



Developing
sustainable
offshore wind
solutions

**Next generation consultancy to
the wind energy market**

Let our expertise accelerate your offshore wind investment

Since the construction of the world's first offshore wind farm in the early nineties - Vindeby in Denmark - NIRAS has been a significant player on the wind energy market.

22 GW in 25 years

For more than 25 years, NIRAS has planned, designed and constructed offshore and onshore wind farms globally: From the wind turbines you see when approaching Copenhagen Airport to today's largest offshore wind farms in Northern Europe and the Strait of Taiwan. NIRAS has been involved in projects with a total capacity of over 22 GW.

Passion for innovation

We take pride in transforming our clients' visions and challenges into competitive and sustainable solutions, and are passionate about taking the offshore industry even further. We continuously invest in developing our experts and their expertise so that they can keep pace with the rapid development of the industry and deliver the most modern and futureproof solutions. Combined with an extensive network of independent specialists, companies and local experts, we provide the full range of skills required for any wind power project.

Wide range of specialised services

NIRAS' services cover the full range of technical consultancy within the life cycle of a project in the clients' organisation or as part of well-defined scope executed at NIRAS' offices. Our experts' in-depth knowledge of the industry helps governments, developers and investors to plan, develop, design, construct, operate and decommission wind power projects of tomorrow.

Our design consultants' expertise spans from preliminary design, evaluation and assessment of hub-harbour

We value a close and trusting relationship with our clients highly and the solutions we develop are based on NIRAS' core values: we listen, we learn and we deliver.

structures and layout to detailed design. We have produced several detailed foundation designs as well as conducting geotechnical investigations and preparing technical specifications.

NIRAS' project managers work closely with our clients to help them successfully navigate the project lifecycle from strategy and planning to decommissioning. We provide in-house support, "package managers" and project development teams and can also supervise and coordinate construction and installation.

With a genuine passion for contributing to the Danish and global wind-power adventure, we wish to evolve the offshore industry with you. Do you want to take offshore wind even further in collaboration with us?

REFERENCE

COPP detailed jacket design and owner's engineering

Client: Fuhai Wind Farm Corporation
Country: Taiwan
Period: 2015-ongoing

Detailed design of jackets and owner's engineering for the Changhua Offshore Pilot Project. The project aims to place two wind turbines on jacket foundations. The detailed jacket design is located in an area where events such as typhoons and earthquakes need to be assessed. The work includes geotechnics, seismics, hydrodynamics, design of steel structures and grouted connection. The owner's engineering work covers FEED studies, project management, design, monitoring of fabrication, installation and commissioning.

NIRAS delivers detailed design for the jacket including all secondary structures documented by structural calculation and structural optimisation, maintenance requirements for O&M. The structural design has been optimised through 2 load calculation iterations with turbine supplier and includes:

- Primary structures: jacket consisting of legs, braces, K-joints, transition piece, flange
- Piles for post-piling: piles, grouted connection at pile sleeve

- Secondary structures external: boat landing, platforms, ladders, railings
- Secondary structures internal: platforms, ladders, railings, attachments, hang-offs
- Corrosion protection system and attachment
- Attachments of lighting and signalling with local registration
- Structures for transportation and storage
- Structures for temporary support and lifting of jacket.

NIRAS' owner's engineering scope includes:

- Review of FEED study: MetOcean report, Design Basis, Concept Design
- Project management: Review of contracts, interface management, project planning, risk assessment, review of quality and HSE plans
- Monitoring of fabrication of WTG and jacket
- Review of documents related to installation and commissioning of jacket, cables and WTG's.



Our world of offshore wind



Snillfjord
 Aure
 Solund
 Kvinesdal
 Beatrice
 Moray East
 Moray West
 Argyll Array
 Seagreen
 Creggan
 Robin Rigg
 Blyth
 WodS
 Walney Extension
 Walney 1+2
 Irish Sea Zone
 Burbo Bank Extension
 Gwynt y Môr
 Arklow Bank
 Barrow
 Ormonde
 Rhyll
 Flats
 Race Bank
 Docking Shoal
 Burbo Bank
 North Hoyle
 East Anglia One
 Galloper
 Gunfleet Sands
 Stanford Hill
 Thanet
 Navitus Bay
 Le Tréport
 Les Deux Cotes
 Fécamp
 Courseulles-sur-Mer
 Saint Brieuc
 Saint Nazaire
 Noirmoutier
 Lincs
 Dogger Bank
 Hornsea 1+2+3
 Triton Knoll
 Borssele III & IV
 Northwind
 Greater Gabbard
 Beaufort
 Princess Amalia
 Hollandse Kust Zuid I & II
 Borkum Riffgrund
 Riffgat
 Hanstholm
 Vesterhav Nord
 Ringkøbing
 Vesterhav Syd
 Horns Rev
 Dan Tysk
 Madsnedø
 Odense
 Lillegrund
 Kappel
 Smålandsfarvandet
 Riffgat
 Anholt
 Samsø
 Sejersøbugten
 København
 Middelgrunden
 Avedøre
 Lillgrund
 Bornholm
 Kriegers Flak
 Baltic I
 Nysted
 Rødsand 2
 Vindeby
 Omø
 Sprogø
 Karcino
 Komarova
 Kårehamn

North America
 NYSERDA

Asia
 Fuhai
 Taiwan
 Taipower Offshore Pilot Project

 Offshore
 Onshore

Our project life cycle

Ensure success of your next offshore project by bringing in NIRAS' expert advice - either for a single phase or for the whole project

PHASE	Feasibility	Concept & Design Basis	Design & Tendering	Manufacturing, Transport & Installation	O&M, In-Service	Decommissioning
OBJECTIVES	<ul style="list-style-type: none"> • Demonstration of concept feasibility • Go-NoGo decision gate 	<ul style="list-style-type: none"> • Site conditions and design basis • Go-NoGo decision gate 	<ul style="list-style-type: none"> • Compliance with design basis • Final Investment decision (FID) 	<ul style="list-style-type: none"> • Compliance with design and MT&I observations • Commissioning, preparation and execution 	<ul style="list-style-type: none"> • Demonstration of safe and reliable O&M • Compliance with design, MT&I and O&M observations 	<ul style="list-style-type: none"> • Demonstration of safe decommissioning • Compliance with statutory requirements
OUR SERVICES	<ul style="list-style-type: none"> • Competition to win the right to develop • Technical Due Diligence • Plausibility check of concept • Demonstration of concept feasibility • Business Plan assessment • Surveys (geophysical and geo-technical) • Preliminary assessment of site condition 	<ul style="list-style-type: none"> • Permitting and Consenting e.g. EIA, engagement with authorities etc. • Conceptual design de-risking and refining • Re-iterations of CAPEX, OPEX and ABEX estimates and synergies • Project Certification for higher bankability • Grid connection feasibility and contracting strategy 	<ul style="list-style-type: none"> • Front End Engineering • Tendering for execution phase contracts e.g. EPCI • Re-iterations of CAPEX, OPEX and ABEX estimates and synergies • O&M strategy ready for implementation • Employer's requirements 	<ul style="list-style-type: none"> • Detailed Design • Planning and implementation • Surveillance and audit to ensure technical compliance • Contractual / commercial compliance • Pre-commission O&M 	<ul style="list-style-type: none"> • O&M strategy execution • In-Service asset management 	<ul style="list-style-type: none"> • Life time extension • Repower • Partial decommission • Total decommission

Project development advice and support on strategic and technical issues

In NIRAS we advise and support our clients through each development phase of their offshore wind project, from concept to operation and decommissioning.

We provide management and support throughout the complex process of consenting and licensing, where clarity of dialogue between the regulatory body and the developer is required. NIRAS also has extensive experience in performing due diligence for the acquisition of offshore wind farm sites, and in providing relevant expertise during pre-application and examination phases.

A solid business case

The development of an offshore wind project requires specialist input to ensure that the project is technically well designed and that a suitable O&M strategy is in place. NIRAS provides the strategic, regulatory and technical expertise necessary to build a solid business case for your offshore wind project.

NIRAS provides in-house technical support on a regular basis. On some contracts our team members are seconded as technical leads, providing expert advice on a full-time basis for the duration of a project. Many of the world's largest investors in offshore wind farms have engaged NIRAS as their advisor in all stages of the offshore wind farm life cycle.

Our strategic and technical expertise includes:

Strategic advice

- Business case
- O&M
- Construction and installation
- Procurement
- Harbour and logistics
- Asset management

Management and Technical advice

- Risk management
- Project management
- Stakeholder management
- Site assessment planning, optimisation and selection
- Consents and licensing
- Tendering
- Environmental Impact Assessment
- Wind resource assessment
- Geological environment
- MetOcean analysis
- UXO risk mitigation
- Transportation and access
- Geotechnical investigation
- Foundation and civil engineering design
- Life cycle and Maintenance planning
- Design of monitoring programmes
- Decommissioning planning and execution

We value close collaboration with our clients around the world.



REFERENCE

Hornsea projects

Client: Ørsted (DONG Energy)
Country: United Kingdom
Period: 2011 - ongoing

NIRAS has been working on projects within the Hornsea Zone since 2011, assisting both SMartWind and DONG Energy across the project lifecycle.

We carried out the due diligence on behalf of DONG Energy for the acquisition of Hornsea Project One Offshore Wind Farm. For both Hornsea Project One and Hornsea Project Two project applications, NIRAS' team members were seconded, on a full-time basis, into SMartWind and DONG Energy respectively to provide in-house support as technical lead on ornithology, marine mammals and Habitats Regulation Assessment (HRA) during the pre-application and examination phase.

NIRAS provided in-house technical support for both Hornsea Project One and Hornsea Project Two during the examination period. We also provided technical ornithological and (HRA) support in response to examination questions, providing input into Statements of Common Ground (SoCG), written representations and clarification notes.

NIRAS is currently providing expert ecology assessment, impact assessment support and expert advice in relation to strategic monitoring across the Hornsea Zone. This involves the management and delivery of LiDAR and digital still camera aerial surveys to determine bird flight heights in a bid to improve predictions of bird mortality from collision risk modelling.

NIRAS is also responsible for the delivery and management of the Hornsea Project Three Evidence Plan and has been undertaking several aspects of post-consent support to the project.

Providing pre- and post-construction environmental expertise

NIRAS has extensive experience in all environmental aspects associated with the development of offshore wind farms. We provide in-depth environmental expertise on a wide range of topics related to environmental impact assessments, consenting and stakeholder engagement.

Smooth and productive dialogue with the authorities

Our environmental expertise is also required following the construction of offshore wind farms. For example, in some cases, licenses require the development of post construction benthic monitoring plans and seabed surveys. In these cases there is often a close interaction between the consultant and the relevant marine management authority. NIRAS can help you to define and outline your project in a way that secures a smooth and productive dialogue with the authorities.

Early identification

Early knowledge and planning in the development of offshore wind projects is essential in order to avoid project delays, legal obstacles and maximise return on investment. For example, prior knowledge of the environmental specifics of an offshore wind farm site enables the early identification of potential environmental impacts and, in turn, methods for mitigation.

We manage all the necessary environmental field studies, analyses and assessments. The key body of work is the

Environmental Impact Assessment (EIA), which is provided in a comprehensive EIA report. In addition, NIRAS frequently produces technical background reports, discussion papers, urban area development plans and plans for onshore facilities. Everything is carried out in cooperation with the client and the relevant authorities.

Our studies often include:

- Hydrography
- Sediment conditions and distribution
- Coastal morphology
- Benthic flora and fauna
- Fish and fisheries
- Marine mammals
- Birds
- Bats
- Shipping and navigation
- Marine archeology
- Land interests
- Visual conditions onshore and offshore
- Noise and subsea noise
- Socio-economy
- Emissions
- Air traffic and other environmental topics.

REFERENCE

Environmental Impact Assessment for Kriegers Flak Offshore Wind Farm

Client: Energinet.dk
Country: Denmark
Period: 2012-2016

This assignment was carried out on behalf of Energinet.dk and culminated in the preparation of the EIA report for Kriegers Flak Offshore Wind Farm in the Baltic Sea.

NIRAS was responsible for the project as head of a consortium of seven sub-consultants, where we managed resources, time and quality assurance. The work included coordination with sub-consultants and the planning of project activities, such as field investigations.

Studies conducted during this assignment included: hydrography, sediment conditions, coastal morphology, benthic habitats, benthic flora and fauna, fish, commercial fishing, marine mammals, birds, bats, shipping and navigation, marine archeology, visual conditions, noise, socioeconomics, emissions, radar, air traffic amongst others. Reports were prepared for the respective subjects, and environmental impact assessments were made in an overall EIA report.

All environmental impacts were highlighted by NIRAS in the Environmental Statement, where the necessary mitigative measures were proposed. The assessments included impacts from the construction, operation and decommissioning phases of the project.

Innovation from early conceptual phase to state of the art detailed design

NIRAS offers engineering expertise and design consultancy from the early conceptual phase to the final detailed design based on state of the art expertise within the key areas of hydrodynamics, geotechnics and structural engineering combined.

We use our extensive experience to identify the best foundation type for a specific site and provide well proven and innovative, tailored solutions. In our design approach, we use in-house software which we have continuously developed and tested over the years.

Innovative projects

NIRAS has participated in several development projects concerned with optimising existing design and developing new structure types:

- Detailed design of foundations for an offshore wind farm in the Taiwan Strait where conditions are extreme. The strait is frequently affected by typhoons, earthquakes and liquefaction of soil. Heavy rain transports sand from the mountains into the sea, constantly changing the seabed.
- In connection with the Carbon Trust project, NIRAS introduced a damping system in order to reduce fatigue and increase the life span of steel monopoles.
- Design of monopiles with bolted connections between monopile and transition piece as well as integrated

monopiles, where the transition piece is omitted. Both designs are combined with an optimised installation and operation procedure.

- A parametric study of various floater concepts has been performed in connection with a 10 MW turbine. The knowledge obtained in the project can be used to consider different floater concepts in early design phase where choice of concept has significant impact on the cost.
- NIRAS has been among the very first to provide hydrodynamic loads to a detailed concrete foundation design based on CFD calculations, certified by a leading certification company. The challenge of this task focused on verification of the model, extracting only relevant results and inclusion of influence of the irregularity of the waves.

NIRAS has considerable knowledge and experience in meeting the multifaceted needs of our clients with offshore wind farm projects in different parts of the world.

Our designs are innovative and under constant development with new methods, techniques and materials. Because of the broad scope of our engineering business – we design everything from bridges to railways – we are always on top of the technological development.

NIRAS designs foundations for any site condition including typhoon and earthquake.



REFERENCE

Northwind Offshore Wind Farm Detailed foundation design

Client: Northwind NV
Country: Belgium
Period: 2011-2015

Northwind Offshore Wind Farm (at Bank Zonder Naam) consists of seventy two 3.0 MW Wind Tower Generators (WTG) and one Offshore High Voltage Station (OHVS). The wind farm is positioned on "zonder naam" Bank approximately 38km off the Belgian coast, in Belgium's exclusive economic zone in the North Sea.

NIRAS developed Design Basis, including design briefs, and performed detailed design which included:

- Geotechnical data interpretation and design profiles per foundation locations
- Natural Frequency of WTG systems and OHVS system
- Extreme Events
- Fatigue (Installation+operational)
- FEM analysis of grouted connection
- Corrosion protection (surface protection, cathodic protection)
- Scour protection
- Ship impact
- Design of primary structures
- Design of secondary structures
- Design of provisional structures
- Design of elastomeric bearing system (Provisional solution in case the vertical bearing capacity of the grouted connection should fail)
- Installation
- Dismantling
- Fabrication
- Operation & Maintenance
- Quality control (Fabrication and Installation)

The detailed design of the monopiles including primary, secondary and tertiary structures, and electrical outfitting on offshore monopile foundations includes several challenges which required alternative solutions. NIRAS developed alternative detailed designs with the purpose of minimising installation risks. This included:

- Development of a new design with Elastomeric Bearings, resting on the TP and the MP top edge, and serving as provisional back-up solution in case the grouted connection should fail.
- Design of an Epoxy Containment Ring (ECR) to be established below traditional grout zone. Purpose of the ECR was to minimize the risk of the crushed grout being washed away. Once the epoxy has hardened, a traditional grout would be injected on top of the ECR. In order to verify the flow pattern of the epoxy and in order to verify that the epoxy would have the required mechanical properties after curing, a full scale test of the epoxy injection was performed and evaluated.

An approach based upon experienced PM and adaptive QA procedures

Offshore wind farm construction projects are complex. Therefore our approach is based upon strong project management with an emphasis on optimisation of the process through solution-oriented strategies. In our consultancy, intensive monitoring, quality assurance, risk management and close dialogue with the client throughout the process are essential. From the very beginning, we consider the market conditions and the availability of components and equipment. We know that identification of risks at an early stage can have a high impact on the time schedule and the financial budget in a positive way.

Contract management

We approach the financing strategy and the structure and strategy of contracts (EPC, split contracts etc.) in close co-operation with the client. We have extensive FIDIC experience and can handle all types of contracts.

We also handle the contract management throughout the project phase.

Custom-made management plans

For the individual project, we prepare plans regarding time-schedule, procurement, interface, construction, risk-management, implementation, QA and HSE. All plans, standards and regulations are prepared and agreed with the client to ensure successful implementation.

Main areas of management expertise comprise:

- Technical package management
- Consent management
- Supply chain management
- Procurement and construction strategy
- Construction management
- Installation methodology/logistics
- Risk management
- Interface management
- Financial and legal management
- Project planning and documentation
- Health & Safety
- Contract strategy and management
- Tender process management
- Dispute resolution
- O&M management
- Audit management
- Certification
- Owner's consultant



We understand our customers' needs - our values are to listen, learn and deliver

REFERENCE

West of Duddon Sands

Client: Ørsted (DONG Energy)
Country: United Kingdom
Period: 2010-2015

NIRAS has been a part of the project management from the initial stages to the final installation and commissioning of this wind farm in the Irish Sea next to Barrow in Furness. The project included 108 monopiles and established a transformer station on land at Heysham with two export cables to the transformer station at sea.

Construction management including planning and implementation of:

- Preparation of construction site manuals
- Staffing plans for the construction site's office
- Budget for construction site including manning, equipment and maintenance of site
- Identification and management of interfaces
- Establishment and management of a contract with Mariane Warranty Surveyer
- Contracts for crew, port assessment and negotiation with ports on the preparation of leases contracts
- Development of logistics plan for crew boats
- Supervision of cable contractors' work including burial assessment and cable crossings

Planning, tendering and managing the process of 'first class' decommissioning

Managing large and complex decommissioning projects is one of NIRAS' core competences. We support our clients with the initial decommissioning studies and inclusion in design, cost and method estimation, authority liaison and tendering. Observing the need for early planning and the challenge of decommissioning, NIRAS has prepared for the future. Through funding from the NIRAS Innovation Fund our experts have studied and put NIRAS fund in a lead position for decommissioning of offshore windfarms through the ODIN-Wind project. NIRAS analysed the full process of decommissioning of offshore wind farm which resulted in a guide book and a management tool for the decommissioning and not the least a NIRAS team with the needed expertises prepared to assist clients in expertise of offshore wind farms.

Overview of the entire process

Overviewing the entire process of decommissioning is a must in order to ensure that matters such as finances, safety, environment, logistics, law and waste management are handled in the best possible way when decommissioning offshore wind turbines. NIRAS has more than 20 years' experience in decommissioning both onshore and offshore installations. This, in combination with NIRAS' tradition for working across disciplines and business units, ensures that our experts are world leaders in their fields.

NIRAS decommissioning expertise and the ODIN wind tool include:

- Waste management
- Mapping hazardous materials
- Feasibility studies
- Cost estimation
- Health and Safety
- Risk assessment
- Laws and legislation
- Environmental Impact Assessment
- Tender management
- Contractor management

Projects worldwide

NIRAS has lately assisted developers around the world in assessing offshore wind farms to find the most efficient method for decommissioning during the initial planning and design phases. NIRAS has also assisted Ørsted (DONG Energy), one of Northern Europe's leading energy companies headquartered in Denmark, in decommissioning of the world's first offshore wind farm in Vindeby north of Lolland in Denmark, as well as made decommissioning planning for operators on existing wind farms.

Included decommissioning from the first stage ensures profit of the wind farm.



REFERENCE

Vindeby - Decommissioning of the world's first offshore wind farm

Client: Ørsted (DONG Energy)
Country: Denmark
Period: 2016-2017

Supporting Ørsted (DONG Energy) NIRAS participated in the decommissioning of Vindeby, the world's first wind farm.

NIRAS provided a precise cost estimation of the full decommissioning including all sub-processes. NIRAS investigated hazardous materials at the site and worked out a waste management plan.

NIRAS prepared a comparative study of the decommissioning methods. Involving senior NIRAS staff, who actually participated in the installation phase, NIRAS was able to profit from hands on knowledge from the commission of the wind farm in the decommissioning planning of the wind farm.

During tendering phase, NIRAS assisted by evaluating contractors' offers and their technical proposals.

O&M strategy - development, implementation and execution

Generating a sound financial return from an offshore wind farm asset throughout a 20 to 25 year period heavily depends on its yield availability. It also depends on the landed operational expenses accounting for 15-30% of total project life cycle costs. The O&M strategy is therefore of paramount importance for all equity holders in the project.

Early development of strategy

Starting with the lessons learned from a long series of offshore wind projects, NIRAS offers services related to early development of the O&M strategy, that is:

- Tailor made to fit asset owners strategic directions.
- De-risked and optimised by way of conducting sensitivity analysis on operational expenses for multiple scenarios.
- Utilising state of the art technology and management principles in order to ensure financial return during the whole operational life.

NIRAS has always recognised the importance of a sound implementation of the O&M strategy during the different project phases, e.g. Front-End-Engineering-Design, detailed design, transport and installation prior to Commercial Operation Date.

NIRAS will thus support undertaking operational readiness activities such as:

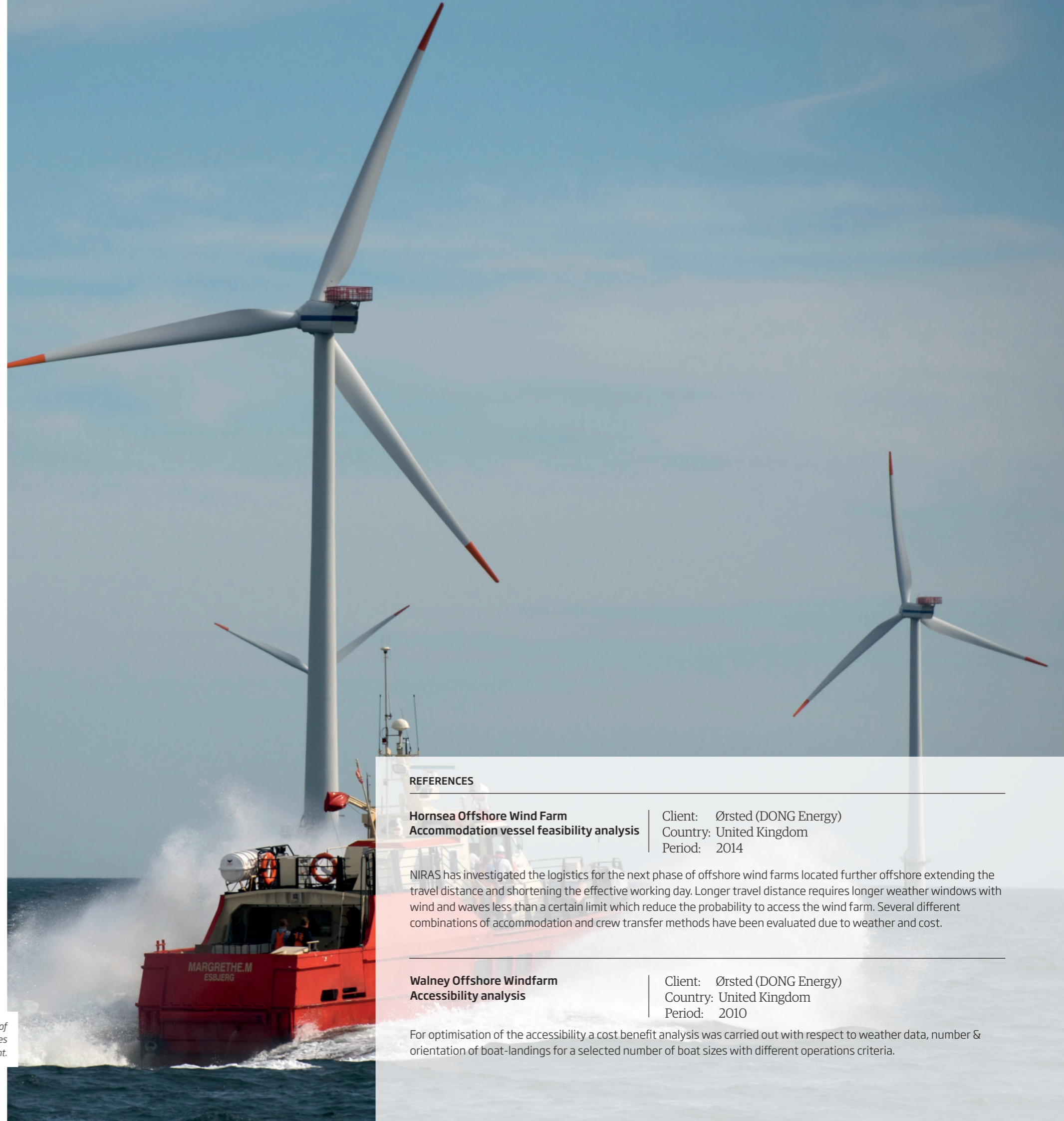
- Re-iterate O&M key strategic elements.
- Establish an organisational readiness for safe operations.
- Plan and implement asset integrity management.
- Prepare onshore and offshore logistics operational setup such as designing, tendering and building adequate O&M facilities, berthing facilities, warehouse management, communication and management systems, marine and aviation safety systems, safe vessels and helicopter operations, marine coordination.

In the operational phase, NIRAS will assist both equity holders and operators with management process validation and business plan proofing by way of implementing the O&M key strategic elements into an asset management framework.

Projects worldwide

NIRAS' engineers have been directly involved in working with O&M offshore wind energy assets in UK, France, the Netherlands, Denmark and Sweden.

Early development of O&M strategy secures return on investment.



REFERENCES

Hornsea Offshore Wind Farm Accommodation vessel feasibility analysis

Client: Ørsted (DONG Energy)
Country: United Kingdom
Period: 2014

NIRAS has investigated the logistics for the next phase of offshore wind farms located further offshore extending the travel distance and shortening the effective working day. Longer travel distance requires longer weather windows with wind and waves less than a certain limit which reduce the probability to access the wind farm. Several different combinations of accommodation and crew transfer methods have been evaluated due to weather and cost.

Walney Offshore Windfarm Accessibility analysis

Client: Ørsted (DONG Energy)
Country: United Kingdom
Period: 2010

For optimisation of the accessibility a cost benefit analysis was carried out with respect to weather data, number & orientation of boat-landings for a selected number of boat sizes with different operations criteria.

De-risk your decision making process on the entire value chain of your project

NIRAS provides technical and financial advisory services to equity holders and project developers. We commit to ensure the highest possible return on investment from offshore wind energy assets all over the world.

We can provide a reliable and independent technical and financial due diligence and our advisory services are essential in project inception, feasibility, competitive bid phases and preferred bidder selection as well as the transaction processes that follow. During project development we support the establishment of the business plan and manage its' iterations focusing on de-risking the investment.

Fit the needs

To achieve optimal results on your project we scale the effort to fit the needs and can therefore help you manage issues such as:

- Wind resources and yield assessment throughout the project life
- Risk, performance and technology assessment in project inception phase
- Work package and interface management in project development
- DEVEX/CAPEX/OPEX/ABEX modelling, optimisation and benchmarking
- O&M strategy, readiness and implementation
- Procurement strategy, tendering and contract negotiation for turbine supply, EPCI or O&M agreement.

Risks are identified and mitigated throughout the project.



REFERENCE

**Eoliennes en Mer Dieppe - Le Treport
Eoliennes en Mer Ile d'Yeu -
Noirmoutier**

Client: Les Eoliennes en Mer
Country: France
Period: 2015 - ongoing

NIRAS provides the ABEX modelling in project development design basis as well as front end engineering design phase (FEED).

As a part of the scope of works NIRAS provides the optimisation between OPEX, CAPEX and ABEX, the decommissioning strategy in strong connection to the O&M strategy of the project.

REFERENCE

Barrow Offshore Wind Farm

Client: Ørsted (DONG Energy)
Country: United Kingdom
Period: 2003 - 2013

NIRAS provided support in the due diligence phase, including data room studies, evaluation of tenders, proposed soil and hydrographical conditions. NIRAS assisted in the contract and construction phase, and undertook monitoring of manufacturing and installation, Client's Representative during foundation installation. NIRAS worked on method statements, risk assessments and review of as-built documentation after completion of the installation. NIRAS was in-house consultant during execution of outstanding and remedial EPIC works in the transition to 'Operation and Maintenance Phase'.

Providing expertise in permitting, marine infrastructure and EIA

NIRAS' competence in subsea cables has developed in tandem with our experience in offshore wind, over the last 25 years.

We provide expert advice regarding regulatory and legislative processes associated with the installation of subsea cables. NIRAS also conducts environmental assessments and supporting studies and assists in the preparation of permit applications, which often involves dialogue with regulators.

Advise based on environmental assessment

Our planning and environmental reports comply with legislative requirements set out by the local regulatory body and assess the environmental impacts a given project could have on the surrounding environment during construction, operation and decommissioning phases. Following the identification of potential environmental impacts, NIRAS can advise on suitable methods for impact mitigation along the designated cable route.

Optimal cable routes

NIRAS can also assist in the optimisation of offshore cable routes, where a number of factors need to be taken in consideration, such as:

- UXO risk: will the cable route run through areas that might contain unexploded ordnance?
- Cable burial: will the cables be buried, or protected on the seabed?

- Identification of obstacles: are there any existing pipelines and cables along the proposed route?
- Seabed conditions: are the sediments mobile and is the area prone to strong currents?

Expertise in permitting and EIA marine infrastructure

Subsea cables are not only an integrated part of every offshore wind project but are, along with pipelines, also important infrastructure projects in their own right, connecting electricity, gas and telecom networks in different countries. For example, NIRAS was appointed as marine consultants to support the permitting for the Viking Link interconnector cable that will link electricity networks in Great Britain and Denmark, through German and Dutch territories using subsea and underground cables. This is one of a number of projects where we have utilised our expertise in permitting and EIA for marine infrastructure across multiple jurisdictions.

NIRAS provides expert advice on environmental impacts of cable installations.



Cable burial is optimised for site conditions.



REFERENCE

Viking Link HVDC cable - Connection between the UK and Denmark

Client: Energinet.dk, National Grid Viking Link Limited
Country: Denmark, Germany, Holland, United Kingdom
Period: 2016 - ongoing

NIRAS, together with the British company Intertek, was responsible for producing applications for the environmental permits necessary for the marine section of Viking Link: a high voltage direct current (HVDC) interconnector cable that will run between Denmark and southern England.

As assistant project manager, NIRAS made a significant contribution to the necessary environmental applications in Germany, the Netherlands and Denmark. Our tasks included: advice regarding regulatory processes; planning and participation in project meetings and workshops in collaboration with Intertek; project management of sub-consultant activities; ongoing dialogue and weekly meetings with the clients.

NIRAS prepared an environmental report assessing whether the installation of the marine section of the Viking Link connection could result in significant environmental impacts. The environmental report also assessed the potential for cumulative impacts and summarised any mitigation measures necessary to reduce environmental impacts. Topics included in the report comprise: hydrography, water quality and sediment conditions, marine habitats, benthic flora and fauna, fish, birds, marine mammals, commercial fishing, marine archeology, shipping and navigation and planning conditions.

Why Computational Fluid Dynamic, CFD?

Fluid mechanics, which in the short terms is about solving Navier-Stokes equations, has for the past few centuries been the focus of many mathematicians, physicians and engineers. Analytical solutions can be derived for simple cases. However, in the past decade, a new tool called Computational Fluid Dynamics (CFD) has made it possible to solve even larger and more complex cases numerically by utilising high-end computers. The tool opens up new possibilities for desk studies of several types of issues related to fluid mechanics such as wind, water, oil, etc.:

- Wind loads and wind speeds for the surrounding areas for buildings, offshore substations, etc.
- Spillways
- Sediment plumes
- Residential time in tanks or other similar systems
- Mixtures of different fluids e.g. air, water, oil, etc.
- Offshore foundation loads due to currents and/or waves
- Propeller jets
- Scour protection and sediment transport

Wind turbine foundations

In general, the hydrodynamic loads on wind turbine foundations are divided into a large number of fatigue waves (FLS) and a few extreme waves (ULS). The critical fatigue waves are generally small and can thus be simplified to linear irregular waves. In the past, extreme waves have been described by regular waves and calculated from analytical expressions. But recent experien-

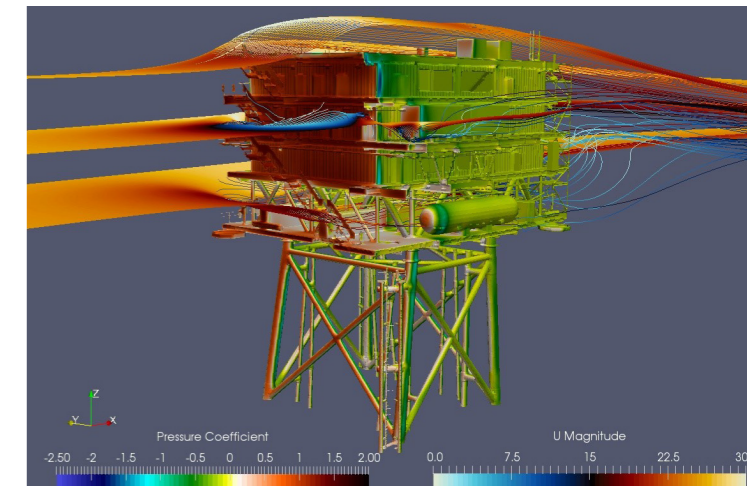
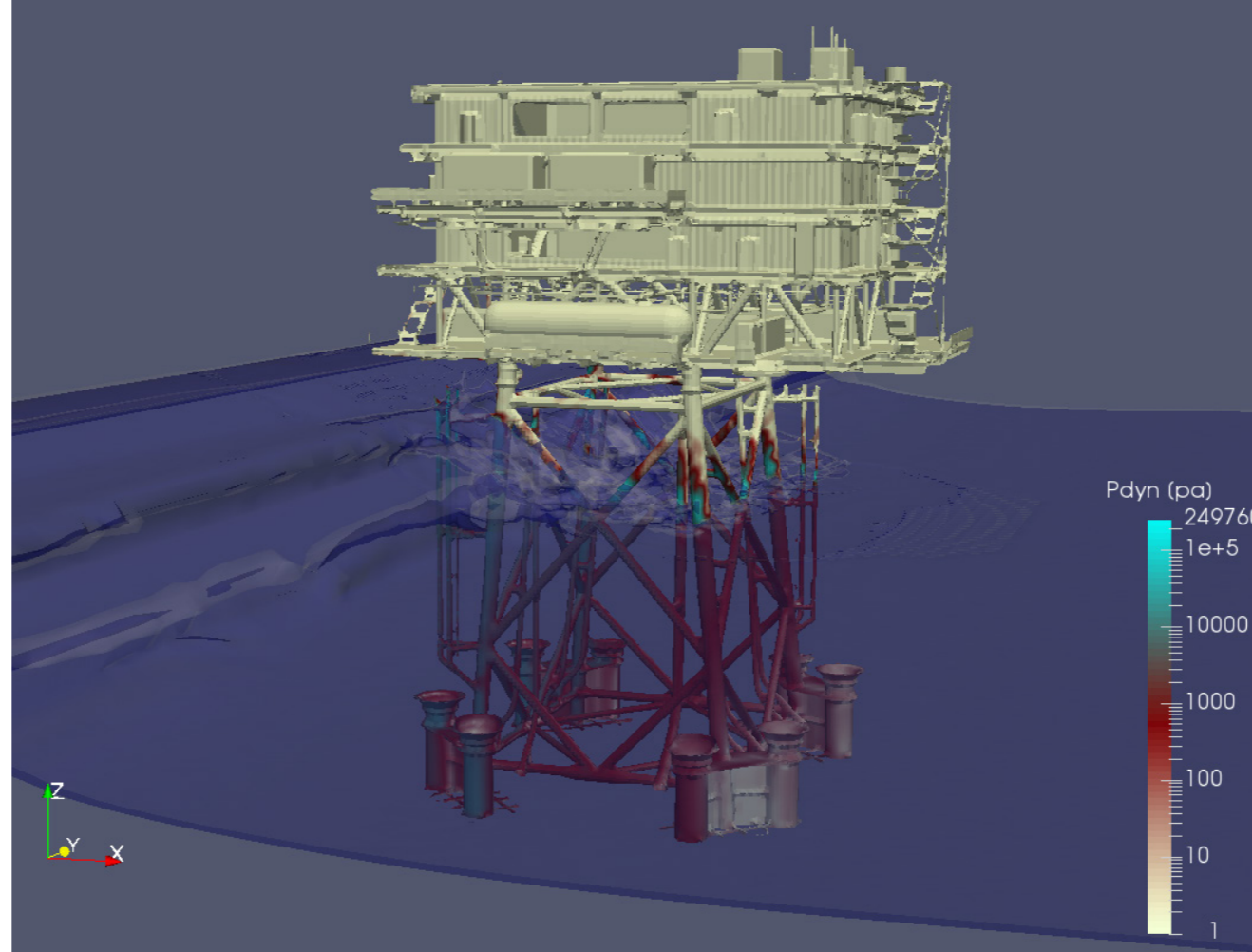
ce from existing offshore projects has highlighted that non-linear regular waves are not sufficient when it comes to extreme waves. The total load due to the non-linear irregular waves can be more than 5 times higher than regular waves. Fully non-linear irregular waves can be studied with CFD.

Jacket and monopile

Wave slamming/breaking waves occur more often than what was assumed in the set-off of the industry. For a sea state with 1000 to 2000 waves, 2-3 of the waves will break and thus the load a structure will be exposed to is a function of both water level, wave height, wave period and crest shape and it is not straight forward to find the critical one. For monopiles, wave slamming due to irregular waves can be described empirically but with significant uncertainty. For more complex structures the derivation of empirical solutions is not as straight forward. Thus for both monopoles and jacket structures CFD modelling can be applied. By using a CFD model the wave breaking can be computed and the correct maximum load therefore derived.

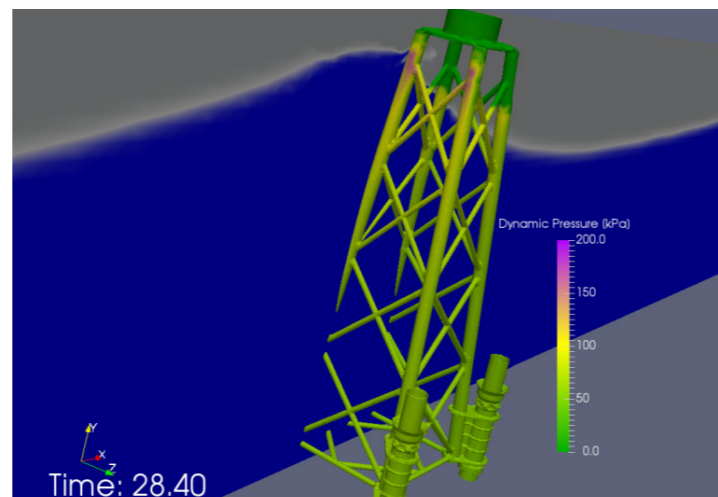
Gravity foundations/caisson

When it comes to gravity foundations the pore pressure beneath the foundation can be crucial for the stability of the structure. CFD models can include the use of porosity layers so that horizontal forces can be computed. In addition, the vertical forces reacting on the top and bottom of the caisson can be simulated to determine the temporal overturning moment.



Wind pressure on surfaces

Traditional building loads from wind are well described in the literature and guides can be found in design guidelines such as Eurocode EN 1991-1-4. When it comes to more complex buildings and topsides the pressure coefficient can vary significantly on the surfaces and thus deviate from the guidelines. Wind tunnel tests are often preferred but as an alternative a virtual CFD wind tunnel can provide similar results faster and more cost-efficiently in a concept phase. The path from a 3D CAD model to the first results is only a few days and even less between each design iteration. The path from a 3D CAD model to the first results is only a few days and even less between each design iteration.



REFERENCE

Borssele III&IV, Concept Design of Monopile Foundation

Client: Jan De Nul
Country: The Netherlands
Period: 2016

Every time NIRAS performs concept design for monopile based foundations it is of great importance to achieve an optimised design as this is a key parameter to drive down the cost of electricity. Thus there is a potential to utilise state of the art knowledge and tools to produce the most optimized design. One of the tools used to fulfil that priority is CFD modelling.

CFD modelling was applied to determine wave loads on both secondary and primary structures. For the primary structures, the influence of the secondary structures for waves coming from various directions was modelled, which enabled NIRAS to accurately predict the wave loads. In addition, CFD modelling was applied to investigate the wave run-up on the structure, and determine the level of the boat landing and external platforms.

REFERENCE

Modelling of splash zone for foundations in China

Client: Goldwind
Country: China
Period: 2017

The task was to apply CFD to investigate the splash zone with respect to the service platform at mean sea level for an offshore wind turbine foundation. With a maximum wave height below 5 m and a wave period between 6 and 9 seconds the project area is reasonably protected compared to the more open waters in the strait. Due to the relatively shallow water wave breaking is likely to be an issue and thus both regular and irregular waves were simulated. As the shape of the wave has significant impact on the run-up the irregular wave scenario was simulated for several positions of the foundation relative to the incoming wave, and thereby an accurate assessment was achieved.

We solve the challenges beneath the surface

Geotechnical engineering is one of NIRAS' core services. Our team has in-depth experience in all aspects of geotechnical engineering, geology and geomorphology. NIRAS has developed expertise within many offshore geotechnical engineering disciplines for more than 25 years from projects worldwide.

Site investigations, geological and geotechnical modelling, geotechnical data interpretation, drivability and liquefaction analyses are examples of disciplines that require thorough knowledge and understanding of soil and rock behaviour.

Soil-structure interaction is part of modelling required for all kinds of foundation structures. We are experienced in pile foundation design for jacket structures and harbours, for monopile foundations and gravity foundations. We also carry out design of mud mats, driving analyses and jack-up assessments following state of the art research in the market including PISA.

We use well known design procedures that have been subject to certification for several different projects concerning foundations types such as gravity based, monopiles and jackets.

Within all of our offshore wind design projects, the ground conditions are evaluated based on the results of ground investigations. These investigations include bore holes with sampling and SPT measurements, CPT tests and subsequent laboratory tests of samples.

NIRAS' geotechnical scope of work normally include:

- UXO risk
- Geotechnical data interpretation
- Evaluation of basic and advanced soil tests
- Establishment of design profiles and characteristic material parameters
- Establishment of soil springs for structural analysis
- Liquefaction potential evaluation
- Drivability of piles
- Deformation analysis
- Bearing capacity of soil for piles and preliminary foundations (mud mats)
- Pile design
- Penetration analysis for installation vessels for jacket structure and pile foundations

REFERENCE

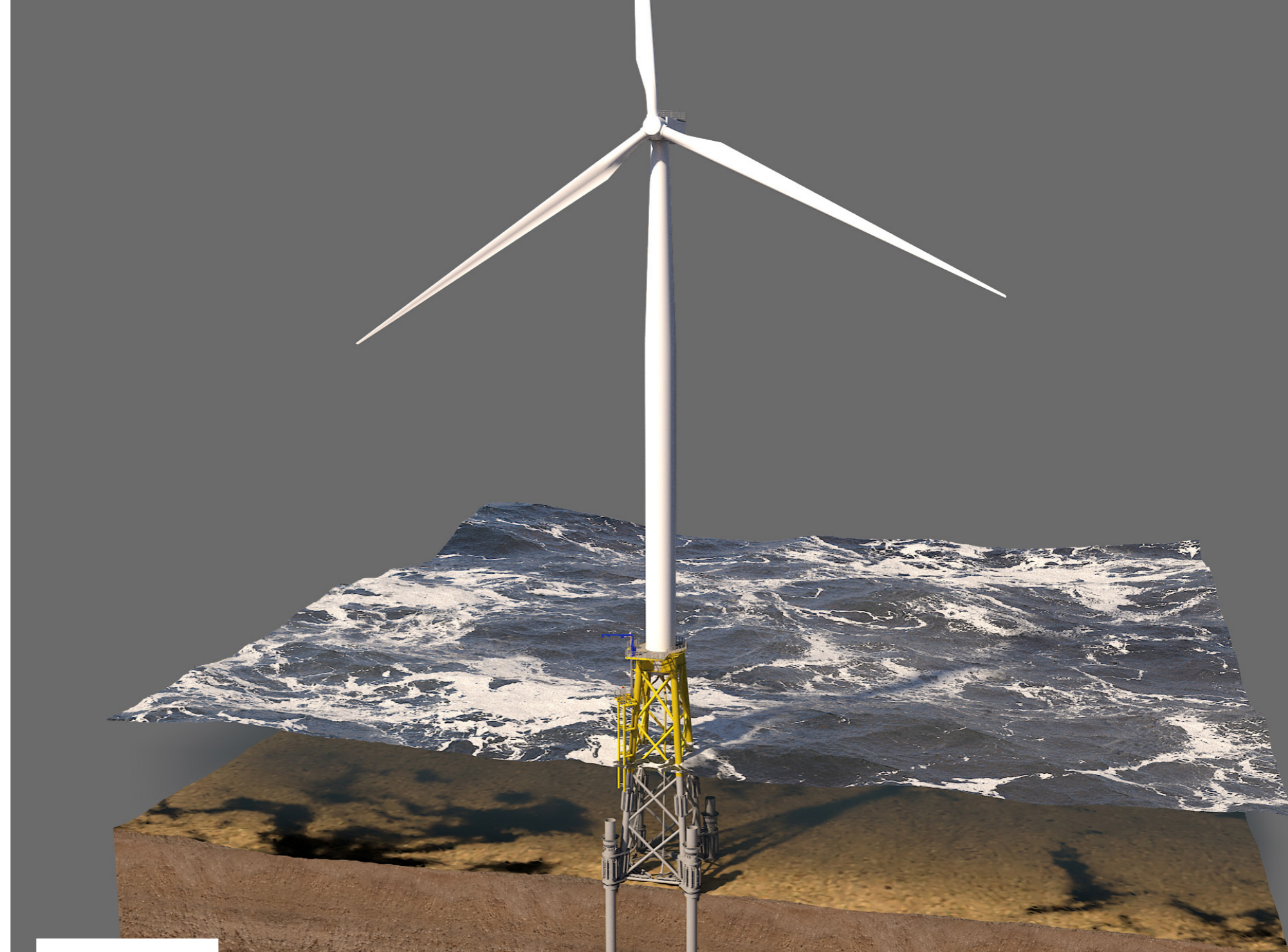
ABLE Marine Energy Park, Killingholme

Client: ABLE
Country: United Kingdom
Period: 2015 - ongoing

NIRAS carried out the preliminary and detailed design for a 1.3 km long combi wall quay with a UDL load of 20 t/m² and a dredge depth along the quay line of -17 m CD. The project also included 20 ha of land reclamation, dredging of the channel and associated quay utilities. The estimated construction value of this project is £165 m.

The geotechnical scope of works consisted of preliminary and detailed design of the following elements:

- Geotechnical data interpretation
- Evaluation of basic and advanced soil tests
- Establishment of design profiles and characteristic material parameters
- Design of 1.3 km long combi-wall
- Design of 2 million m³ reclaimed land



Foundations are designed for liquefaction of soft soil.

REFERENCE

COPP detailed jacket design

Client: Fuhai Wind Farm Corporation
Country: Taiwan
Period: 2015-2017

Detailed design of jacket foundation for the Changhua Offshore Pilot Project. This project aims to place two wind turbines on jacket foundations. The geotechnical ground conditions were re-evaluated based on available ground investigations including bathymetry, a geotechnical survey with 80 meter deep boreholes with sampling and SPT measurements, CPT tests of the upper 20 m and laboratory tests of samples. NIRAS' scope of work within geotechnical engineering included:

- Geotechnical data interpretation
- Evaluation of basic and advanced soil tests
- Establishment of design profiles and parameters
- Establishment of soil springs for structural analyses
- Liquefaction potential evaluation
- Drivability of piles
- Deformation analyses
- Bearing capacity of soil for piles and preliminary foundations (mudmats)

Next generation consultancy

With 2,200 employees in 51 offices spread across 27 countries, chances are you've experienced our work first hand. We have completed projects in more than 100 countries on all continents, working with a range of sectors - from food and beverage plants, construction and energy to environment, infrastructure and urban planning.

Sustainability is our key focus in our work with customers and we are committed to the UN's sustainable development goals. Whether working on production facilities, infrastructure projects, construction, or development aid, we are dedicated to creating sustainable solutions with lasting business, environmental and social value.



As a knowledge consultancy of the future, we work hard to acquire and understand the challenges facing our partners and the world in which they operate. This is how we gain insights that help us solve some of society's biggest challenges.

Discover how we can help you plan for the future. Our knowledge is your competitive edge.



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