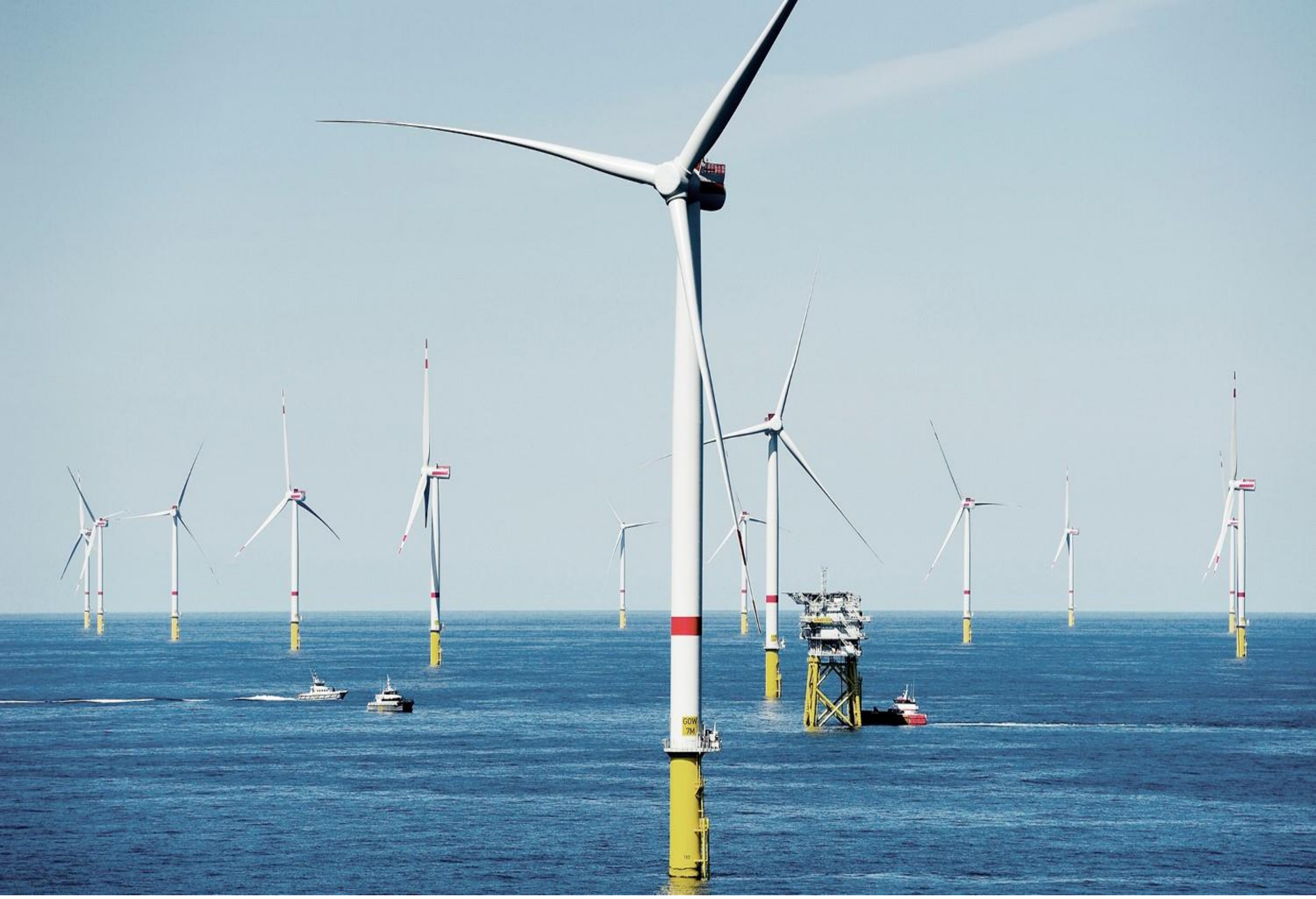

SRW01 - Feasibility Study for Wind Turbine Generator Monopile Foundations

Prepared	Themis Stergiou (THEST), Alice Ridgway Hill (ALIRH)
Checked	Alice Ridgway Hill (ALIRH), Alexander Hall (AHALL), Yiorgos Perikleous (GEOPE), Michael Francis (MICHF)
Accepted	Alexander Hall (AHALL), Miguel Pacheco Andrade (MIGPA), Sandra Sillemann (SASIL), Avi Shonberg (AVISH)
Approved	Domenico Saporito (DOMSA), Francesco Stevanato (FRAST)

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Table of Contents

1 Introduction

This feasibility study serves as part of the supplementary filing of the Sunrise Wind Offshore Wind Farm Construction and Operations Plan (COP), which is being submitted by Sunrise Wind LLC, a 50/50 joint venture between Ørsted North America Inc. and Eversource Investment LLC, to support the siting and development of the Sunrise Wind Offshore Wind Farm Project (SRW01 or project in the following). The project is being developed pursuant to the Bureau of Ocean Energy Management (BOEM) requirements for the Sunrise Wind BOEM Lease Area OCS-A-0487[1] Commercial Lease of Submerged Lands for Renewable Energy Development on the Outer Continental Shelf. The wind turbine generators (WTGs) will be located in Federal waters approximately 30 miles (24 km) east of Long Island's Montauk Point.

Monopiles (MP) have been proposed as the foundation solution for the project's WTGs. This report presents a feasibility study for the proposed foundations, focusing on the design and installation with particular emphasis on geotechnical aspects. The specific purpose of this report is to demonstrate technical feasibility of the project's design envelope for the WTG foundations based on site-specific data. Following detailed investigation of glauconite-rich sediments within the site and [redacted], this study has been revised to incorporate those findings.

Extensive geophysical and geotechnical surveys have been completed to inform siting and design of the project. This report relies on and utilises the geotechnical data collected during the site surveys and the subsequent interpretation, to derive the geotechnical profiles suitable for design, as presented in the Marine Site Investigation Report (MSIR), supplemented by [redacted]

[redacted]

2 Evaluation of glauconite rich sediments

Glauconitic sands are present offshore in several parts of the world, but those most relevant to recent developments in offshore wind are along the east coast of the US and to a lesser degree at some European sites (predominantly in Belgium and the Netherlands).

Glauconitic minerals are commonly deposited during periods of stratigraphic condensation within marine sediments which are generally associated with global eustatic sea level changes. Glauconite minerals typically occur as rounded aggregates or pellets and are most commonly formed slightly below the

[1] A portion of Lease Area OCS-A 0500 (Bay State Wind LLC) and the entirety of Lease Area OCS-A 0487 (formerly Deepwater Wind New England LLC) were assigned to Sunrise Wind LLC on September 3, 2020, and the two areas were merged and a revised Lease OCS-A 0487 was issued on March 15, 2021. Thus, when using the term "Lease Area" within this report, Sunrise Wind is referring to the new merged Lease Area OCS-A 0487

sediment-water interface in mildly reducing, marine mid- to outer-shelf environments during periods of slow to absent sedimentation or net erosion. Glauconitic minerals have a range of “maturities” ranging from glauconitic smectite to glauconitic mica.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3 Design of support structures

The support structures are designed to withstand hurricane, wind and wave conditions. In addition to the environmental conditions the support structures are also designed to withstand accidental loading. An MP foundation typically comprises a single steel tubular pile, consisting of several sections of rolled steel plates welded together. The upper part of the MP includes boat landing features, ladders, a crane, and other ancillary components as well as an interface connection to the WTG.

As part of the design process, it is verified that all support structures have sufficient design resistance and the required strength to withstand the design load effects during their lifetime in the following limit state calculations:

- [redacted]
- [redacted]
- [redacted]
- [redacted]

For the purpose of the feasibility studies, scour protection is conservatively assumed not to be installed for the positions, i.e., local scour or erosion of the soil will occur, and provision is made for this in the analyses.

The final foundation design specifications will be determined by the engineering design process, informed by various factors including soil conditions, environmental aspects, project economics, installation considerations and procurement. Foundations will be designed individually. Detailed information on the foundation design will be included in the Facility Design report (FDR) / Fabrication and Installation Report (FIR), to be reviewed by the Certified Verification Agent (CVA) and submitted to the Bureau of Ocean Energy Management of the Department of the Interior (BOEM) prior to construction.

3.1 Monopile design approach

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

3.2 Project design envelope

The project design envelope dimensions for the WTG foundations is summarised below.

Table 3-1. Summary of project design envelope.

Monopile	Maximum parameters
Outer diameter at seabed	12m (39ft)
Embedment depth (below seabed)	50m (164ft)
Maximum impact hammer energy	4,000kJ

3.3 Monopiles design feasibility study

A realistic, yet conservative, design was carried out for feasibility purposes to verify the project design envelope parameters. This considered appropriate load levels for the project design envelope, site conditions and the project design envelope seabed diameter and was based on the site-specific soil information included in the MSIR. The design was carried out based on the methodologies detailed in Section 3.1 for all exploratory positions (both CPTs and BHs) investigated and presented in the MSIR.

To estimate the design envelopes for the WTG positions a conservative, preliminary analysis of SRW01 was used to establish the expected geometrical bounds. Preliminary position-specific soil profiles were used along with conservative estimations for structural, scour and load inputs. [redacted]

- [redacted]
- [redacted]
- [redacted]

For the project design envelope, the maximum outer diameter of 12m is provided to allow for potential future design changes. [redacted]

[redacted]

4 Installation

For the purposes of installation feasibility, the following sections present the driveability calculation results performed for the MP foundations. Following the initial analyses results from the joint industry project analyses were used to inform predictions in glauconite-rich sediments, these are discussed in Section 4.2.

4.1 Installation of MPs [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted]

[redacted]

Table 4-1. Driveability results for MP feasibility installation study.

[redacted]

4.2 [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Table 4-2. [redacted]

[redacted]

[redacted]

5 Conclusions

[redacted]

[redacted]

[redacted]

[redacted]

6 References

/1/ PISA Project (2016), *PISA Final Report*, Doc. No 2595138, Ver. No. 2450193D.

/2/ DNVGL-RP-C212, Recommended Practice, *Offshore Soil Mechanics and Geotechnical*.

/3/ ISO 19902:2007, Petroleum and natural gas industries -- Fixed steel offshore structures.

/4/ Alm, T., & Hamre, L. (1998). *Soil Model for Driveability Predictions*. Offshore Technology Conference (OTC) - Paper no. 8835. May 1998.

/5/ Alm, T., & Hamre, L. (2001). *Soil model for pile driveability predictions based on CPT interpretations*. International Conference on Soil Mechanics and Geotechnical Engineering, Volume 2, pp. 1297-1302.

/6/ Smith (1960). E. A. L. Smith. *Pile-Driving Analysis by the Wave Equation*. Journal of the Soil Mechanics and Foundation Division, proceedings paper 2574.

/7/ DS/EN ISO 19901-4:2016, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations.*

A. Monopile example load case results

[redacted]

[redacted]

B. Monopile geometry and location stratigraphy for installation analysis

[redacted]

C. Graphical pile driveability results

[redacted]

D. Installation feasibility summary results for all positions with glauconite

[redacted]

[redacted]

E. Monopile geometry and location stratigraphy for installation analysis – position with Glauconite

[redacted]

F. Driveability results within glauconite rich stratum

[redacted]

G. Monopile geometry and location stratigraphy for installation analysis – additional position with Glauconite C23

[redacted]

H. Driveability results within glauconite rich stratum for the additional position C23

[redacted]

Foundation Feasibility Report

EPC Projects – Transmission Solutions
Offshore: Sunrise Wind Offshore Converter Station

Document Type: Procedure

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1 Introduction

This foundation feasibility study serves as part of the supplementary filing of the Sunrise Wind Offshore Wind Farm Construction and Operations Plan (COP), which is being submitted by Sunrise Wind LLC, a 50/50 joint venture between Ørsted North America Inc. and Eversource Investment LLC, to support the siting and development of the Sunrise Wind Offshore Wind Farm Project (SRW01 or project in the following). The project is being developed pursuant to the Bureau of Ocean Energy Management (BOEM) requirements for the Sunrise Wind BOEM Lease Area OCS-A-0487[1] Commercial Lease for Renewable Energy Development on the Outer Continental Shelf. The Offshore Converter Station with Direct Current (OCS-DC) will be located Lease Area OCS-A 0487 which is in Federal waters approximately 30 miles (48 km) east of the Long Island's Montauk Point.

A piled jacket is proposed as the foundation solution for project's OCS-DC. This report presents a feasibility study for the proposed foundation, focusing on the design and installation with particular emphasis on the geotechnical aspects. The specific purpose of this report is to demonstrate technical feasibility of the project's design envelope for the OCS-DC foundation based on site-specific data.

Extensive geophysical and geotechnical surveys have been completed to inform siting and design of the project. This report relies on and utilizes the geotechnical data collected during the site surveys and the subsequent interpretation, to derive the geotechnical profiles suitable for design, as presented in the Marine Site Investigation Report (MSIR).

[redacted]

[1] A portion of Lease Area OCS-A 0500 (Bay State Wind LLC) and the entirety of Lease Area OCS-A 0487 (formerly Deepwater Wind New England LLC) were assigned to Sunrise Wind LLC on September 3, 2020, and the two areas were merged and a revised Lease OCS-A 0487 was issued on March 15, 2021. Thus, when using the term ''Lease Area'' with in this report, Sunrise Wind is referring to the new merged Lease Area OCS-A 0487.

2 Design of the OCS-DC foundations

The OCS-DC foundation structure is designed to withstand hurricane wind and wave conditions. In addition to the environmental conditions the OCS-DC foundation structure is also designed to withstand accidental loading. An OCS-DC jacket foundation is typically comprised of steel tubular piles, consisting of several sections of rolled steel plates welded together. The upper part of the piles is grout connected to the pile sleeves at the jacket legs.

As part of the design process it is verified that the OCS-DC foundation structures have sufficient design resistance and the required strength to withstand the design load effects during the lifetime in the following limit state calculations:

- [redacted]
-
-
-

The final foundation design specifications will be determined by the engineering design process, informed by various factors including soil conditions, environmental aspects, project economics, installations and procurement. Foundations will be designed individually. Detailed information on the foundation design will be included in the Facility Design Report (FDR) / Fabrication and Installation Report (FIR), to be reviewed by the Certified Verification Agent (CVA) and submitted to the Bureau of Ocean Energy Management of the Department of the Interior (BOEM) prior to construction.

2.1 OCS-DC jacket pile design approach

[redacted]

2.2 Project design envelope

The project design envelop dimensions for the OCS-DC jacket piles is summarised below.

Table 2-1 Summary of project design envelope.

Jacket pile	Maximum parameters
Pile outer diameter	4.0 m (13 ft)
Embedment depth (below seabed)	90 m (295 ft)
Maximum impact hammer energy	4,000 kJ

2.3 OCS-DC jacket pile design feasibility study

A realistic, yet conservative, design was carried out for feasibility purposes to verify the project design envelope parameters. The design was carried out based on the methodologies detailed in Section 2.1. This considered appropriate load levels for the project design envelop and site-specific soil conditions (CPTs and BHs) investigated and presented in the MSIR Ref. /1/, Ref. /2/ and Ref. /3/.

To estimate the design envelopes for the OCS-DC jacket pile preliminary analysis was used to establish the expected geometrical bounds. The analysis yielded the maximum penetration depth of 90 m (295 ft) for a diameter of 4.0 m (157 inch). The pile axial load capacity in compression and tension loading vs pile penetration depth below mudline is included in Appendix A. In Appendix A the following information is provided:

- Axial pile load capacity with pile depth below mudline, pile diameter 4.0 m (157 inch) embedment depth below mudline 90 m (295 ft) and wall thickness 70 mm (2.75 inch)

3 Installation

For the purpose of installation feasibility, the following sections present the driveability calculation results performed for OCS-DC jacket foundation piles.

3.1 Installation of OCS-DC jacket piles

To assess the installation feasibility of the jacket piles the maximum geometrical properties from the project design envelope (Table 2-1), i.e. 4.0 m maximum outer diameter and 90 m penetration below seabed were considered. This represents the most conservative scenario in terms of installation and the driveability results are presented below.

An IHC S-4000 double acting impact hammer, with a 95% maximum rated impact energy has been assumed for the studies. Table 2-1 below shows summary of hammer data used for the driveability analysis.

[redacted]

3.2 Soil resistance during driving (SRD) and driveability results

The SRD profiles are established according to the method developed by Alm and Hamre, ref. /7/. This method is based on the friction fatigue concept and has been calibrated against installations involving driving of similar piles through major layers of both dense sands and very hard clays. [redacted]

At the target penetration depth of 90 m and a pile diameter of 4.0 m, the SRD values calculated by the Alm and Hamre method are shown in Table 3-2.

[redacted]

[redacted]

4 References

/1/ Geotechnical Investigation for Sunrise OWF SRW01 - Field Operations and Preliminary Results - L-ORS-USA-0421 FLD Rev. 00 (06738581_A). Horizon Geosciences. 14/10/2020

/2/ Geotechnical Investigation for Sunrise OWF SRW01 - Laboratory and In-Situ Testing Factual Results Report - L-ORS-USA-0421 SRW01 FAC Rev. 03 (07027392_A). Horizon Geosciences. 10/05/2021

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/6/ DNVGL-RP-C212, Offshore soil mechanics and geotechnical engineering, August 2017

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/8/ Roussel, H. J. (1979) “Pile driving analysis of large diameter high capacity offshore pipe piles”, Ph. D Thesis, Department of Civil Engineering, Tulane University, March 2009

/9/ DNV SESAM. SESAM SYSTEM. User's Manuals SPLICE - Structure/pile/soil interaction analysis- Latest Edition.

/10/ Pile Dynamics Inc. (2010). GRLWEAP, ‘Wave Equation Analysis of Pile Driving.’ Procedures and Models, Version 2010.

Appendix A Pile axial load capacity in compression and tension

[redacted]

[redacted]

[redacted]