ISC
Innovative Engineering

NYSTED OFFSHORE WIND FARM
TRANSFORMER PLATFORM

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Introduction

In 1998 a decision was made by the Danish Government, that two large scale offshore wind power parks should be established.

The two offshore areas chosen for the wind power parks were located in the North Sea outside the west coast of Jutland and in the Baltic Sea south of the island of Lolland.

The North Sea Wind Park, Horn Rev was established and in 2002. The Baltic Sea wind power park, named Nysted, is located on the sandbank "Rødsand" and was established in 2003.

This article will describe the design and installation of the offshore substation (transformer platform) which is part of the Nysted Wind Power Park as well as general design criteria for this type of installation.

Fig. 1 View of Nysted Wind Power Park

The establishment of the wind power park was carried out by a joint venture of the energy companies Energi E2, DONG and the Swedish energy company Sydkraft. The power distribution net from the park was to be established by SEAS Transmission that has responsibility for the overall power network in the region and as part of this, the offshore substation (transformer platform).

The Nysted wind power park consists of 72 wind power turbines placed in a parallelogram pattern made up from eight rows of nine wind turbines each. Output from each wind turbine, delivered and installed by Danish manufacturer Bonus (now part of Siemens), is 2.3MW yielding a total output for the wind park at 165.6MW, slightly larger than Horns Rev 160MW.

As part of the project to erect the offshore park the grid network on the island of Lolland and further north had to be upgraded. All high power cabling inside the park and upgrading of the onshore grid was at the responsibility of SEAS Transmission. With a distance to shore of approximately 10 km, and about 15 km to the onshore switchgear station the solution was to establish a local offshore substation (transformer platform) to transform the 33kV delivered by the wind turbines to 132 kV suitable for transfer to the onshore power grid.

The transformer platform was geographically located so that a minimization of the internal cabling between the wind turbines and the transformer platform was obtained as well as an optimization of the main export cable to the onshore station.

The complete design of the offshore transformer platform was carried out by ISC Consulting Engineers A/S, except for the high voltage cabling and communication systems (substation control). The latter was carried out by the technical department at SEAS.

Platform Concept and Layout

It was important that the platform should be functional, efficient and economical with regard to the main functions. At the same time it should be architecturally attractive and disturbance of the many sailors in the area should not occur. Therefore ISC came up with several different architectural design proposals for the platform during the project start-up phase.

Using ISC's extensive experience from offshore Oil & Gas platform design in the Danish North Sea and abroad, ISC proposed to employ a tailor-made steel topside structure with all equipment installed and tested onshore before installation in order to minimize offshore work hours.

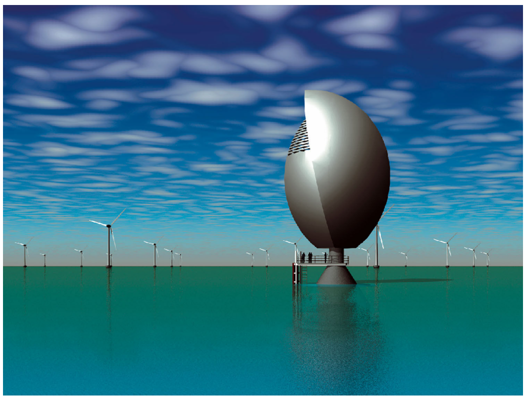


Fig. 2 Early Platform Concept

Having evaluated multiple layouts and exterior designs, finally a rectangular transformer module with an open cable deck and with a small base steel tube/tower similar to a North Sea marginal field oil platform jacket was chosen as the most competitive solution. The topside was also to have an architectural stainless steel cladding with cladding profile cross sections reflecting the sun and sea.

With the park located at a moderate distance from the servicing harbor in the town of Gedser, a decision not to install helicopter facilities was made, e.g. all transport to/from and within the park is by boat transport. Safe operation of the service boats, with regard to access through the boat landing, requires that wave heights are below 1.5 m.

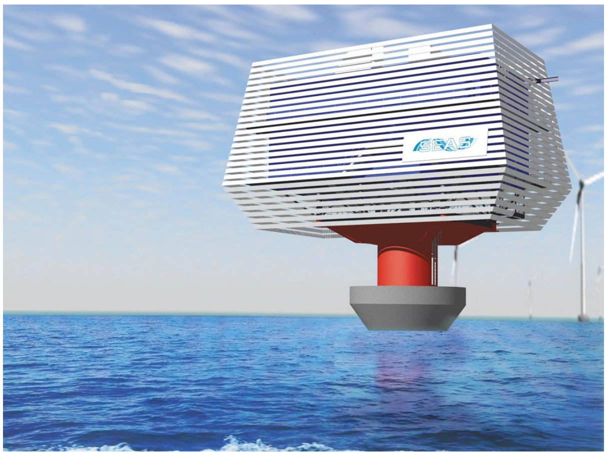
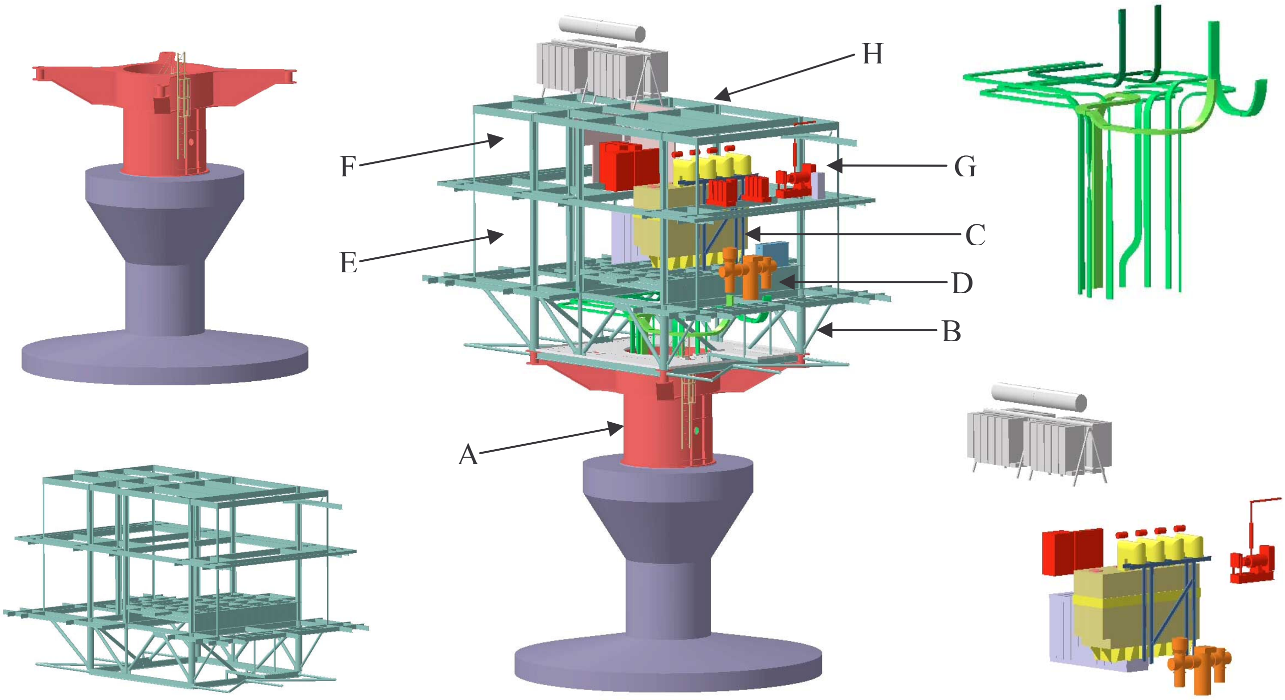


Fig.3 Nysted Transformer Platform, 3D CAD model

To ensure optimization of the location of the various main components as well as the main cabling, ISC applied the 3D program CATIA, throughout the design phase. The entire platform including the steel structure, foundation, equipment and main cabling was incorporated into the ISC 3D model.

The overall platform layout incorporates the following main parts which are indicated on the figure and described in detail below:



- Column (**A**) with access stairway from Foundation Deck to Cable Deck, HV cable routing to Cable Deck, access to Sump Tank.
- Cable Deck (**B**) with access to the closed module, HV cable raceways between the HV components, life saving equipment.
- Transformer Room, two storeys (**C**) with Main Transformer (132 kV/33 kV) and Oil/water Separator.
- GIS Room (**D**) with Gas Insulated Switch GIS (132 kV).
- HV Switchgear Room (**E**) with HV Switchgear (33 kV) and Auxiliary Transformer (33kV/400 V)
- Living Room (**F**) for temporary staying.
- Low Voltage Room (**F**) with 400kV Panels, Wind Turbine Control Panels, Fire Safety Panel, Communication Panel.
- Utility Room (**G**) with Emergency Generator (90 kVA), Battery Bank,
- Roof Deck (**H**) with Cooling/Expansion Unit for Main Transformer, antennas.

Fig. 4 3D CAD Model, Platform Main Elements.

Specifically 3D modeling of the high voltage cable installation, having allowable bend radiuses of about 1200 mm was important in order to ensure that the necessary space was available and that clashes would not occur.

The topside steel tube base structure serves as access stairway from the boat landing leading up to the cable deck. The cable deck is open to the environment only shielded by the cladding and functions as distribution area for the in- and outgoing cables as well as housing muster stations with lifesaving equipment, e.g. inflatable lifeboats etc..

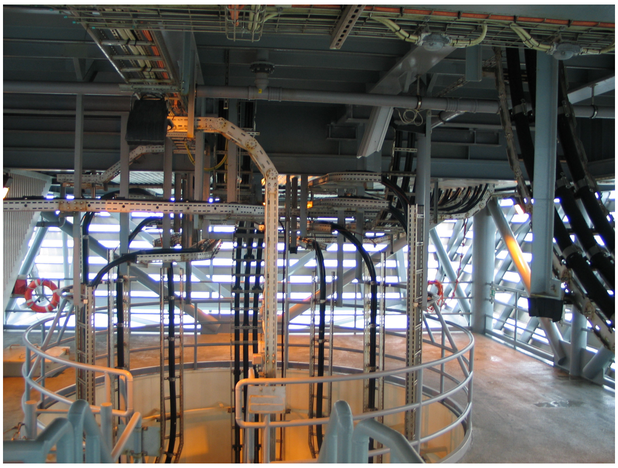


Fig. 5 View of Cable Deck.

The Cables are brought up from sea bottom level inside the foundation through pipes in the concrete in an equal angle of 29/32 degrees in between. Above the foundation level the outer sea cable armor is dismantled from the cable and the three core cables are brought up on steel cable trays to the cable deck through the steel tube tower, where they are distributed to the above switchgear equipment inside the topside module. All high voltage equipment is connected from this cable deck, including the 2x3 33kV cables to the transformer, the 132kV cables from the transformer to the export gas insulated switchgear and the export cable which is brought down to the foundation and further onshore.

The possibility for emergency evacuation of personnel has been an important issue in the lay-out work. The internal topside staircase as well as the staircase within the transition steel tower leading to the boat landing has been designed to be wide enough for an emergency transport with a stretcher in case of an accident. On the top deck sufficient open area space is provided to make a helicopter lifting rescue operation possible.

The transformer room is located approximately in the center of the topside. The heavy system of the transformer support beams incorporates an emergency oil spill collector that will lead any leaked oil from the transformer to the collector sump which is located inside the foundation.

The switchgear equipment room is located on the main deck as well as an adjoining office room and a general store room. The low voltage room is located above on the upper deck. On the opposite side of the of the transformer room the GIS room is located as well as a mechanical room, a battery back up room with the emergency diesel generator room above.

The size of the 33 kV switchgear room is practical when servicing of the switchgear equipment is needed. The platform internal transformer which steps down the 33kV from the wind turbines to the 400V applied as main level on the platform is also installed here. The internal transformer is sized to suit the needs for the unit regenerating the main 33/132kV transformer cooling oil, so under normal conditions the work load is very low.

Fig. 6 Switchgear Room

With the Nysted Wind Power Park being the second only offshore transformer platform in the world serving as a substation for an offshore wind park an office/visitor room has been established on the upper level. It is an airy room with windows looking out at the wind park turbines. Adjacent to the visitor room a general storeroom is located for small parts and service equipment.

All low voltage cabinets for the top side local power supply and the communication cabinets for control and surveillance of the park is located in a separate room also adjacent to the office room. The control centre for the wind park is located at SEAS-NVE's office in Haslev on Sealand some 85 km from Nysted harbor. All measurements and surveillance data from the turbines are collected at the platform and transferred by fiber optic cable to the Haslev office.

To minimize noise in the office/control room from the diesel power generator (in case of continuous operation), the diesel installation is located as far as possible from the living room on the upper deck. As emergency power back-up a

90kVA generator set with diesel supply for 24 hour continuous operation has been installed. The diesel power is intended to supply the communication systems and platform light as well as beacons for sea navigation. The diesel engine is equipped with an air cooled radiator with duct connection to exhaust. Supply air for cooling purpose comes from an air intake with back draught shutters leaving normal room ventilation undisturbed when the diesel is not in service. The diesel power room has walking access doors as well as a double door with an overhead lift beam reaching outside of the outer cladding making heavy lifts from a ship deck possible.

Foundation

For economical reasons it was decided that the foundation for the platform was to be the same type, though slightly modified, as for the wind turbines. The foundations are of a concrete gravity type with the upper elevation 3m above the mean water level.

Fig. 7 Installation of Foundation.

The upper layer of the seabed was locally dredged and a gravel pad was laid out to provide the foundation a level and steady base to stand on. Following the positioning of the foundation, ballast material was placed on top of the foundation base. Scour protection was placed on the outer perimeter of the foundations.

The difference between the wind turbine foundations and the platform foundation is a slighter shaft diameter for the platform foundation and the provision of a sump volume inside the foundation. The sump shall contain any oil leaking from the transformer. Furthermore, the platform has 10 pcs. of tubes for cabling from the 8 rows and for the export cable plus one spare.

Topside Structure

The topside structure rests on the modified wind mill concrete foundation to which it is fixed by 60 anchor bolts in a T-stub type joint. The centre of gravity for the entire topside, including equipment, has been optimized as part of the layout in order to impose an absolute minimum of unbalanced forces from self weight on the steel tube to concrete foundation joint.

The steel topside structure is made up from the following main parts:

Foundation to cable deck transition steel tube structure which consist of a 5 meter diameter steel tube with a horizontal diagonal pattern of heavy beams at the top. The four endpoints of the beams acts as support for the cable deck and levels above. As the steel tube has an open cross-section from cable deck to foundation, the beams are fixed to the steel tube by means of a circumferential box girder, which is able to transfer the load to the tube.

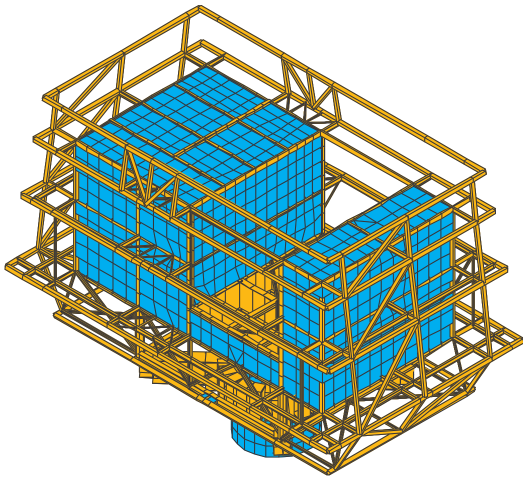


Fig. 8 Global GTSTRUDL Finite Element Model

The Lattice steel structure is made from circular hollow sections and reaches out to support the main stringers of the upper levels as well as the outside cladding bearing structure.

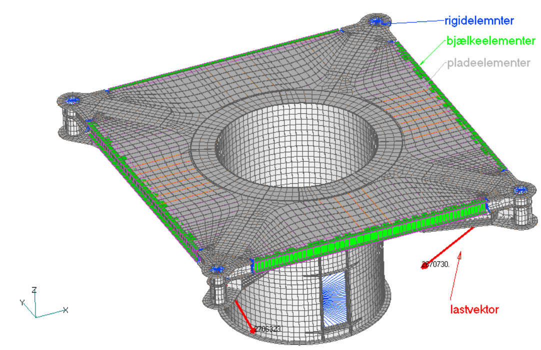


Fig. 9 Detailed FE-model of Base Steel Tube

From the main deck and above, the structure is closed and built up as a system of stiffened steel wall and floor panels with tension/compression stringers at the edges. This kind of system is well known from the oil and gas industry offshore topsides and the shipbuilding industry. The panels are made from 6 to 8 mm steel plating stiffened by bulb flats combined with larger T-sections placed beneath heavy equipment items. Stringers are mainly T, H and rectangular hollow sections.

In the event that the transformer needs to be replaced it can be either lifted through the roof or skidded out through one of the side walls. Therefore both the roof and the side walls of the transformer room have been left out of the structural system, so that they can be dismantled if needed.

The Transformer, being the heaviest piece of equipment at approx. 230 tons self weight is supported on a heavy grid system of welded girders that rests directly on four of the main vertical compression stringers. The outside stainless steel cladding is supported by vertical IPE sections, which in turn are supported by the outside walkway/floor panels at deck levels and the extended lattice system at the cable deck.

The structure has been analyzed by use of one main GTSTRUDL 3D finite element model (previous page right figure) and several MSC.NASTRAN detailed finite element sub models of the wall panels as well as the lower steel tube main support structure.

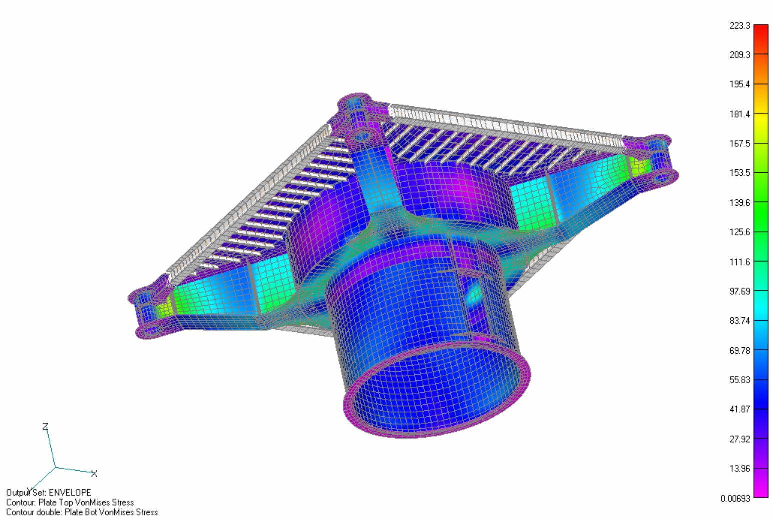


Fig. 10 FE-Model, Stress Plot of Lower Base Steel Tube

Ventilation and cooling

A flexible solution was designed to keep the indoor climate at acceptable levels for the electrical equipment. The solution incorporates ventilation and heating/cooling by using dehumidifying units keeping temperature and humidity at the required levels. Electrical panel heaters supplement the heating during the winter season with outdoor temperatures reaching below -10° C. Three dehumidifying units and one conventional ventilation unit servicing the diesel power room are installed. Under normal conditions the generated excess heat from the transformer is removed by natural ventilation cooling. If the natural ventilation in the future turns out to be insufficient, it will be possible to install axial fans on the roof area beneath the lantern which has large louvers in the wall areas.

Fig. 11 Cooler System on Roof

The transformer cooler consists of two connected banks with fan equipped radiators for individual control with an overhead oil expansion tank. Due to the level difference between the transformer and the cooler banks the circulation system incorporates two pumps working in single or parallel mode depending on the load. On the roof, the condensers for the fan coils in the low voltage and switchgear rooms are located. In order to protect the environment from accidental oil spills from the free standing cooler banks, the roof beneath the coolers was made into a huge drip tray with low point drain piping leading to the sump in the concrete foundation. In order not to collect all the rain water from the roof area in the sump, an oil/water separator was installed; disposing the water to sea and accumulating the oil in the separator. A level switch in the sump sets off an alarm at the onshore control centre indicating when the sump shall be emptied.

High Voltage Equipment

SEAS undertook the specification of the high voltage equipment such as the 33kV switchgear for the incoming power cables from the wind turbines, the 33/132kV transformer (Tironi make) and the 132kV GIS equipment on the export cable. Also SEAS had the responsibility for high voltage cable specifications. SEAS ordered the equipment which was delivered to the construction yard in Aalborg and installed by Bladt Industries. The final assembly of the transformer along with the transformer cooling system was executed by Tironi employees on site. Specification of these items were carried out in close cooperation with ISC to ensure that equipment cable connections and footprints as well as weight loads on the top side structure were correct.

Fig. 12 Topside during Fabrication in Yard.

Fabrication & Installation

The topside steel structure was fabricated in three main parts in Poland and then transported to the Bladt Industries Yard in Aalborg, Denmark. At Bladt Industries the entire topside was put together and all equipment installed and tested.

From Aalborg, the topside was then barged to the site where it was lifted onto the foundation by a floating crane and fixed into the final position.

The offshore erection work on the wind park began with preparation of the seabed for foundations in March 2002. Installation of foundations started in the autumn of 2002 and the heavy lift of the transformer platform took place in April 2003. The first wind turbine to produce power was connected to the power grid in late June and the last wind turbine was ready for start up in mid December 2003. Since final commissioning of the wind power park the turbine availability is up to 97% and no major problems for the wind turbines or transformer substation has occurred.

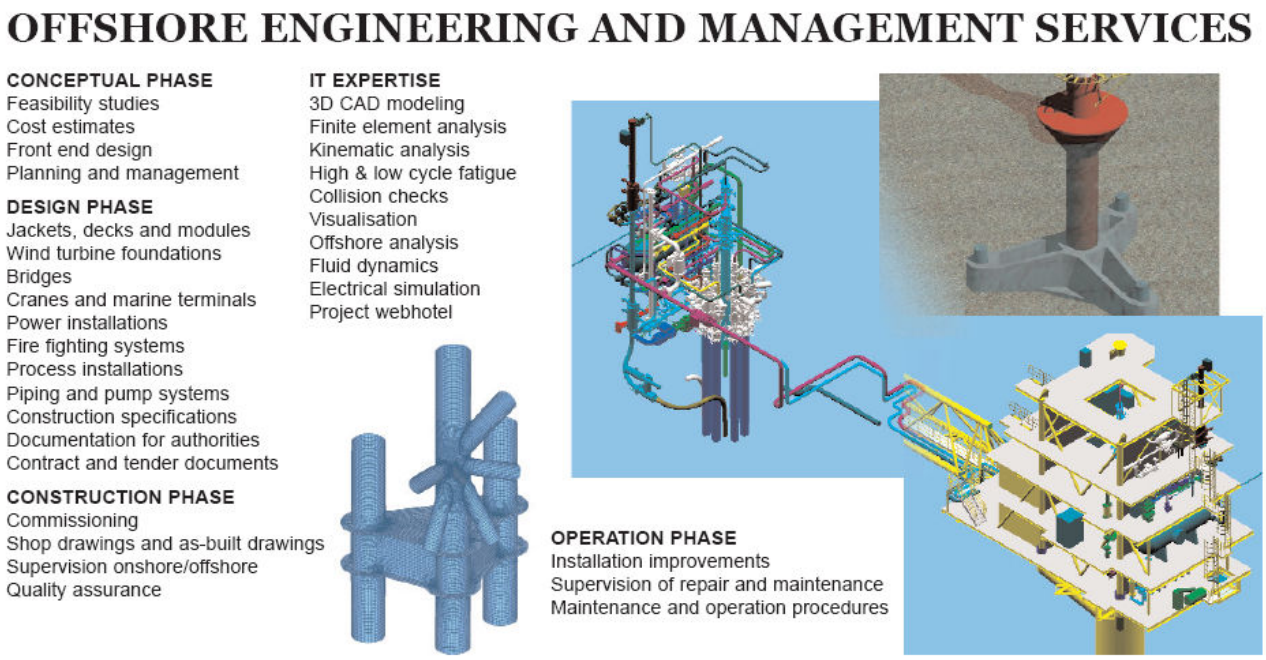
Fig. 13 Installation of Entire Topside

Future installations

ISC is continuously active in the wind power industry with several current activities involving both design of offshore wind turbine foundations and several planned offshore substations.

About ISC Consulting Engineers

ISC Consulting Engineers A/S was founded in 1967 by the current CEO and president Mr. Kjeld Thomsen, M.Sc, Struct. Eng.. The staff comprises more than 160 dedicated engineers and technicians. The company's head office is located in Copenhagen and has branches in Esbjerg, Viborg and Kalundborg. ISC’s experienced project leaders and specialized engineers covers a wide range of main activities and special disciplines and offers comprehensive consultant services and solutions for individual assignments within all fields of civil-, heating and ventilation -, process-, electrical-, industrial-, mechanical- and bridge engineering. In the offshore and marine engineering business ISC has been active for more than 30 years and offers a wide range of services within general marine engineering, for Oil and Gas installations as well as for the offshore wind power industry.



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