Collision risk at high sea

Sea-going vessel versus wind turbine

Offshore wind power: Wind turbines off the German coast generally represent obstacles in the traffic routes of ships. What if a large sea-going vessel, unable to manoeuvre, were to impact an offshore wind turbine? The analyses used to determine and assess the potential risks of a collision for people, ships, turbines and the environment are currently based on computer models and simulations. However, these models do not adequately consider important aspects – such as routine landing operations by service boats. Do we have to alter the course of collision analysis?

As the authority in charge of the approval of German offshore wind farms, the Maritime and Hydrographic Agency (Bundesamt für Seeschifffahrt und Hydrographie, BSH) must ensure that Germany can guarantee the safety of international maritime transport at all times. To do so, the distance between a wind farm and any shipping routes must be at least 4.5 kilometres. In addition, the authority requires evidence of the collision-friendly design of wind-turbine foundations for each offshore wind project. Given this, as part of the approval process, the project owners must go through the worst-case scenario and simulate events, i.e. a ship hitting an offshore wind turbine or a transformer platform.

Breaking new technological ground at high sea

However, the required simulations and analyses confront the wind power industry with numerous challenges as they are largely based on pioneering work and there is no long-standing practical and operational experience to fall back on. So far, the offshore sector is still lacking an adequate range of clear and straightforward frameworks and standards. While some of the pilot projects that have been realised off the coast are delivering initial findings that can be used in future projects, many aspects indicate that the methods established today are not fully suitable for identifying and specifically assessing all hazards and risks involved.

The same also applies in particular to the recurrent "intentional" collisions, when a moving service boat first makes contact with the fixed, but flexible offshore structure. The coincidence of only one boat-landing position and unfavourable wave direction generates the biggest risk of higher impact loads. The ongoing landing operation of the service boat, where the pilot maintains forward thrust – even in high stern waves – to keep the ship in contact with the boat landing platform do not typically apply higher loads. Today's methods of static analysis work with estimated figures for a single static equivalent load (= Ultimate Limit State). The results of these calculations cannot be absolutely exact and, even worse, cannot be used for structural stability of the wind-turbine foundation and the components of the boat landing platform in the long term (Fatigue Limit States). The question now is whether wind turbines are designed in such a manner that safe servicing and maintenance operations are ensured on a long-term basis, while the risks in the case of a collision are kept to a minimum.

At present, the BSH only requires the usual structural analysis plus a calculation of the consequences in the case of a collision. Both the calculation model and the analysis are based on a reference ship representative of the sea area in question and on the foundation structure of the planned offshore wind turbine. Collision-friendly design is proved if the calculations demonstrate that an individual wind turbine is "weaker" than the reference ship, i.e. that the turbine would fail first in the case of a collision. In concrete terms this means that the hull of a ship (or, in the case of double-hull ships, the inner hull) will not tear.

Does the model adequately reflect reality?

Given this, the BSH does not require collision analysis to supply exact quantification of the extent of damage, but to give qualitative answers to the following questions: (1) what will fail first, the ship or the turbine, and (2) will the possible damage caused by a collision be minor, moderate, major or catastrophic? Of course the assumptions on which a collision scenario is based and which are included in the calculation models significantly influence the analysis results and their informative value. These are: Which type of ship is selected as reference ship? At what speed will the vessel hit the turbine? While the BSH defines the key parameters, experts are given plenty of leeway in the preparation of the finite-element models (FE models) that are needed for the analysis and the simulations.

Conservative assumptions for simplification

Simplifying the very complex models and analyses by using assumptions suggests itself and is acceptable and expedient, provided the experts use conservative data and values. When this is done, the results are always on the safe side because a wind turbine that fails in a collision with a "weaker" reference ship in the calculation model will definitely fail in a collision with a ship that is more robust in reality. The offshore wind industry has shown a tendency to adopt this approach, i.e. the ships modelled in calculations so far have been more "fragile" than they are in reality

However, as the standard does not define comprehensive requirements as to which parameters must be taken into account and how; the various scenarios cannot be compared to each other. Given this, we do not know the extent to which the individual models actually reflect reality. This shows that – in the medium term – the development of standardised models and procedures is necessary and that all stakeholders should work together to develop a safety-focused strategy. Within the framework of a harmonisation process, stakeholders would benefit considerably from binding standards and directives in terms of safety, sustainability and not least profitability.

Further aspects at a glance: the reference ship

All collision analyses are based first and foremost on the choice of a representative reference ship. A critical aspect in this context is the identification of the type of ship representative for the sea area in question. Once this choice has been made, the finite element model (FE model) used in collision analysis is prepared. The FE model is generally based not on a real ship, but on a typical design. Since the BSH standard does not specify the required accuracy, the engineers will decide on a case-by-case basis whether and to what extent the FE model can be simplified. For example, instead of detailed consideration of all stiffening elements of a ship, the form of the stiffening or the thickness of the hull plating can be increased in the virtual model. However, the comparability of results would be improved if the standard defined acceptable normative limits of the side-impact force-deformation ratio for each type of reference ship.

Where does the ship hull hit the turbine or platform?

The BSH requires the reference ship to drift at a speed of 2 m per second perpendicular to its longitudinal axis and impact on the steel construction of the wind turbine at its precise centre of gravity. In this case, the entire kinetic energy is transformed into elastic and plastic deformation. In practice, however, this scenario is rather unlikely. The actual point of contact is more likely to be in front of or behind the centre of gravity. Consequently, at the start of local deformation the ship will simultaneously start to rotate. Given this, the contact energy at the time of collision will be lower and deformations less pronounced. However, the further drift (after the first contact) causes the 60 to 120 mm-thick plating of the wind turbine's foundation structure to scrape alongside the outer hull of the ship, which is only 15 to 25 mm thick and which may be dented and – in a worst-case scenario – torn open by the secondary contact (tin-opener effect).

What forces are developed by the displaced water mass?

The water mass moved along with the ship depends on the displacement caused by the ship and is simply added in most analyses. Other calculation models, by contrast, assume the kinetic energy of the water to be already included in the kinetic energy of the floating ship. No agreement has been reached until now on how the displaced water mass behaves after collision. For the first moment of collision, the movement of the water can in fact be assumed to stop together with the movement of the ship. However, where secondary movements of the ship – e.g. turning – are concerned, the validity of this across-the-board addition approach must be questioned.

Will the nacelle stay in position?

The nacelle plus rotor of a typical wind turbine weigh between 400 and 600 tonnes. Given this, the highest mass of the wind turbine is concentrated in the nacelle. If a horizontal load is imposed by the mass (of the ship) impacting on the foot of the tower, mass inertia will cause a risk of buckling of the tower segments below the nacelle. In the worst case, this secondary failure scenario may result in falling of the nacelle and the rotor, damaging the ship, particularly when the turbine is in operation. In past studies by Hamburg/Harburg Technical University which included a simplified buckling analysis, such a risk scenario certainly appeared realistic. Given this, wind-power experts recommend that calculation models should also include a more detailed bucking analysis.

Are operating loads relevant?

In the case of a collision, it cannot be assumed in principle that there will be no wind. Ships are more likely to be unable to manoeuvre or to get into distress in bad weather. However, in this case, wind and waves already impose significant forces on the wind turbine, exposing both the tower and the components to high pre-existing stresses. In view of this, experts must consider whether these operating loads must be taken into account in terms of critical rotation and failure of tower stability. So far, simulations have been based on the assumption that the materials are not exposed to any stresses. Calculations should take into account in addition that wind turbine structures become weakened over years of operation, for example by corrosion, high cyclic loads and complex damage mechanisms.

Loads caused by service boats

As already explained, experts have so far assumed that landing operations of service boats do not affect the primary structure of the wind-turbine foundation in the long term. However, although the regular landing manoeuvres cause horizontal impact forces of up to 200 kN, analyses focus solely on the impacts that these manoeuvres have on the installed secondary structures of the boat landing platform. Nevertheless, experts should take into consideration that the probability of critical material fatigue as a consequence of operational loads and corrosion increases, the longer the turbines are in operation and the more frequently they are exposed to extreme weather and storms.

Accepting challenges

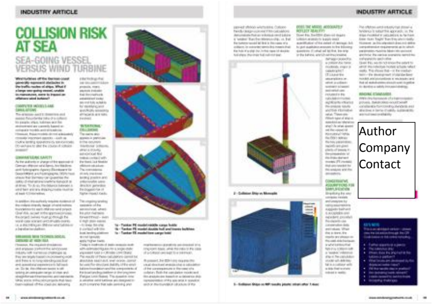
To determine the forces in contact with the offshore wind turbine, exact models of the wind turbine are required including the soil profile and, where appropriate, calculations carried out with a fluid dynamic programme (CFD). This systematic analysis is very complex and cannot always be solved completely and in a satisfactory manner. Damage that has occurred so far has shown that closer examination makes good sense. The use of improved analysis models frequently provides added-value to owners and operators. Given this, the regulatory requirement to prove collision-friendly foundation design need not be a cost-intensive additional measure, but may be an opportunity that significantly improves reliability and safety. After all, it would increase the lifespan of the primary structure of the wind turbine, preventing subsequent time- and cost-intensive repairs. In addition, the secondary structures of the wind turbines and the service boats landing at the wind farm could be better aligned to each other, making them more durable and safer. This benefits turbine and ship-owners, insurance companies, ship-building yards and the mechanics and service staff working on the steel structure, but also helps indirectly to ensure security of power supply from the project.

To address these and other issues, the Hamburg-based Offshore Wind Power department of *our client* has continuously increased its expert staff and computer capacities to enable the simulation of maritime collision processes to be performed.

Several innovative projects examine complex technological issues, including the collision of ships and offshore wind farms or the preparation of concept studies on floating wind-turbine foundations. Shipbuilders, geologists, hydrodynamicists and wind-power specialists cooperate closely on these multidisciplinary issues, focusing on maximum safety and customer benefits.

Published in:

WindEnergy NETWORK


INDUSTRY ARTICLE
COLLISION RISK AT SEA
SEA-GOING VESSEL VERSUS WIND TURBINE
INDUSTRY ARTICLE
Author
Company
Contact

Wind Energy Network
Circulation: 8.000

Contact:

Intellisource GmbH
Solmsstraße 6a
60486 Frankfurt am Main
Tel: +49 69 981964-0
Fax: +49 69 981964-45
E-Mail: office@intellisource.de
Internet: www.intellisource.de