NoordzeeWind

# Off shore Windfarm Egmond aan Zee
# General report

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# Definitions and Abbreviations

| | |
|---|---|
| BCE | BouwCombinatie Egmond |
| EPC | Engineering, Procurement and Construction |
| HAZID | Hazard Identification meeting |
| HSSE | Health, Safety, Security and Environment |
| ITC | Inter-turbine cable |
| LTI | Lost time injury |
| MEP | Monitoring and Evaluation Program |
| MP | Monopile |
| MSL | Mean sea level |
| NZW | NoordzeeWind |
| NSW | Near Shore Wind |
| OWEZ | Offshore Wind farm Egmond aan Zee |
| PEP | Project Execution Plan |
| PPA | Power Purchase Agreement |
| PTW | Permit to Work |
| SCC | Shore Connection Cable |
| TP | Transition Piece |

# 1 Introduction

In relation to emerging concerns on climate change and sustainable energy provision, the Dutch government identified offshore wind power as the largest feasible renewable energy resource in the country. In order to explore the viability of this technology, a feasibility study was carried out in 1997 on the development and construction of a 100 MW offshore wind farm. The report was issued in September 1997 by Novem (now SenterNovem) and concluded that the wind farm would be technically and economically viable, provided that appropriate subsidies were granted.
Subsequently, the government (through the department of economic affairs) initiated a *demonstration project* for a 100 MW offshore wind farm and acted in a lead role for site identification. This was the start of what is now the Offshore Wind farm Egmond aan Zee (OWEZ).

NoordzeeWind (NZW), a joint venture between investors Shell WindEnergy and Nuon Duurzame Energie, installed the Offshore Wind farm Egmond aan Zee (OWEZ) off the Dutch coast near Egmond aan Zee in 2006. The investors each own 50% of the project.

The OWEZ comprises 36 Vestas V90 wind turbines and associated support systems and is located in Dutch territorial waters of the North Sea, between 10 and 18 km from the coast. Each wind turbine is connected by a transition piece to a steel monopile foundation, piled to a penetration depth of about 30 m.

The power generated is transmitted through three 34kV cables to shore, which land north of IJmuiden harbour. A substation, located near Wijk aan Zee, transforms the voltage from 34kV to 150kV and transmits the power into the national grid.

Part of the project is a Monitoring and Evaluation Program (NSW-MEP, further to be referred to as MEP) aiming to generate knowledge that will be beneficial to the development of offshore wind energy in The Netherlands. The MEP outline is defined by the Dutch government and covers two areas:

- Environment including public opinion;
- Technology & economics;

The OWEZ[1] went through three different phases. The first phase started with the site selection for the demonstration project and ended when NoordzeeWind won the competitive tender for the concession in June 2002. The second phase was the project development phase which ran from June 2002 until the end of May 2005 when financial close was reached and all contracts were signed including the construction contract with Bouw Combinatie Egmond (BCE). The third phase was the construction phase of the OWEZ which began in June 2005 and lasted until the end of December 2006 when the wind farm was handed over by BCE and became operational.

[1] On June 1st 2005 NoordzeeWind decided to replace the name “Near Shore Windfarm” with “Offshore Wind farm Egmond aan Zee” (OWEZ) because “near shore” was not well understood in the offshore industry. Due to the timing of this change all governing documents related to the MEP still mention the abbreviation NSW. This report refers to OWEZ instead of NSW.

Except submission of a tender document, NoordzeeWind was not involved in the first phase. The second phase of the project was reported separately by NZW [2]. Within the MEP framework this General Report is published with reference to the third (construction) phase only. It covers the period from June 2005 until commissioning at the end of 2006.

# 2 Partners and contractual basis

NoordzeeWind is a separate legal entity and is a joint venture between Shell WindEnergy and Nuon Duurzame Energie. All documents governing the OWEZ project are contracts between the joint venture and third parties.

## 2.1 Project organisation

The figure below shows the general relationships between the main parties in the project.

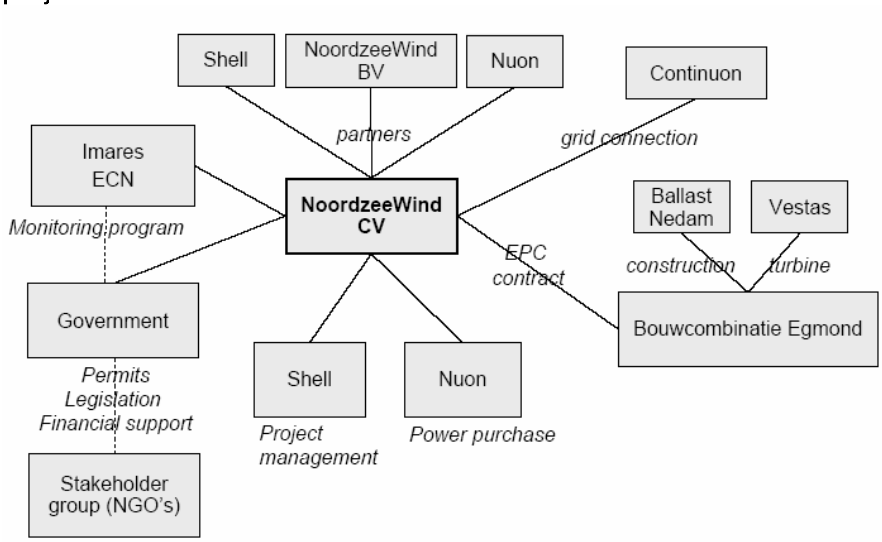
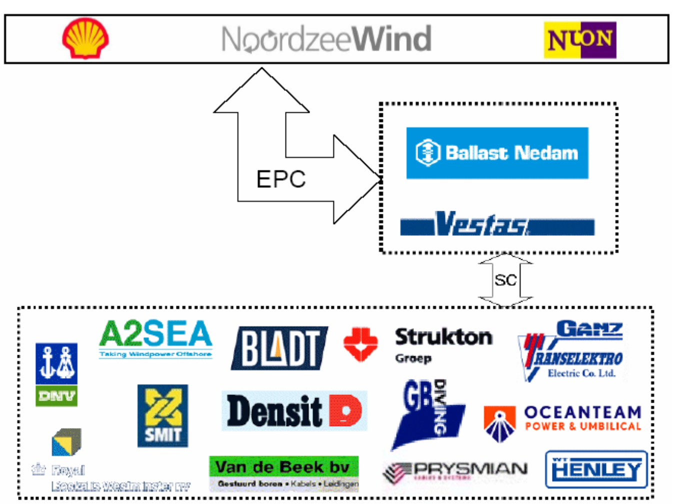



Figure : parties involved in the project.

An engineering, procurement and construction (EPC) contract is in place between NoordzeeWind and Bouw Combinatie Egmond (BCE). BCE is a project joint venture of Ballast Nedam & Vestas. All other parties involved have been sub-contracted (SC) by BCE. See Figure below.



A project team, comprised of Nuon and Shell staff, managed the EPC contract. Staff members were selected based on their skills and professional background. The EPC scope (see 2.2) was divided into tasks and package managers were given responsibility for delivering each task (see figure below).
The NoordzeeWind team comprised up to 25 people, depending on the phase of construction (the number of site representatives varied over time). The NoordzeeWind project manager acted as the formal single point of contact between BCE and the NoordzeeWind project team.

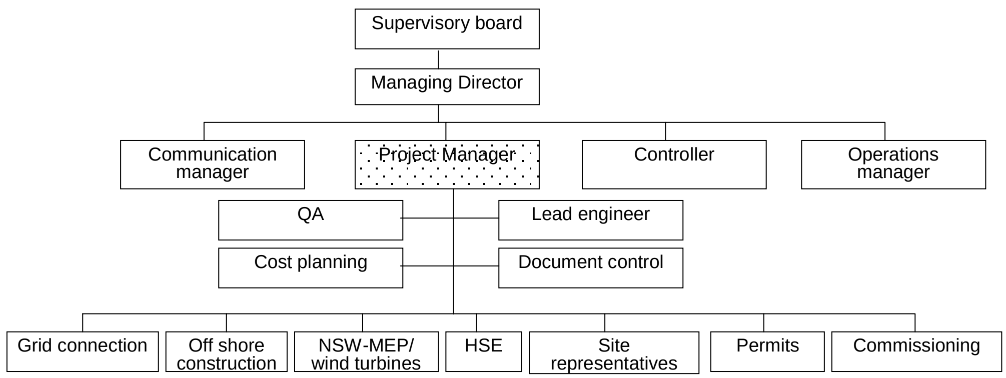



Figure: NoordzeeWind organization chart

NZW representatives were on site and aboard vessels during the day-to-day execution of the project. These representatives were the ‘eyes and ears’ of NZW on site and they reported directly to the package managers.
To ensure a smooth transition from the construction to the operations phase, the NoordzeeWind operations manager was also part of the team.

## *2.2 EPC Contract Scope*

The NZW project was implemented by way of an EPC contract with BCE as the main contractor. The main contractor was responsible for the turnkey delivery of the OWEZ :

- all Project and construction management, production management, Work Site management, and health, safety and environmental management;
- all inspection, investigation and testing of the Work Site required for the Works;
- all design, procurement, construction, installation, equipment, start-up, and testing and commissioning of the 36 wind turbines, foundations, cabling, substation and support systems;
- the provision of site specific and NVN 11400 certification by DNV or a similar organisation prior to starting the construction of the wind farm.

Areas which have been excluded from the EPC contractor's scope include:

- the 150kV onshore grid extension;
- the data evaluation and assessment as part of the monitoring and evaluation program (the installation of the sensor hardware however is included in the EPC contract).

## *2.3 Grid connection agreement*

A contract for the grid connection of the OWEZ was placed with Continuon, the local grid operator. The contract comprised delivery and installation of a 150 kV connection by means of an underground cable between the sub station near Wijk aan Zee and the Continuon sub station in Velsen Noord. The ownership of the connection will be with Continuon. According to current Dutch legislation NoordzeeWind had to bear the costs of this grid extension.

## *2.4 Permits*

The OWEZ project is governed by a number of permits (refer to report OWEZ_R_192_20070820 vergunningen), including the Wbr (construction) and Wm (environmental) permits. The requirements under these permits, such as execution of the compensation plan, submitting technical information to the authorities and the like, were managed by NoordzeeWind. The EPC contractor managed the construction work permits, like special dispensation and traffic measures during transport of the blades and nacelles, work permission for access and working on the beach, temporary storage and parking permissions, permission to work from Corus for the substation works, an environmental permit for the loadout yard and the like. The EPC contractor also managed the notifications of ship movements to the port authorities. Continuon arranged the grid connection and managed the permits and concessions for the cable from substation to the substation in Velsen.

# 3 Technical description of the OWEZ

## *3.1 Design process*

The design of the wind turbine support structures (combination of foundation and transition piece) was performed by the in-house engineering company of Ballast Nedam, Infra Consult and Engineering (IC+E) in Nieuwegein.

As first design step an assessment was made of a basic design monopile foundation with and without scour protection. The deepest scour holes will occur during heavy storms. To cope with this design condition an unprotected foundation would be much heavier (longer pile with larger diameter) compared to a pile design with protection. A cost comparison, made by BCE, led to the conclusion that protected piles would be more cost efficient.

The table below indicates the iterative design process that was followed when designing the support structure.

| Item | Loads | Design by | Method |
|---|---|---|---|
| Tower | Vestas Flex 5 | Vestas | Spread sheet |
| Transition piece | Vestas Flex 5 | IC+E | Spread sheet |
| Grouted connection | Vestas Flex 5 | IC+E | Ansys FEM |
| Monopile above sea bed | Vestas Flex 5 | IC+E | Ansys FEM + Spread sheet |
| Monopile below sea bed | Vestas Flex 5 | IC+E | Ansys FEM with P-Y springs |

Turbine manufacturer Vestas initially modeled the OWEZ wind turbines including support structure and the OWEZ specific environment using their in-house developed FE-package FLEX5. Since the foundation details were not known at that time, a spring stiffness of the foundation had to be assumed.
In accordance with IEC 61400-3, a total of 63 load cases were run including 22 normal production conditions for a range of wind speeds. The load cases also covered a number of exceptional situations: 12 power production with fault occurrence, 11 start-up procedures, 4 normal shut down procedures, 2 emergency shut down procedures and 12 parked situations (including storm conditions).

The governing load cases for the following design conditions were submitted to IC+E:

- Ultimate Limit State (ULS) condition: extreme loads
- Fatigue Limit State (FLS) condition: endurance loads

Consultancy IC+E applied the above wind loads to their Ansys FE-Model of the support structure, and added wave and current loads. This showed resultant forces and moments in the transition piece and monopile, and the associated steel stresses were calculated and checked by means of spreadsheets. Maximum design bending moment

for the monopiles, occurring approximately 10m below seabed level, is in the order of magnitude of 150 MNm (unfactored), of which 46% is driven by wind loads at the turbine and 54% by waves hitting the foundation.
In addition to monopile and transition piece sizing, the action of the soil on the monopile was modeled as non-linear springs by means of PY-curves. This allowed pile deformations to be analyzed and pile penetration optimized. A pile drivability check confirmed suitability of the selected hammer (IHC S-1200) and provided driving fatigue damage information for inclusion in the structural design.
Adding tower and turbine extended the FE-model, and allowed the natural frequency of the complete structure to be calculated. This was found to be the determining factor for the design of the substructure, since this frequency had to be outside the range of rotor frequencies specified by Vestas: at least 0.31 Hz corresponding to 18.4 rotor rotations per minute. In particular selection of a 4.6m diameter monopile was a direct result of this stiffness requirement. The steel wall thickness along each pile was optimized for bending stresses and had to be sufficient to resist shell buckling (maximum thickness 60 mm).

The soil conditions and water depths at the 36 locations were summarized into 14 sets of design conditions, where the soil conditions were taken to be the most important factor. For each set the largest water depth was taken into account for the monopile design. It was possible to cover the 14 sets using four detailed foundation designs. Applying these to the actual water depth at the intended site of each pile was done by shortening the pile from the top end. The total steel weight of the monopiles was on average 8250t or 230t per pile and the steel weight of the standard transition pieces was approximately 150t.

Following this support structure optimization, the resulting foundation stiffness was passed back to Vestas, and their FLEX5 load cases were run again. The reason for this is that the aerodynamic rotor loads depend on aerodynamic damping, which in turn depends on the bending stiffness of the support structure.
An updated load set was sent to IC+E, and their monopile and transition piece design calculations were revisited.

It was necessary to repeat the above iterative process a number of times before the foundation stiffness in FLEX5 and Ansys converged. The iterative process may appear protracted but it was necessary to achieve a fully optimized support structure design for OWEZ.

## 3.2 Support structure

The foundation used is a steel monopile, 45m long on average with a diameter of 4,6m and a wall thickness of 40 to 60mm. Its weight is approx. 230 tons. These piles were made at Bladt industries in Denmark.

Photo: foundation piles

Around the foundation a layer of rocks was placed to provide scour protection. As seawater flows around the monopile it creates turbulence which erodes the seabed sand directly around the monopile (this is the actual scour process) and so endangers the stability of the foundation. The scour protection prevents the sand from being eroded away. In total about 50.000 tons of stone have been installed on the seabed around the monopiles (see also Figure below).

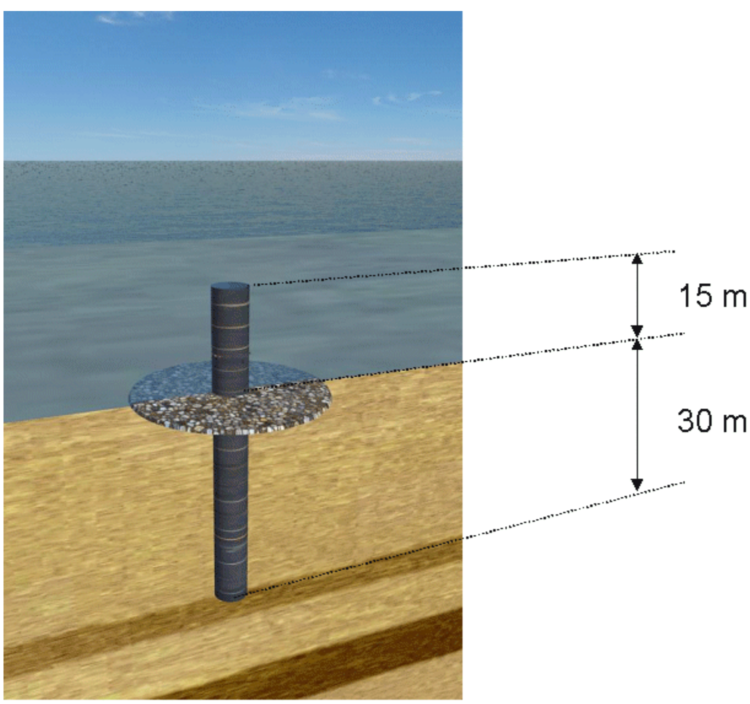
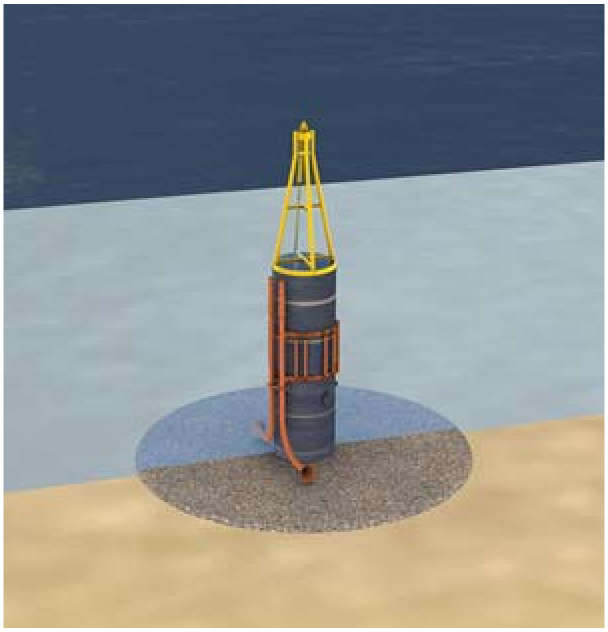



Figure: monopile and scour protection



In order to prevent corrosion of the steel components exposed to the seawater around the monopile foundation a steel 'ring' is attached that carries +/-10 anodes. Also attached to this 'anode-ring' are the J-tubes (they're so called because of their shape). Through the J-tubes the cables are pulled and in this way guided from the seabed along the foundation towards the wind turbine that stands on top. The yellow part on top of the foundation in the Figure below is a specific guidance tool used to facilitate installation of the steel 'anode-ring'. The anode ring has the same diameter as the monopile foundation (4,6m) and weighs approximately 10 tons including anodes and J-tubes.

Figure: anode ring and guidance tool

At the top end of the monopile foundation the transition piece is inserted into the monopile foundation. From the photo below it can be seen that several items are welded onto the transition piece. For example, boat fenders for access boat positioning, a ladder to facilitate access to the platform and J-tubes extension pipes for cable guidance.

Transition pieces ready for sea transport

The transition piece acts also as an intermediate platform that can be used to level out small inaccuracies in the vertical angle of the monopile foundation. Therefore the transition piece has a diameter slightly smaller than the monopile foundation. The gap between the monopole and transition piece is filled with grout.

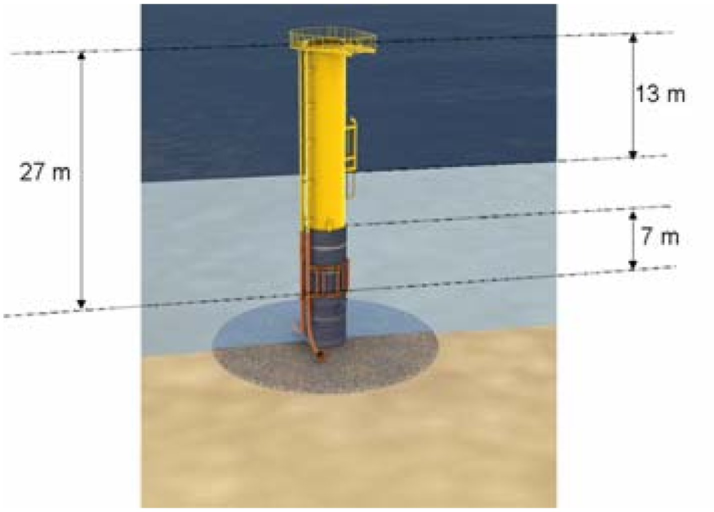


Figure: monopile and transition piece

Once the transition piece is installed the installation is as shown in the figure left. Each transition piece has a weight of approx. 147 tons. Seven meters of transition piece is lowered into the monopile leaving 20m extending above the monopile. The platform elevation (13.2 m above mean sea level) has been based on the highest wave crest level plus 1.50 m allowance for wave run-up. The maximum 100-year wave is 11.7 m, resulting in a wave crest height of approximately 0.65 * 11.7 + 1.4 = 11.7 m (thus platform height 11.7 + 1.5 = 13.2 m).

## 3.3 Wind turbines

The project utilises 36 3MW Vestas V90 wind turbines. The Vestas V90 wind turbine is a pitch regulated three bladed up wind design. The rotor diameter is 90m and the hub height is 70m above MSL. Power output is controlled by pitching the blades with the aid of power electronics. The nominal rotor speed is 16.1 RPM and the operational rotor speed interval is 9.0 – 19.0 RPM.
The gearbox is a combination of a two-stage planetary gear and a one-stage helical gear.
Braking is achieved by pitching the blades. Independent braking systems are realised by individual blade pitching cylinders. A parking brake is mounted on the high-speed shaft.
Maximum height of the installation (tip of the blade in upright position) is 115m above MSL.

The wind turbines used are “standard” V90 wind turbines. Only the tower was designed for the OWEZ project (refer to 3.1)

Two of the wind turbines (#12 and # 21, at the north western end of the wind farm) are equipped with a navigational support radars. The Harbour operational Centre of IJmuiden required a support radar to ensure that reflections from OWEZ would have no impact on the onshore based vessel tracking radar. To achieve redundancy, two identical radar systems were installed.

## 3.4 *Electrical design*

The electric system of the OWEZ is illustrated below. In total 72km of sub sea cables were installed.

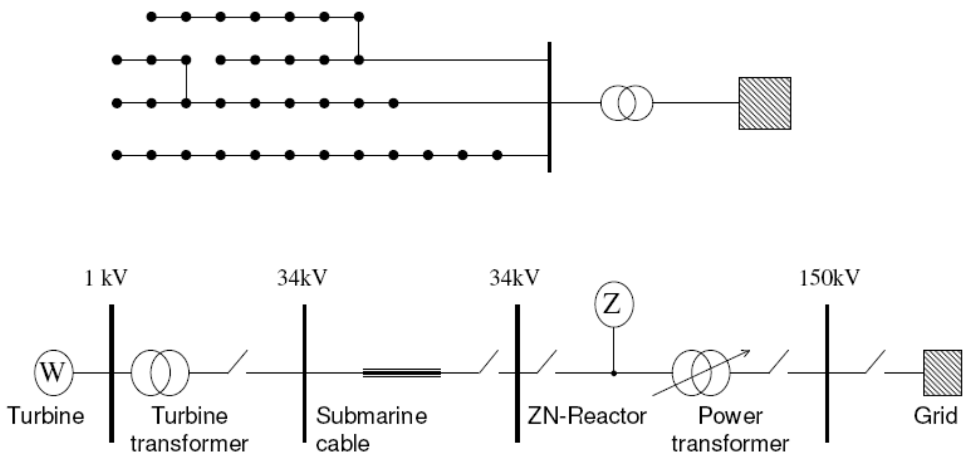



Figure: Single line diagram OWEZ

The wind farm is divided into three strings with 12 wind turbines per string. For the Inter-Turbine Connections (ITC) between turbines two different copper core cable diameters are used, depending on the occurring loads in the string: 3x300 mm$^2$ or 3x120 mm$^2$ with a total cable length of approximately 27km. See figure below which shows how the cables enter each wind turbine.

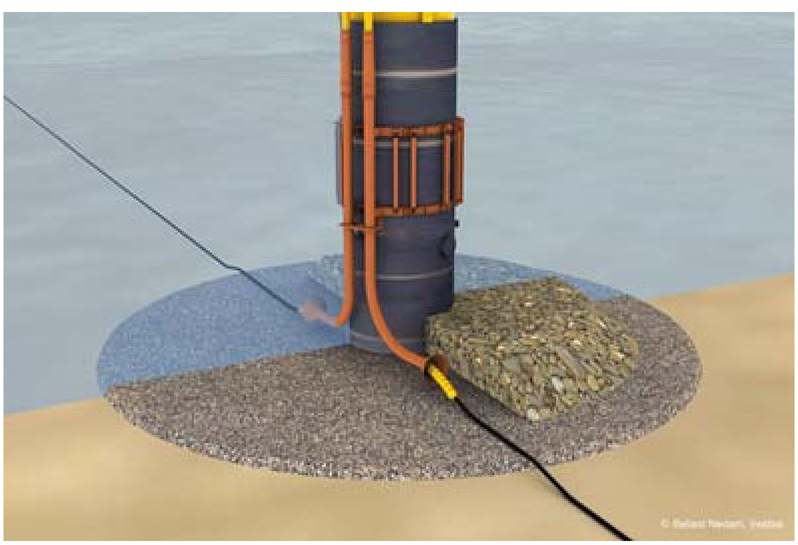


Figure: ITC's

After the ITCs had been installed a second (armour) layer of scour protection was applied around the monopile covering both the end of the J-tubes and the cables. Each string is connected to the OWEZ onshore substation by a Shore Connection Cable (SCC). The three SCC's come ashore on the beach near the Corus premises in Velsen Noord.

For the three SCC's a 36 kV 3x500 mm$^2$ copper core cable is used and all three together have a combined length of approximately 45km.

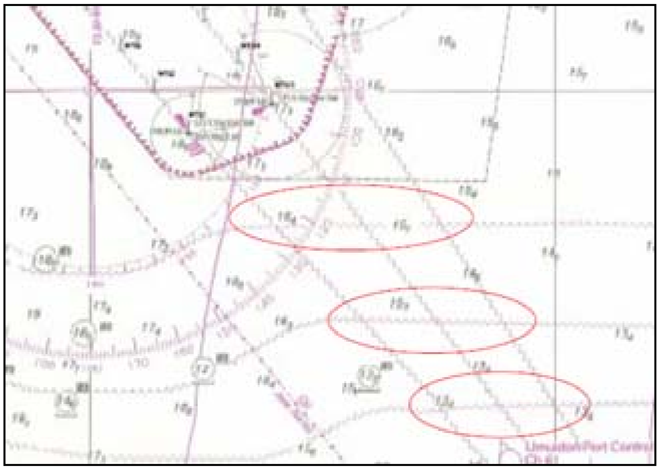


Figure: cable crossings, detail of map in annex 3

On the way from the wind farm to shore the SCC's cross three data cables, which can be seen in the figure left. These data cables run from the Netherlands to Great Britain and are buried in the seabed.

At these crossing points the OWEZ SCC's are separated from the data cables by what are known as 'mattresses' to prevent physical contact between the cables throughout their life taking into account the flow of seawater and/or 'walking sand dunes'. A photo of these mattresses is shown below. On top of the SCC's there is a final protection layer consisting of concrete mattresses and artificial seaweed. This seaweed will trap drifting sand therefore creating a 'natural' dune over the crossing for extra protection of the cables.


Photo: Mattress used for cable crossing separation

The OWEZ substation (A) is located just behind the dunes and the Corus premises (see photo below). From the OWEZ substation three Horizontal Dune Drillings (HDD) have been made under the dunes towards the beach. In these holes plastic pipes (B) have been pulled underneath the dunes. Through each of these pipes one cable was pulled in from the beach towards the substation in order to connect the SCC's to the OWEZ substation.

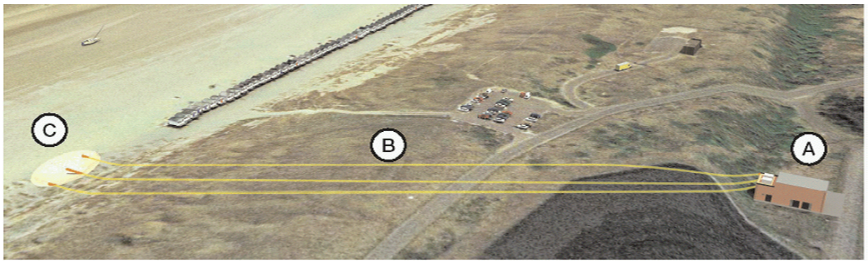


Figure: dune crossing

In the OWEZ substation the voltage of the electric power from the wind park is stepped up from 34kV to 150kV. One transformer has been installed which was manufactured by Ganz of Hungary. The size of the transformer itself is about (lxwxh) 10mx5mx4m and it weighs 22 tons excluding the 4 tons of oil needed for insulation and cooling. To prevent pollution of the transformer by salt and dust it is housed inside a concrete building, the building sizes (lxwxh) 24mx6mx7m.

The 150kV element of the OWEZ substation is the grid connection point or the point at which the power is transferred to the grid operator Continuon. The system from this point in the OWEZ substation onwards is operated and maintained by Continuon. This includes a 7km grid extension which takes the power from the substation to the switching yard at the Continuon premises in Velsen Noord. From there, the electrical power goes into the regional network and on to consumers, see also figure below. For the grid connection 3 single core cables of type 150kV aluminium 1200mm$^2$ have been used.

Grid connection OWEZ

In this chapter all 'hardware' components of the OWEZ were described. For an overview they are presented again in the following table.

Table: summary of OWEZ components and their characteristics

| **Component** | **Weight** | **Dimensions** |
|---|---|---|
| Scour protection per monopile | 1500 ton | 25 m x 1,8 m |
| One foundation monopile | 250 ton | 45m x 4,6m |
| One anode ring & J-tubes | 10 ton | 4,5m diameter |

| | | |
|---|---|---|
| One transition piece | 147 ton | 27m length |
| Tower of one WTG | 94 ton | 55m x 4m |
| Nacelle and blades of one WTG | 114 ton | 44m per blade |
| Sub sea cables (total) ITC | 500 ton (in air) | 27km |
| Sub sea cables (total) SCC | 1500 ton (in air) | 45km |
| Transformer (total) | 22 ton | 10mx5mx4m |
| Transformer housing (total) | - | 24mx6mx7m |
| Grid connection cable (total) | 270 tons | 7km length |

# 4 Assembly and installation

## *4.1 Transportation*

Components were fabricated at their respective factories and then transported to IJmuiden harbour. The fabrication of components was monitored by NZW as part of the project's Quality Assurance process. This included factory visits to monitor component quality and documentation control to ensure all relevant information was properly documented and stored.

Transportation was done by road and sea. Monopiles, transition pieces, towers and most of the nacelles were shipped from Denmark and the High Voltage transformer for the OWEZ substation was shipped from Hungary. The blades were transported by road from Germany.

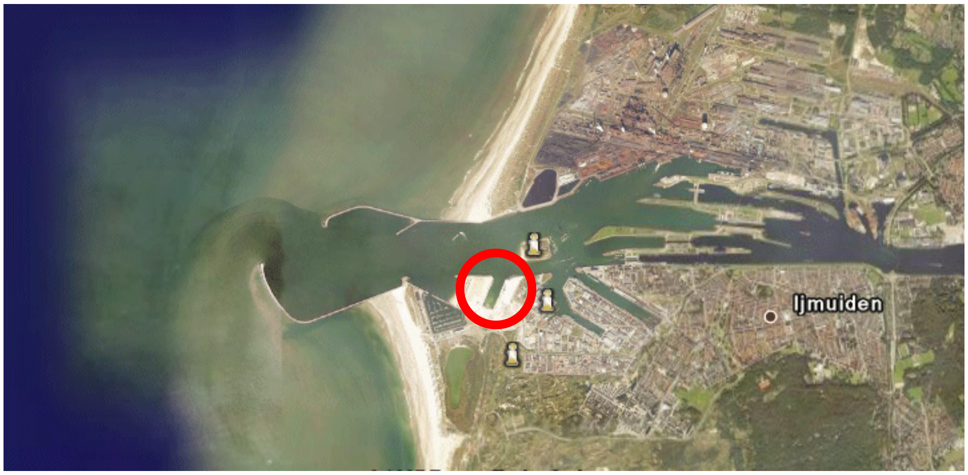
Monopile and Transition piece on transportation barge, one set per barge.


Nacelle transport by vessel.


Blade transport

During transportation no difficulties arose. Due to their length (44m) particular care had to be taken when transporting the blades.

All components were brought to the pre-assembly quay site located at the IJmondhaven in IJmuiden harbour as indicated below. From there the components were taken offshore for installation. In the harbour inspections were made and if damage had occurred during transport this was repaired.



Location of the pre assembly site in IJmuiden harbour (Google earth image)


Wind farm components in IJmuiden harbour.


Blade storage in IJmuiden harbour

## 4.2 *Monopile foundation and transition piece*

From the pre-assembly site in IJmuiden harbour each monopile (MP) and transition piece (TP) set was transported to the site by the vessel Svanen. In the initial project plan it was indicated that a choice had to be made between transportation of the MP's and TP's to the site by the Svanen or by transportation barge. The second option required loading both the MP's and the TP's from the barge to the Svanen under offshore conditions. After installation of the first MP's and TP's the Svanen proved capable of achieving a very acceptable installation speed despite having to go back to the harbour to pick up the each MP and TP set. Due to this, and also for safety reasons, it was decided not to use the barge option to avoid loading the Svanen offshore.

Both the MP's and TP's arrived complete at the harbour. This meant that no or very little work had to be done before they could be loaded onto the Svanen. The Svanen is equipped with four independent lifting hoists. One was used to lift and transport a monopile, another for a transition piece and a third block for the pile driving hammer. Each pile and transition piece was upended in IJmuiden harbour from a flat top transportation barge, which was maneuvered in the bay of the Svanen. The main block was hooked to the upper end of the pile, and the lifting block in the A-frame at the stern of the Svanen was hooked to the lower end. By hoisting the main block and subsequently the A-frame block in combination with tilting the A-frame, each monopile and transition piece was upended, see photo sequence below.


Upending monopile


Upending transition piece

Once the MP, TP, J-tubes and anode ring were loaded onto the Svanen, it left the harbour.

Photo: the Svanen going out with monopile and transition piece on board.

Before the Svanen began installing each MP a first (filter) layer of scour protection was installed. This was done by means of a crane dropped the stones on the seabed as shown in this photo.

Photo: rock dumping

The Svanen sailed to the pile position and was connected to eight anchors at the spot that were laid down in advance. By tensioning and loosening the relevant anchor cables the ship was brought into position and kept there. The next step was to position the monopile using an adjustable piling frame fixed to the Svanen. Once in an exact vertical position the monopile was driven into the seabed using a hydraulic hammer (make and type IHC S-1200). To achieve the target penetration depth no additional measures were required. On average for each monopile 2400 blows were required and the average energy required for each monopile was 1200 MJoule. Piling depth was monitored and the measured values corrected to take account of the actual sea water level.

Monopile in piling frame with hydraulic hammer on top.

Once the MP had been installed the anode ring with the J-tubes attached to it was installed. To facilitate installation of the anode ring and J-tubes a temporary frame was put on top of the monopile to guide the anode ring and J-tubes towards the outer edge of the monopile.

The TP was then lifted and placed inside the monopile and temporarily stabilised for the grouting operation. The TP had a pre-installed grout seal which avoided the need to use divers. The grout seals used were made of rubber, shaped like a tyre, and attached to the outside of the bottom end of the TP. Once the TP was in place and stabilised, the seal was filled with water up to a certain pressure. At the start of the installation phase it proved difficult to achieve the right pressure. The pressure level had to be sufficient to support the grout that was to be poured on top of it. Too high a pressure could result in damage to the grout seal. Once the seal had reached the right pressure, the gap between the monopile and the transition piece was filled with grout. The grouting layer is about 10cm thick and 7m high.

View from top of Svanen after TP installed

Once a complete set of MP and TP had been installed the Svanen returned to IJmuiden harbour to collect another monopile /transition piece/J-tube set.

## 4.3 Tower, Nacelle and Blades

To reduce time spent offshore and therefore dependency on weather conditions the main components were assembled onshore and then brought of shore leaving only three remaining offshore construction steps:

1: mounting the tower onto the foundation;
2: mounting the nacelle onto the tower;
3: mounting the last blade.

The tower, nacelle and blades were installed using an A2Sea installation vessel called The Sea Energy. During these works installation of MP's/TP's/J-tubes by the Svanen continued at other locations.

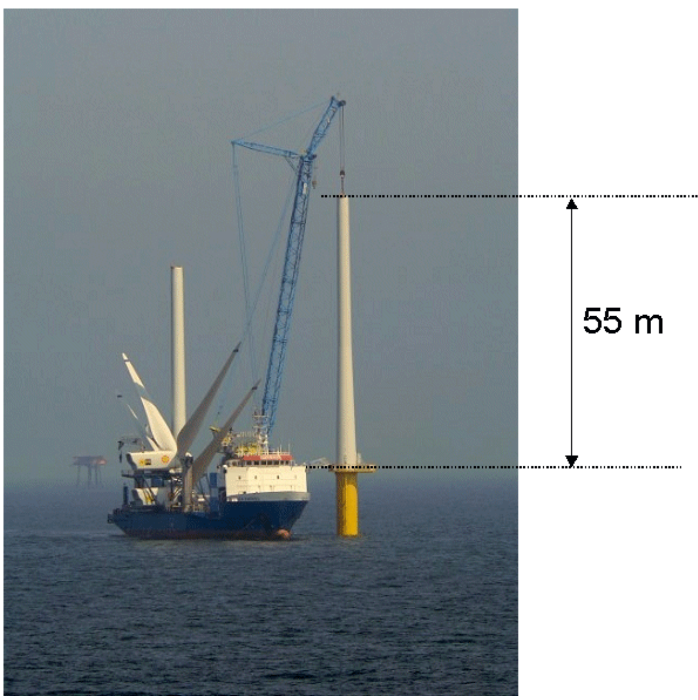
The nacelle, hub and two blades were assembled in IJmuiden harbour (photo left) as were two sections of the tower, including all cabling. Once this was finished they were loaded onto the installation vessel.

The Sea Energy could carry two complete assemblies (two nacelles with two blades each and two towers. The vessel had an onboard crane for the lifting and installation of the wind turbine.

Sea Energy with two nacelle assemblies, seen from a just installed tower


The Sea Energy going out with 2 assemblies

At the installation site the tower was upended and bolted to the TP.



Tower installation with the Sea Energy.

The nacelle, hub and two blades were then lifted and connected to the tower. The combination of the two weighed about 108 tons.

Nacelle installation with the Sea Energy

The third blade was lifted and installed separately.

After each installation of a single wind turbine was complete the wind turbine components were inspected prior to the installation vessel moving to the next foundation or returning to IJmuiden to load-up.

## 4.4 Subsea cable installation

Cable installation started with horizontal directional drilling (HDD) through the sand dunes. The drilling rig was positioned behind the dunes and drilled a pilot hole followed by a larger hole to take the cable casing (PE pipes), which were pulled through the hole. A separate HDD operation was done for each of the three cables. Once the shore connection cables (SCC) were pulled into the substation, the PE pipes were filled with bentonite.

HDD drilling equipment

Prior to laying the SCC each cable route was surveyed to identify any obstructions on the seabed. No significant obstructions were found. The cable laying vessel was positioned near to shore, and an onshore winch was used to pull the cable from the vessel to shore.

Cable lay vessel in front of shore and cable pull on beach.

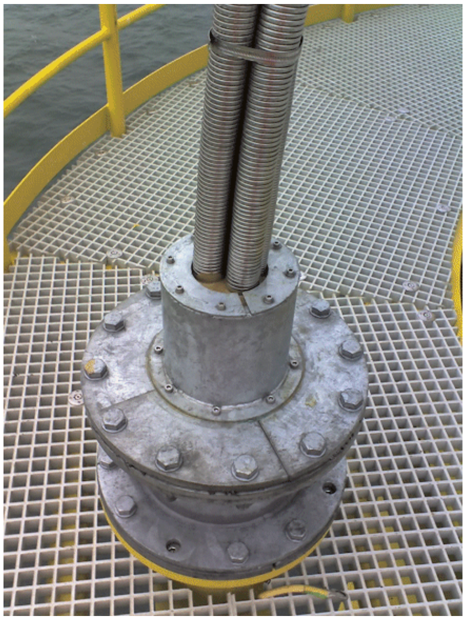
When the cable was pulled into the substation and secured, the cable laying vessel moved towards the wind park laying the SCC in the seabed.

The SCC were to be laid by water jetting, to a burial depth of around 3m for the first 3km from shore and then to a depth of 1.5m for the rest of the cable length. The cable lay operation involved crossings three communication cables. The three SCC were connected to wind turbines 1, 13 and 22.

Photo: water jetting equipment

A separate cable lay vessel was used for the inter-turbine cable connections. The inter-turbine connections were made after installation of the MP/TP/J-tubes.

The cables were connected to a pulling wire inside each J-tube and pulled onto the transition piece platform using a winch. These cables were buried using water jetting.



Cables at platform level

## 4.5 OWEZ substation and grid connection

The construction of the OWEZ substation was less complex than the wind farm itself. The substation is a building consisting of a concrete foundation, a roof and brick walls.

The building contains the 34/150kV transformer, switchgear, conveyance point or grid connection and an Operator room for the SCADA system. On the photo left the floor of the substation is presented together with the 3 HDD pipes for the SCC to enter the substation. The 34kV SCC cables enter the substation in the basement.

Substation floor and 3 pipes to conduct wind farm cables.

Once the substation building was nearing completion the transformer was lifted into the building, see photo below.


Transformer ready for lifting into substation building

After installation of the transformer its oil cooler was installed on the roof of the building. The cooler uses the natural oil flow (hot oil rises while cool oil goes down) so doesn't require a pump.

Continuon, the local grid operator, installed the 7km grid extension cable from the OWEZ substation to the grid substation at Velsen-Noord.

## *4.6 Commissioning*

BCE was responsible for testing and commissioning the Works and had to demonstrate its reliability. The OWEZ test program comprised a number of successive steps which examined individual elements of the Works as well as on the entire wind farm. The tests were classified as follows:

Factory acceptance tests (FAT's)
Technical Completion Tests (cold and hot)
Reliability Tests

Substantial Completion was achieved after passing the Reliability Tests (incl. agreed Punch list)

**Factory Acceptance Testing (FAT)**

Test certificates, statements of quality, quality plans and testing and inspection schedules had to be provided to NZW on a pre-defined list of components (see also chapter 10, QA management).

On each specific item Audits and\or Factory Acceptance Tests and\or a Production Inspections were performed and witnessed by a NZW representative.

**Technical Completion Tests**

Technical completion tests were undertaken by the Contractor and witnessed by a NZW representative to ensure that the Works could operate acceptably and safely after installation.

The requirements for the Technical completion tests were:

| | |
|---|---|
| Mechanical Systems: | It should be demonstrated that all mechanical connections were made according to the specifications; |
| Cold Technical Completion Tests: | Demonstrate the correct installation of equipment prior to electrification and the start of functional testing. |
| Hot Technical Completion Tests: | Perform a functional testing program on each individual wind turbine. |

The technical completion certificate was issued after completion of the test program, evidence of HSE/QA-QC compliance and determination of the punch list for each individual wind turbine and support structure. This allowed reliability testing to be started.

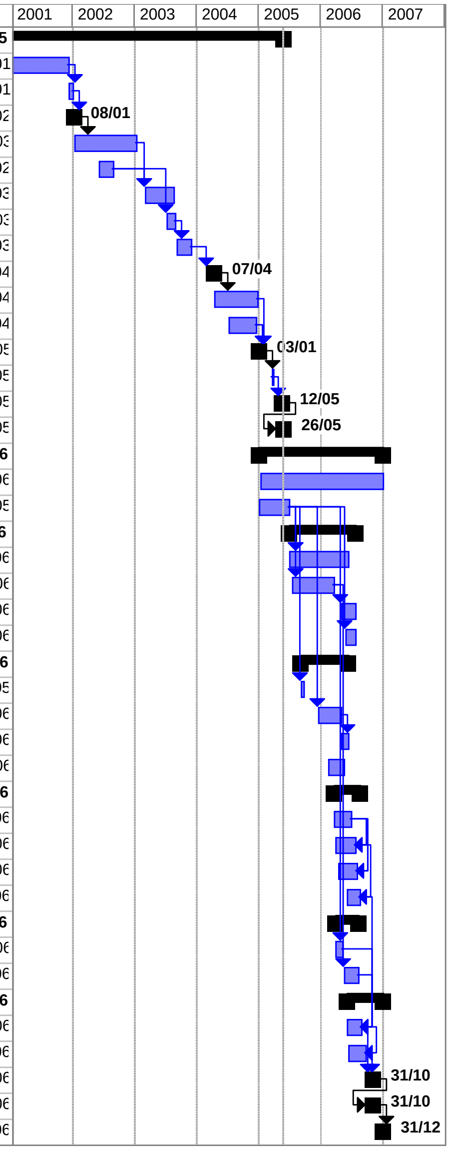
**Reliability Tests**

The aim of the reliability test was to show a period of defect-free operation for each individual wind turbine and the entire wind farm. Parameters involved during these tests were: minimum required availability, maximum allowed number of resets, minimum capacity factor and short power curve (impression of PV curve based on limited number of bins).

# 5 Planning Versus Execution

Upon signing the EPC contract a project plan was agreed between NZW and the EPC Contractor BCE. This plan is shown in below.

| ID | | Task Name | Start | Finish |
|---|---|---|---|---|
| 1 | | **Development Phase** | **Mon 01/01/01** | **Thu 26/05/05** |
| 2 | | Dutch Government Tender for Demonstration Project | Mon 01/01/01 | Fri 30/11/01 |
| 3 | | Project Award to NZW | Mon 03/12/01 | Fri 28/12/01 |
| 4 | | EPC Term Sheet with BCE signed | Tue 08/01/02 | Tue 08/01/02 |
| 5 | | Environmental Studies | Tue 08/01/02 | Mon 06/01/03 |
| 6 | | Offshore Surveys Phase I | Mon 03/06/02 | Fri 23/08/02 |
| 7 | | Metmast Contract | Mon 03/03/03 | Fri 15/08/03 |
| 8 | | Offshore Surveys Phase II | Tue 01/07/03 | Mon 25/08/03 |
| 9 | | Memast Installation | Mon 01/09/03 | Fri 21/11/03 |
| 10 | | BAFO request to BCE | Wed 07/04/04 | Wed 07/04/04 |
| 11 | | EPC Contract Negotiations | Mon 12/04/04 | Fri 17/12/04 |
| 12 | | Objections filed against permits | Thu 01/07/04 | Wed 15/12/04 |
| 13 | | Permits irrevocable | Mon 03/01/05 | Mon 03/01/05 |
| 14 | | VAR4 | Tue 15/03/05 | Thu 17/03/05 |
| 15 | | Final Investment Decision (FID) | Thu 12/05/05 | Thu 12/05/05 |
| 16 | | Notice to Proceed (NTP) to BCE | Thu 26/05/05 | Thu 26/05/05 |
| 17 | | **Execution Phase** | **Mon 03/01/05** | **Sun 31/12/06** |
| 18 | | NZW Project Management | Thu 06/01/05 | Fri 29/12/06 |
| 19 | | Design and Engineering | Mon 03/01/05 | Thu 30/06/05 |
| 20 | | **Procurement and Deliveries** | **Fri 01/07/05** | **Tue 18/07/06** |
| 21 | | Monopiles and Transition Pieces | Fri 01/07/05 | Wed 07/06/06 |
| 22 | | Subsea Cables | Wed 13/07/05 | Mon 20/03/06 |
| 23 | | Towers | Wed 03/05/06 | Tue 18/07/06 |
| 24 | | WTG Section A/B/C | Wed 24/05/06 | Tue 18/07/06 |
| 25 | | **Onshore Works** | **Thu 01/09/05** | **Fri 09/06/06** |
| 26 | | HDD dune crossing | Thu 01/09/05 | Wed 21/09/05 |
| 27 | | Transformer station (civil works) | Tue 13/12/05 | Fri 28/04/06 |
| 28 | | Transformer station (electrical) | Tue 02/05/06 | Fri 09/06/06 |
| 29 | | Grid Connection (Continuon) | Wed 15/02/06 | Mon 15/05/06 |
| 30 | | **Offshore Works** | **Tue 21/03/06** | **Sat 19/08/06** |
| 31 | | Scour protection (Filter Layer) | Tue 21/03/06 | Wed 28/06/06 |
| 32 | | Installation Monopiles and Transition pieces | Wed 29/03/06 | Tue 25/07/06 |
| 33 | | Scour protection (Armour Layer) | Fri 14/04/06 | Tue 01/08/06 |
| 34 | | Installation towers and WTGs | Tue 30/05/06 | Sat 19/08/06 |
| 35 | | **Electrical Infrastructure** | **Tue 28/03/06** | **Wed 09/08/06** |
| 36 | | Main subsea cables | Tue 28/03/06 | Mon 08/05/06 |
| 37 | | Inter-turbine subsea cables | Fri 12/05/06 | Wed 09/08/06 |
| 38 | | **Testing & Commissioning** | **Sun 04/06/06** | **Sun 31/12/06** |
| 39 | | Technical completion tests | Sun 04/06/06 | Thu 24/08/06 |
| 40 | | Reliability tests | Mon 12/06/06 | Sun 17/09/06 |
| 41 | | Substantial Completion Section A | Tue 31/10/06 | Tue 31/10/06 |
| 42 | | Substantial Completion Section B | Tue 31/10/06 | Tue 31/10/06 |
| 43 | | Substantial Completion Section C | Sun 31/12/06 | Sun 31/12/06 |




Initial project plan at contract signature

During construction of the wind farm different factors resulted in an execution schedule deviating from the planning. In the next figure the final execution schedule (in green) is compared to the plan as agreed in the Contract (in blue).

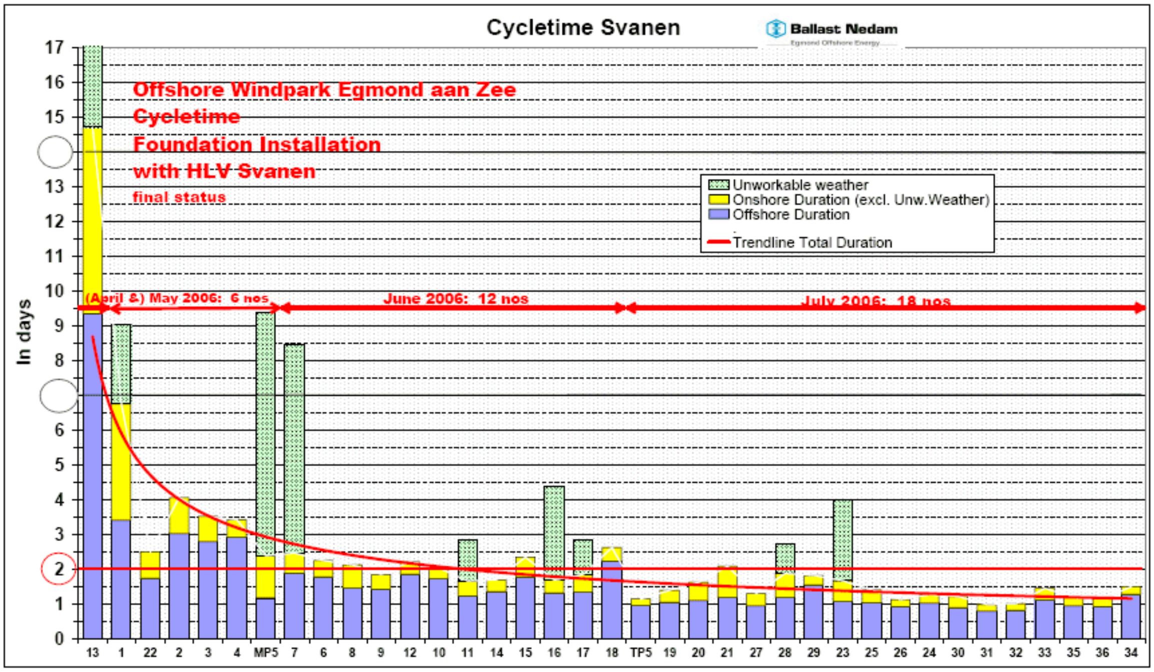
Execution (green) versus initial planning (blue) except for punch list items and remedial works

The figure above shows that most phases of the project were executed as planned. The final execution of a phase depends on a number of factors, some of which are out with the management's control (for example weather conditions). Therefore it is not possible to pinpoint individual factors that resulted in deviations from the plan. However, during each phase various factors and events can be seen to have influenced the execution schedule, either contributing to delays or acceleration of the construction process. For each phase these factors are given below.

<u>Design, delivery and pre-assembly</u>
For all design activities the most important factor determining whether the planning could be met was resources. Due to the fact the project was executed under an EPC contract, these activities were more difficult for NZW to monitor than for example offshore and transportation works.

Execution of the delivery and subsequent pre-assembly of towers, nacelles and blades was determined by the progress of offshore installation works and the available space in the harbour. At certain points it was decided to store a limited number of towers in an up-right position to create space for other components at the harbour.

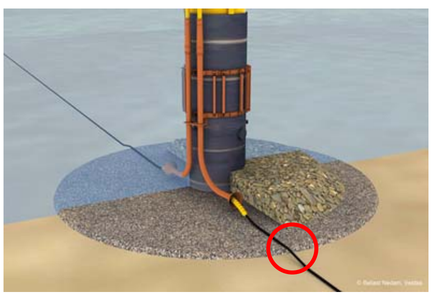
<u>Installation</u>
The most noticeable deviations are that installation of the MP's/TP's was done more quickly than initially estimated, The faster than anticipated installation times for the MP's/TP's was mainly due to how quickly the crew of the Svanen learned to execute the installation process See also next figure.



Cycle time Svanen.

In the figure above the blue part of the graph indicates the time spent offshore transporting and installing each foundation MP and TP set. The yellow part indicates the time spent in harbour loading the Svanen. The initial estimate was that the process would take about 2 days in total, however some sets were installed in only 24 hours.

Delay in installation of the offshore cables was mainly due to insufficient equipment availability. The specified cable burial depth could not be reached before commissioning, therefore an extra guard vessel was operational until full burial of the cable.



The transition of the cables from armour layer (red circle in figure left) to the sea floor had to be covered by the same type of mattresses (refer to 3.4) used at the cable crossings. This was not anticipated in the design. Remedial work on cable burying and mattress laying continued after commissioning of the windfarm.

Diving works took considerably more time than anticipated, and a second vessel was employed to bring this back on schedule.

The initial grout-seal was not adequate to withstand the level of pressure and some seals broke when filled. Improvements were made during the construction phase and this prevented the issue causing delays.

Testing and commissioning

Testing and commissioning of the electrical system took less time than anticipated. However, this did not result in an earlier completion date because work on the wind turbines could not be brought forward. The final completion, or take over date, for this project was 31st December 2006, which was as planned.

Considering the ground-breaking nature of this project the final execution of the project did not differ greatly from the initial project plan.

# 6 Budget

## *6.1 Budget at start of construction*

Since the project was executed through a lump sum turnkey EPC contract, the price of this contract is the main determining factor of the capital budget. However, in addition to this there were a number of other costs that the project had to bear. The total project costs are detailed below.

Table: price breakdown total project costs

| **Item** | **Costs [EUR]** |
|---|---|
| EPC contract | 200.000.000* |
| Offshore met mast | 3.000.000** |
| Development costs | 8.000.000 |
| Grid Connection (EPC Continuon) | 5.000.000* |
| Owner's project management | 4.000.000 |
| Capital items NSW-MEP | 1.000.000** |
| Construction All Risks insurance | 3.500.000** |
| Wm permit Compensation plan | 500.000 |
| Infocentrum Egmond aan Zee | 200.000 |
| **Total:** | **217.700.000** |

* approximate amount, the exact number is confidential
** included in the EPC contract price

It is not possible to give an exact breakdown of the EPC contract due to the lump sum nature of the contract. However, an estimate of the percentage attributable to each activity is given below.

Table: price breakdown EPC contract

| **Activity** | **Costs** |
|---|---|
| Development | 5% |
| Design | 2% |
| Procurement | 53% |
| Fabrication | 8% |
| Installation, incl. Transport | 21% |
| Testing & commissioning | 2% |
| Other | 9% |
| **Total:** | **100%** |

## 6.2 Deviations to the budget during construction

Due to stringent project management and the EPC contract, the project was delivered on time and on budget.

# 7 Health, Safety, Security and Environment Management

HSSE is a core line management responsibility. During construction NZW had a HSSE policy in place which was implemented via the project's HSSE plan. This policy committed NZW to:

- Pursue the goal of no harm to people;
- Protect the environment;
- Use material and energy efficiently;
- Play a leading role in promoting best practices in our industry;
- Manage HSSE matters as any other critical business activity;
- Promote a culture in which all persons working on the OWEZ project share this commitment;

Minimum HSSE requirements were included in the EPC contract, so that both client and contractor had clear and realistic expectations. During the detailed engineering phase, before construction commenced, significant efforts were made by both contractor (BCE) and client (NZW) to develop detailed HSSE management systems (HSSE MS). This mutual effort was driven by senior management at both organizations, and created a culture of awareness and attention to HSSE. As part of the working culture on the project, detailed method statements and risk assessments were carried out between BCE, subcontractors and NZW for all phases and work scopes. The inclusion of experienced engineers from Shell and Nuon provided an effective platform for the direct transfer of experience and expertise from the offshore oil and gas sector to the offshore wind sector.
NZW appointed a separate HSSE manager to assist the package managers, who reported to the NZW project manager.

## *7.1 HSSE performance*

In order to maintain a high level of awareness on HSSE related issues the following activities were organised.

- HAZID (hazard identification meeting) workshops were held by BCE prior to all construction activities, such as diving and cable laying. NZW experts were actively involved and led some of these workshops.
- Minimum offshore competence requirement for project staff (3 day or 1 day offshore survival training, depending on type of offshore activities) and tower climbing and rescue training.
- BCE established an Offshore Logistics Control Center (OLCC) responsible for controlling all vessel movements at the offshore site and the entrance to the pre-assembly site.
- Entrance to the pre-assembly site, construction site and work vessels was tightly controlled. Only those personnel required at site were allowed entrance, and this was only after completion of site induction training. The site induction training introduced the work site, potential dangers and the safety rules to be followed.
- BCE Directors support was sought to embrace a project "one step up" to continue HSSE improvement. Education programs were held.

- Internal workshop for emergency response was held and followed up by a meeting with the Dutch coast guard. Inspections (Safety, Security and Environmental) and vessel audits were conducted in accordance with an inspection plan both onshore and offshore.
- Regular safety audits were held, frequently led by senior contractor and/or client personnel. Findings were systematically tracked and closed out.
- An operations readiness review audit was held by Shell Global Solutions, and it's findings were addressed.
- Ongoing attention was paid to the transition to the operations phase, including documentation completion and an HSSE plan for operations.
- HSSE plans for the operations phase were issued in December 2006.

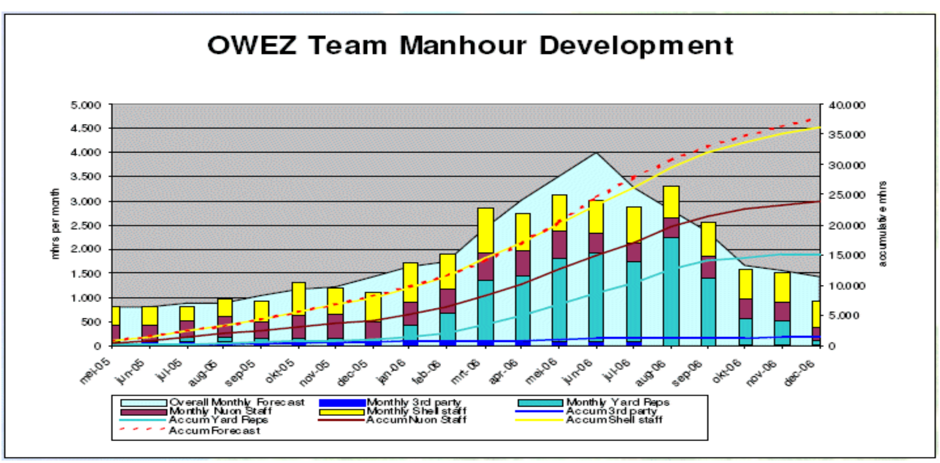
## *7.2 Man hour recording*

All hours spent on the project were reported to the HSE manager. This provided an overview of when and where most hours were spent and this is presented in the table below.

Table: Recordable man hours spent on the OWEZ project during construction.

| **Recordable man hours** | **2005** | **2006** | **2006** | **2006** |
|---|---|---|---|---|
| | **Total** | **Total** | **Onshore** | **Offshore** |
| BCE | 22.255 | 106.696 | 97.691 | 9.005 |
| Vestas | 6.600 | 64.038 | 41.588 | 22.450 |
| Subcontractors Civil | 12.410 | 113.737 | 42.576 | 71.161 |
| Subcontractors Electrical | 1.282 | 43.559 | 24.959 | 18.600 |
| Operations & Maintenance | 617 | 882 | 560 | 322 |
| | | | | |
| NSW-MEP work scope | 701 | 4.625 | 4.265 | 360 |
| | | | | |
| NoordzeeWind | 8.007 | 27.937 | 23.130 | 4.807 |
| | | | | |
| **Total project exposure** | **51.872** | **361.474** | **234.769** | **126.705** |

Almost all NZW staff hours were spent onshore. Offshore works started in April 2006 when the first filter layers were laid on the seabed. The majority of NZW staff offshore hours were made by the offshore representatives, this can also be seen from the graph below, which details the hours spent by the NZW team (excluding BCE).



## 7.3 Incident reporting

The overriding HSSE objective was to prevent accidents from happening through a process of rigorous work method statements, each submitted to NZW before execution of the work, and risk analysis for all phases of the work. In order to create awareness, reporting of near-misses and unsafe situations was encouraged all in the context of a blame-free culture. The results are given in the table below.

| **Incident** | **Total** |
|---|---|
| | |
| Near misses*/safety reports | 198 |
| Medical treatment cases | 7 |
| Lost Workday cases | 0 |
| Partial or total disability cases | 0 |
| Fatalities | 0 |
| Lost Time Incidents (LTI)** | 0 |

* Near Miss – An unplanned event or sequence of events that does not have actual consequences but that could have unwanted and unintended effects on people's health and safety, on property, on the environment of on legal or regulatory compliance.
** LTI – Lost Time Incidents include, Fatalities, Permanent Total / Partial Disabilities and Lost Workday Cases (but exclude Restricted Work Cases, Medical Treatment Cases and First Aid Cases)

The high number of near miss/safety reports is due to the fact that NZW encouraged reporting of all situations that were considered to be unsafe.. The following table lists the causes of the seven medical treatment cases.

| | INCIDENT | CAUSE |
|---|---|---|
| 1 | Individual fell down open spud hole on transport barge, and received a laceration to his right knee. Happened at night whilst turning off nav light on barge. | Lack of risk assessment. Lack of proper tools, e.g. flashlight. |
| 2 | Individual fell on deck and suffered 3 deep cuts to the back of the right hand. | Could not establish. |
| 3 | Individual stumbled backwards over a block and the wire he was pulling landed on top of his leg, causing a hematoma. | Poor housekeeping |
| 4 | Individual was torquing bolts inside the tower. The individuals right pinkie finger was caught between the tool and bolt, damaging finger tip. | Not paying attention? |
| 5 | During transport pontoon unmooring the right hand of the individual was caught between tug boat fender and stern navigation light holder on the pontoon. Bruised hand. | Poor equipment design. |
| 6 | Individual slipped whilst walking up the first stair, and fell back to the deck. To break the fall individual placed the left hand back which hit the deck first. | Did not hold hand rail. |
| 7 | The individual was positioning a pin into a shackle. The shackle moved slightly and the individual slammed the pin in and caught his right ring finger between the pin and the shackle. Safety glove did not prevent top of finger being damaged, which needed stitches. | Not aware of risks. Not paying attention. |

Note that all incidents were preventable and none of them were due to innovative equipment or technology being used.

# 8 Risk management

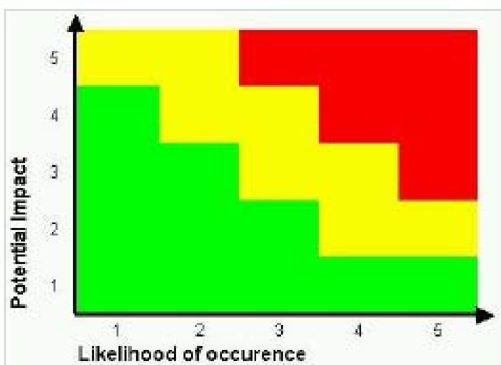
Risks are managed in accordance with the NZW Risk Management Plan. Below is a short summary of the NZW Risk Management Plan for the OWEZ project. This overview provides an insight into the approach of NZW towards risk management on the project.

Risks can be defined as a combination of the ‘probability of the occurrence’ of an event and the ‘likely consequences’ should it occur. Or putting it mathematically: R = P x C.

Risk assessment therefore concentrates on two main questions:

- What is the probability of the risk occurring?
- What are the likely consequences should it occur?
- Is the risk **internal**? (Can it be influenced and managed by the project team? – if it can then it is probably a low category risk)
- Is the risk **external**? (Can it be managed directly by the project team? – if not, then it is likely to be a high category risk)

To provide a visual overview of the major project risks, the identified risks can be plotted on a graph showing ‘Probability’ on the x-axis and ‘Potential Impact’ on the y-axis.




The project accepts that while it is rarely possible to design a risk response which will completely remove the risk (risks are part of doing business), it is generally possible to provide a risk response, which will provide reasonable assurance of managing the risk effectively.

The aim is to have an integrated and structured portfolio of risk responses, designed to:

- Provide reasonable assurance of achieving the business objectives by minimising the likelihood of the risk occurring;
- Maintain an actual RIE (risk assessment and evaluation);
- Balance the cost of responding to risks against the potential for loss or reward;
- Mitigate the impact of a risk, by early alert and recovery initiation.

The decision for an appropriate risk response will depend on the complexity of the risk, the cost of controls and the potential to manage the risk. In any case the risk response should be fit-for-purpose and adequate to deal with the risk”.

NZW has made risk inventories during various phases of the project. The focus and topics of the inventories changed with the phase of the project. During the development phase the main risks identified related to permitting, stakeholder relations and the contracting process. During the construction phase the focus was more on HSSE and construction planning issues. However, stakeholder relations continued to play an important role due to high public awareness of the project. The NZW risk inventories are confidential, nevertheless the following table (part of the risk assessment made in the of summer 2006) gives an example of the wide range of risks identified and managed.

| **Identified risk** | **Measure to limit the impact** |
|---|---|
| Fog: marine collision | Fog horns will be provided to cover the wind farm area. Special arrangements will be required during installation. This is a marine exclusion area, but there is a risk for small vessels especially during construction. Ensure adequate interface with the coastguard. Recognise that there is a different situation for large vessels and small private craft where the risk is to the vessels/crew rather than to the towers. |
| Trespass: people are likely to visit and board the tower platform | The access to the tower is locked. This is a restricted area but there is no protection against people visiting the platform. Develop an appropriate warning system to prevent / limit public access but this should recognise that the towers may represent an appropriate refuge for a small vessel in distress. |
| Stakeholder engagement: this is part of the permit and ongoing project. This project is regarded as a demonstration project. | Social issues exist but none that would affect the construction of the wind farm. Ongoing involvement will be through a continuous monitoring and evaluation programme. |
| Simultaneous construction and operation: twelve (12) turbines may be running whilst the others are under construction. May also be an issue if individual turbines are being commissioned during operation of other turbines in the same string. | Potential competition for transfer boats, complication of emergency response etc. Potential command and control issue during normal concurrent operation as well as emergency response. Review the emergency response plan to ensure there is adequate facilities for all SIMOPS. Confirm there is electrical safety protection within a working string if individual turbines are being started. Hold a meeting/workshop to review concurrent operation safety and emergency response. |
| Various safe working issues: working at height in confined space, lifting heavy equipment, working at night, etc. | Ensure all safe working practices are incorporated into operating procedures. |
| Crane operations during construction. | These are critical operations. Review all lifting operations, procedures and equipment, training to demonstrate that the risks are tolerable and ALARP (As Low As Reasonably Possible). |
| Cable installation: burial depth of offshore cables may not be sufficient resulting in stagnation and additional costs for reburial. | Burial assessment. |

For the contractors the most important risks during the construction phase were the weather, interfaces between contractors and the timing of component delivery. These construction risks were managed by BCE under the EPC contract.

# 9 Financing, Insurance and PPA

## *9.1 Financing*

The investors Nuon and Shell financed NZW using internal funds. The construction costs were supported by a capital grant of up to € 27.2 million from the Department of Economic Affairs and administered by SenterNovem under the $CO_2$ Reduction Scheme.

## *9.2 Insurance*

The main insurances needed for the OWEZ project are the Construction All Risk insurance (CAR) for the EPC contract and the operational insurances. For the operational phase property insurance and third party liability insurance are needed.

The CAR insurance has been tendered with Marsh / London as insurance broker and with continuous advice from Shell and Nuon risk and insurance advisors.

## *9.3 Financial Government support*

As the costs of the project were too high relative to the revenues from power available in the competitive open market, the Dutch government created a financial framework to enable the development, construction and operation of the project. Specifically, the project has benefited from three support arrangements.

*Energie Investerings Aftrek*
Capital investments in clean and efficient energy products qualify for an additional deduction in corporation tax (*vennootschapsbelasting*) called the EIA (*Energie Investerings Aftrek*). The maximum eligible amount and the rate are announced annually by the Department of Finance. NZW benefited from the EIA in 2005, with a maximum eligible amount of €106 million at an additional rate of 44%. With a corporation tax rate of 30% this is a net benefit of circa €14 million.

*$CO_2$ grant*
In the original project tender of 2001, developers interested in the project concession could apply for a capital grant of up to €27.2 million from the $CO_2$ Reduction Scheme. NZW applied for the full amount, which was subsequently awarded. Under the scheme grant payments are made to NZW in arrears as a percentage of costs paid by NZW to its contractors.

*MEP support*
NZW has been granted support under the MEP (*milieukwaliteit elektriciteits productie*) regulation at a level of €97/MWh for a 10-year term commencing on 1st November 2006 during initial production, and runs until 1st November 2016. Payments are made monthly on basis of metered electricity production by EnerQ, a wholly owned subsidiary of TenneT.

*EU approval of state aid*
During preparation for the tender in 2000, the Dutch government obtained state-aid approval from the European Commission for the $CO_2$ grant. Such approval was required because the grant amount, up to €27.2 million (at the time, 60 million guilders),

exceeded the national authority level for providing state aid of €5 million. After the introduction of the MEP and due to changes in the relevant European regulation a further review by the European Commission was deemed desirable. The final approval for the total support package of EIA, $CO_2$ grant and MEP support was received from Brussels in early 2006.

## *9.4 Power Purchase Agreement*

NZW entered into a Power Purchase Agreement (PPA) with Nuon on the following principal terms and conditions:

- Subject of the PPA: The purchase, sale, delivery, acceptance and scheduling of:
  - 108 MW of electricity generated by the Wind Farm;
  - environmental consequences of generating electricity from the Wind Farm;
  - electricity consumption by the Wind Farm itself.
- Power produced following substantial completion will receive a market related price, lowered by a fixed amount per MWh for all variations in electrical output, including those caused by wind and technical availability.
- The PPA is a long-term agreement, duration 10 years.
- NZW has left the management of the Programme Responsibility obligations to the PPA contract partner.
- NZW will therefore provide the contract partner during the PPA with detailed information (as specified in the Notification Protocol) on the Wind Farm's commissioning programme, annual maintenance plans, forecast availability, actual availability and scheduled outage programme.
- Invoices will be issued monthly.

# 10 Quality assurance management

The goal for the owners of NZW, Nuon and Shell, as well as for the construction consortium BCE, was to assure that the project runs safely with a minimum of quality problems and all contract conditions are fulfilled upon completion. The quality assurance management system was designed jointly with BCE. First step was setting up a system of QA and QC procedures. The following steps were identified:

- Engineering design reviews. These focused on the design processes and documentation produced, and to a lesser extent the technology itself.
- Quality system reviews, used to judge to what extent the QA systems in place were considered to be fit for purpose.
- Production and document audits, to inform NZW on the actual production processes and QA documents produced.
- Quality control during manufacturing and installation. Quality control during these stages was the responsibility of BCE. During pre-assembly and installation NZW's site representatives also played an important role by checking if the correct procedures were being followed.
- Document control audits. These focused on the paper flow around the project, to ensure correct handling and storage of all project documentation.

The joint approach to QA management by NZW and BCE enabled Nuon and Shell to offer their experience to BCE. As a result NZW got a direct insight into the quality approach taken by the suppliers and sub suppliers.

To achieve the required level of quality efficiently a QA system was set up based on a risk assessment of the applied technology, instead of focusing on all production stages of all components. Design reviews in the pre-contracting phase gave an insight into the areas to focus on. The QA management program was then run on these areas, which are listed below.

- Step up transformer manufacturing.
- Sea cable design.
- Monopile and transition piece manufacturing.
- Turbine tower. Main emphasis was given to corrosion protection systems.
- Turbine mainframe and hub.
- Blade pitch system, the hydraulic system, the blade bearings and the pitch cylinders
- Drive train, gearbox and generator
- Turbine transformer
- Rotor blade design and manufacturing
- Nacelle assembly
- Control cabinets
- Turbine switch gear
- Scada system
- Pre-assembly work at IJmuiden
- Assembly work offshore
- Engineering clarification meetings

A clear distinction could be seen between the quality management set-up of the turbine manufacturer, where existing and working systems were used, and that of the project related works, were QA/QC systems had to be tailor made, set up and implemented.

# 11 Requirements and Qualifications

## *11.1 Policies, standards and codes*

For this project many policies, standards and codes were prescribed and enforced through the EPC contract with BCE. These standards were attached to the contract as schedule 4.2, and shown in Annex 2 of this report.

The EPC construction contract specified that the design of the support structure had to be in accordance with DNV OJ-101. The entire design also had to be certified by DNV, and a summary of their scope of work is indicated in the table below.

| DNV | Wind turbine | Support structure | Electrical system |
|---|---|---|---|
| Design basis | ***V*** | ***V*** | ***V*** |
| Detailed design | ***V*** | ***V*** | ***V*** |
| Manufacturing | | ***V*** | |

The Vestas V90 turbine came with a type (not project specific) approval certificate from DNV, therefore avoiding the need for certification from DNV. The tower also came type approved, although wall thickness had to optimized for the OWEZ wind climate,. The towers were designed and manufactured by Vestas in Denmark.

The design of the support structure required significant DNV attention. All calculation reports and drawings were reviewed and checked by DNV. In a number of cases, as part of normal certification process, DNV performed their own FE analysis to verify the IC+E work, including:

- Load set generation;
- Grouted connection between monopile and transition piece;
- Engineering critical assessment of steel welds.

The design certification subcontract was assigned to BCE, which allowed one-on-one communication between discipline engineers. The findings of DNV were discussed in several meetings with IC+E, some of which were attended by NZW.

DNV were also asked by BCE to witness the fabrication of monopiles and transition pieces at Bladt in Denmark.

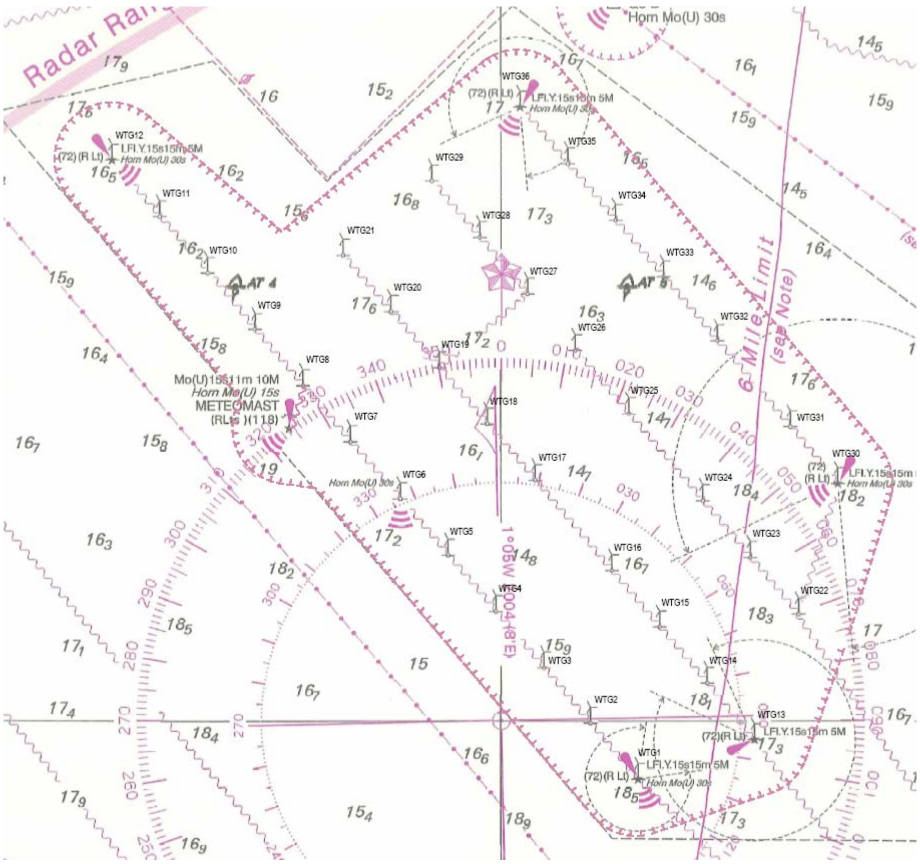
In October 2006 a number of statements of compliance were issued by DNV, including those relating to design and manufacturing of the OWEZ turbines and support structures.

## 11.2 Permits

For an overview of all permit requirements reference is made to a separate report by NZW which describes the permitting procedure for OWEZ: OWEZ_R_192_20070820, available at [www.noordzeewind.nl](http://www.noordzeewind.nl).

## 11.3 Restricted area

The site of the wind farm is closed to all shipping traffic, except Rijkswaterstaat vessels or vessels allowed by NZW to enter. The boundary of the closed area extends 500mbeyond the outermost wind turbines, see map below (detail of annex 3).




The Dutch Coast Guard is responsible for enforcing the closed area. NZW has, together with BCE, implemented a system of vessel access control. Only after obtaining a Permit To Work, issued by the operations centre of BCE, can vessels enter the site.

# 12 Monitoring and Evaluation Program

As part of the OWEZ project a monitoring program was set up to gather information on environmental and technical aspects of the wind farm. The aim of the environmental research is to generate knowledge to support decision making for future projects. Results from the research on technology will support attempts to reduce the costs of generating power from wind energy at sea in the future. This chapter describes the hardware installed to support the program.

## *12.1 Meteorological (met) mast*

At the site a met mast was erected to measure the actual weather and wave conditions [5]. A cable connection between the met mast and the wind farm provides power and data transport capacity.

To achieve sufficient stability for the instruments the met mast is constructed as a triangular lattice tower, mounted on a monopile foundation, driven in the seabed. The distance between the instruments and the lattice tower is sufficient to limit the inaccuracy of wind speed measurements to 5% (except wake effects).
Instruments are installed at three levels: 70m above mean sea level, which is the hub height of the wind turbines, at 21,6m and 116m. The latter two heights enable the wind speed profile over the entire rotor diameter of 90m to be calculated. At each level wind speed and wind direction are measured using three booms situated at 300º (NW), 60º (NE) and 180º (S).
At each level the wind speed is measured by cup anemometers and by an acoustic instrument, capable of measuring detailed horizontal and vertical wind speed and direction variations.
Additional instruments like rain sensors, temperature sensors, air pressure and an Acoustic Doppler Current Profiler (ADCP) were also installed.

## *12.2 Instrumentation technology research*

Wind turbines 7 and 8 were equipped with extra instrumentation. At these two turbines loads in the blades and towers are measured as well as lightning currents. Data is collected and stored in the relation database, made by ECN [1]. Detailed operational data of wind turbine 7 and 8 will be stored as well and can be used to improve understanding of the load data. Production data from individual wind turbines is also stored as well as event logs. This data is supplied by the Scada system of the wind farm. At the substation, equipment is installed capable of measuring the temperatures occurring in the SCC and this data is also fed into the database.

Except the wind data, all other data is available from NZW on request, which can be done via the website at www.noordzeewind.nl

## 12.3 Instrumentation environmental monitoring

At the met mast, two bird radar systems were installed. One system scans in a vertical direction, thus registering birds passing the wind farm. The second system is a horizontal radar used to monitor the flight paths of migrating birds. Both systems use the glass fibre data network of the wind farm to transmit their signals to shore.

## 12.4 Research during construction

During construction environmental monitoring was conducted, and focussed on bird movements and under water noise level generated during piling activities. Results are published elsewhere [3,4].

# 13 Lessons Learnt

Design, construction and commissioning of a large project such as OWEZ is a major task. The offshore wind industry is still in its early years of development. The main lesson learnt from OWEZ is that it is possible to design, construct and deliver a 108MW offshore wind farm in 19 months on time and on budget, without serious injuries or problems. This achievement is due to the combined efforts of many hundreds of people working on vessels, in factories and offices, with NZW, BCE, Continuon, and the many subcontractors, all of whom worked hard to make the project a success. Key experiences and lessons for future projects are summarized below.

## *13.1 Contracting and contract management*

The bulk of the work was carried out under a lump sum turnkey contract, which put the burden of interface management on BCE. In order to create alignment between contractor and client objectives, close cooperation was established between the management teams of BCE and NZW. Weekly project progress meetings between client and contractor were held throughout the project. Regular design and method reviews ensured alignment between contractor deliverables and client expectations. A high degree of flexibility and adaptability was required on both sides to ensure that issues were identified and resolved in an efficient manner.

Project management teams at contractor and client side mirrored one another to an extent, with project managers responsible for the main packages including civil design and installation, wind turbines, and the electrical system. The core NZW project team was supported by discipline experts from the parent organisations Shell and Nuon, as well as external specialists. Site representatives were present at all main onshore and offshore construction sites, with a remit to ensure a high quality and safe execution of the work.

Managing a contract and controlling costs requires a clear scope of work in the contract and a common understanding of that scope by both the contractor and client. Whilst it is relatively straightforward to define the technical scope, this is more difficult for the "softer" issues, such as assessment of safe working methods, because company culture and management style play a greater role. Ideally, concept selection and all main work methods should be discussed and agreed prior to signing the contract. This would require nomination of all main subcontractors and installation vessels at the contracting stage.

## *13.2 Design process*

The wind turbine tower was designed by Vestas, and the Ballast Nedam company IC+E designed the support structure. The design process became an iterative one requiring a number of repetitions before the stiffness of the foundations in FLEX5 and Ansys converged. In hindsight it would have been easier to use an integrated software package capable of modeling rotor aerodynamics, turbine rotating equipment, tower, waves, foundation structure and non linear seabed. However, a suitable software package was not available. Furthermore Ballast Nedam and Vestas decided that each would bear responsibility for their own detailed design. In general, wind turbine manufacturers are not keen to sharing the detailed aerodynamic properties of their turbines, and insist on in-house load modeling. The iterative process may appear protracted but it has resulted in a fully optimized support structure design for OWEZ. On the one hand it is recommended to design the tower, support structure and foundation using one integrated software package. This would save time and reduce the risk of interface errors made in the iterative process. On the other hand, suitable software packages are limited and most are developed by turbine manufacturers and not commercially available. OWEZ has shown that it is possible to split tower and foundation design, and still perform the necessary iterative design process.

## *13.3 HSE (Health, safety and environment)*

The strict safety policy of the project was a success. Client, contractors and subcontractors adopted the project's "target zero", which meant zero serious incidents (i.e. incidents resulting in absence from work). No serious injuries took place and the project's target was met. Crucial factor in this success was the continuous management attention at all levels of both client and the contractor.

This was a learning process that was driven by senior level management commitment, and implemented by addressing safety at all key steps. The key theme was "ALARP", meaning: getting risks down to a level that is as low as reasonably practicable. This was achieved by design reviews, and by method statements and risk assessments that were produced for all main parts of the construction process. Frequent joint client-contractor workshops were held addressing special topics, such as the design of the access system, and diving works – these were a very effective forum for transfer of expertise and for alignment of expectations.

The 'no blame' culture encouraged reporting of accidents and incidents which reduced the risk of them happening again. Whilst HSE management is a top responsibility for all line managers, the assistance of dedicated HSE managers was very valuable. They provided the necessary support systems, and enabled project managers to keep track of the developments. Though safety was not their primary job, the NZW site representatives also played an important role in achieving good HSE performance.

## *13.4 Installation procedure*

The OWEZ project was the first offshore wind turbine foundation installation job performed by the heavy lift vessel Svanen. The vessel, originally built for the construction of large bridges, was adapted to be suitable for this job. A support crane and piling frame were added and used for pile handling during loading onto the Svanen and the piling operation itself.

Loading the piles from the transportation barge onto the Svanen was a complex operation. After the first planned trial the working method was adjusted, resulting in a two week delay on the first pile being driven. This was more than compensated for by the speed with which the Svanen crew learned to execute the installation process (refer to chapter 5 "Svanen cycle"). After the first 10 foundations the cycle time had come down to 2 days and later ones were installed in a cycle of one day. The Svanen has no fixed crew. A learning cycle will therefore apply again in a next project as is usual in construction projects with a unique nature. To a certain extent the rapid installation was also due to good weather conditions.

Following the piling operation the anode rings were put in place. This design choice was made to prevent the anodes being subject to heavy loads during piling. The resulting installation works were rather complex and a design without anode rings would have been easier to install.
The wind turbines were installed using state of the art installation methods proven to work in earlier projects (Horns Rev, Kentish Flats etc.). This worked well also in OWEZ.

## *13.5 Electrical system*

The chosen ungrounded electrical system (star point without earth connection) is not the optimal choice from an operational point of view. An ungrounded system makes it very difficult to find earth faults in a cable and in earth fault situations higher than desirable voltages do occur in other parts of the system. By adding a grounding transformer in the substation the ungrounded system was replaced by a non-effective earthing system. A non-effective earthing system with grounding transformer restricts the fault currents in case of a grid failure and realizes controlled damage at the fault location. This kind of damage enables faster fault location determination and restoration of the grid. The non-effective earthing system with grounding transformer restricts the ground currents and therefore reduces the step and touch voltages that pose a human safety risk.

At the point of connection between the shore connection cables and the wind turbines, circuit breakers are installed that can only be operated manually when the line voltage is not present. These circuit breakers are cable terminations that are plugged into the switchgear. This means that when an entire string of twelve turbines is down, any switching needs to be done at the turbine offshore and requires a boat trip. Ideally, this should be done by remotely operated switchgear in order to restrict downtime and provide more operational flexibility.

## *13.6 QA management*

As with safety management, effective quality assurance needs to be driven by client and contractor jointly. The quality assurance plan that was developed in an early phase of the project, was used to create alignment, and subsequently quality inspections and site visits were mostly done jointly. These joint efforts of NZW and BCE worked quite well. The quality assurance program focused on manufacturing, assembly and installation processes, rather than on detailed design. It is recommended for future projects that such a joint quality program is implemented, in order to reduce non-conformances and quality issues in a later phase. This is cost-effective and minimises any delays.

# 14 Reference list

[1] NSW-MEP; Technology, Economics and Safety; Detailed action plan; NoordzeeWind, July 2nd 2004
[2] OWEZ_R_192_20070820 vergunningen (in Dutch with English summary)*
[3] OWEZ_R_221_Tc_20070525 birds*
[4] OWEZ_R_251_Tc_20071029 underwater noise*
[5] User manual data files meteorological mast NoordzeeWind**

* Reports can be downloaded from www.noordzeewind.nl, for publication date refer to report number

** Can be downloaded from www.noordzeewind.nl

# Annex 1 Met mast OWEZ

The set up of the met mast and instrumentation can be found in the “user manual data files meteorological mast NoordzeeWind”. This document will be updated from time to time. Please refer to the NoordzeeWind web site www.noordzeewind.nl for the latest version.

# Annex 2 Schedule 4.2 EPC contract (applicable standards)

# NEAR SHORE WINDPARK PROJECT

**SCHEDULE 4.2**

**POLICIES, STANDARDS AND CODES**

**REV H DATE: 07-03-2005**

**NUMBER OF PAGES: 15 including this cover**

For and on behalf of

**NOORDZEEWIND INVESTOR I CV**

For and on behalf of

**BALLAST NEDAM EGMOND OFFSHORE ENERGY BV**

For and on behalf of

**VESTAS OFFSHORE APPLICATIONS BV**

Checked

# SPECIFICATION

## Policies, Standards and Codes

### Issue and Revision Record

| Rev | Date | Originator (Print) (Signature) | Checker (Print) (Signature) | Approver (Print) (Signature) | Description |
|---|---|---|---|---|---|
| A | Jan 04 | | | | Draft issue for review |
| B | 11 Mar 04 | | | | Draft issue for review |
| C | 15 Mar 04 | GR | | | Draft issue for review |
| D | 31 Mar 04 | GR | | | Draft issue for review |
| E | 7 April 2004 | GR | | | Final |
| F | 1 December 04 | MH | | | Minor changes for final version |
| G | 3-March 05 | MH | | | Addition to electrical specs |
| H | 7-March-05 | MH | | | Formatting changes |

**NOTE:**

**REFERENCES TO "EPC CONTRACT" MEAN "THE CONTRACT AND LEGAL REQUIREMENTS".**

## Table of Contents

# 1 Introduction

## 1.1 Scope

This Specification forms part of an EPC Contract to install an offshore wind farm and should be read in conjunction with the EPC Contract and associated Scope of Work and other Project Specifications attached to the Scope of Work.

This Specification lists all the policies, standards and codes relevant to the Project and shall be the source document for all standards called up in other Specifications in this series. As far as is practicable the policies, standards and codes are grouped by discipline.

The standards and codes listed in this Specification shall be the minimum basis of design and construction for all aspects of the Project. These standards and codes shall apply to design and construction, along with any standards and codes specifically mentioned within any individual specifications related to the EPC Contract or Scope of Work for the Project.

## 1.2 In-house Standards

Any in-house standards employed by the Contractor during the design or construction of the project shall be clearly identified by the Contractor, highlighting any specific clauses applied. Any use of the Contractor's own in-house standards shall be brought to the attention of the Owner. All cases of work where no specific Code or Standard exists shall be identified, and sufficient data regarding these shall be provided to enable the Owner to evaluate the standard to which the work shall be carried out.

## 1.3 Definitions

Definitions used in this schedule comply with the definitions of the Contract with the exception of the following:

- The word **shall** indicates a requirement.
- The word **should** indicates a recommendation.

# 2 Policies

The policies listed below have been identified as relevant to the Project:

- Royal Dutch/Shell Group of Companies - 'Statement of General Business Principles'
- Shell WindEnergy "HSE-Management System". Particularly note the "Hazards and Effects Management Process (HEMP)" and "Appendix 12: SWE Generic Hazards and Effects Register"
- Shell WindEnergy "Contractor Health/Safety/Environment (HSE) Minimum Requirements, Guidelines and Best Practices"

- Shell Expro "Adverse Weather Working Policy", document number 3108-001

The document below is listed for reference and it shall be given full consideration by the Contractor:

- Near Shore Windpark Monitoring and Evaluation Programme (NSW – MEP)

# 3 Permits

Compliance with all permits listed in Schedule 3 must be achieved during all phases of the Project.

# 4 Standards

## 4.1 Introduction

This section lists the standards that shall be referenced with regard to the design and construction of the Near Shore Windpark. While every effort has been made to ensure a comprehensive list, the Contractor should inform the Owner of any omissions.

## 4.2 Wind Turbine Standards

- NVN 11400-0 Wind Turbines Part 0 – Criteria for Type-certification – Technical Criteria
- IEC WT-01 IEC System for Conformity Testing and Certification of Wind Turbines – Rules and Procedures
- IEC 61400-13 Mechanical Load Measurements
- IEC 61400-21 Power Quality
- IEC 61400-23 Blade Structural Testing
- IEC 61400-24 Lightning

## 4.3 Quality Standards

- ISO 9000-serial: 2000

## 4.4 Corrosion Protection Standards

- Shell Expro ES/115 Corrosion Protection of Fixed Steel Structures: Offshore Installations

  *Note: Corrosion allowance has been agreed to be 6 mm, based on suitable and agreed coating being applied.*

## 4.5 Painting and Coatings

- Shell Expro ES/011 Painting and Coating Systems Vol. 1, 2 & 3.

*Note 1: The Owner agreed to remove the requirement for polychloroprene coating on the inside of the J-tubes. It was agreed that a suitable cable protection similar to 'Uraduct' or 'Omtec' would be used in the area near the monopole beyond the J-tube mouth and that the J-tube would be sealed at the bottom.*

*Note 2: NZW advised that for the North Sea usually 500 μm coating thickness are applied. NZW stressed the importance of surface preparation and strict quality control throughout the coating appliance. BCE agreed to involve NZW at a very early stage when defining the coating for the transition piece and to forward coating procedures as soon as drafts are available. Specifically 'HOLD points' during the coating process need to be selected in agreement with NZW.*

*Note 3: NZW explained that the experience with measuring potential without direct contact to the anode was bad. NZW agreed to delete the requirement for a constant cathodic protection (CP) monitoring system subject to an increased inspection regime. It was agreed that a baseline survey (ROV stabbing the anodes and inspecting them visually) would be carried out as well as identical follow-up surveys every two years. This regime would be reviewed based on the results after 5 years.*

## 4.6 Electrical Standards, General

- NEN 1010, Safety requirements for low-voltage installation
- NEN 1041, 1982, Safety regulations for high-voltage installations
- NEN-EN 50110, 1-2 , 1998, Operation of electrical installations
- NEN 3840, 1998, Operation of electrical installations; Additional Netherlands requirements for high-voltage installations
- NNI, Oct. 1998, Operation of electrical low voltage installations
- IEEE 519 Electrical system harmonics
- IEC 60085:1984 Method for determining the thermal classification of electrical insulation
- IEC 60726 Dry-type Power Transformers
- EN 10257-2, medium voltage cables
- IEC 332, Flame retardant in cables
- BS 5308, Control & Instrumentation cables
- IEC 60034-serial: Generator

## 4.7 Power transformers

- IEC 60076-1, Power transformers - Part 1: General
- IEC 60076-2, Power transformers - Part 2: Temperature rise
- IEC 60076-3, Power transformers - Part 3: Insulation levels and dielectric tests
- IEC 60076-4, Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing; Power transformers and reactors.

- IEC 60076-5, Power transformers - Part 5: Ability to withstand short circuit
- IEC 60076-8, Power transformers - Part 8: Application guide for power transformers
- IEC 60606, Application guide for power transformers
- IEC 60214-1, Tap-changers; Part 1: Performance functional specifications and test methods
- IEC 60354, Loading guide for oil-immersed power transformers
- IEC 60542, Application guide for on-load tap-changers
- IEC 60137, Insulating bushings for alternating voltages above 1000 V
- IEC 60044-1, Current transformers
- IEC 60551, Determination of transformer and reactor sound levels
- IEC 60296, Specification for unused mineral insulating oils for transformers and switching gear
- IEC 60034-1,Rotating electric machines - Part 1: Rating and performance
- IEC 60289, Reactors
- IEC 60422, Supervision and maintenance guide for insulating oils in electrical equipment
- IEC/TR 60616, Terminal and tapping markings for power transformers
- IEC 60076-3,1,Power transformers. External clearances in air.
- IEC 60071-1, Insulation co-ordination - Part 1: Definitions, principles and rules
- IEC 60071-2, Insulation co-ordination - Part 2: Application guide
- IEC 60071-3, Insulation co-ordination - Part 3: Isolations co-ordination

## 4.8 Switch gear

- IEC 60694, Common specifications for high voltage switchgear and control gear standards

## 4.9 Instrument transformers

- IEC 60044

## 4.10 High voltage switch gear ant control gear

- IEC 62271

## 4.11 Lightning Protection

- IEC/TR 61400-24NEN 1014, 1992/C2: 2000, Protection against lightning

## 4.12 Power cable

- IEC 60502, Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV),
- IEC 60811, Common test methods for insulating and sheathing materials of electric cables and optical cables,
- IEC 60885, Electrical test methods for electric cables,
- VDE 220, Bestimmung für Pressverbinder in Starkstrom-kabelanlagen,
- VDE 472, Prüfung an Kabeln und isolierten Leitungen. deel 631 Teil 631: Härteprüfung nach shore D.,
- IEC 60230, Impulse tests on cables and their accessories.
- IEC 61442, Electric cables - Test methods for accessories for power cables with rated voltages from 6 kV (Um> = 7,2 kV) up to 30 kV (Um > = 36 kV)
- IEC 60840, Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um=36kV) up to 150 kV (Um=170 kV) - Test methods and requirements
- Cigre, magazine Electra, CE/SC 21, 2000, ref 189, Recommendations for testing of submarine cables with extruded insulation for voltages from 30 (36) to 150 (170) kV, revision 990811, editorial amendment 00013

## 4.13 Communications and Optical Fibre Cables

- IEC 60793-serial Termination and testing of Optical Fibre Cables
- IEC 60794-serial Mechanical Structure for Optical Fibre cables
- ISO 11801 Structured cabling Optical Fibre Cables
- BS 7718 Installation of Optical Fibre Cables
- EN 188000 Generic specification Optical Fibre Cables

## 4.14 Control & Instrumentation

- BS 6739 process control, installation and practice (instrumentation)
- BSEN 60529 IP codes for housings (dust and water exclusion)
- IEC 61131 PLC programming languages

## 4.15 Mechanical Standards

- DNV-OS-J101 Design of Offshore Wind Turbine Structures

## 4.16 Safety Related Standards

- BS EN 3 Portable Fire Extinguishers
- NEMA MG-1 National Elect. Manufacturers Association – Motors & Generators
- BS 7671:2001 IEE Wiring Regulations 16th Edition

## 4.17 Earthing Standards

- 
- NEN 1041, 1982, Safety regulations for high-voltage installations
- NEN 1010, Safety requirements for low-voltage installations
- NEN-EN 50110-1 , 1998, Operation of electrical installations
- NEN 3840, 1998, Operation of electrical installations; Additional Netherlands requirements for high-voltage installations
- NEN 3140, 1998, Operation of electrical installations; Additional Netherlands requirements for low-voltage installations
- NNI, Oct. 1998, Operation of electrical high voltage installations
- NNI, Oct. 1998, Operation of electrical low voltage installations
- NEN-EN-IEC 61000 Electromagnetic Compatibility
- NPR 2760, 1991, Mutual influence of pipelines and high-voltage circuits
- CENELEC HD 637 S1:1999 Power installations exceeding 1 kV a.c.
- Cenelec prEN 50179, Power installations exceeding 1 kV a.c.
- IEEE guide for safety in AC substation grounding ANSI/Std 80-2000
- IEC 60044 Instrument transformers
- IEC 62271 High-voltage switchgear and control gear

## 4.18 Electromagnetic Compatibility Standards & Electrostatic Immunity Standards

- 
- NEN 1041, 1982, Safety regulations for high-voltage installations
- NEN 1010, Safety requirements for low-voltage installations
- NEN-EN 50110-1 , 1998, Operation of electrical installations

- NEN 3840, 1998, Operation of electrical installations; Additional Netherlands requirements for high-voltage installations
- NEN 3140, 1998, Operation of electrical installations; Additional Netherlands requirements for low-voltage installations
- NNI, Oct. 1998, Operation of electrical high voltage installations
- NNI, Oct. 1998, Operation of electrical low voltage installations
- NEN-EN-IEC 61000 Electromagnetic Compatibility
- NPR 2760, 1991, Mutual influence of pipelines and high-voltage circuits
- CENELEC HD 637 S1:1999 Power installations exceeding 1 kV a.c.
- Cenelec prEN 50179, Power installations exceeding 1 kV a.c.
- IEEE guide for safety in AC substation grounding ANSI/Std 80-2000
- IEC 60044 Instrument transformers
- IEC 62271 High-voltage switchgear and control gear
- IEC 60044 Instrument transformers

## 4.19 Materials Standards

- DNV-OS-J101 Design of Offshore Wind Turbine Structures
- BS 7191 Weldable Structural Steels for Fixed Offshore Structures, as amended by (Shell International DEP number 37.19.10.30)
- Shell International DEP number 37.19.10.30 Weldable Structural Steels for Fixed Offshore Structures (Amendments / Supplements to BS 7191)
- BS EN 10219 Cold formed welded structural hollow sections of non-alloy and fine grain structural steel

  *Note on 'Through live inspection': BCE explained that their philosophy was based on checking against fatigue by using the highest category of DNV standard J101. If designed to this category (FD=3), DNV only requires visual inspection, no other through life inspection. Governing design criteria is currently the ultimate state, not fatigue.*

  *As long as the governing design criteria is the ultimate state the Owner agrees with the above approach. If fatigue should become the governing design factor, the design has to be discussed and agreed with the Owner.*

  *In any case BCE will carry out a risk assessment of the critical welds in line with the DEP.*

## 4.20 Structural Design Standards

- DNV-OS-J101 Design of Offshore Wind Turbine Structures
- NVN-ENV 1993-1 Eurocode 3; Design of steel structures

## 4.21 Meteorological Mast Standards

- IEA (1999): International Energy Agency Annex Xi, "Recommended Practices for Wind Turbine Testing - 11. Wind Speed Measurement and Use of Cup Anemometry", ED. R S Hunter 1st edition 1999
- IEC 61400-12:1998 Wind Turbine Generator Systems – Part 12: Wind Turbine Power Performance Testing. Also covers wind vanes, pressure and temperature

## 4.22 Certification Standards

- DNV-OS-J101 Design of Offshore Wind Turbine Structures.
- NVN 11400-0 Wind Turbines Part 0 – Criteria for Type-certification – Technical Criteria

## 4.23 Health and Safety Standards

- NVN 11400-0 Wind Turbines Part 0 – Criteria for Type-certification – Technical Criteria
- PrNEN-EN 50308 Wind turbines-Protective measures-Requirements for design, operation and maintenance

## 4.24 Environmental Standards

- ISO 14001

## 4.25 Welding Standards

- Shell International DEP 30.10.60.18 Welding of Metals
- DNV Offshore Standard DNV-OS-C401 'Fabrication and Testing of Offshore Structures'

## 4.26 Through Life Inspection

- Shell International document DEP 37.19.60.10, Structural Inspection of Offshore Installations

  *Note: See note under 4.19.*

## 4.27 Marine & Aviation Warning Lighting

- "Recommendations for the marking of Offshore Wind Farms", International Association of Marine Aids to Navigation and Lighthouse Authorities, IALA Recommendation O-117.

## 4.28 Drawing and Documentation Standards

- ISO handbook 12, second edition, 1991
- NEN Bundel 10, Standards for construction drawings, 1987
- IEC 61082

## 4.29 Unit Standards

- ISO 1000 SI units and recommendations for the use of their multiples and of certain other units

## 4.30 Marine Operations

- Shell International document "Mooring of Mobile Units" DEP 37.91.10.11.
- Shell UK document 'Exploration and Production Marine Operations Manual 3503-001'
- DNV Code for Lifting in a Marine Environment, RP 5

## 4.31 Diving Operations

- EP-2005-0365 Underwater Operations
- Dutch Legislation: Mining and Safety Rules; SR 3: Operations under water or under pressure
- IMCA Information Note IMCA D 05/03 Netherlands Offshore Diving Regulations
- SIEP / Shell Operating Companies Underwater Handbook – Draft
- NAM document S.UW.1.101 Underwater operations Guidance Manual
- NAM document S.UW.3.401 Marine Operations In Support of Underwater Operations.

## 4.32 Building/Civil Construction

- Bouwbesluit 2003
- KOMO certificates for all building materials, processing according to relevant BRL
- IEC 60364 Electrical Installations of Buildings
- Nen-EN 1838, Lighting applications; Emergency lighting
- NEN 6088, Fire safety of buildings; Escape route signs; Characteristics and determination methods
- NEN-EN 12665, Light and lighting; Basic terms and criteria for specifying lighting requirements
- NEN-EN 12464, Light and lighting; Lighting of work places
- NEN 1010, Safety requirements for low-voltage installations
- NEN-EN 50172, Emergency escape lighting systems

- NEN 3011, Safety colours safety signs
- IEC 60598-2-22, Lamp control gear - Part 2-7: Particular requirements for d.c. supplied electronic ballasts for emergency lighting
- CUR aanbeveling 24, Krimparme cementgebonden mortels
- FIP-CEB Bulletin de Information 197 High strength concrete, 1998

## 5 Grid Codes

The following codes have been identified as relevant to the Noordzee Offshore Wind Farm project:

- The "Netcode", the "Systeemcode" and "Meetcode" of the Dutch regulator DTe ("Dienst uitvoering en toezicht Energie") .

# Annex 3 Nautical map