Multiple Facility Contingency

Double circuit tower line, line with failed breaker (Line-FB) and bus fault contingencies for the full output of the interconnection:

1. MD OSW at 400 MW:

There was one newly identified facility overload at this level.

- Edgemoor - Linwood 230 kV: The post-contingency flow of this facility was above its emergency rating for a Line-FB contingency of DP16.

2. MD OSW at 800 MW:

There were three 230kV facilities that were overloaded at the 800MW level.

- Edgemoor - Linwood 230 kV: The post-contingency flow of this facility was above its emergency rating for a Line-FB contingency of DP16.

[18] Note that there were no reliability violations for the capacity portion of the analysis at the assumed 30% capacity factor.

- Cartanza - Silver Run 230 kV: The post-contingency flow of this facility was above its emergency rating for a Line-FB contingency of DP 23, 24 and for a tower contingency of DBL_1N.

- Milford - Steele 230 kV: The post-contingency flow of this facility was above its emergency rating for a Line-FB contingency of DP 23. Note that the normal and emergency ratings for this facility were the same (550MVA). Similar 230 kV facilities in the area have a normal rating of 550 MVA and an emergency rating of 679 MVA. The post-contingency flow was less than 679 MVA.

C. Contributions to Previously Identified Overloads

The MD OSW project contributes to the following contingency overload, i.e. "network impacts," identified for earlier generation or transmission interconnection projects in the PJM Queue:

There were seven overloaded facilities that were previously identified at both the 400 MW and 800 MW levels:

- Clay - Linwood 230 kV facility for a breaker contingency of LINWO225
- Edgemoor - Clay 230 kV facility for a breaker contingency of LINWO225
- Church – Townsend 138 kV facility for a tower contingency of DBL_1N
- Townsend – Middletown Tap 138kV facility for a tower contingency of DBL_1N.
- Middletown TP – Mt. Pleasant 138 kV facility for a tower contingency of DBL-1N.
- Preston – Todd 69 kV facility for a breaker contingency of DP11.
- Preston – Tanyard 69 kV facility for a breaker contingency of DP11.

D. Short Circuit

The short circuit analysis is a critical component of the evaluation of the electrical system. Interconnection of new generation into the existing power system will increase the available short circuit current. The analysis was performed using the following methodologies:

- Calculating Short Circuit Currents per IEEE C37.010-2016.
- Breaker Interrupting Rating Calculation per IEEE C37.010-2016.

In addition to the methodologies and references above, the following references were also used to provide background information relating to the scope of this project:

- IEEE Standard C37.04-2018 – IEEE Standard Rating Structure for AC High-Voltage Circuit Breakers.
- IEEE Standard C37.06-2009 – IEEE Standard for AC High Voltage Circuit Breakers Rated on a Symmetrical Current Basis – Preferred Ratings and Related Required Capabilities for Voltages Above 1000V.
- IEEE Standard C37.10-2016 – IEEE Application Guide for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis.

The purpose of the study was to determine if the short circuit ratings of the existing breakers that are near and at Indian River Substation are exceeded with the addition of an 800 MW OSW project. No overstressed breakers were identified.[19]

[19] Because no overstressed breakers were identified at the 800 MW capacity level, an additional study at the 400 MW increment was unnecessary in order to similarly conclude that no overstressed breakers exist at the 400 MW level.

VI. System Reinforcements and Estimated Costs

A. New System Reinforcements

[Network upgrades required to mitigate reliability criteria violations, i.e. "network impacts" initially caused by the addition of this project's generation.]

Note that the 230kV loop system on the lower portion of the Peninsula was originally planned and built to accommodate generation expansion at Indian River. However, if more than 1200 MW of OSW generation development is expected to be interconnected within this area, a comprehensive transmission expansion plan may provide a more efficient solution than mitigating individual network impacts to accommodate individual projects. As Maryland and neighboring states develop their respective plans to facilitate offshore wind development, a comprehensive transmission expansion plan developed under state agreement approach or an alternative approach may result in an effective and efficient integration of large-scale offshore wind resources.

The analyses provide network upgrades to mitigate the individual network impacts identified in the power flow study.

MD OSW at 400 MW:

- The Edgemoor - Linwood 230 kV circuit is approximately eight miles and on double circuit structures with Clay - Linwood and Edgemoor - Clay 230kV circuits. Based on previous studies, the network upgrade to mitigate the Edgemoor - Linwood 230kV facility overload will require partial rebuilding, reconductoring and terminal upgrades.

MD OSW at 800 MW:

- Edgemoor - Linwood 230kV: see above.

- Cartanza - Silver Run 230kV circuit is approximately 28 miles on steel monopole structures. Reinforcements to mitigate the overloading conditions will include reconductoring the existing circuit with pole replacements and terminal upgrades.

- Milford - Steele 230kV is approximately 24 miles on H-Frame structures. The fact that the existing emergency rating is equal to the normal rating may suggest that the limiting element is a terminal equipment at either substation or a clearance limit on a section of the circuit. An emergency rating of 679 MVA would have been more than sufficient to accommodate the MD OSW project at 800 MW. Since information was not available on identifying the limiting element, the study assumed that the line would have to be completely rebuilt. Reinforcements to mitigate the overloading conditions will include reconductoring the existing circuit with pole replacements and terminal upgrades.

B. Contribution to Previously Identified System Reinforcements

[Contribution to network upgrades for previously identified system reinforcements]

All the previously identified upgrades were below $5 million resulting in $0 allocation to the MD OSW project. Withdrawals of queue projects from prior queues could change the need of these upgrades by prior queue projects and could potentially impact the cost allocation assumptions.

C. Estimated Costs

The estimated capital expenditures were derived from:

1. Planning-level estimates based on unit cost data and recent estimates.
2. Economic analysis to translate the planning-level estimates[20] into constant 2012 dollars[21] and to reflect additional cost escalation – in excess of actual and expected general inflation – (or real escalation) through the assumed completion date of construction.[22]

See Attachment 2 for a summary of estimated costs.

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[20] Planning-level costs reflect mid-2020 current dollar estimates.

[21] The estimated costs are provided in constant 2012 dollars to mirror the statutory specifications regarding a potential Commission order on Offshore Wind Renewable Energy Credits. The statutory language states, for example: "the price set in the proposed OREC price schedule does not exceed $190 per megawatt-hour in 2012 dollars." PUA § 7-704.1.

[22] Estimated real escalation was derived from the previous five-year history of nominal escalation using Mid-Atlantic region data in the *Handy-Whitman Index of Public Utility Construction Costs*, Bulletin No. 180. As a measure of inflation, the Gross Domestic Price Implicit Price Deflators ("GDP-IPD") was used. A compound average annual growth rate ("CAGR") was developed to estimate the annual rate of real escalation. The real escalation CAGR was applied to the planning-level estimates to calculate real escalation as of the in-service date for each facility. To restate the in-service date estimate into 2012 dollars, the escalated amounts were deflated using a cumulative deflation factor.

VII. Summary and Conclusion

A Qualified Offshore Wind Project will be required to secure capacity resource status located on the outer continental shelf of the Atlantic Ocean in the area designated for lease by the United States Department of Interior after coordination and consultation with the State. The area designated is between 10 to 80 miles offshore and is located off the coast of Maryland. The offshore wind project is to be interconnected to the PJM Interconnection Grid at a point located on the Delmarva Peninsula.

This report summarizes the results of a system impact study for interconnecting 400 MW to 800 MW nameplate capacity of potential offshore wind generation connecting to the Indian River 230kV substation. The purpose of the study was to identify potential interconnection facilities, network upgrades and associated cost estimates. The cost estimates may be used as a proxy by applicants when submitting an application for a proposed offshore wind project with the Maryland Commission. Designing, constructing, and operating the offshore wind farm and the interconnection of the project to the existing grid operated by the PJM Interconnection is the responsibility of the applicant(s).

A 30% capacity factor was applied to calculate the resulting capacity values: 120 MWC and 240 MWC, respectively. Evidence likely exists to support a capacity factor above PJM's currently effective class average rate of 14%-17% for wind resources. Per PJM regulations, owners/developers of immature intermittent resources are permitted to substitute an alternate class average capacity factor with suitable documentation and approval by PJM.

The analysis utilized the most current PJM base case (2023 Queue AF1 – Generation Base Case) for generation interconnection. For the generation deliverability analyses the case included all PJM queue projects with a signed Interconnection Service Agreement and/or

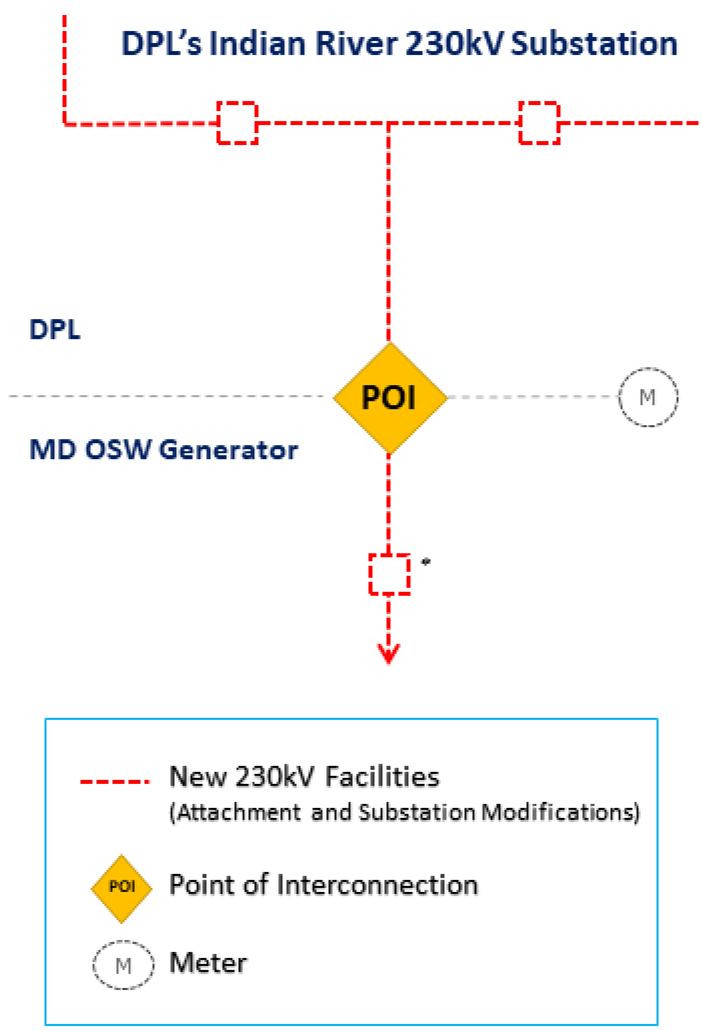
Facility Service Agreement. The analyses were updated to exclude all queue projects that withdrew from the queue process through July 10, 2020.

The results show that MD OSW at 400 MW will trigger one new network impact and MD OSW at 800 MW will trigger three new 230kV system reinforcements. The MD OSW project will have 100% allocation towards any upgrade costs stemming from the newly triggered facility overload. The MD OSW project will not contribute to any previously identified facility overloads with estimated costs below $5 million.

Estimated costs are summarized in Attachment 2. This report provides planning-level estimates of network upgrade costs based on PJM and industry information available at the time of the study. The estimated costs are provided in constant 2012 dollars to mirror the statutory specification regarding a potential Commission order on Offshore Wind Renewable Energy Credits.

ATTACHMENT 1A

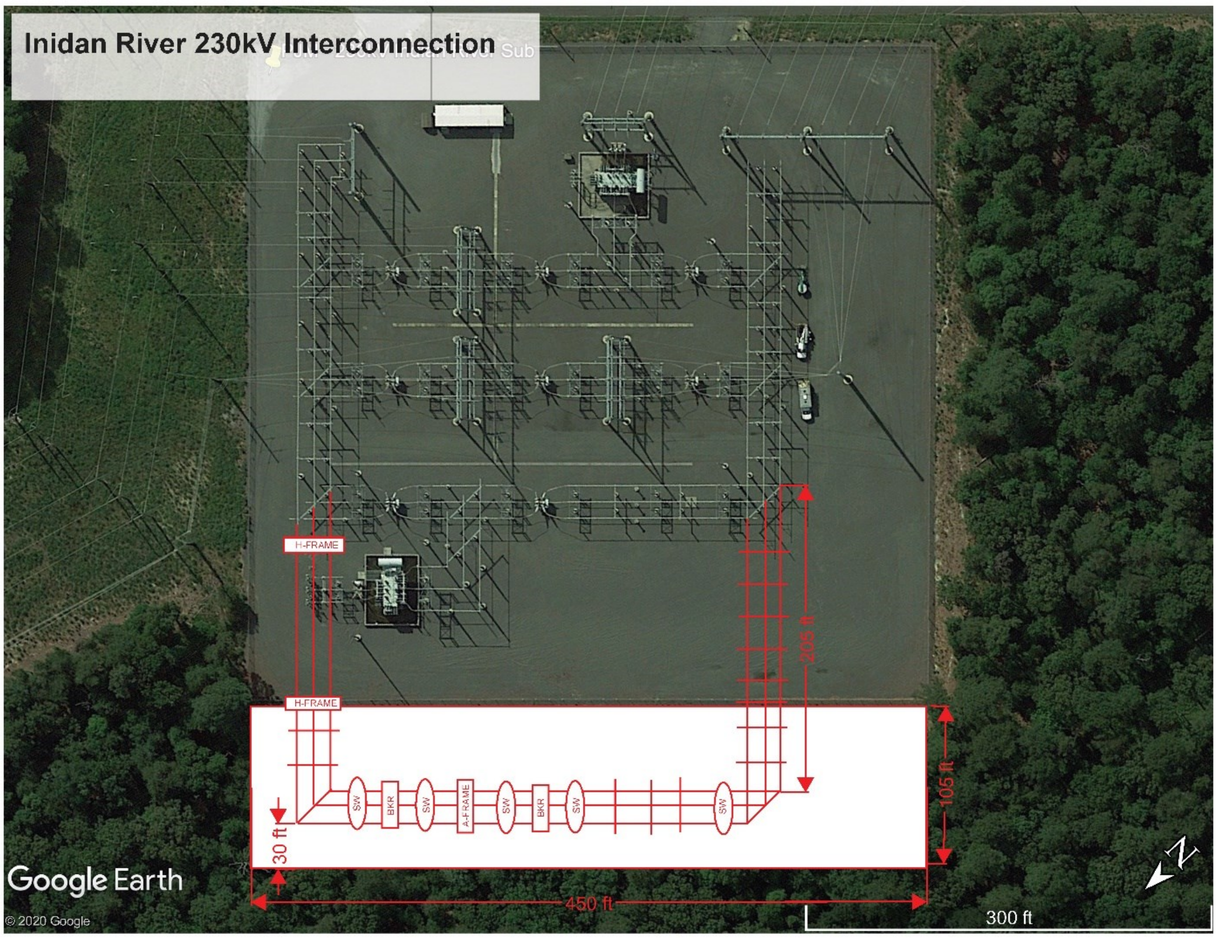
MD OSW PROJECT INTERCONNECTION FACILITIES



Per DPL's Criteria, the interconnection customer circuit breaker will be required no more than 500 feet from DPL substation.

ATTACHMENT 1B

MD OSW PROJECT – ATTACHMENT FACILITIES



ATTACHMENT 2

ESTIMATED COSTS

	MD OSW at 400 MW	MD OSW at 800 MW
	Estimated Costs ($ x 1,000)*	Estimated Costs ($ x 1,000)*
1. Interconnection Facilities		
• Substation Work: New 230kV line terminal at Indian River	$ 6,075	$ 6,075
Interconnection Facilities - TOTAL	**$ 6,075**	**$ 6,075**
2. New System Reinforcements		
• Edgemoor – Linwood 230 kV	$ 17,949	$ 17,949
• Cartanza – Silver Run 230 kV	$ 0	$ 44,264
• Milford – Steele 230 kV	$ 0	$ 37,744
SUBTOTAL	$ 17,949	$ 99,957
3. Contribution to Previously Identified System Reinforcements		
• None (Upgrades cost estimates were below $5M)	$ 0	$ 0
SUBTOTAL	**$ 0**	**$ 0**
Network Upgrades - TOTAL	**$ 17,949**	**$ 99,957**
TOTAL	**$ 24,024**	**$106,032**

* The estimated costs are provided in constant 2012 dollars to mirror the statutory specifications regarding a potential Commission order on Offshore Wind Renewable Energy Credits. The statutory language states, for example: "the price set in the proposed OREC price schedule does not exceed $190 per megawatt-hour in 2012 dollars." PUA § 7-704.1.