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INTERACTION BETWEEN OFFSHORE WIND FARMS AND MARITIME NAVIGATION

The World Association for Waterborne Transport Infrastructure

PIANC

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PIANC REPORT N° 161

MARITIME NAVIGATION COMMISSION

INTERACTION BETWEEN OFFSHORE WIND FARMS AND MARITIME NAVIGATION

2018

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This report has been produced by an international Working Group convened by the Maritime Navigation Commission (MarCom). Members of the Working Group represent several countries and are acknowledged experts in their profession.

The objective of this report is to provide information and recommendations on good practice. Conformity is not obligatory and engineering judgement should be used in its application, especially in special circumstances. This report should be seen as an expert guidance and state-of-the-art on this particular subject. PIANC disclaims all responsibility in the event that this report should be presented as an official standard.

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1 GENERAL ASPECTS

1.1 Scope

This report provides an approach, guidelines and recommendations to assess the required *manoeuvring space for ships in the vicinity of offshore wind farms (OWF) and the minimum* recommended distance between shipping lanes and sea areas for OWF in order to ensure a minimal risk to navigation. The report specifically addresses issues with OWF but these are a subset of Offshore Renewable Energy Installations (OREI) and some of the recommendations will have a wider application to other OREI.

This report:

- provides references to international conventions and regulations
- provides guidelines to define an appropriate safe distance to navigation for different situations
- describes the electromagnetic radiation effect on radio navigation and radio communication systems
- indicates mitigating measures to be taken into account for the safe navigation of shipping
- covers emergency situations that may occurred within or close to an OWF

This report is intended as a guide for the Marine Spatial Planning (MSP) of any Coastal State covering the identification of wind farm areas and the design, planning, construction, operation and dismantling of a wind farm.

1.2 Introduction

1.2.1 Terms of Reference

1.2.1.1 Historical Background – Definition of the Problem

Increased activity within Europe's marine waters has led inevitably to growing competition for maritime space. Competing claims from a range of activities, including fisheries, leisure navigation and locations allocated for military exercises, old ammunition dumps, navigation and anchoring areas, oil and gas exploitation, sand extraction and wind and wave energy generation are accompanied by increased pressure on vital marine ecosystems and habitats. Without the means to coordinate a common approach to the allocation of maritime space among different sectors, the problems of overlap and conflict between sectors and individual stakeholders is evident. There are also cross-border issues as developments in the maritime area of one country may well have impacts for another. The relatively new notion of Marine Spatial Planning has emerged as a means of resolving conflicts over maritime space.

In order to increase the amount of electrical energy produced by environmentally friendly means, some coastal states have decided that a significant part of the total yearly consumption has to be produced at sea. Production areas are preferably located as close as possible to the shore in order to achieve low transmission costs. For those areas which are situated between or near shipping lanes, there is a potential conflict between shipping and the production areas.

Offshore Wind Farms (OWFs) have specific issues where they are in conflict with traditional activities such as navigation. Particular aspects of OWFs that need to be considered are:

- OWFs are situated in open sea, where mariners do not expect to encounter obstacles
- OWFs have parts both under and above the water surface
- OWFs have fixed parts and moveable parts (the turbine blades)
- OWFs are individual constructions, formed into an array
- OWFs are interconnected with electrical and data transmission cabling
- OWFs are strategic energy infrastructure, making them sensitive to damage
- OWFs generate invisible perturbations in the form of electromagnetic radiation

When a sea area for the production of energy of considerable size is located close to a navigation route junction or converging area of ships' routeing or in any other way in the vicinity of ship's routeing systems or shipping lanes, it is necessary to maintain the risk to shipping at a minimum but certainly not higher than the present level of risk. In some countries navigation within the borders of an OWF is allowed; in that case crossing traffic can be expected to emerge from the wind farm. **In particular, when an OWF is located at the starboard side of a shipping lane, the Collision Regulations (COLREGs) state that vessels in the shipping lane must give way to vessels emerging from the OWF.**

1.2.1.2 Objective and Product of the Study

In order to ensure that a sea area for the production of energy from water, currents or wind, will not interfere with sea lanes essential to international navigation or other navigation activities and will not cause problem to electronic navigation aids, the Working Group has developed a set of recommendations and guidelines to assess sufficient manoeuvring space and the minimal distance between navigation and the offshore installations, to ensure that the risk to shipping is acceptable.

The sufficient manoeuvring space and minimal distance will depend on various situations and criteria as:

- Traffic density
- Ships routeing systems/precautionary areas
- Radar and VTS
- Size of ships including manoeuvring characteristics
- Recreational activities
- Fishing activities
- Available width of the [established] traffic lane
- Crossing traffic incoming from starboard in front of a wind farm
- Crossing traffic emerging from the wind farm
- Crossing traffic incoming from starboard behind a wind farm
- The possibility of fishing vessels or other small craft being present in the area between wind farms and traffic lanes
- Weather conditions (wind and waves)
- Tidal current conditions
- The positioning of anchorage areas
- Areas for (dis)embarkation of pilots
- Effects of wind farms on the ship's radar display

The Working Group has considered international rules such as the Collision Regulations and the General provisions on ships routeing, etc.

1.2.1.3 Methodology

The approach taken by the Working Group has been to:

- review the actual practice of setting distances between shipping and OWFs to date by consultation with stakeholders
- collect available background information and review the approach taken
- give considerations for determining the safe distance for different situations, according to the various uses of the sea, the size of the vessels, the layout of the shipping routes, anchorages, pilot stations, etc.
- review of recent developments in design tools (such as risk assessments and simulation techniques) in order to assess the appropriate manoeuvring space and minimal distance between shipping and OWF in order to achieve safe navigation
- develop risk-based considerations, recommendations and guidelines for assessing the sufficient manoeuvring space and the minimal distance between shipping and areas for OWFs, in order to ensure a minimal risk level for navigation

1.2.2 Structure of the Report

The structure of this report can be summarised as follows:

Chapter 1: General Aspects
Chapter 2: Identification of Interactions & Difficulties

Chapter 3: Legal Background
Chapter 4: Navigation Constraints, Collision Avoidance and Marine Navigational Marking
Chapter 5: Electromagnetic Radiations (EMR)
Chapter 6: Emergency Procedures
Chapter 7: Guidelines and Recommendations to Assess the Required Safety Distances in Vicinity of Offshore Wind Farms

1.2.3 Related PIANC Reports

The following PIANC report is also relevant to the design and operation of approach channels:

PIANC Report N°121	Harbour Approach Channels. Design Guidelines	2014

1.2.4 Members of the Working Group

The Working Group comprised membership from PIANC some of whom are also members of IALA. WG 161 consisted of the following members:

- Capt. Jean-Charles Cornillou, WG 161 Chairman, 'Centre for Studies and Expertise on Risks, Environment, Mobility and Country Planning' (Cerema), France
- Gonzalo Montero, WG 161 Secretary, 'Engineering, Resources & Development, S.L.' (ENRED), Spain
- Raul Atienza, WG 161 Alternate Secretary, 'SIPORT XXI S.L.', Spain
- Wim Hoebee, Port of Rotterdam, the Netherlands
- Marc Huygens, DEME, Belgium
- Geert Mertens, 'Power at Sea', Belgium
- George Detweiler, United States Coast Guards, United States of America
- Hans Karl von Arnim, BSH, Germany
- Mike Pinkney, Ove Arup and Partners, United Kingdom
- Johan Eriksson, Swedish Maritime Administration, Sweden
- Jarkko Hirvelä, Finnish Transport Agency, Finland
- Haruo Yoneyama, Port and Airport Research Institute (PARI), National Institute of Maritime, Port and Aviation Technology, Japan

1.2.5 Meetings

A total of 8 meetings of the WG were held during the course of the project in Brussels, Madrid, Rotterdam, Saint-Germain-en-Laye, Le Havre.

1.2.6 Acknowledgements

The following individuals and organisations also contributed substantially to the successful completion of this report:

- Francis Zachariae, IALA Secretary-General
- Capt. Phil DAY, Chairman IALA ARM Committee, Northern Lighthouse Board, UK
- Capt. Roger Barker, Chairman IALA ARM Committee WG 1, Trinity House Lighthouse Service, United Kingdom
- David Patraiko, Nautical Institute, United Kingdom
- David Edwards, Chairman IMO/ICAO JWG on the harmonisation of SAR procedures, United States Coast Guards, United States of America
- Capt. Mohammed Kahn, Maritime Coast Guard Agency, United Kingdom
- Dr Krzysztof Bronk, National Institute of Telecommunications, Poland
- Matthieu Zekar, geographer, teacher in charge of research, National Maritime Academy Le Havre, France
- Jochen Ritterbusch, BSH, Germany

2 IDENTIFICATION OF INTERACTIONS

This chapter describes Marine Spatial Planning (MSP) and Maritime Emergency Planning (MEP) as main management tools to identify interactions between OWF and maritime navigation. From this general description, chapters 3, 4 and 5 provide detailed information and methodology.

2.1 Marine Spatial Planning (MSP)

2.1.1 What is Marine Spatial Planning

Marine Spatial Planning (MSP) is defined by UNESCO as a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic and social objectives that are typically specified through the political process. MSP is an element of sea use management.

Historically, MSP has been driven by the need to preserve ecological zones and was started as a management approach for nature conservation in the Great Barrier Reef Marine Park over 30 years ago. More recently, it has been adopted in the more crowded seas of European countries and several countries in Asia, including China and Vietnam, are now using MSP to achieve both economic and environmental objectives.

In 2006, UNESCO held the first International Workshop on MSP and in 2009 they published a step-by-step approach to MSP from establishing authority, through to monitoring and evaluation. The process of establishing MSP as recommended by UNESCO is shown in Figure 1. (taken from 'Marine Spatial Planning – A step by step Approach, toward Ecosystem-based Management', UNESCO).

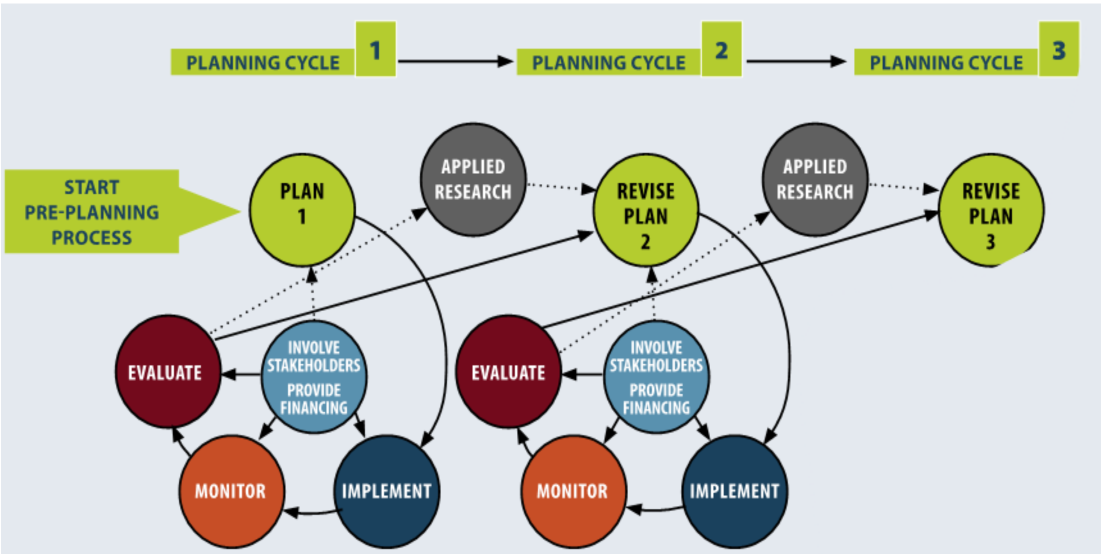


Figure 1: MSP Process – As envisioned by UNESCO

Therefore, MSP:

- is the responsibility of each maritime state
- extends over its EEZ (Exclusive Economic Zone) which is normally the lesser of 200 NM from the shore or the centreline of a strait between two countries
- is ecosystem-based
- takes a holistic view of the human activities in the area
- is place-based or area-based
- is an adaptive and iterative process following a number of planning cycles

In 2014, the EU published a directive (2014/89/EU) requesting all European maritime Member States to establish MSPs by 31 March 2021[1]. The Directive suggests that member states should consider:

- aquaculture areas
- fishing areas
- installations and infrastructures for the exploration, exploitation and extraction of oil, of gas and other energy resources, of minerals and aggregates, and for the production of energy from renewable sources, **including OWF**
- maritime transport routes and traffic flows
- military training areas
- nature and species conservation sites and protected areas
- raw material extraction areas
- scientific research
- submarine cable and pipeline routes
- tourism
- underwater cultural heritage

Since the United Nations Convention on the Law of the Sea (UNCLOS, 1982) states that the uses of ocean space are closely interrelated and need to be considered as a whole, MSP can also be seen as a logical way of structuring a country's rights and obligations over its EEZ as defined by UNCLOS. The legal background is fully described in Chapter 3.

Although all MSPs are based on the same international laws and most follow the UNESCO guidance, not all MSPs have the same basis. MSPs are the responsibility of each maritime State. Plans are based on the State's policies. These are not all the same and will probably change with time. For instance, in the North Sea there are a number of MSPs drawn up by the different coastal States. Germany has a policy that Special Areas of Conservation are a 'no-go' area for development whereas in the United Kingdom, they are not. The different policies can affect the MSP activities in adjacent waters. Government policy may support the deployment of one industry over another, i.e. offshore renewables above the interests of the Commercial Fishing Industry. Policy drivers will change the outputs of the MSP and will change over time.

2.1.2 Which Part of MSP Do We Cover?

Part of the responsibility of those tasked with setting up MSPs is to inform all interested parties and consult with the relevant stakeholders and authorities, and the public concerned, at an early stage in the development of the MSP including an OWF.

Maritime Authorities are one of the key stakeholders in any consultation process and should be engaged at all stages through from setting the policy on which MSPs are established, through to defining, implementing monitoring, evaluating and revising the MSPs.

IALA developed guidance for AtoN Authorities on the use of Marine Spatial Planning within its AtoN Requirements and Management (ARM) Committee. The final IALA documents on this subject are:

- IALA Recommendation R1010 – 'The Involvement of Maritime Authorities in Marine Spatial Planning (MSP)'
- IALA Guideline G1121 – 'Navigational Safety within Marine Spatial Planning'

Marine Spatial Planning should therefore not only be seen as a national or cross-border issue but should also take into consideration international navigational interests. It will contribute to facilitate engagement in the process and inter-stakeholder co-operation at local, national and international level.

1 *Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning*

2.2 Maritime Emergency Planning (MEP)

In order to cover a complete risk analysis when performing a Maritime Spatial Planning (MSP), it is recommended that the State authority responsible for maritime safety around OWF coordinate a **Maritime Emergency Plan** (MEP).

MEP is a similar process to MSP covering all risks identify within the scope of the MSP. MEP can be defined as follows:

Maritime Emergency Planning (MEP) is the process of risks analysis and contingency planning within a Marine Spatial Plan (MSP)[2].

2.2.1 Contingency Planning

Whatever the cause of an accident or disaster there are well-known general guidelines to responding through an emergency management system. Contingency planning consists of 5 phases: planning, prevention, preparedness, response and recovery.

Figure 2: The 5 phases in contingency planning [adapted from FEMA]

Planning ① – Identify potential risks causing an emergency

> Effective risk management allows identification of a project's strengths, weaknesses, opportunities and threats. By planning for unexpected events, the organisation or project can be ready to respond if they arise. Risk management has to be done as a first step in the emergency planning.

Prevention ② – Mitigate future emergencies or minimise their effects

> This phase includes any activities that prevent an emergency, reduce the likelihood of occurrence, or reduce the damaging effects of unavoidable risks. Mitigation activities should be considered long before an emergency happens, but also after an emergency has been resolved (to learn lessons and reduce the chance of re-occurrence) [FEMA, 1998].

Preparedness ③ – Preparing to handle an emergency

> This phase includes developing a contingency plan before an event occurs including actions that will improve chances of successfully dealing with an emergency. For instance, drafting a detailed

2 *The concept of MEP was generated by WG 161*

emergency response flow chart for each identified risk, organizing emergency drills, training staff of involved emergency response parties, evaluating planning and taking corrective actions where needed. All these preparedness activities take place before an emergency occurs [FEMA, 1998].

Response ④ – Responding safely to an emergency

This phase includes actions taken to save lives and prevent further property damage in an emergency situation. Response is putting your preparedness plans into action. Response activities take place during an emergency [FEMA, 1998].

Recovery ⑤ – Recovering from an emergency

After an emergency and once the immediate danger is removed, the recovery phase activities will be implemented. Recovery includes actions taken to return to a normal or an even safer situation following an emergency. Plainly, recovery takes place after an emergency [FEMA, 1998].

Many of the Contingency planning phase graphics like in Figure 2 show overlap of adjacent phases. This acknowledges that critical activities frequently cover more than one phase, and the boundaries between phases are seldom precise. Most sources also emphasise that important interrelationships exist among all the phases. For example, 'mitigating' risk by decreasing the possibility of occurrence will reduce the problems in the 'responding' phase [Baird, 2010].

2.2.2 What Kind of Emergency Do We Cover?

At sea, and in particular around OWF, we can order risks by their nature of consequences on:

- **People**: all accidents affecting health, safety and security of persons with search and rescue (SAR) as the most important respond.
- **Planet**: all accidents affecting the environment with pollution control as a primary focus.
- **Property**: all accidents affecting properties, in particular ships and wind turbines, with salvage as the main emergency respond.
- **Profession**: all accidents affecting business and threatening the liability and reputation of any socio-economic activities.

On 18 June 2015, IMO adopted MSC-MEPC.2/Circ.12/Rev.1 revised guidelines for formal safety assessment (FSA) for use in the IMO rule-making process. These guidelines can also be used in the MEP process. Formal Safety Assessment (FSA) is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost-benefit assessment. FSA may be useful in those situations where there is a need for risk reduction but the required decisions regarding what to do are unclear, regardless of the scope of the project. In these circumstances, FSA will enable the benefits of proposed changes to be properly established, so as to give a clearer perception of the scope of the proposals and an improved basis on which they take decisions.

In the case of OWF, the State authority responsible for maritime safety should:

- develop 'stress tests' crisis management tools, in the spirit of exercises developed within the France-United Kingdom agreement 'MANCHEPLAN' to combine resources for Search and Rescue (SAR) operation and in particular for major disaster management
- include in emergency plans the concept of major industrial risks by testing scenarios involving a merchant ship subjected to damage

Although the MEP would normally follow the MSP, for larger projects the MEP should be an integral part of the MSP.

9 steps of the Maritime Emergency Planning (MEP) can be identified:

1) Area analysis around the future wind farm

1. Provision of risk reduction study, by the developer of OWF, for the benefit of the State authority
2. Definition of the distances separating the OWF from other marine infrastructures, maritime safety infrastructures and trade routes leading to it
3. Summary of planned maritime activities after commissioning the OWF

2) Study of a scenario of crisis and implementation of resistance testing

4. Simulation of emergencies after commissioning the OWF
5. Identification of key operational roles of the emergency management system (Search and Rescue, salvage, towing response, etc.)
6. Simulation of emergency scenarios including those that could lead the emergency management system to operate in degraded mode (incidents involving a large vessel, dangerous cargo, etc.)
7. Evaluation of the ability to contain the emergency
8. Identification of related functions that might assist in managing the emergency (monitoring of navigation, emergency anchorage, port services, VTS, etc.)

1. Nautical Recommendations

9a Level 1: Recommendations for changing operational procedures for:

- emergency prevention
- emergency management
- contingency planning

Then, if necessary:

9b Level 2: Recommendations for changes to equipment, infrastructure and regulations.

3 LEGAL BACKGROUND

This section discusses the most important international provisions, regulations and guidelines for marine spatial planning related to safe distances to multiple offshore structures, such as wind farms.

3.1 International References

3.1.1 UN (UNCLOS)

The United Nations Convention on the Law of the Sea (UNCLOS), also called the Law of the Sea Convention or the Law of the Sea treaty, is the international agreement that resulted from the third United Nations Conference on the Law of the Sea (UNCLOS III), which took place between 1973 and 1982. The Law of the Sea Convention defines the rights and responsibilities of nations with respect to their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. The Convention, concluded in 1982, replaced four 1958 treaties. UNCLOS came into force in 1994.

In this respect, Member States and private companies planning offshore wind farms have to comply with UNCLOS for the use of the sea.

3.1.2 UNESCO (MSP)

UNESCO – the United Nations Educational, Scientific and Cultural Organisation – is responsible for coordinating international co-operation in education, science, culture and communication. Between November 2007 and May 2009, UNESCO developed a guide that provides a 'Step-by-Step Approach for Marine Spatial Planning towards Ecosystem-based Management'. The guide was presented at the International Marine Conservation Congress [IMCC, 2009] in Washington DC. The guide uses a clear, straightforward step-by-step approach to show how marine spatial planning can be set up and applied toward achieving ecosystem-based management. Most steps are illustrated with relevant examples from the real world.

3.1.3 IMO (SOLAS, COLREGs, GPSR, ...)

IMO – the International Maritime Organisation – is the United Nations specialised agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. As a specialised agency of the United Nations, IMO is the global standard-setting authority for the safety, security and environmental performance of international shipping. Its main role is to create a regulatory framework for the shipping industry that is fair and effective, universally adopted and universally implemented.

International Convention for the Safety of Life at Sea (SOLAS), 1974 was adopted on 1 November 1974 and entered into force on 25 May 1980. The SOLAS Convention in its successive forms is generally regarded as the most important of all international treaties concerning the safety of merchant ships.

The Convention on the International Regulations for Preventing Collisions at Sea (1972), as amended (COLREGs), is published by the IMO. The COLREGs set out, among other things, the 'rules of the road' or navigation rules to follow by ships and other vessels at sea to prevent collisions between two or more vessels. COLREGs is detailed in chapter 4.2.1 for the concept design of OWF and the estimation of the safety distance between the traffic lanes and an OWF, in order to help OWF developers and planners to understand the risk of collision.

The General Provisions on Ships' Routeing (GPSR) aim for improving the safety of navigation in converging areas and in areas where the density of traffic is heavy or where freedom of movement of shipping is inhibited by restricted sea room, the existence of obstructions to navigation, limited depths or unfavourable meteorological conditions.

3.1.4 ITU (RR)

The International Telecommunication Union (ITU), based in Geneva, co-ordinates and standardises the operation of telecommunication networks and services and advances the development of communications technology. The Radio Regulations (RR) is an intergovernmental treaty text of the ITU. The first Radio Regulations were concluded in Berlin in 1906 as the Radiotelegraph Service Regulations. The RR cover both legal and technical issues. The Regulations serve as a supranational instrument for the optimal international management of the spectrum.

The Radio Regulations define:

- the allocation of different frequency bands to different radio services
- the mandatory technical parameters to be observed by radio stations, especially transmitters
- procedures for the co-ordination (ensuring technical compatibility) and notification (formal recording and protection in the Master International Frequency Register) of frequency assignments made to radio stations by national governments
- other procedures and operational provisions

3.1.5 ICAO (ICA Convention Annex 14)

The International Civil Aviation Organisation (ICAO) is an UN specialised agency, created in 1944 upon the signing of the Convention on International Civil Aviation (Chicago Convention).

ICAO works with the Convention’s 191 Member States and global aviation organisations to develop international Standards and Recommended Practices (SARPs) which States reference when developing their legally-enforceable national civil aviation regulations.

There are currently over 10,000 SARPs reflected in the 19 Annexes to the Chicago Convention which ICAO oversees.

The ICAO Annex 14 sets out the fundamental rules and requirements for Airport Design and Operations, which States undertake to apply through national laws. These rules are also applicable for wind farms in relation to aviation.

3.2 International Recommendations

This section discusses the most important international provisions, regulations and guidelines for marine spatial planning related to safe distances to multiple offshore structures such as wind farms. The section focuses on those regulations that are definitive for the minimum distance from the border of a shipping route (or anchorage) to an area with multiple objects (e.g. wind turbines).

Points to note:

- 80 % of all disasters at sea are caused by human error. It is therefore realistic to keep certain margins when considering a safe distance
- This section is not applicable to areas with multiple objects in shallow waters, where shipping traffic inside such area is not possible
- When the provisions and regulations were designed, multiple structures such as wind farms did not yet exist. However, the existing provisions and regulations provide sufficient guidance to argue a safe distance to such arrays.

The following internationally established, regulations and guidelines are applicable for this purpose:

- United Nations Convention on the Law of the Sea (UNCLOS)
- General Provisions on Ships’ Routeing (GPSR) of the International Maritime Organisation (IMO)
- Standards for ship manoeuvrability

The relation of these provisions and regulations with the minimum distance to areas with multiple objects will be discussed.

3.2.1 UNCLOS

United Nations Convention on the Law of the Sea (UNCLOS)

Extract from UNCLOS article 21:

Laws and regulations of the coastal State relating to innocent passage

The coastal State may adopt laws and regulations, in conformity with the provisions of this Convention and other rules of international law, relating to innocent passage through the territorial sea, in respect of all or any of the following:
(a) the safety of navigation and the regulation of maritime traffic;
(b) the protection of navigational aids and facilities and other facilities or installations;

In conformity to UNCLOS Article 21.1 a):
Any State may take any action on safety issues of navigation.

In conformity to UNCLOS Article 21.1 b):
This implies that the coastal State shall adopt provisions for the 'protection of equipment and systems with navigation and other equipment or facilities' to ensure the right of innocent passage to all ships in accordance with Article 171 of UNCLOS. Those measures may include for instance the protection of vessel traffic services radars, aids to navigations, radionavigation or radio communications systems.

Extract from UNCLOS Article 60:

1. In the exclusive economic zone, the coastal State shall have the exclusive right to construct and to authorize and regulate the construction, operation and use of:

(a) artificial islands;

(b) installations and structures for the purposes provided for in article 56 and other economic purposes;

(c) installations and structures which may interfere with the exercise of the rights of the coastal State in the zone.

4. The coastal State may, where necessary, establish reasonable safety zones around such artificial islands, installations and structures in which it may take appropriate measures to ensure the safety both of navigation and of the artificial islands, installations and structures.

5. The breadth of the safety zones shall be determined by the coastal State, taking into account applicable international standards. Such zones shall be designed to ensure that they are reasonably related to the nature and function of the artificial islands, installations or structures, and shall not exceed a distance of 500 meters around them, measured from each point of their outer edge, except as authorized by generally accepted international standards or as recommended by the competent international organization. Due notice shall be given of the extent of safety zones.

6. All ships must respect these safety zones and shall comply with generally accepted international standards regarding navigation in the vicinity of artificial islands, installations, structures and safety zones.

7. Artificial islands, installations and structures and the safety zones around them may not be established where interference may be caused to the use of recognized sea lanes essential to international navigation.

The 500-metre zone described in paragraph 6 is for 'protection of the structure' and is not meant as a safe distance for safe manoeuvring according the COLREGs.

Interference (paragraph 7, above) means, for example, limited ability to comply with the COLREGS. The COLREGS do not define how much space is required for this. However, with the knowledge of guidance provided to shipbuilders regarding maximum room for full round turns (Standards for Ship Manoeuvrability (MSC/Circ. 1053), there is an argument for the definition of a minimum distance.

3.2.2 IMO

A. General Provisions on Ships' Routeing

GPSR 1.1

The purpose of ships' routeing is to improve the safety of navigation in converging areas and in areas where the density of traffic is great or where freedom of movement of shipping is inhibited by restricted sea room, the existence of obstructions to navigation, limited depths or unfavourable meteorological conditions.

To demonstrate that the routeing measure improves safety, a Formal Safety Assessment (FSA) is recommended. This FSA can provide arguments for selecting a certain route and is based on a probabilistic risk assessment.

The master will make his own risk assessment when passing structures along this route, and will keep a certain distance, depending on the size of the vessel, status of the main engine, weather conditions, traffic, so he can act according the COLREGs. This risk assessment is deterministic, since the master does not want any accident at all.

If all masters are of opinion that the applicable routeing measure takes the vessel too close to multiple structures, they all shift to one side of the routeing measure, causing the density of shipping to increase at that side, which is not in line with the starting point of GPSR: to improve safety of navigation.

Therefore, demonstrating that a new routeing measure improves safety of navigation can be done by means of FSA. However, determining the safe distance to structures along that route should be done via a deterministic approach, using the rules and regulations which a master should follow.

GPSR 6.4

Course alterations along a route should be as few as possible and should be avoided in the approaches to convergence areas and route junctions or where crossing traffic may be expected to be heavy.

Bearing in mind that masters keep a safe distance to certain structures, again the structures should not be positioned in such a way that certain vessels will change course in order to reach that safe distance.

GPSR 6.8

Traffic separation schemes shall be designed so as to enable ships using them to fully comply at all times with the International Regulations for Preventing Collisions at Sea, 1972, as amended (COLREGs).

The safe distances to structures should be determined in such a way that a vessel can act according to the COLREGS <u>at all times:</u> i.e. also when sailing on the border of a routeing measure.

GPSR 6.10

Traffic lanes should be designed to make optimum use of available depths of water and the safe navigable areas, taking into account the maximum depth of water attainable along the length of the route. The width of lanes should take account of the traffic density, the general usage of the area and the sea-room available.

It is not easy to determine a safe width of a routeing measure. A guideline that has proved to be accurate, based on an AIS study by Maritime Institute Netherlands (MARIN), takes into account the:

- Number of vessels: based on AIS study, keeping in mind the future developments during the lifespan of the structures
- Maximum size of vessels: keeping in mind the future developments in ship size during the lifespan of the structures
- Number of vessels using the route, allowing 2 ship lengths per vessel:

< 4,400 vessels per year:	2 vessels side to side
> 4,400 vessels and < 18,000 vessels:	3 vessels side to side
> 18,000 vessels:	4 vessels side to side

Example: a traffic lane which accommodates 18,000 vessels per year with a maximum size of 400 meters should be at least 3,200 metres wide (= 4 x 2 x Length = 4 x 2 x 400 m).

This figure matches with most of the present traffic lanes (e.g. approach Rotterdam, TSS Maas West).

In section 3 (Responsibilities of Contracting Governments and recommended and mandatory practices) of the General provisions on ships' routeing, a new paragraph 3.13*bis* is added, as follows:

GPSR 3.13bis

In planning to establish multiple structures at sea, such as extensive concentrations of wind turbines, Governments should take into account, as far as practicable, the impact these could have on the safety of navigation. Traffic density and prognoses, the presence or establishment of routeing measures in the area, the manoeuvrability of ships and their obligations under the International Regulations for Preventing Collisions at Sea, 1972, as amended, should be considered when planning to establish multiple structures at sea. Sufficient manoeuvring space, e.g. for allowing evasive manoeuvres extending beyond the side borders of traffic lanes (i.e. separation zones or lines) of Traffic Separation Schemes, should be accommodated for ships making use of routeing measures near multiple structure areas.

In practice, Member States submit to IMO, at the Sub-committee on Navigation, Communications and Search and Rescue (NCSR), their ship’s routeing proposals (ship’s routeing Measures) such as Traffic Separation Schemes (TSS) in the high-density areas of navigation, such as the TSS that France proposed off Ushant, Casquets or Pas-de-Calais. The proposal for the TSS for the Pas-de-Calais/Dover Strait was submitted to IMO together with the United Kingdom. Other ship’s routeing measures around OWF in the high sea or next to international ship’s routeing measures already adopted by the IMO should also be submitted to the sub-Committee NCSR.

B. Standards for Ship Manoeuvrability

IMO resolution MSC.137(76) Standards for ship manoeuvrability and MSC/Circ.1053 explanatory notes for the standards for ship manoeuvrability are the IMO Standards for ship manoeuvrability. The Standards should be used to evaluate the manoeuvring performance of ships and to assist those responsible for the design, construction, repair and operation of ships.

The Standards were selected so that they are simple, practical and do not require a significant increase in trials time or complexity over that in current trials practice. The Standards are based on the premise that the manoeuvrability of ships can be adequately judged from the results of typical ship trials manoeuvres. It is intended that the manoeuvring performance of a ship be designed to comply with the Standards during the design stage, and that the actual manoeuvring characteristics of the ship be verified for compliance by trials. Alternatively, the compliance with the Standards can be demonstrated based on the results of full-scale trials, although the Administration may require remedial action if the ship is found in substantial disagreement with the Standards. Upon completion of ship trials, the shipbuilder should examine the validity of the manoeuvrability prediction methods used during the design stage.

The ‘manoeuvring characteristics’ addressed by the IMO Standards for ship manoeuvrability are typical measures of performance quality and handling ability that are of direct nautical interest. Each can be reasonably well predicted at the design stage and measured or evaluated from simple trial-type manoeuvres.

Turning Tests

A turning circle manoeuvre is to be performed to both starboard and port with 35° rudder angle or the maximum design rudder angle permissible at the test speed. The rudder angle is executed following a steady approach with zero yaw rate. The essential information to be obtained from this manoeuvre is tactical diameter, advance, and transfer (See Figure 3). Turning circle manoeuvre will be used in Chapter 4.2.1 to explain the concept design of the safety distance between a traffic lane and an OWF.

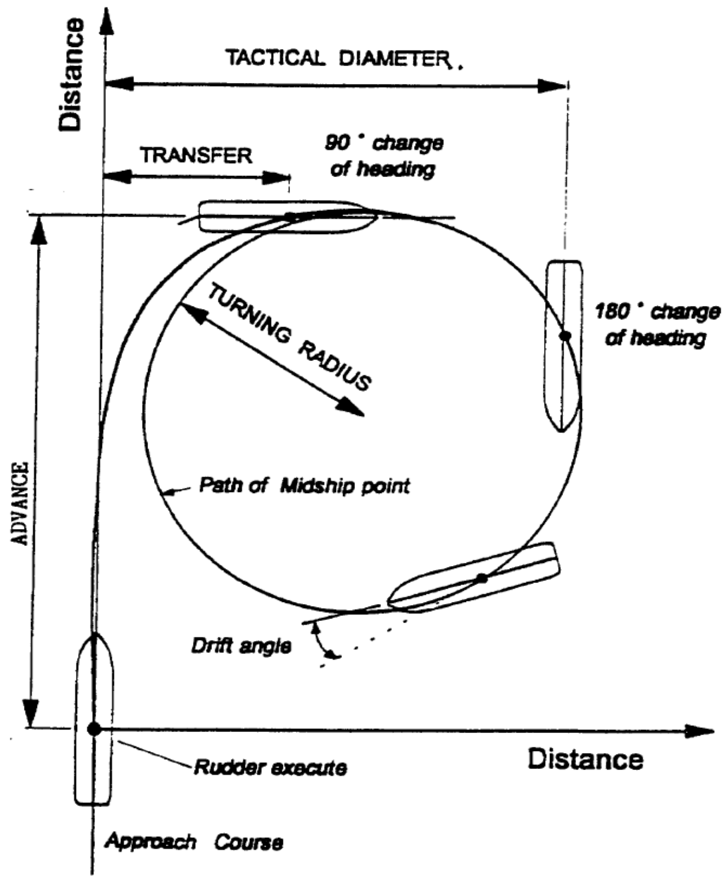


Figure 3. Definitions used on turning circle, extracted from IMO resolution MSC.137(76)

3.2.3 ICAO (ICA Convention Annex 14) and CAA

ICAO – International Civil Aviation Organisation

Particularly if airfields are located in the vicinity of the proposed site of a windfarm an aeronautical study should be carried out. Wind turbines may extend above the ‘obstacle protection surface’ (OPS) and hence adversely affect the safety of operations of airplanes in which case additional measures should be taken. A minimum distance for wind turbines to the runway of up to 15 kilometres may be required in order to prevent penetration of the obstacle protection surface.

The standards for wind turbines were developed at a time when the overall height (nacelle plus vertical blade) of wind turbines was less than 150 m. The advent of wind turbines of more than 150 m necessitates that these be addressed in revised standards.

In this respect proposals for changes in ICAO Annex 14 are in discussion, but have not been formalised at the date of this report. In discussion are amongst other things:

- simplification and clarification of Annex 14 Volume I on visual aids
- clarification on light intensity distribution
- marking and lighting of wind turbines over 150 m in height

The specification is restricted to structures with a height not greater than 315 m. It is considered that wind turbines higher than 315 m would require a different approach for protection.

CAA – Civil Aviation Authority (UK)

Offshore windfarm developers should check their plans with the (national) competent aviation authority and have their approval.

As an example in the UK (under the Civil Aviation Act), the Civil Aviation Authority (CAA) is responsible for providing advice about aviation safety. The main topics of CAA's policy on wind turbine developments are summarized below:

1. Wind turbine developments and aviation need to co-exist. However, safety of the air is paramount and will not be compromised.
2. Due to the complex nature of aviation operations, and the impact of local environmental constraints, all potential negative impact of proposed wind turbine developments on aviation operations must be considered on a case by case basis.
3. To provide timely advice to aviation and wind development stakeholders the publication of CAP 764 (CAA Policy and Guidelines on wind Turbines) is available on the CAA website: www.caa.co.uk/windfarms.

4 NAVIGATION CONSTRAINTS, COLLISION AVOIDANCE & MARINE NAVIGATIONAL MARKING

This section discusses the most important factors that must be considered in safety of navigation related to recommended distances to offshore wind farms (OWF).

4.1 Elements

4.1.1 Ships

The analysis of safety distances between shipping routes and OWF require a good description of the ships that may be navigating close to the OWF. In this respect all kinds of ships in the area should be considered:

- Commercial ships (goods and passengers)
- Fishing vessels
- Pleasure boats
- Supply vessels, tugboats, maintenance boats

The main characteristics of the ships must be defined in order to have a good description of the fleet. It is recommended to make a compilation of factors such as type of ship and goods carried (hazardous or not), main dimensions (length, beam, draught), manoeuvring characteristics (result of manoeuvring tests if available, number of propellers, rudders and thrusters), auxiliary systems such as tugs (in restricted areas or close to ports).

4.1.2 Marine Traffic

As a complement to the fleet description, it is important also to analyse the routes and the frequency of the ships since traffic density is an important parameter. This analysis will provide information about the real navigation areas and it is an important input to the risk analysis.

It is recommended to make a traffic survey of the area that includes all the vessel types found in the area and cover at least one year of information in order to account for seasonal variations in traffic patterns, fishing operations and recreational activities. In that respect, AIS data records are very useful for traffic analysis. This study must be complemented by a forecast of future traffic taking into account market trends, infrastructure investments in the area or changes in traffic routes.

One of the aims of this analysis should be to provide a good definition of the different actual shipping routes in the area. In this respect, TSS or marked channels shown on Nautical Charts may provide a first approximation but also, actual shipping lanes should be defined based on recorded traffic statistics.

Shipping routes are routes regularly used by ships, which are determined by geographical and hydrographic parameters. These routes cover long distances, particularly between two TSS and also include the approaches to the entrance channels of a port as well as passages between two ports.

The distance between a wind farm and a shipping route is defined as the distance between the physical boundary of the wind farm and the nearest edge of the shipping route or navigation channel.

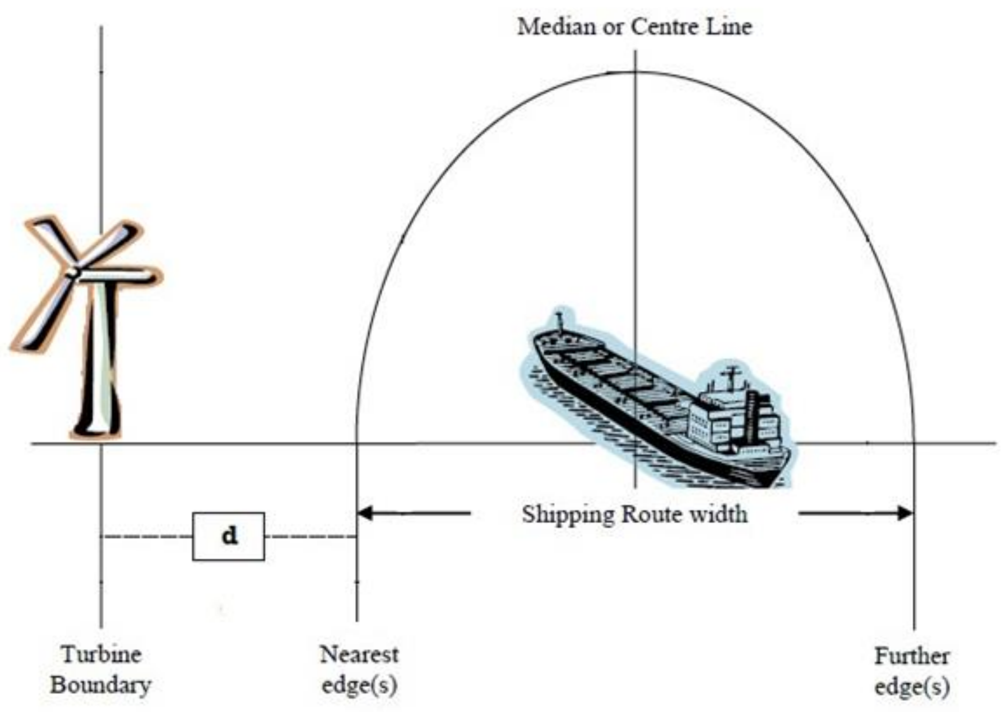


Figure 4: Distance between wind farm and shipping route

4.1.3 Geometric Configuration of the Water (Hydrographic)

A good description of the hydrographic conditions is also needed in order to identify the areas of interaction between navigation and wind farms installations. Nautical Charts include the most important information related to the hydrographic and marine environment and should be the first reference point for the study of the physical environment. In addition, a detailed bathymetric survey of the whole affected area (wind farm and navigation routes identified in previous section) is recommended.

The identification and description of navigation channels will provide good information for the analysis of the interaction areas. It is important to understand the behaviour of the ships in the vicinity of the wind farms. TSS (Traffic Separation Schemes), marked channels, approach channels or open water are examples of navigation areas that impose different behaviour on the navigation of the ships.

Combining bathymetry and navigation area descriptions it is possible to identify the interaction areas that should be analysed. It is important to bear in mind that these areas can be different depending on the ships considered. For example, a large vessel (with deep draught) might ground before entering the wind farm area while a smaller one may not. In another respect, TSS or marked channels impose more discipline on the ships and, in consequence, a lower probability of navigation out of them. Therefore, the analysis of the physical environment for navigation should be made considering the previous analysis of ships and marine traffic.

4.1.4 Aids to Navigation

The existence (or not) of Aids to Navigation (AtoNs) is another factor to take into account in the analysis of interaction between navigation and OWF. AtoN provide information to ships in order to assist them to maintain their desired position and route.

A compilation of the existing AtoNs should be made in order to complement the analysis of marine traffic and to get a good understanding of the restrictions to navigation. IALA distinguishes visual, sound and radio AtoNs. The study of existing AtoNs should be complemented with an analysis of the future configuration of the area (after construction of the wind farm) including any proposal for new AtoNs for OWF marking and new channels or restrictions.

There is potential for a wind turbine to actively interfere with certain active AtoNs by producing its own low energy radio frequency (RF) signal. The problem at sea arises because there are many radio communications and radio navigation systems dedicated to safety at sea. These systems are based on terrestrial and satellite radio communications. Chapter 5 deals with this phenomenon in detail.

SOLAS V/13.2 states that: "In order to obtain the greatest possible uniformity in aids to navigation, Contracting Governments undertake to take into account the international recommendations and guidelines when establishing such aids". Therefore, IALA recommendations O-139 on the Marking of Man-Made Offshore Structure should be followed.

4.1.5 Maritime and Atmospheric Conditions (Hydrodynamics)

For a good understanding of marine navigation is essential to have a good knowledge of hydrodynamic conditions in the area. Waves, winds and currents have a great influence in ships' behaviour. Also, shallow water effects, such as the bank effect (the tendency for a vessel to stern to steer into a nearby shallow water bank), which might be most noticeable at low tide affect ships behaviour. Therefore, hydrodynamic studies should be performed to collect information and to provide a good description of the maritime conditions.

In the event of an accident, evasion manoeuvring or drifting events are very sensitive to the meteorological and ocean conditions. So, it is important to include these factors.

It is important, not only to provide an accurate characterization of the area, but also to identify the risk of bad weather or restricted visibility conditions that could present difficulties to the vessels that might pass close to the wind farm. Also, it is important to identify the local conditions that can cause collision in case of loss of control or power.

4.1.6 Pilotage, Escorting & Towing Requirements

A navigation area where pilotage is mandatory requires a different analysis from the point of view of manoeuvrability and traffic conditions. Where a pilot has the control of navigation, marine traffic will be more organised and there will be a higher degree of manoeuvring safety. In this case, recommended safety distances could be decreased, taking into account that marine traffic interactions are under tighter control.

A similar logic is applicable to areas where escorting or towing is required. These factors are especially relevant in detailed design stage but also can be relevant at the risk assessment stage.

Compulsory pilotage, escort or towing could also be used as mitigation or preventive measures if the need is identified in risk assessment.

Nevertheless, vessels should always be able to comply with the COLREGs as discussed in Chapter 3.2.2.

4.2 Processes in Safety Distance Estimation

The recommendations concerning safety distance between OWF and navigation should be in accordance with the elements described in the section above.

However, different levels of analysis can be performed depending on the aims and the phase of the project.

The philosophy of PIANC WG 121 considers the following two stages of design:

- **Concept Design** includes preliminary design of windfarm and navigation areas layout using data and formulae given in design guidelines together with other relevant data relating to ships and environment. At the very first design stage only rough estimates of the safety distance are determined. The process is intended to be rapid in execution and not require excessive input data, so that alternative options (for trade-off studies) can be evaluated rapidly.

- **Detailed Design** is a more rigorous process intended to validate, develop and refine the Concept Design. The methods used in Detailed Design rely on numerical analysis (for example simulation) and therefore require more extensive and detailed input, as well as proper judgement and experience in the interpretation of their output. The outputs of the Detailed Design may be subjected to further checking for acceptability by means of marine traffic analysis, risk analysis and cost/benefit estimates. The results of these checks may lead to adjustments and a further cycle of Detailed Design.

In case of an existing OWF where the safety distance has not been taken into account, it is recommended to performance a Risk Assessment (see Section 4.2.3) that shall be approbed by the corresponding administrative authority of each country.

The safety requirements, on which bases existing OWF are build, are laid down in national or local developed safety criteria. If these criteria do not match with actual knowledge, the responsible administrations may decide to request an updated Risk Assessment (see Section 4.2.3) to be carried out to evaluate appropriate measures to reduce the risk of human life and natural resources.

4.2.1 Concept Design

The Concept Design stage is adequate for preliminary design using limited data and empirical formulae, together with data relating to ships and their environment. Concept design procedures estimate the safety distance in a conservative way, because general guidelines cannot assess all case-specific features and conditions.

In all cases the ColRegs are a good starting point for the estimation of safety distances. The main references to take into account are the following:

COLREG 2a) and b) – Responsibility

Nothing in these Rules shall exonerate any vessel, or the owner, master or crew thereof, from the consequences of any neglect to comply with these Rules or of the neglect of any precaution which may be required by the ordinary practice of seamen, or by the special circumstances of the case.

In construing and complying with these Rules due regard shall be had to all dangers of navigation and collision and to any special circumstances, including the limitations of the vessels involved, which may make a departure from the Rules necessary to avoid immediate danger.

The master is held responsible for having mitigating measures in place for unforeseen conditions such as a 'Not Under Command' situation. So, sailing very close to islands or multiple structures is not in accordance with the 'ordinary practice of seamen'.

A study regarding 'Not Under Command' situations (AIS tracks in combination with Dutch Coast guard reports) shows that 90 % of the vessels drift for one hour– resulting in a drifting distance of 1.7 nautical Mile. This distance is a result of local conditions and should be evaluated for each situation.

COLREG 7c) – Risk of Collision

Assumptions shall not be made on the basis of scanty information, especially scanty radar information.

Because radar targets of vessels within an area with multiple structures tend to swap to the structures, a Closest Point of Approach (CPA) is hard to establish. Only when the vessel departs the areas can the CPA be determined. The time needed to identify and plot the vessel has been determined to be 6 minutes. If a service vessel exits the wind farm with a speed of e.g. 10 knots, crossing the course line of a passing vessel, the minimum distance needed to get a reliable CPA is 1.0 nautical miles.

AIS information is available, but a CPA based on AIS information should not be used to determine the risk for collision, since the speed input is based on absolute GPS and not on the speed through the water.

Wind farms cause radar interference in addition to the effect of swapping targets. The safe distance to avoid interference has been determined by deep sea pilots to be 0.8 NM and surveys have identified **a minimum distance of 1.5 NM** from a OWF is necessary to minimise the interference on ship born radar and the automatic radar plotting acquisition (ARPA, see chapter 5.2.5).

COLREG 15 – Crossing-Situation

When two power driven vessels are crossing so as to involve risk of collision, the vessel which has the other on her own starboard side shall keep out of the way and shall, if the circumstances of the case admit, avoid crossing ahead of the other vessel.

COLREG 8 – Action to Avoid Collision

Action taken to avoid collision with another vessel shall be such as to result in passing at a safe distance. The effectiveness of the action shall be carefully checked until the other vessel is finally past and clear.

If the stand on vessel (i.e. the vessel with the other on her port side) does not act according the COLREGs, the give way vessel's last resort is a full round turn over starboard.

The required room for turns to starboard and port are shown in figures 5 and 6. The space for the round turn is determined as follows:

1) Start of the round turn. A round turn is not started right away. Normally one first deviates course, while observing the other vessel. This requires time. In the meantime, one deviates from the original track. The distance is normally taken as a minimum of 0.3 NM

2) The round turn itself is determined as described in the IMO Standards for Ship Manoeuvrability (IMO resolution MSC.137 (76) and MSC/Circ.1053):

- Para. 5.3.1: Turning ability: The advance should not exceed 4.5 ship lengths (L) and the tactical diameter should not exceed 5 ship lengths in the turning circle manoeuvre.
- Para. 1.2.3.5: Turning ability: Turning ability is the measure of the ability to turn the ship using hard-over rudder.

These requirements apply under controlled conditions during sea trials. It is reasonable to take an extra ships length to compensate for the fact that the Officer on Duty is not fully prepared for this manoeuvre. Therefore, the diameter of the round turn has been determined to be 6 ship's lengths.

3) The round turn should not bring the vessel closer than the 500-metre safety distance zone.

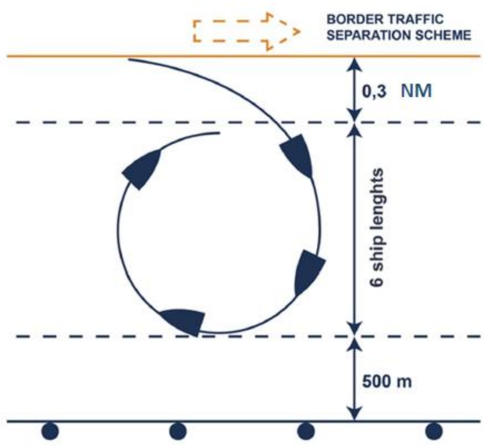


Figure 5: Required space between shipping route and a starboard side wind farm

A round turn could also be made over to port side, in case the starboard aft quarter is blocked due to an overtaking vessel for example. However, in that case the vessel will not first deviate to port, but start a round turn right away (see Figure 6).

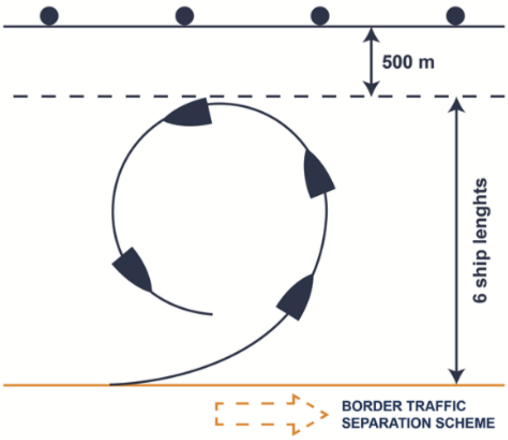


Figure 6: Required space between shipping route and a port side wind farm

Points to notice:

- It quite often happens that, after making a round turn, a Not Under Command situation occurs, due to mechanical problems (e.g. low-level alarm on oil levels, etc.)
- On many vessels, the Officer on Duty will hesitate to use hard rudder at once. One would be particularly cautious before starting such a turn on passenger ships and container vessels as it can result in significant damage to passengers, crew and cargo.
- Round turns are also made in case of a Man Over Board situation.

COLREG 10 h), I0, j)

A vessel not using a Traffic Separation Scheme shall avoid it by as wide a margin as is practicable.

A vessel engaged in fishing shall not impede the passage of any vessel following a traffic lane.

A vessel of less than 20 meters in length or a sailing vessel shall not impede the safe passage of a power-driven vessel following a traffic lane.

Fishing vessels and pleasure craft normally use the area next to the traffic lane. However, Figure 7 shows that there is little room left for sailing vessels that need to beat up against the wind for example.

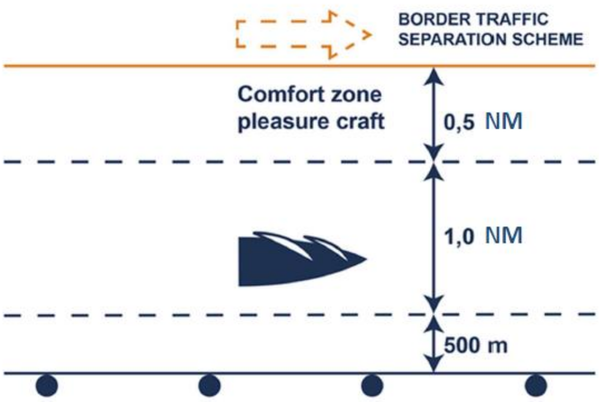


Figure 7: Required room to a TSS

Anchor Areas

There are no regulations that relate to anchorages.

However, safe anchorages should provide sufficient room to manoeuvre:

a) when the anchor is dragging
b) in the approach to an anchorage

A safety study for an offshore platform shows that the required space for a vessel to start her engines and manoeuvre when an anchor is dragging is 1.7 NM from the safety zone around a multiple structure. The same distance was found to be sufficient to provide manoeuvring space in the approach to the anchorage for all vessels making use of that particular area.

Again, this study is related to a specific area – different areas might require a separate study, but it does provide some indication of the required distances.

To Summarise

Based upon the guidelines, provisions and regulations as discussed above a **minimum distance between** a shipping route and a wind farm can be determined as follows:

- Starboard side of any route: 0.3 NM + 6 ship lengths + 500 metres
- Portside of any route: 6 ship lengths + 500 metres

4.2.2 Detailed Design

Detailed Design is a more rigorous process intended to validate, develop and refine the Concept Design. Operational aspects should be checked with reference to weather conditions, ship size and manoeuvring capacity, marine traffic, water areas, bathymetry, tug assistance, piloting, AtoN, etc. If the conditions are relatively simple and all the design criteria are easily fulfilled, there may be no need to make significant adjustments to the Concept Design. But in most cases additional analyses are necessary to determine an optimum design that will definitely be safe and usable.

Taking into account the philosophy of PIANC WG 121, detailed design involves the use of computer models whose type, purpose and methodology are outlined below. The Detailed Design of safety distances is considered using techniques which represent good present-day practice.

As in Concept Design, main design parameters are considered separately although, as already pointed out they are all interlinked. The following are a number of items which may require Detailed Design consideration:

- Critical factors including:
    - (a) cargo
    - (b) bottom conditions
    - (c) traffic intensity
    - (d) currents
    - (e) waves
    - (f) layout
    - (g) complicated ship handling
    - (h) special ships
    - (i) detailed hydraulic modelling
- Accuracy (human factors)
- Optimisation
- Benefits
- Risk acceptance criteria

Tools and methods for Detailed Design include the following:

- Detailed parametric design and special formulae
- Simulation Models:
  - Ship navigation/maneuvering simulation models: Fast-Time and Real-Time Simulation models
  - Traffic Flow Model to Determine Safety Levels

Ship navigation/manoeuvring simulation models are used to determine the safety distances to wind farm and dimensions of manoeuvring areas, while traffic flow simulation models are used to determine safety levels and efficiency including quantitative risk assessment.

4.2.3 Risk Assessment

Risk assessment comprises the first step in the development and application of MEP (Maritime Emergency Planning). The aim of the risk assessment is to establish the risks which need to be managed in the area and to identify means to control them to acceptable levels.

The risk assessment process should identify the hazards, together with the events or circumstances which may give rise to their realisation, determine the risk posed by them and identify the measures that can be put in place to control the risk by preventing the realisation of the hazard and/or mitigating its effect if it does occur.

In the context of this document:

- 'Hazard' is defined as something with the potential to cause harm
- 'Risk' is defined as the combination or product of frequency of occurrence and consequence of a hazard

The risk assessment process consists of five parts:

- Data gathering
- Hazard identification
- Risk analysis
- Assessment of existing mitigation measures
- Identification of any additional risk control measures/options

Data Gathering

The data gathering process aims to establish an initial list of hazards. In essence, data gathering involves familiarisation with all aspects of the existing area where the OWF will be establish. This will include gaining a detailed understanding of:

- Topography of the OWF area and its approaches
- Environmental data (currents, tides, climate and weather, etc.)
- Traffic flows and cargoes handled
- Leisure crafts and users
- Fishing vessels
- General environment of the future OWF area, including VTS, pilotage, tug services, etc.
- Existing policies and procedures
- Priorities and safety culture of the Maritime Authority
- The organisational structure of the Maritime Authority

From this information, existing and potential hazards can be identified, together with an appreciation of how they are managed within the current safety management system. The process should include a detailed review of the existing incident database.

A number of tools can be used to accomplish hazard data gathering including:

- Questionnaires and interviews with the Maritime Authority, harbour masters and other port operations officers, pilots, other port employees, contractors and representative port users, including leisure users, fishing vessels and environmental groups
- Auditing marine and safety procedures
- Firsthand observation of various port operations (VTS, pilotage, tug operations, mooring, etc.)
- Identifying leisure harbours
- Identifying fishing harbours
- Collection of AIS data, maritime routes, etc.

Hazard Identification

The process of hazard identification attempts to list all the hazards which currently exist within the local sea area as a result of operations conducted therein. This includes and builds upon the hazards identified in the data gathering process.

One of the most effective tools for this is the group 'HAZID' (Hazard Identification) or SWIFT (Structured What-IF Techniques) meeting(s) where stakeholders (under the guidance of a suitable facilitator), identify new hazards and authenticate existing hazards and their risk control measures.

These stakeholders should include representatives of the Maritime Authority, port managers, marine professionals (including harbour masters, port control/VTS officers, pilots, PEC holders, tug masters) other port workers and users (both commercial and leisure). In all cases, personnel from management to the lowest operational level should be included to facilitate the full identification of the different levels of hazard.

Risk Analysis

Risk can be defined as the product of the probability of an event occurring and the consequences flowing from it. Thus, an event which occurs infrequently and has a low level of consequence constitutes a lower risk than one which occurs more frequently and has a higher consequence. The analysis for each hazard requires the establishment of probability of occurrence and the consequences reasonably expected to be associated with that level of probability.

While incident data can be helpful in identifying hazards, its value in assessing likely frequency of occurrence is marginal due in part to the scarcity of significant incidents and measures which have been put in place subsequent to those incidents. Near miss data may give a better impression but should still be treated with extreme caution. There will also be a number of potential major incidents identified which have never actually occurred within the particular area.

The consequences of an event are best developed by consideration of event scenarios by suitably experienced personnel. The consequences should be broken down into categories, assessing the effect of the event on personnel, on the environment, on users, and on the continued operation of the OWF (which will include the effect upon the reputation of the OWF operator). The potential for escalation of an unwanted event should be included in the consideration of consequence. The analysis can be established by qualitative or quantitative methodology, or a combination of both. Qualitative risk assessment is generally conducted on the basis of objective estimates of risk and consequences.

Quantitative Risk Assessment involves analysis based on historical data, mathematical modelling or other calculations of the probability and consequence for each hazard. Whichever method is used it will greatly assist the subsequent (ranking) process if a numerical value can be assigned to each risk. The baseline condition for the analysis should be clearly identified, and in particular which existing risk control measures are assumed to be in place. Ideally, the baseline condition would assume no existing risk control measures in place (ground zero). However, if effective use is to be made of current experience and historical data (where such measures would generally have been in place), this is difficult to achieve in practice. The analysis should generate a complete hazard list which is ranked by severity of the risk associated with each hazard. The ranking assigned should be proportional to the level of risk determined and referenced to the ALARP ('As Low As Reasonably Practicable') level. The definition of what constitutes a tolerable level of risk can usually be determined by inspection and comparison of various hazards on the ranked hazard list, although it should be noted that it may be the subject of legislation within the country or region where the OWF will be located.

Assessment of Existing Measures

Existing control measures and defences identified in the Data Gathering and Hazard Identification stages should be reviewed. Additional control measures may be identified to address gaps, or where enhanced measures are indicated as being required by the analysis. There may be areas where risk control measures are disproportionately high, considering the risk involved, and may be reduced with subsequent benefit to resource allocation.

Risk Control

This stage identifies the specific control measures to be put in place to achieve the risk profile required by the Maritime Authority safety policy and/or other relevant legislation/standards. This will include consideration of all identified risk control options, together with the resource requirements, benefits and other consequences of their implementation.

Once the risk assessment has been completed, with risk control measures selected, the Marine Emergency Plan (MEP) can be established (or modified). The operation of these measures then becomes part of the MEP. As the MEP includes performance measurement and an audit and review process, the control measures adopted will be checked, audited and reviewed on a regular basis. The frequency of these reviews may be fixed, or may vary depending on the degree of risk identified.

The risk assessments themselves should also be subject to regular review of their applicability and effectiveness. Further information on compiling Risk Assessments for Port Operations can be obtained from References.

Software

Risk management software is available from a number of established sources. This can assist, not only with the collation, storage and updating of hazard data and risk control measures, but also with processing such data in a systematic and objective way. The software can typically process the data so as to give ‘ranked’ hazard lists, i.e. lists of hazards and/or risk control options which are prioritised in order of ascending or descending risk. As these systems are generally capable of continuous updating, it follows that they can show the current risk management status of the area on demand.

Such software can also generally accommodate MATRA (Multi Agency Threat and Risk Assessment) platforms to address terrorism, crime and other similar hazards. The information obtained from the system may be used by the operators to decide priorities for the allocation of resources to achieve a balanced risk profile within the targets set out in the OWF’s Safety Management Policy.

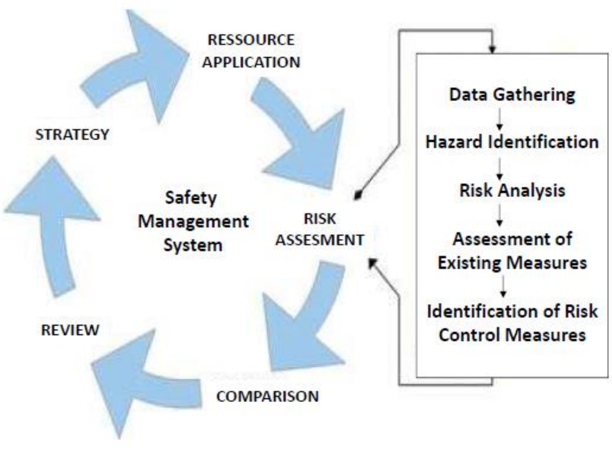


Figure 8: Safety Management System and Risk Assessment

5 ELECTROMAGNETIC RADIATIONS (EMR)

5.1 General Introduction to Electromagnetic Radiation

5.1.1 What is Electromagnetic Radiation?

Electromagnetic radiation (EMR) includes X-rays, ultraviolet, visible light, infrared and radio waves. Radio frequency (RF) EMR is commonly used for a wide variety of communications applications from the broadcast of television and radio, through to radars and mobile phones. It is important that wind farms do not impact the quality of this communications or, when necessary, that the effect is compensated by appropriate means.

5.1.2 What Do Wind Farms Have To Do With Electromagnetic Radiation?

Electromagnetic radiation (EMR) is naturally generated a body in motion in the air. Moreover, any power plant generate EMR with more or less power depending from the installation. This is the case with blades of OWF turning in the air as the wind is blowing and the same device generates electric power. From a wind resource perspective, height and exposure are attractive. It is not unusual for any of a range of telecommunications installations; radio and television masts, mobile phone base stations or emergency service radio masts, to be located close to terrestrial wind turbines and at a similar height to marine wind turbines. Care must be taken to ensure that wind turbines do not passively interfere with these facilities by directly obstructing, reflecting or refracting the RF EMR signals from these facilities. The problem at sea is similar to that on land but more sensitive because there are many radio communications and radio navigation systems dedicated to safety at sea. These systems are based on both terrestrial and satellite radio communications systems.

5.1.3 What Are Electromagnetic Radiation Interferences?

Unwanted radio emissions and background noise can impair effective telecommunications which rely on a sufficient signal to noise ratio. An appropriate transmitting antenna can dramatically improve this signal to noise ratio. A transmitting antenna can also increase the signal strength in a particular direction (i.e. toward a receiver). The directionality of a receiving antenna can also be enhanced, thus reducing the amount of unwanted noise.

5.1.4 How Can Electromagnetic Radiation Issues Be Managed?

Point to Point Communications: careful siting and directional antenna can eliminate any impact on point-to-point links.

Mobile Radio Services: interference can be overcome by moving the mobile unit a short distance away as per normal practice for avoiding any other structure. Any interference to mobile radio services is usually negligible and limited to mobile communications within the wind farm site itself. Nevertheless, ship mobile stations need to be operated in a homogeneous medium in order to comply with the requirement of radio watch-keeping of the global maritime distress and safety system (GMDSS) as it will be explained further.

Active interference is minimised or completely avoided by ensuring that all equipment complies with relevant electromagnetic compatibility standards, as all wind farm equipment does. In the unlikely event that a problem arises over time at a particular site, the wind farm operator will usually be able to rectify it.

In the focus of Interaction between offshore wind farms and maritime navigation, we will deal with the following equipment:

- radar (in particular vessel traffic service radar and shipborne radar)
- maritime radio communications in line with the GMDSS
- Automatic Identification System (AIS)
- shore-based Radio Direction Finder (RDF)

- Global Navigation Satellite Systems (GNSS)
- others navigation systems

5.2 Principles To Prevent Radar Interference

The wind farm developers are invited to seek the advice of radar operators before submitting their application for building permit. This phase should allow the developer to obtain elements to guide the project and avoid rejection on the occasion of its possible application for a building permit. This pre-consultation also allows the radar operators to provide as soon as possible to the competent authority their opinions during the investigation of the building permit.

Given the impact on air, sea and river safety, emergency services in general, and the prevention of natural disasters, radar operators opinion should be considered in a decision making process on the application for a building permit by a wind farm developer. We have considered below the principal radar operators: civil aviation, National Defence, weather office, and vessels traffic services (VTS). Because the use of radar is mandatory on many ships for the prevention of collision at sea and navigation, the National Competent Maritime Authority should also be consulted in order to take into account the proper safe distance from wind farms for ships to use radar without interference.

Radar operators should decide on the risk of disruption of their equipment especially in view of:

- security issues such as the need to monitor the national airspace
- radio, land and aviation restricted areas
- constraints related to air and sea traffic
- forecasting of weather disasters

Each radar operator should be consulted. There may be a competent authority in charge to co-ordinate the consultation, but the rules depend on national regulations. The guidelines below provide guidance to assist radar operators or any competent authority if no regulations on radar protection are implemented.

Around any radar installation the radar operator may consider three possible areas:

- **'Protected area**' where the risk of disruption to radar is too high, no wind turbine can be built.
- **'Regulated area'** where it is important to conduct a special study to assess the risk of disruption to radar in coordination with the different services concerned with the wind farm. Wind turbines could be built subject to restriction or further protection required by the radar operators or, depending of the case, the option could be the prohibition of any wind turbines.
- **'Authorised area'** where it is possible to build wind turbines.

The cases below provide values for the distance (d) for the radius of a 'protected area' and a 'regulated area' centred on the radar to be used by different operators (civil aviation, National Defence, weather and VTS) based on the experience of different countries.

In the absence of co-visibility of a wind turbine with a radar the risk of disruption of the radar is zero. If co-visibility of radar with a wind turbine exists, the method in the following chapters is proposed in order to organise space around a wind farm to determine whether a wind turbine is located in a 'protected area' or 'regulated area'.

5.2.1 Civil Aviation Radars and Systems

To protect flight paths and approaches, Civil Aviation authorities operate three types of equipment:

- **Primary radars** to detect aircraft. They provide monitoring without any cooperation from the target intervention.
- **Secondary radars** to communicate with the aircraft. They provide a cooperative surveillance through the active participation of target detection, the target being equipped with an answering machine, called transponder, which receives questions and answers from the radar.

- **Navigation systems** enable the aircrafts to position themselves. Some systems are working on global navigation satellite systems (GNSS) or different radio systems such as Visual Omni Range (VOR). VOR are ground-based system located at the airports and in the countryside.

a. Primary radars

<table>
<tr><th colspan="4">Recommended distance between a wind turbine and a primary radar in co-visibility (d)</th></tr>
<tr><th>Elevation angle originating home to the radar antenna (α)</th><td>d < 5 km</td><td>5 km ≤ d < 30 km</td><td>d ≥ 30 km</td></tr>
<tr><th>α ≤ 0.5°</th><td rowspan="2">Protected area</td><td>Authorised area</td><td rowspan="2">Authorised area</td></tr>
<tr><th>α > 0.5°</th><td>Regulated area</td></tr>
</table>

b. Secondary radars

Recommended distance between a wind turbine and a secondary radar in co-visibility (d)		
d < 5 km	5 km ≤ d < 30 km	d ≥ 30 km
Protected area	Regulated area	Authorised area

c. Navigation systems

Civil aviation authority should be consulted to assess the reduction of EMR from wind turbine on the different navigation systems. A protected area, where no wind turbine can be built, will be in force depending from the navigation systems in place.

A study by the French Civil Aviation showed that wind turbines within a radius of less than 10 km from a VOR is likely to cause deviations from 1.5° to 2°. In fact, under the precautionary principle, a protected area in a 2 km radius around a VOR should be established. A regulated area, 10 km around VOR should be created to study case by case the risk of interference between a wind turbine and a VOR.

There are two types of VOR: conventional VOR and Doppler VOR. Given the greater immunity to interference of Doppler VOR to reflections on obstacles a change from a conventional VOR into a Doppler VOR could be considered in some cases. In this case, a contribution to the cost of the change by wind energy developers might be agreed with the civil aviation authority.

5.2.2 National Defence radars

Most National Defence radars are located on air force or naval bases. External deployments can also be made, including for the protection of sensitive sites or to ensure maximum detection for both service air traffic control and territorial surveillance. In addition, the National Defence may have radars dedicated to space surveillance and trajectory on shooting ranges for air/ground radars.

Following the attacks of 11 September 2001, in many countries no wind turbine can be installed in a temporary prohibited area mentioned in the aeronautical publications or the triangular surface(s) joining ground-based radar to a temporary prohibited area less than 30 km distant from the radar. This distance and definition of area may change depending of the national and local requirements.

5.2.3 Weather radars

Weather radars are used to locate precipitation (rain, snow, hail), measure their intensity in real time and perform wind measurements by Doppler (vertical profiles of wind fields and volume). Spread over the whole country in many States, they have a range of about 100 km for measuring precipitation and 150 to 200 km for the detection of hazardous precipitating events.

1) A project should be authorized if all the following conditions are met:

- no wind turbine is allowed within the protected area of the radar
- concealment of the radar beam by any group of wind turbines is less than 10 %
- wind turbines are not aligned in the direction of prevailing winds
- the size of the Doppler area of the wind farm does not exceed 10 km in its largest dimension

2) Sensitive sites cases:

A sensitive site is a geographic area defined by the competent Authority:

- which is responsive to the meteorological risk, including risks of strong wind exposure,
- which has an important socio-economic issues, such as industrial area or an area with high urban concentration,
- and whose time responsiveness requested to the weather office is compatible with warning capabilities for short-term forecast.

Thus, companies for which a special contingency plan is developed and aerodromes are considered sensitive sites. The Doppler area of a wind farm should be at least 10 km distant from a sensitive site.

	Recommended distance between a wind turbine and a weather radar in co-visibility (d)				
Frequency band of the radar	d < 5 km	5 km ≤ d < 10 km	10 km ≤ d < 20 km	20 km ≤ d < 30 km	d ≥ 30 km
Band C	Protected area	Regulated area		Authorised area	
Band S	Protected area		Regulated area		Authorised area

5.2.4 VTS Radars

"*Vessel Traffic Services (VTS) contribute to the safety of life at sea, safety and efficiency of navigation, the protection of the marine environment, the adjacent shore area, worksites, and offshore installations from possible adverse effects of maritime traffic*". [SOLAS V/12]

IMO Resolution A.857(20) states: "*A clear distinction may need to be made between a Port or Harbour VTS and a Coastal VTS. A Port VTS is mainly concerned with vessel traffic to and from a port or harbour or harbours, while a Coastal VTS is mainly concerned with vessel traffic passing through the area. A VTS could also be a combination of both types. The type and level of service or services rendered could differ between both types of VTS; in a Port or Harbour VTS a navigational assistance service and/or a traffic organisation service is usually provided for, while in a Coastal VTS usually only an information service is rendered*."

Performance requirements for VTS radars are generally different to the requirements for marine navigational radars. VTS radars normally need to operate simultaneously on short and long range and this leads to dynamic requirements that far exceed those required on board a ship.

Effect of the presence of a wind farm on VTS radar:

1) Since the angle of a VTS radar has to be near horizontal it is inevitable that confusion will exist between the position of ships and wind farms, but It should be noted, that wind generators are normally placed in a well define pattern, ships in the vicinity can be identified by breaking symmetry.

2) If Doppler analysis or Moving Target Indicator (MTI) is not used in the signal processing the rotation of the rotor doesn't cause interference.

3) The fineness of presentation depends on:

    a. the azimuth angle of the radar beam which depends on the antenna size of the radar
    b. the pulse length which defines the separation distance needed so that objects behind each other are shown separately

4) In close proximity to an OWF radars can be rendered inoperative by saturation if the power level of the received signal from reflection from the OWF is too large compared to its operating range.

5) Blind sectors behind wind turbines generated by the towers of the wind turbines and the masking blades whose attenuation is low. The average attenuation is about 0.3 dB on a reflected signal (see Figure 9).

6) The appearance of false targets, based on strong radar signatures of the wind turbines can generate false echoes. These are based on the side lobes of the radar antenna. These echoes appear with an angular offset relative to the wind turbine. Multi-path reflection of the radar signal to or from the desired target, based on passing vessels (see Figure 910), may also generate false targets.

In consequence these disturbances can significantly degrade the capabilities of detection, localisation and identification of radar around wind turbines.

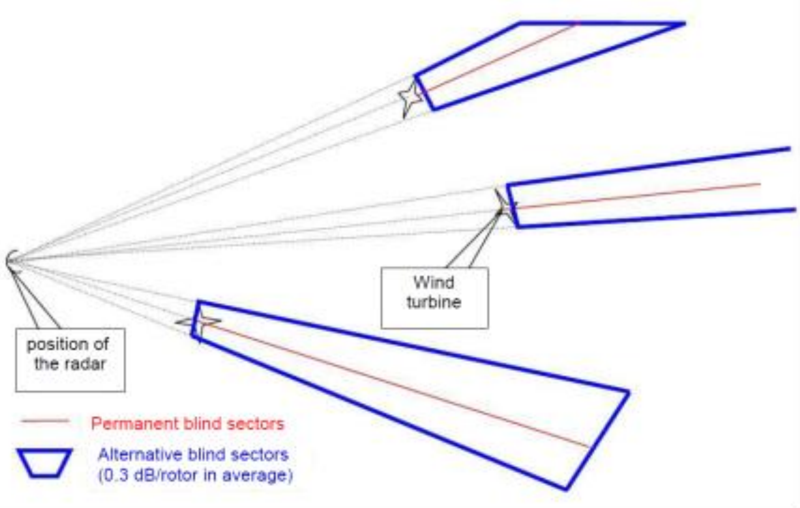


Figure 9: Blind sectors generated by wind turbines

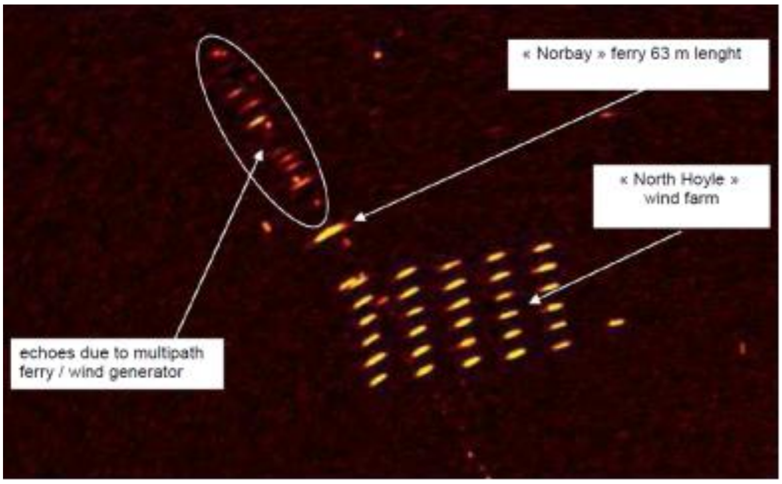


Figure 10: False target phenomena seen temporarily by a land based radar

	Recommended distance between a wind turbine and a VTS radar in co-visibility (d)		
Frequency band of the radar	d < 10 km	10 km ≤ d < 20 km	d ≥ 20 km
Band X	Protected area	Regulated area	Authorised area

In addition, the protected area should be restricted to ± 6 ° on either side of the operating sector of the VTS radar (see
Figure *11*).

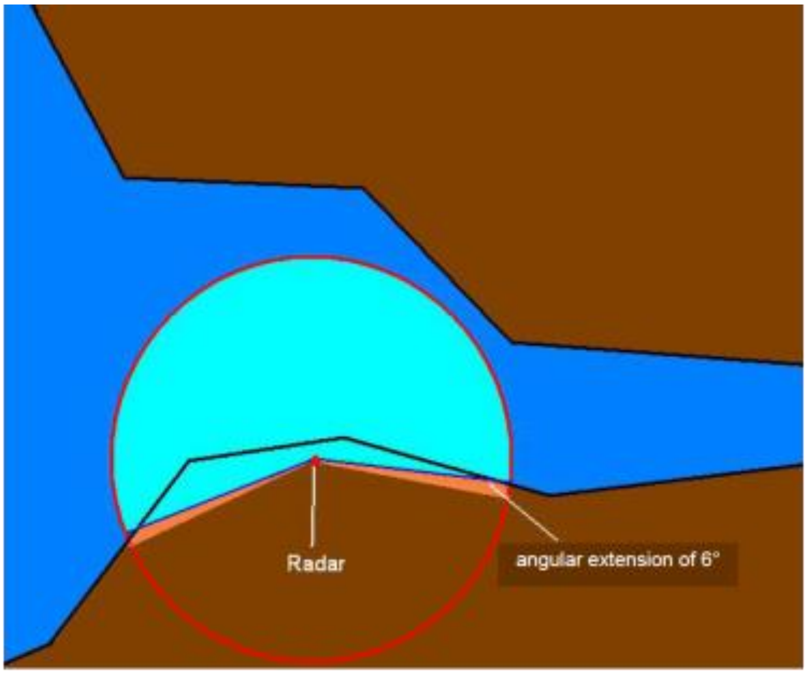


Figure 11: Recommendation for VTS radar protection on either side of the operating area

5.2.5 Ships Radars

Ships use two types of radar:

1) X band radar (9.2 to 9.5 GHz frequency) with a short wave length of 3 cm. This type of radar is mainly used for accurate navigation and to detect targets around the ship.

2) S band radar (3 GHz frequency) with a longer wave length of 10 cm. This type of radar is used for long distance detection and navigation system, but it is less sensitive to sea and rain clutter.

Depending of their size, merchant ships above GT 3000 carry both type of radar to be in compliance with Chapter V of the SOLAS convention. Band X radar is also used by VTS and band S radar is also use by weather services (see above). In consequence ship radar are disturbed in the same way as described above. When automatic radar plotting acquisition (ARPA) systems are used to track targets close to a wind farm target swaps may occur. Surveys have identified that at **distances below 1.5 NM** from a wind farm special care regarding the selected range, pulse length and gain is necessary to minimise the interference on ship born radar.

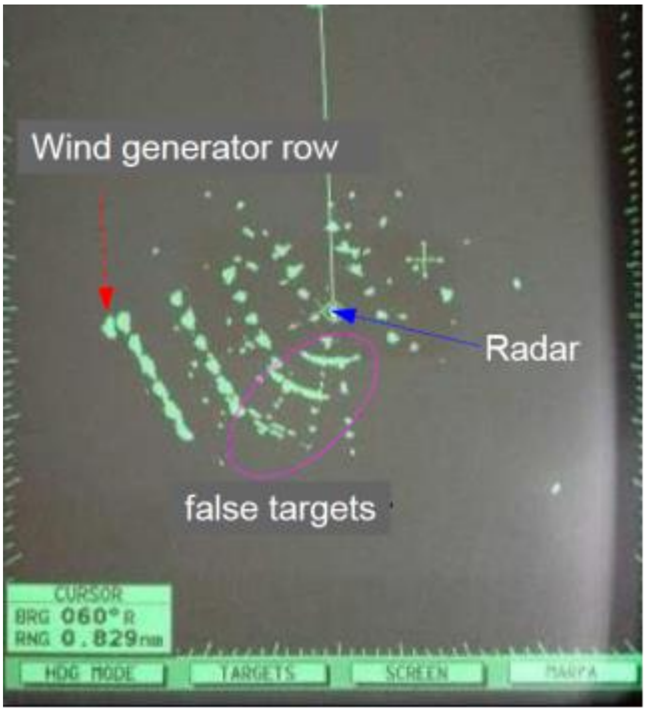


Figure 12: Example of false target generated on a ship radar screen (ship is in the wind farm close to a wind generator)

Interaction between wind turbines and ship radar can generate false targets by the side lobes of the antenna (as shown in Figure 12). Clutter is located at the same distance as the wind turbine.

5.3 Radio Communications

In addition to their potential impact on radar systems, offshore wind farm structure may also affect communications systems operating in the marine environment. This includes vessel-to-vessel, vessel-to-shore and vessel-to-space links. Examples of systems that potentially may be affected include satellite links such as GPS (global positioning system, 1.6 GHz) for navigation and Iridium (1.6 GHz) and Geostationary Operational Environmental Satellite (GOES on 400 MHz) for data relay by various ocean monitoring sensors, VHF (160 MHz) radio for marine communications, and AIS (automatic identification system on 160 MHz) for vessel identification and tracking.

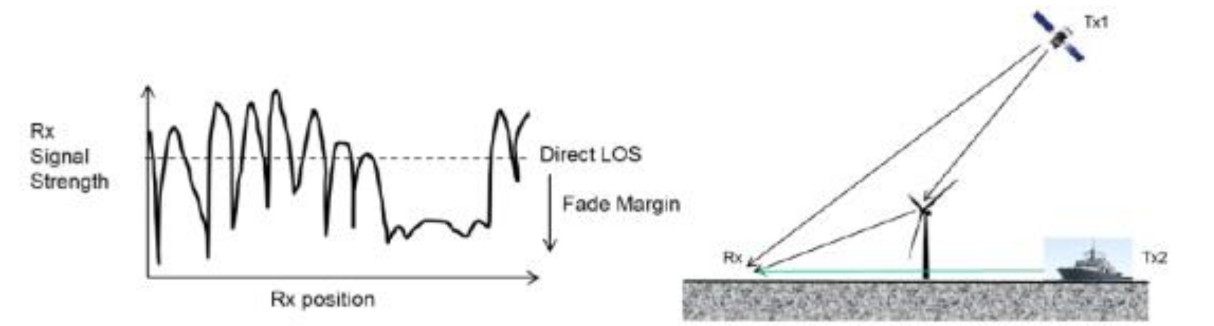
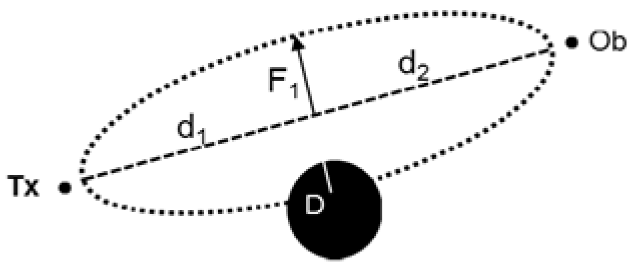


Figure 13: Illustration of communications channels encountered in the marine environment

A number of analytical and numerical approaches have been applied to model the wind farm blockage problem. A simple, approximate geometrical blockage estimate can be derived based on the Fresnel zone argument. This is the standard methodology used to estimate the shadowing effect due to wind turbine structures by the Federal Aviation Administration (USA) obstruction evaluation process.



$$F_1 = \sqrt{\frac{\lambda d_1 d_2}{d_1 + d_2}}$$

$$\frac{E^{tot}}{E^i} = 1 - \frac{D}{F_1}$$

Figure 14: Fresnel zone blockage calculation for assessing wind turbine blockage

Based on various studies around the world, we can summarise the effect of wind farms on marine communications are as follows:

1) A distinct shadow region is observed behind the tower. Multi-path interference is observed outside the shadow region.

2) The shadow becomes more optical-like as frequency is increased, leading to longer, narrower and deeper shadows. However, the signal fade is still less than 6 dB relative to the direct line of sight (LOS) signal up into the GHz range.

3) The vessel-to-vessel link and the vessel-to-shore station links are worst-cases compared to vessel-to-satellite links.

4) The shadow becomes deeper when more than one turbine is lined up with respect to the transceiver (Tx) line of sight (LOS) and then the fading risk is higher.

5) Most communications systems have built-in link margins to compensate for signal fading. For example, typical GPS receivers have a fading margin of 15 dB or greater.

The Global Maritime Distress and Safety System (GMDSS) is an internationally agreed set of safety procedures, types of equipment, and communication protocols used to increase safety and make it easier to rescue people from ships, boats and aircraft in distress at sea. The GMDSS is internationally regulated in the ITU Radio Regulation and the related equipment on board the vessel by the IMO in chapter IV of the SOLAS convention.

Within the GMDSS several communication systems are used, some of them are new, but many of them have been in operation for many years. The system is intended to perform the following functions: distress alerting (including position determination of the unit in distress), search and rescue coordination, locating (homing), broadcasts of maritime safety information, general radio-communications, and bridge-to-bridge communications. Specific radio carriage requirements depend upon the ship's area of operation, rather than its tonnage. The system also requires redundant means of distress alerting, and emergency sources of power.

Vessels in national waters and those under 300 Gross Tonnage (GT) as well as recreational vessels are not subject to the convention. They do not need to comply with GMDSS radio carriage requirements, but increasingly the Digital Selective Calling (DSC) VHF radios are installed on voluntary base on these vessels.

Despite the use of DSC in the GMDSS, it is still mandatory to maintain a continuous watch on VHF channel 16 (156.8 MHz).

IMO Res.A.801(19) adopted on 23 November 1995, provides provisions for radio services for the GMDSS. It is the reference document to establish the different GMDSS sea areas. In particular, the formula to determine the coverage for a Coastal Radio Station (CRS) is defined. This helps Coastal States to declare their GMDSS infrastructure to IMO as requested in SOLAS IV/5.

The IMO secretary consolidated the collection of all GMDSS sea areas within the GMDSS master plan.This master plan helps to define the radio equipment to carry on board ships, which depends on the radio communication infrastructures onshore in the area of operation of the ship.

VHF Radio Communications and AIS

Because of possible EMR perturbations on the reception of distress alerts with a direct consequence on the safety of life at sea, and the potential new risks generated by the OWF additional VHF radio-communication resources may be required for:

- watch keeping distress call and alert
- broadcasting maritime safety information to prevent accidents
- co-ordination of search and rescue operation
- co-ordination for oil spill cleaning
- co-ordination of salvage operations

Automated Identification Systems (AIS) is a tracking system, which involves radio communication from ship to ship and also from ships to AIS shore based stations. The VHF transmissions of the system integrates identification of the vessel, positioning, speed and heading information. The purpose of AIS is first to identify ships. In that respect AIS assists in collision avoidance, but it should be kept in mind that AIS is not mandatory on all vessels. AIS are transceivers operating in the VHF Band. They are subject to the EMR interference of the OWF in the same way as the VHF radio communication systems.

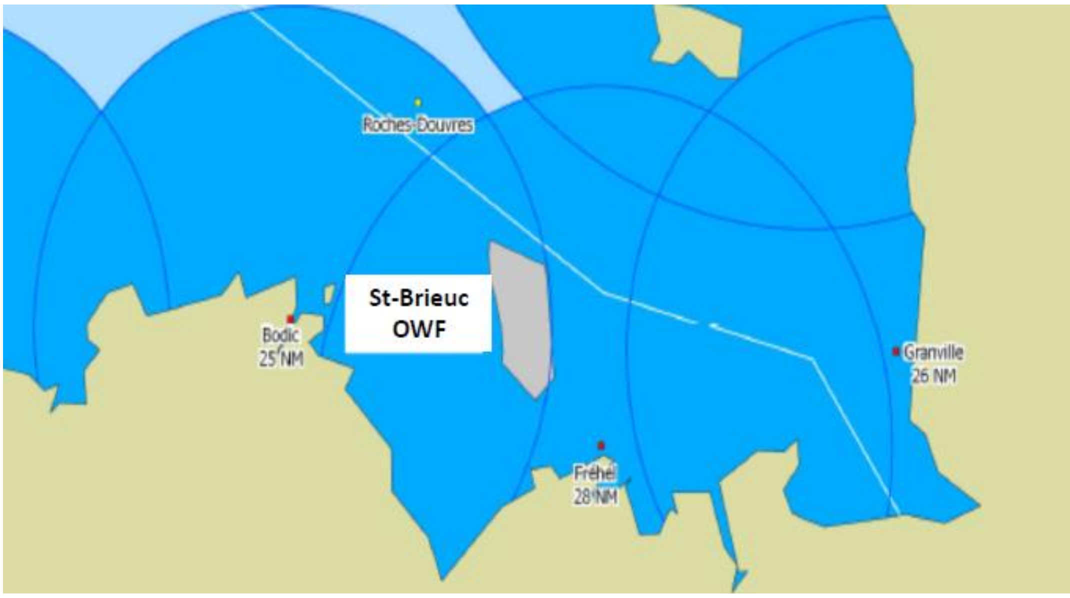


Figure 15: Saint-Brieuc (France) OWF project and the different VHF coverages
(GMDSS sea area A1 in blue) around VHF CRS

The establishment of wind farms is likely to impact the operational range of systems of monitoring and communication. This has an impact mainly for ships within VHF range when located behind OWF. There are several studies that confirm interference of VHF, which under certain conditions can impact not only the analogue voice communications but also DSC and AIS signals. The following precautionary principles would ensure maritime safety in and around the wind farms and facilitate radio communications in case of emergency operations:

- Study of the potential impact on VHF and AIS transmissions and coverage of the A1 area are to be considered during the planning process for a wind farm. The operator needs to approach in particular the services in charge for search and rescue (SAR) operations, such as the rescue coordination centre (RCC), but also VTS and harbour masters' office.

- On request, the operator may install in the offshore wind farm an extra VHF station with two sets of multi-channel equipment. Each unit will consist of a transmitter (Tx) and a receiver (Rx) on VHF frequencies.
- This VHF equipment would reinforce the VHF capacity of the RCC in the area during the construction phase of the OWF.
- During the months following the commissioning of the OWF, propagation measurements on VHF in and near the OWF should be carried out and the results are to be communicated to the services involved (RCC, VTS or harbour masters' office) for their study and conclusion of the effect of the OWF.
- During this transitional phase and until the results of the study are known, VHF equipment in the offshore wind farm may be made available to the RCC, VTS or harbour masters' office. The operator shall be responsible for the procedure of integration and installation of this equipment, including aerials.
- If studies reveal disturbances the RCC might require that the operator installs a GMDSS coastal radio station, as compensatory measures to preserve the integrity of the defined GMDSS sea area A1. VTS or harbour masters' office compensatory measures on VHF may be less stringent, in particular if these services are not related to the distress watch which is the primary task of RCC.
- AIS compensatory measures are to be checked case by case depending on the AIS base stations affected and the needs of the service affected. It would be possible that an additional AIS base station is placed on an appropriate position in the OWF.
- If no disturbance is detected, the operational requirement to keep up the equipment should be assessed. In the event that the station should be maintained for operational reasons, the RCC or any other service involved has to initiate a contractual procedure with the operator to define the maintenance of facilities and access to the sites.

In all cases, it is considered best practice to identify the possible implications for radio-communication systems and AIS operating in the area around a wind farm, and to carry out a study of the potential impact on radio-communication to the extent possible. Field measurements should be carried when OWF is completed in order to confirm the need for and location of any additional VHF coastal radio station or AIS base station in the OWF or simply to check the sea area A1 coverage.

5.4 Radio Direction Finder (RDF)

The disruption of phase due to OWF may cause some concern on applications where phase information is used, such as direction finding and precise GPS relative and absolute positioning techniques based on carrier phase measurements. These should be further examined.

In the case of the use of a shore based radio direction finder (RDF), whether for the purpose of a VTS or SAR, the D/F may be degraded due to the EMR area of the wind farm.

In this case it is suggested to study an alternative solution to any RDF shore based station.

5.5 Other Navigation Systems

Depending on the importance of the information provided by GNSS or local radio navigation systems, it is suggested that a study of the potential impact on GNSS and radio navigation transmissions and coverage be considered during the planning process for a wind farms. Last but not least, the electromagnetic field generated by wind generator should be considered on magnetic compasses.

5.5.1 GNSS

Multi-path disturbance effects of the satellite communication already exist on merchant ships. These effects are generated by cranes and mast of the ships. It is possible to minimise the disturbance on the GNSS receptor by dedicated settings.

Studies focussed on the DGPS which is a corrected signal of GPS transmitted by shore-based stations in a frequency range around 300 kHz:

1) The risk of disruption affects only the GPS signal from the reference station.
2) The reference station uses signals from satellites positioned more than 10° above the horizon.
3) In order to avoid interference it is necessary to respect a minimum distance:
   - Between the reference station and wind turbine and
   - Between the ship and the wind turbine.
4) As an example, for a wind turbine of 160 m height a distance greater than 1,200 m and an angle of 8 ° above the horizon overcomes the potential impact of multiple-paths between satellite, ship, wind turbines and DGPS reference station.

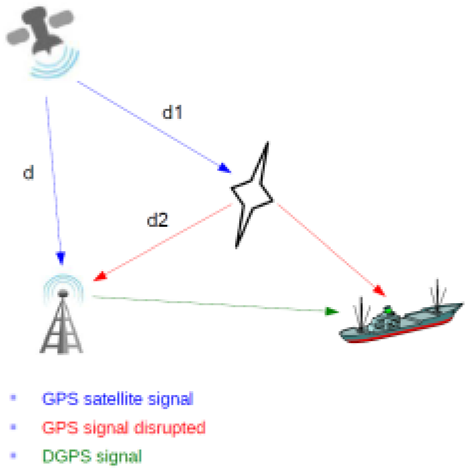


Figure 16: Disruption of DGPS

To maintain the accuracy of DGPS, it is necessary to ensure a safe distance between wind turbines and ships, and between wind turbines and the DGPS reference station. For 160 m high wind turbines this distance is 1.2 km.

5.5.2 Local Radio Navigation Systems

The hyperbolic radio navigation systems (DECCA, LORAN C) are discontinued, there may be others local systems (RTK or other systems) in some harbours to give an accurate position for piloting, survey ships or dredgers. There are new radio navigation systems under study such as R-mode. Whatever the terrestrial radio navigation systems, the operating principle is always the same and based on EMR. All these systems are subject to multi-path effects which reduce the accuracy of the position information in the same way as GNSS and DGPS.

5.5.3 Magnetic Compass

It is quite unlikely that the wind generators and the seabed cabling within the site and onshore produce electromagnetic fields affecting compasses and other navigation systems.

Nevertheless, it is always recommended to navigate with caution and check the proper operation of all navigation equipment.

6 EMERGENCY PROCEDURES

6.1 Introduction

As explained in chapter 2 emergency response is one of the crucial links in the global chain of contingency planning and associated risk management, which is described in Chapter 4. Maritime Emergency Planning (MEP) should be part of a holistic Safety Management System (as described in chapter 4) covering both risks to maritime navigation from OWF and vice versa. In order to avoid a complex identification of separate risks ordered by (direct-indirect) causes, risks are globally ordered by the nature of their consequences on:

1. People (health, safety & security) with SAR as the most important response
2. Planet (marine environment) with pollution (oil spill) contingency as the primary focus
3. Property & Assets (materials) with salvage as the main emergency response
4. Professions/Business (socio-economy, liability, reputation, etc.)

6.2 General Concepts

The main objective of a Contingency Plan is to establish a consultative structure in which various authorities with their specific competences come together under the leadership of a general response and crisis coordinator. Good understanding between all on-scene parties and adequate onshore-offshore emergency planning synergy is crucial for a successful emergency response. In every operational Contingency Plan, the tasks of the engaged rescue services are divided amongst five groups of disciplines [Debyser, 2015]:

- Discipline 1 = Rescue Operations
- Discipline 2 = Medical, sanitary and psychosocial assistance
- Discipline 3 = Law enforcement (Police)
- Discipline 4 = Logistic support
- Discipline 5 = Information-communication

Tiered preparedness and response is recognised as the basis on which to establish a robust incident preparedness and response framework and provides a structured approach to establishing a mechanism to build the required response effort. The established three-tiered structure allows those involved in contingency planning to describe which response capabilities can be identified to mitigate any potential emergency scenario; from small operations to a worst-case emergency at sea or on land. The structure provides a mechanism to identify how individual elements of capability will be cascaded. The aim is to provide suitable response resources at the right place at the right time. Response capabilities are defined as the resources required to deal with the incident and can be broadly considered in three categories [OGP, 2015]:

- Response personnel
- Equipment
- Additional support

Collectively these resources combine to establish response capability, and are categorised according to whether that capability is held locally, regionally or internationally. This geographical distinction is at the core of the tiered model, and enables capability to be built around the potential severity of the incident and the time frame in which resources are needed on scene [OGP, 2015].

- **Tier 1**: Resources necessary to handle a local emergency and/or provide an initial response (locally available resources)
- **Tier 2**: Shared resources necessary to supplement a Tier 1 response (regional or nationally available resources)
- **Tier 3**: Global resources are necessary to support the Tier 2 response due to the incident scale, complexity and/or consequence potential (internationally available resources)

The model also relies on successful cooperation between the different stakeholders that may be involved in the response.

6.2.1 People – Search And Rescue (SAR)

Maritime SAR is clearly defined in the international convention on maritime search and rescue 1979, also named Hamburg Convention or SAR 79. The IMO/ICAO joint working group on the harmonisation of aeronautical and maritime SAR (named IMO/ICAO JWG) has developed international guidelines for SAR. The references documents for National Administration in charge of SAR is contained in the international aeronautical and maritime search and rescue manual (IAMSAR manual).

United Kingdom has provided an interesting document at 22nd IMO/ICAO JWG (document ICAO/IMO JWG-SAR/22-WP.10) in relation to SAR procedures, processes and techniques for SAR helicopters and rescue boats responding to OWF and other renewable energy installations. This section is based on this input.

The number, size (of wind turbines and fields) and geographical coverage of offshore renewable energy installations impacts the sea-space and it is recognised that there will be an increasing SAR challenge caused by large numbers of physical obstacles at sea. The presence of OWF creates new, physical obstacles to both surface vessels and low flying aircrafts.

SAR helicopters normally have radar fitted for search, surveillance and navigation. The effects of wind turbines on an airborne radar picture have undergone limited assessment and it has been noted that wind-turbine radar returns may merge together into a single, large radar image at medium to long ranges (see Chapter 5). Discrimination between individual turbines may only become apparent at shorter ranges e.g. 1.5 to 5 NM. The discrimination is, of course, dependent on beam width and radar processing techniques available in the type of radar in use on the SAR helicopter. When operating amongst wind turbines, at night and/or in poor weather, nose-mounted, sector scan radar (e.g. 120 degree scan) may have limitations and 360 degree scan radars may be more effective as a flight safety and search aid. No significant data is yet available for the effects on radar picture quality when using radar inside a larger wind farm.

Navigating a SAR helicopter through a wind farm is difficult and requires careful mission management. The feedback from United Kingdom and some European SAR aircrew currently indicates that searches are possible within wind farms but that search quality may be lower than that expected in open water. Crew will need to refer to the available detailed OWF charts and ID numbers of turbines in their vicinity to visually navigate and cross-check location with electronic navigation systems and to plan a route to a rescue location or when searching. Aircraft are likely to need to fly slowly (e.g. 50 to 60 knots) and crew will be concentrating on obstacle avoidance and accurate navigation along the 'SAR access lane' centreline.

It is, therefore, likely that the number of crew able to conduct an effective search will be reduced: the two pilots would most probably focus on flight path management and safety, leaving only the rear crew to look for SAR objects. This may be a reduction in the normal search mode where one pilot may be sufficient to manage flying the aircraft and flight safety, leaving three crew members to look for SAR objects. It is also believed probable that, at times, all crew will be needed to conduct flight safety lookout tasks e.g. locating and identifying OWF structures, finding safe exit routes, etc. and that this will impact on the overall effectiveness of searches. There may also be further distractions caused by crew inadvertently watching for obstacles instead of looking for SAR objects.

An additional problem is that, depending on the wind farm layout and spacing of turbines, the use of SAR access lanes may lead to a reduction in coverage if the spacing between SAR access lanes is greater than the required sweep width. OWFs should, wherever possible, be laid out in a regular grid pattern (this is not always possible for engineering and construction reasons, e.g. seabed conditions and water depths, preventing turbines being laid in a regular pattern).

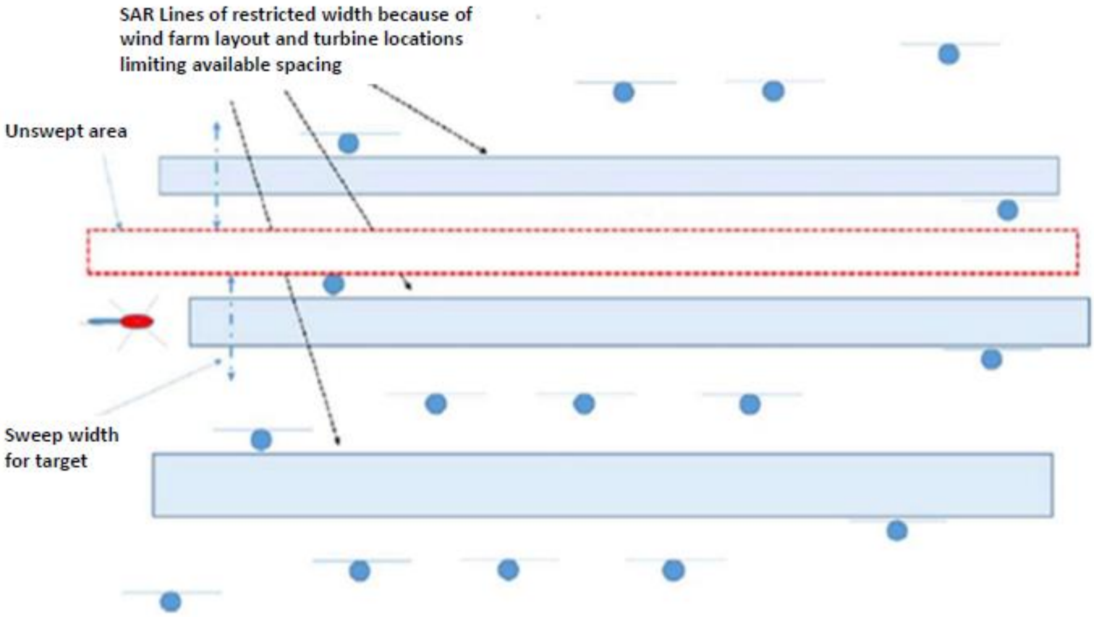


Figure 17: Effect on sweep width of SAR lane spacing. An unswept area (red rectangular) originates due to the wind farm layout limiting available spacing [ICAO/IMO JWG, 2015]

Because SAR lanes are 'fixed', in some weather conditions (strong winds for helicopters, and sea and swell direction for rescue boats) SAR units may find that they need to steer large offset headings to maintain their track over the ground. This is particularly important for SAR helicopters who may be trying to hold track within a wind farm SAR access lane. In extreme cases search effectiveness and flight safety may be compromised and the SAR helicopter may have to abort the mission. The same problem may be encountered by surface craft which may find that they cannot steer an effective search track without the vessel rolling and pitching excessively, and so search effectiveness will be significantly reduced.

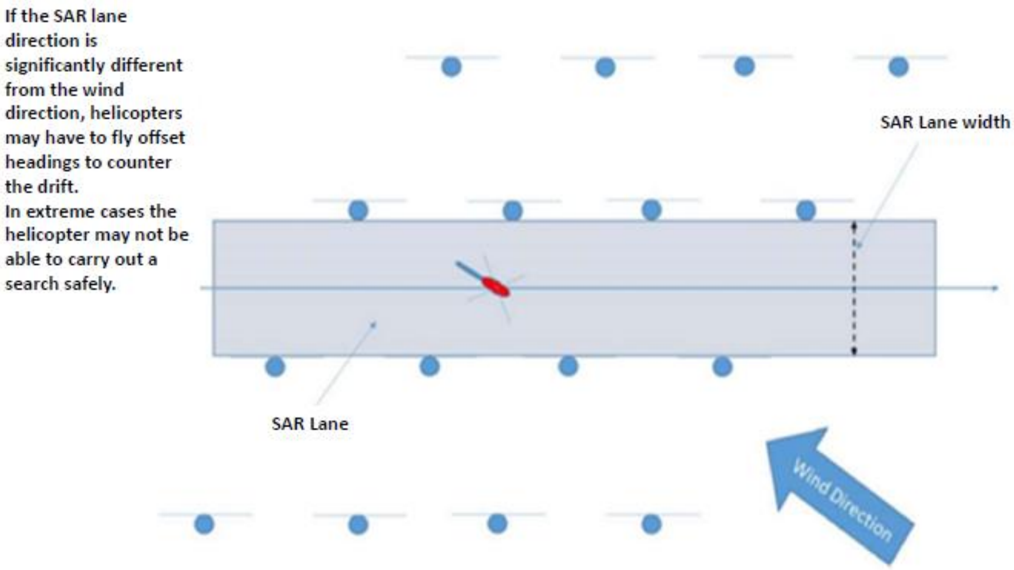


Figure 18: Effect of wind on SAR helicopter following SAR lane [ICAO/IMO JWG, 2015]

The existence of a large number of structures within an individual separate OWF field means that, during searches, lookouts may be distracted by occasional 'visual confusion' and interference caused by relative movement amongst the structures and rotating blades as the Search and Rescue Unit (SRU) moves. Also, in certain light levels, sea and visibility conditions, the structures may be between a SAR object and the lookout at a critical moment – a 'detection opportunity'. This problem may be most likely to occur during rough sea and swell situations.

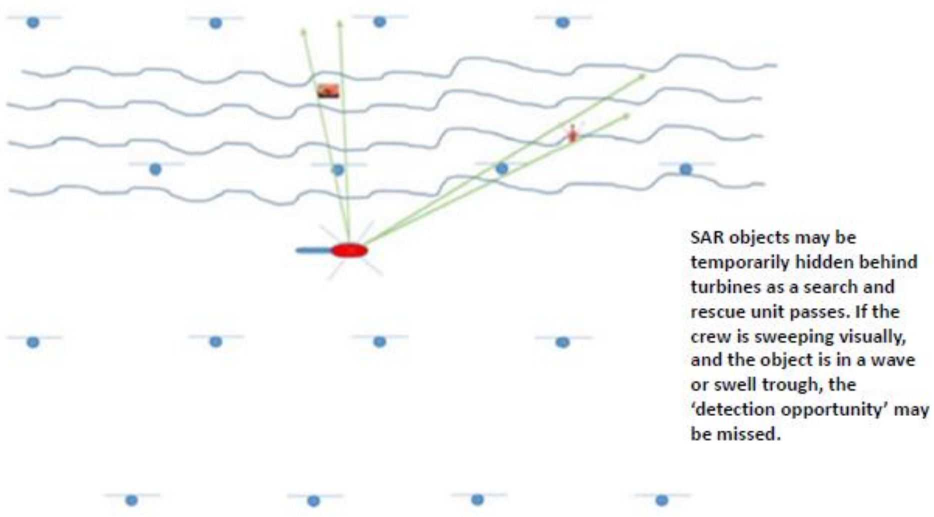


Figure 19: Effect of wind turbines blanking SAR objects – detection opportunities [ICAO/IMO JWG, 2015]

6.2.2 Planet Environment – Pollution (Planet)

The second consequence type defines the marine environment as the main driver for emergency response. When developing response actions for pollution of the environment at sea it is important to realise that incidents involving Hazardous and Noxious Substances (HNS) differ from oil spills, particularly with regard to the type and range of hazards, the need for appropriate protection to responders, the available response options and the fundamental requirement to safeguard the general public. HNS has a wide spectrum of physical properties which may impact upon the environment. Whilst some materials behave in a similar way to oil spills (not least because a number are derived from petroleum products) by forming surface or subsurface slicks, others can behave in a radically different manner, for example forming gases, evaporating into the atmosphere, dissolving into sea water, igniting, etc. It is therefore more helpful to think of an HNS incident as having the potential to 'release' a substance into the environment rather than 'spill' in the same way as oil. Depending on the substance involved, each release has its own characteristics, behaviour, impact, hazards and associated risks. One principle difference to an oil spill is that recovery of released HNS is often not appropriate using commonly available tools and techniques [EMSA, 2007].

A number of EU/EFTA coastal Member States have concluded cooperation agreements at a sub-regional or regional level, so-called 'Regional Agreements', in order to provide mutual assistance in responding to marine pollution or the threat thereof. The European Community is also a contracting party to the major Regional Agreements and EMSA has close cooperation and coordination with them on various common issues [EMSA, 2007].

6.2.3 Property – Salvage (Materials)

Salvage

The most important emergency measure to cover the third type of consequence (i.e. property & assets) is clearly salvage. Marine salvage is the process of recovering a ship, its cargo, or other property after a shipwreck. As the wreck of a (partly) destroyed wind turbine structure forms an equally important asset in this analysis, marine salvage should not only focus on the recovery/removal of ships and their property. Similar techniques and procedures will be implemented for both assets. Salvage encompasses towing, re-floating a sunken or grounded vessel, or patching or repairing a ship or an OWF. Today the protection of the environment from cargoes such as oil or other contaminants is often considered a high priority [Australia Parliament, 2004].

A salvage operation in relation to an OWF has not (yet) occurred at the time of writing this document. An operational example of removing material, wrecks or debris from a wind farm area can therefore not been given. Both, vessel and wind turbine structure wrecks can be handled similarly; each with their own detailed specifications as a direct consequence of their respective ‘content’.

Removing wrecks is a major undertaking which can incur great cost. Analysis of the most expensive wreck removals from the past decade suggests that the following factors are central to the cost of wreck removal: location; the contractual arrangements; cargo recovery from container ships; effectiveness of contractors and the vessel’s special casualty representative; the nature of bunker fuel removal operations; and the influence of government or other authorities. Of all these factors, government influence, reflecting public concern, appears to be the dominant factor in rising costs [Lloyd’s, 2013].

Challenges of Salvage

Saving the cargo and equipment aboard a vessel may be of higher priority than saving the vessel itself. The cargo may pose an environmental hazard or may include expensive materials such as machinery or precious metals. In this form of salvage, the main focus is on the rapid removal of goods and may include deliberate dissection, disassembly or destruction of the hull. Wreck removal, on the other hand, focuses on the removal of hazardous or unsightly wrecks that have little or no salvage value. Because the objectives here are not to save the vessel, the wrecks are usually re-floated or removed by the cheapest and most practical method possible. [Black Sea Diving Centre LTD, 2015].

The location of a wreck or turbine debris is central to the cost of removing it. Wrecks in remote locations far from supply bases and sources of necessary equipment are likely to be more expensive. The conditions at the wreck site are also important; a rocky site surrounded by deeper water will present more of a challenge than a gently shelving sandy beach. The weather conditions at the location are also important. For example, whether the wreck or debris site is a lee shore exposed to prevailing winds and waves, or whether it is in a sheltered location. Similarly, whether the tide, or waves will scour the sand or mud from under the wreck/debris, causing instability, could be an important factor. A wreck/debris occurring in the approaches to a major port or close to active berths could represent additional risk in the form of major business interruption [Lloyd’s, 2013].

Increasing size and growing content volumes (both in volume and value) drive up wreck/debris removal costs. Both vessels and wind turbine structures have generally increased in size. Larger ships and wind turbine components are generally harder to handle as casualties, and will take longer to remove as wrecks, partly because of the larger volume of content that will have to be taken off. In the case of container ships, removing cargo can be a long and difficult process, driving up costs. Due to the complex infrastructure (electrical components, data transmission, oil components, etc.) of a wind turbine also the removal/recovery of the content might be a difficult task. Representatives from owners, the design industry, the salvage industry and insurers should consider exploring ideas together aimed at the challenges of salvaging mega-ships and structures [Lloyd’s, 2013].

6.2.4 Professions – Social Economic Impact – Business

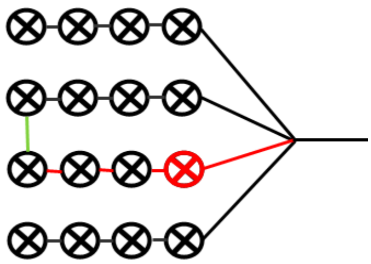
Type 4 forms a trans-boundary phase between emergency response and recovery. In case an emergency occurs in an OWF, two businesses can be impacted: the vessel/OWF and its owner but also the (socio-)economy supported by the vessel and/or windfarm operations.

The effects and cost implications due to equipment loss are discussed in the section about salvage but there is also a large implication for the wind farm’s guaranteed energy production, transfer and delivery. Apart from the obvious costs related to the damage of property, the (re)liability of the wind farm operator and/or owner (vessel or OWF) might become questionable. In the event a wind turbine (and the wind turbines connected to the same in field connection cable) is idle, the continuity of energy delivery to the shore might become uncertain.

An accidental disturbance/interruption of the energy transfer of the produced electricity from the OWF through the export cable towards the onshore distribution network induces the same level of business emergency. Contractual agreements with energy consumers could become impossible to comply with as the amount of produced energy will be reduced – both in volume as time span.

The (re)liability and reputation of the energy producer could be irreversibly damaged in such case. This example is given from a wind farm owner point of view, but also vessel owners could suffer reputational damage in case an emergency occurs with - one of - their vessel(s).

Since such reputation damage is not covered by insurances, owners and operators have to cover this emergency related risk in different ways. An OWF is usually monitored by an onshore control unit which continuously checks the amount of energy that is delivered by the wind farm via an online system (SCADA – Supervisory control and data acquisition). A reduction (caused by whatever reason) in the supply chain, is immediately noted and corrective actions can start to be implemented immediately. A possible solution is described in the example below. These risks of potential loss of liability and/or reputation are more and more being considered in the cost estimations.

Example: 	In case one of the OWF boundary is damaged to the point here it becomes idle (red circle) and the other 3 wind turbines connected to the same connection cable cannot transmit energy to the shore. The loss of 1 wind turbine therefore causes the reduction of energy produced by (in this case) 4 wind turbines. To overcome this problem, a connection can be made between the isolated but working wind turbine chain and a fully operational chain (green line). However, such a redundant solution should have been planned in the design phase of the wind farm as the connection cable would need to be able to carry the addition power of the extra wind turbines.

Vessel and OWF owners take a whole range of measures and means aimed towards ‘recovery’, or at least reducing the extent of damage when an emergency occurs and/or increasing the inherent capabilities for recovery. These operational measures and means are mainly covered in a global maintenance contract for the OWF and its respective elements (wind turbines, electrical cabling, transformation stations, export cable, etc.) together with associated insurance coverage.

Dealing with this kind of recovery has been ignored mostly by organizations and projects because it is assumed that the risk management, prevention and preparation of an emergency and even the contingency planning will minimise the recovery efforts. Nonetheless, emergency events will occur and recovery will be required even though the phase has large unidentified complexities. There should be for example a difference between short-term and long-term recovery.

Short-term recovery is immediate and overlaps with response. It includes actions such as providing essential health and safety services, restoring interrupted utility and other essential services by salvage (removal of vessel, damaged structures, drifting items, or pollution), re-establishing transportation routes, reimplementation of the no go zone and providing food, shelter and medical means for those displaced by the incident. Although called “short term,” some of these activities may last for weeks.

Long-term recovery, which is outside the scope of the Risk Management Framework, may involve some of the same actions but may continue for a number of months or years, depending on the severity and extent of the damage sustained. For example, long-term recovery may include the complete reconstruction of parts of the OWF or the reestablishment the operator’s reputation.

The recovery phase includes associated responsibilities and factors that influence business recovery. The importance of business recovery is widely acknowledged – importance for the owners of the business, the employees of the business, the suppliers, the customers, the economy, governmental agencies depending on tax revenues, and the community at large. The immediate consequences of an extreme event are often relatively easy to quantify and comprehend. However, the ‘systemic community consequences’ depend on a number of secondary events and the ‘reverberations’ in the community and the ‘outside world’ [Baird, 2010].

7 SUMMARY OF RECOMMENDATIONS

7.1 Important Notice

Due to their particular character offshore wind turbines and their positioning in an offshore cluster configuration, present new challenges to safe and efficient maritime navigation in their neighbourhood. Interactions between OWF and shipping activities induce an operational need to integrate OWF design and planning with navigational mitigation-management and emergency procedures in order to assure this safe and effective navigational safety and emergency response preparedness. The recommendations which are presented should be used primarily by OWF developers seeking consent to undertake works, but also by Maritime Authorities to ensure safety of navigation and emergency response management. Finally, navigators also can use these guidelines for a safe and efficient practice of navigation in the vicinity of an OWF.

It is important to recognise that the recommendations in this report are not prescriptive tools but need intelligent application and advice provided on a case-by-case basis. It is noted that specific details of individual sites (local factors or boundary conditions) or national-regional (legal) requirements may vary from the general guidance which is presented.

7.2 General Recommendations

7.2.1 Identification of Interactions

The identification of the interactions between OWF and navigation can best be achieved by Preparing (or amending existing) a Marine Spatial Plan (MSP) and by preparing a Marine Emergency Plan (MEP) (see Chapter 2)

7.2.2 Legal Background

When the OWF is located in the high sea or close to an international ship's routeing scheme, a submission to IMO, NCSR sub-committee, should be made if ship's routeing measures around the OWF are foreseen in order to safeguard the safety of navigation (see Chapter 3).

7.2.3 Navigation Constraints, Collision Avoidance & Marine Navigational Marking

The basic rule which should firstly be adopted by navigators around or within OWF zones is: 'Navigate with caution and avoid these OWF areas as much as possible'.

During all phases of the OWF project (exploration including planning and design, construction, exploitation and maintenance and decommissioning) a dedicated marine navigation safety management plan is to be established, which could include:

- analysis of safety distances between shipping traffic and OWF which requires a good description of the ships involved (see Chapter 4.1.1)
- perform a risk analysis of the routes and the frequencies of the ships (see Chapter 4.1.2)
- analysis of the geometric [geographic and hydrographic] configuration of the sea area in respect of the shipping traffic (see Chapter 4.1.3)
- Identify local met-ocean conditions that could present difficulties to vessels (see Chapter 4.1.5)
- pilot or towing vessel may be a mitigation or preventive measures (see Chapter 4.1.6)
- provisions and regulations as discussed in Chapter 4.2.1 for a **minimum distance between** a shipping route and a wind farm can be determined as follows:

- Starboard side of any route: 0.3 NM + 6 ship lengths + 500 m (i.e. for a ship of 400 m length a minimum distance of 3,456 m, which is almost 2 NM)
- Portside of any route: 6 ship lengths + 500 metres
- In most cases additional detailed design analyses are necessary to determine an optimum design that will definitely be safe and usable (see Chapter 4.2.2)

- For the offshore infrastructure of the OWF, marine navigational marking is required according to IALA recommendations O-139 on the Marking of Man-Made Offshore Structures (see Chapter 4.1.4)
- The risk assessment process should identify the hazards, together with the events or circumstances which may give rise to their realisation determine the risk posed by them and identify preventative measures that can be put in place to control the risk by preventing the realisation of the hazard and/or mitigating its effect if it does occur (see Chapter 4.2.3).

7.2.4 Electromagnetic Radiations (EMR)

RADAR

The main principle in the prevention of shore-based radar interferences is that each radar operator shall be consulted. Radar operators include, civil aviation, weather office, national defence, VTS and ports. There may be a competent Authority in charge to co-ordinate the consultation, but the rules shall depend on national regulations (see Chapter 5.2).

Whatever the distance of vessels from OWFs, they may generate multiple echoes on the radars of the VTS. The VTS Authority might also need to secure the full visibility of sensitive sectors and avoid any obstacle for this purpose.

For shipborne radar each navigator should properly adjust their radar equipment to prevent interferences and to obtain accurate results from operation of automatic Target Tracking facility such as ARPA. In case of an improper setting of the radar, false targets and loss of small targets may occur whatever the distance of the ship from the OWF.

Risk	On board mitigation	External mitigation	Distance where risk may be significant**
False targets	**Adjust Selected range, Gain**	**Adapt design (e.g. radar absorbing coating)***	**< 0.25 NM** (500 m)
Small targets lost	**Increase gain**	**Reflector for calibration**	**< 1.5 NM** (2,778 m)

***** radar absorbing coating or material is a very expensive mitigation solution.
****** the distances indicated are the minimum distances where the risk is intolerable (< 0.25 NM), or tolerable if as low as reasonably practicable (< 1.5 NM).

General guidance for precautionary use of S or X band radar

It should be noted that especially inside and around a port, since ships can recognise the range and direction of a shipping route by using navigation marks, appropriate measures can be examined in each country to mitigate the influence of an offshore wind farm on radar.

RADIO COMMUNICATIONS

In all cases, it is considered best practice to establish the implications for radio communication systems and AIS operating in the area around a wind farm, and to carry out a study on the potential impact on radio communications to the extent possible. Field measurements should be carried out when OWF is completed in order to confirm the location of any extra VHF coastal radio station or AIS shore based station or simply to check the sea area A1 coverage (see Chapter 5.3).

The same conclusion should be adopted for RDF and others radio navigation systems (GNSS, local radio navigation systems, magnetic compass, etc). To maintain the accuracy of DGPS, it is necessary to ensure a safe distance between wind turbines and ships, and between wind turbines and the DGPS reference station. For 160-m high wind turbines this distance is 1.2 km.

7.2.5 Emergency Procedures

It is recommended to establish a contingency plan within and around the OWF (see Chapter 6)

Potential impacts or difficulties caused to (individual) mariners or emergency response services (by competent authorities) in the OWF area or its direct environs, should be assessed in a Maritime Emergency Plan (MEP), leading to a proper list of mitigation measures or operational risk management tools. In close collaboration with all stakeholders, a protocol between parties is set up to ensure a safe and efficient emergency response preparedness and operation.

Setting up a MEP for the specific interaction between offshore wind farm operations and maritime navigation is basically developed from a mutual interaction: risks induced by impact from off-shore wind farm (OWF) towards maritime navigation (MN) and vice versa. In order to avoid a complex identification of separate risks ordered by (direct-indirect) causes, risks are globally ordered by their nature of consequences. Doing so, the associated emergency management (and consequently emergency planning and response) is also categorised following the 4 basic types of consequences:

1. People (health, safety and security) with SAR as most important emergency action
2. Planet (marine environment) with pollution (oil spill) control as primary focus
3. Property and Assets (materials) with salvage as main emergency measure
4. Professions/Business (socio-economy, liability, reputation, etc.), where business can be impacted on two levels: the vessel/OWF and its owner but also the socio-economy supported by the vessel and/or windfarm operations and activities in the vicinity.

The effects and cost implications due to equipment loss are discussed in the section about salvage (see Chapter 6.2.3) but there is also a large implication for the wind farm’s guaranteed energy production, transfer and delivery. Ship and OWF owners take a whole range of measures and means aimed towards ‘recovery’, or at least reducing the extent of damage when an emergency occurs and/or increasing the inherent capabilities for recovery. These operational measures and means are mainly covered in a global maintenance contract for the OWF and its respective elements (wind turbines, electrical cabling, transformation stations, export cable, etc.) together with associated insurance coverage.

7.3 Extra Notice

It is important to recognise that the table below is not a prescriptive tool, but need intelligent application and advice provided on a case-by-case basis.

There may be opportunities for the interactive safety distance to be flexible where, again, for example, vessels may be able to distance themselves from OWF to provide more comfort without significant penalty, or where OWF could be distanced from shipping nodal points. It is recognised that larger ships, high speed crafts, hazardous cargo and passengers carrying vessels may have larger domains and then require more space for manoeuvring.

Traffic surveys would also establish any route traffic bias where mariners may naturally turn to starboard to facilitate passing encounters in accordance with the COLREG 72. Additionally, marine traffic surveys would identify vessel type or category which may consequently require larger domains to ensure that the following factors can be taken into consideration in determining corridor widths:

a. Compliance with the best practices of seamanship and principles to be observed in keeping a navigational watch including the composition of the watch
b. The manoeuvrability of vessels with special reference to stopping distance and turning ability in the prevailing conditions
c. Provisions that may be required with mechanical failure of vessels involved and level of support services
d. The state of visibility, wind, sea and tidal stream, and the proximity of navigational hazards
e. The traffic density including concentrations of fishing vessels or any other vessels

f. The draught in relation to the available depth of water and the existence of submarine cables and obstructions
g. The effect on radar detection of the sea state, weather and other OWF sources of interference (see precautionary use of radar in Chapter 7.2.4 above)

In the approaches to ports this is particularly relevant. This additional information would influence where safety distance need to be established.

Where larger developments have to provide corridors between sites to allow safe passage of shipping a detailed assessment will be required to establish the minimum width of the corridor. The assessment of the required sea room (corridor width) will be undertaken on a case-by-case basis and should take into account not only the requirements of the traffic survey but also the general location and sea area involved. It will not always be possible to make a course that is planned and experience shows that in heavy sea conditions it is much harder to stop or turn the vessel around. Deviations from track by as much as 20°, or more, are common and must be considered. This deviation is used as the baseline for calculating corridor widths contained in the OWF.

Both MSP and MEP tools which should be prepared for the OWF project will further refine the suggested safety distances in the table below which are based on unrestricted navigation (i.e. the largest vessels).

Distance in miles of the first wind generator row from the shipping route	Factors for consideration	risk	Tolerability for SOLAS ships
< 0.25 NM (500 m)	Inter-turbine spacing only recommended for small craft	**VERY HIGH**	**Intolerable** Unless for very small craft (small leisure craft)
0.5 NM (926 m)	Distance between a high traffic navigation route, used by ships covered by the SOLAS Convention and a wind farm	**VERY HIGH**	
1 NM (1,852 m)	Distance between a high traffic navigation route, used by ships covered by the SOLAS Convention and a wind farm	**HIGH**	**Tolerable** If ALARP (As Low As Reasonably Practicable)
2 NM (3,704 m)	Compliance with COLREGs becomes less challenging	**MEDIUM**	
5 NM (9,260 m)	Distance between shipping route and a wind farm in restricted waters	**LOW**	**Acceptable**
10 NM (18,520 m)	Ideal distance between a TSS and a wind farm	**VERY LOW**	

Table of general guidance for planning safety distance between a shipping route and the first obstacle of an OWF

Note:

- No OWF must be installed in a zone situated in the extension of a traffic lane.
- Shipping routes are routes regularly used by ships, whose definition is governed by geographical and hydrographic parameters; these routes cover long distances, particularly between two TSS. These routes concern the approaches of the channels of a port as well as travel between two ports.
- The width of the waterways through an offshore wind farm or between two OWFs will be interpolated from the table above. The general principle of separation of the waterway should follow the following scheme:

5 NM	**Between 2 and 5 NM**	**1 NM**	**Shipping route**	**1 NM**	**Between 2 and 5 NM**	**5 NM**

Red area: **Intolerable** unless for very small craft (small leisure craft)
Orange area: **Tolerable** If ALARP (As Low As Reasonably Practicable)
Green area: **Acceptable**

It should be noted that especially inside and around a port, since it is normally physically difficult for a ship to execute a round turn because of a completely specified shipping route, the safety distance between a shipping route and an offshore wind farm can be defined based on the existing standards in each country.

In order to illustrate the complexity of the precept to determine a safety distance between a shipping route and an OWF, examples showing current practice in different countries related to the safety distance between shipping traffic and OWF are indicated in annexes of the report.

APPENDIX A: REFERENCES

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APPENDIX B: GLOSSARY

- AIS: Automatic Identification System
- ARPA: Automatic Radar Plotting Assistance
- COLREGs: Collision Regulations
- CRS: Coastal Radio Station
- DGPS: Differential GPS
- DSC: Digit Selecting Calling
- EEZ: Exclusive Economic Zone
- EFTA: European Free Trade Association
- EMR: Electromagnetic Radiation
- EU: European Union
- FEMA: Federal Emergency Management Agency (USA)
- GMDSS: Global Maritime Distress and Safety System
- GNSS: Global Navigation Satellite System
- GPS: Global Positioning System
- GPSR: General Provision for Ship Routeing
- GT: Gross Tonnage
- ICAO: International Civil Aviation Organization
- IALA: International Association for Lighthouses and Aids to navigation
- IMO: International Maritime Organization
- ITU: International Telecommunications Union
- JWG: Joint Working Group
- LOS: Line Of Sight
- MEP: Maritime Emergency Planning
- MSP: Marine Spatial Planning
- MTI: Moving Target Indicator
- NM: Nautical Miles
- OWF: Offshore Wind Farm
- RCC: Rescue Co-ordinating Centre
- RDF: Radio Direction Finder
- RF: Radio Frequency
- RR: Radio Regulations
- Rx: Receiver
- SAR: Search And rescue
- SOLAS: Safety Of Life At Sea
- Tx: Transmitter
- UN: United Nations
- UNCLOS: United Nations Convention on the Law Of the Seas
- UNESCO: United Nations Educational, Scientific and Cultural Organization
- VHF: Very High Frequency
- VOR: Visual Omni Range
- VTS: Vessel Traffic Services

APPENDIX C TERMS OF REFERENCE OF WG 161

Interaction between Offshore Wind Farms and Maritime Navigation

TERMS OF REFERENCE

Historical Background – Definition of the Problem

Increased activity within Europe's marine waters has led inevitably to growing competition for maritime space. Competing claims from a range of activities, including fisheries, leisure navigation locations allocated for military exercises, old ammunition dumps, navigation and anchoring areas, oil and gas exploitation, sand extraction and wind and wave energy generation are accompanied by increased pressure on vital marine ecosystems and habitats. Without the means to co-ordinate a common approach to the allocation of maritime space among different sectors, the problems of overlap and conflict between sectors and individual stakeholders is evident. There are also cross-border issues as developments in the maritime area of one country may well have impacts for another. The relatively new notion of Maritime Spatial Planning has emerged as a means of resolving conflicts over maritime space.

In order to increase the amount of environmentally friendly produced electrical energy, some coastal states decided that a significant part of the total yearly consumption has to be produced at sea favourably as close as possible to the shore in order to achieve as low as possible transportation losses. For these areas, which are situated between or near the shipping lanes, a conflict between shipping and the areas appears.

When a sea area of considerable size for the production of energy is to be located in a route junction or converging area of ships' routeing or in any other way in the vicinity of ship's routeing systems or shipping lanes, it is necessary to maintain the risk to shipping at a minimum but certainly not higher than the present level of risk. One of the relevant issues is that in some countries navigation within the borders of a windfarm is allowed; in that case crossing traffic can be expected to emerge from the windfarm.

Objective and Product of the Study

In order to ensure that a sea area for the exploitation of mineral resources or for the production of energy from water, currents or wind, will not interfere with sea lanes essential to international navigation or other navigation activities and will not cause problem to electronic navigation aids, the Working Group aims at the development of a set of recommendations and guidelines for consideration to assess the sufficient manoeuvring space and the minimal distance between navigation and the offshore installations, making sure that the risk to shipping is acceptable.

The sufficient manoeuvring space and minimal distance will depend on various situations and criteria as:

- Traffic density
- Ships routeing systems/precautionary areas
- Radar and VTS
- Size of ships including manoeuvring characteristics
- Recreational activities
- Fishing activities
- Available width of the [established] traffic lane
- Crossing traffic incoming from starboard in front of a wind farm
- Crossing traffic emerging from the wind farm
- Crossing traffic incoming from starboard behind of a wind farm
- The possibility of fishing vessels or other small craft being present in the area between wind farms and traffic lanes

- Weather conditions (wind and waves)
- Tidal current conditions
- The positioning of anchor areas
- Areas for (dis)embarkation of pilots
- Effects of windfarms on the ship's radar presentation

The Working Group will pay attention to international rules like the Collision Regulations and the General provisions on ships routeing etc.

Previous PIANC Reports

WG 30 – Approach Channels: A Guide for Design, 1997 (95)
WG 49 – Horizontal and Vertical Dimensions of Fairways

Method of Approach

- review of actual practice of distances between shipping and offshore wind farms so far by consultation of stakeholders
- collect the available background information and review the approach taken
- give considerations for determining the safe distance for different situations, according to the various uses of the sea, the size of the vessels, the layout of the shipping routes, anchorages, pilot stations etc.
- review of recent developments in design tools (such as risk assessments and simulation techniques) in order to assess the appropriate manoeuvring space and minimal distance between shipping and wind farms in order to achieve safe navigation
- develop risk-based considerations, recommendations and guidelines for assessing the sufficient manoeuvring space and the minimal distance between shipping and areas for wind farms, in order to ensure a minimal risk level for navigation

Suggested Final Product of the Working Group

The final report of the Working Group will provide an approach, guidelines and recommendations to assess the required manoeuvring space in the vicinity of offshore windfarms and the minimal distance between shipping lanes and sea areas for offshore windfarms, in order to ensure a minimal risk level for navigation.

Desirable Disciplines of the Members of the Working Group

It is proposed this working group should include practising engineers engaged in maritime disciplines or responsible for design or use of maritime infrastructure; navigation captains.

Relevance for Countries in Transition

The recommendations of the Working Group will be appropriate for the maritime spatial planning in Countries in Transition.

APPENDIX D: CURRENT PRACTICE IN THE NETHERLANDS

The 2016-2021 North Sea Policy Document

Introduction

This Annex summarises the relevant sections of the 2016-2021 North Sea Policy Document for the Dutch Exclusive Economic Zone related to wind farms and shipping.

On the North Sea, a large number of (user) functions must be assessed so that the best use can be made of the limited space. The current ‘2016-2021 North Sea Policy Document’ offers integral frameworks for the use of space on the North Sea.

The Ministry of Infrastructure and Environment instigated the process that produced this new policy document. Central government agencies, local governments, international parties and users of the North Sea have all helped to update the policy.

The ‘2016-2021 North Sea Policy Document’ describes the current situation on the North Sea, maps out the developments for the years to come and records the policy choices for the upcoming planning period.

The North Sea Policy Document describes three societal demands that require a new policy:

- Marine Strategy Framework Directive (MSFD) Program of measures
- Offshore wind energy
- Sand extraction strategy

Other subjects covered in the North Sea Policy Document include oil and gas extraction, shipping, defence exercise areas, CO_2 storage, tourism and recreation and underwater cultural heritage. It also pays specific attention to the interaction between land and sea and international co-operation.

Please find below the link to the 2016-2021 North Sea Policy Document: 2016-2021 North Sea Policy Document.

Design Criterion: Distance between Shipping Routes and Wind Farms

For the purposes of reserving space, the ‘reference ship’ is important. Depending on the route, the reference ship is 300 or 400 metres long. The routes to Amsterdam, for example, have a reference ship 300 metres long.

The largest manoeuvre a ship must be able to make, and hence for which there must be sufficient space, is the so-called round turn. 6 ship lengths are required for this. An extra 0.3 NM evasive manoeuvre is necessary on the starboard side prior to a ship executing the round turn, because an initial effort will be made to avoid performing a round turn. The overall space required on the starboard side is therefore 0.3 NM + 6 ship lengths. Moreover, a safety zone of 500 metres around single objects (wind turbines) is in force. Within this zone no passage is possible at present. The required safety distances for shipping are therefore:

- In the case of ships 400 metres in length: 1.87 NM on the starboard side and 1.57 NM on the port side
- In the case of ships 300 metres in length: 1.54 NM on the starboard side and 1.24 NM on the port side

For the clearways, the connecting routes between the formal routes, these distances have been included in the width of the clearway path. For anchorages and precautionary areas, the same safe distances can be maintained as for a traffic separation scheme.

Please note: The ‘Design Criterion: Distance between Shipping Routes and Wind Farms’ has been worked out together with the shipping sector. It is intended to determine the space between the shipping route and wind farms at sea that shipping needs to be able to navigate swiftly and safely. It has been applied to the wind energy areas ‘Coast of Holland’ and ‘North of the Wadden Islands’. The design criterion has not been applied to the wind energy areas ‘Borssele’ and ‘IJmuiden Ver’, designated in 2009. In this regard a provisional distance of 2 NM applies for the shipping route.

Passage and Multiple Use

At present, passage through and multiple use of wind farms at sea are not permitted. Various users of the North Sea, such as recreational sailing and (professional) fishing, want these areas to be accessible. The closure of the wind farms for these and other users will, in the future, cause increasing pressure, due to wind farm development within the framework of the Energy Agreement, the increasing activities at sea and the reduction of the fishing zones. Passage through and multiple use of wind farms can contribute to efficient use of space, as well as presenting opportunities to bolster the sustainable use and biodiversity of the North Sea.

The policy is that, from 2017, passage and multiple use will be allowed in all operational wind farms under the following conditions:

- Passage will be facilitated for smaller vessels with a maximum length, under enforceable conditions that ensure an acceptable level of SAR possibilities.
- Multiple use will be made possible for recreational purposes and activities that do not disturb the seabed, as well as for aquaculture and other forms of sustainable generation of energy. Furthermore, interests will be weighed up in the context of installing a safety zone around the wind farm or - where the various uses of permanent constructions are concerned – in the context of granting a permit pursuant to the Water Act.
- For the purposes of innovative activities that do not require a permit, not all forms of passage through and multiple use of wind farms can be allowed. Approval needs to be obtained for each individual initiative on the basis of an assessment of: the risks related to possible nuisance and damage to the wind farm, the legally protected ecological values and enforceability.

Not all forms of passage and multiple use are deemed suitable, due to the safety risks, the chance of damage to the wind farm or obstruction of its management and maintenance and ecological risks. On the other hand restrictions in multiple use can also create possibilities for ecological development. For these reasons and to be able to maintain responsible passage and multiple use, this policy will be elaborated in policy rules.

In the operational farms to be opened in 2017, the activities taking place there and their frequency will be monitored. Effective implementation will be carried out by revising the Act of General Application regarding Installing a Safety Zone for each individual wind farm.

Prior to opening the wind farms, the Central Government will provide the infrastructure and facilities necessary for setting the conditions and, in cooperation with the sectors involved, initiate an information campaign.

On the basis of monitoring and evaluation of the farms opened from 2017 onwards (for two high seasons following opening), any amendment to the policy rules and the acts for installing a safety zone will take place in mid-2020. The stakeholders will be expressly involved in the monitoring and evaluation.

Because of high costs for enforcement of the conditions for passage and multiple use in the remote windfarm Gemini, this farm will remain closed. In the foreseen evaluation of 2020 this decision could be reconsidered.

Design Process: Distance between Mining Sites and Wind Farms

The characteristics of a mining platform, the location and format of the wind farm, and the possibility of multiple use of space will vary for each site. Consequently, accessibility to helicopters will have to be assessed for each platform individually. To this end consultation will be held with the mining company concerned, with due regard for relevant aspects from the perspective of flight safety and the interests of the future wind farm operator. A procedure leading up to the establishment of a draft plot decree for a wind farm is applicable.

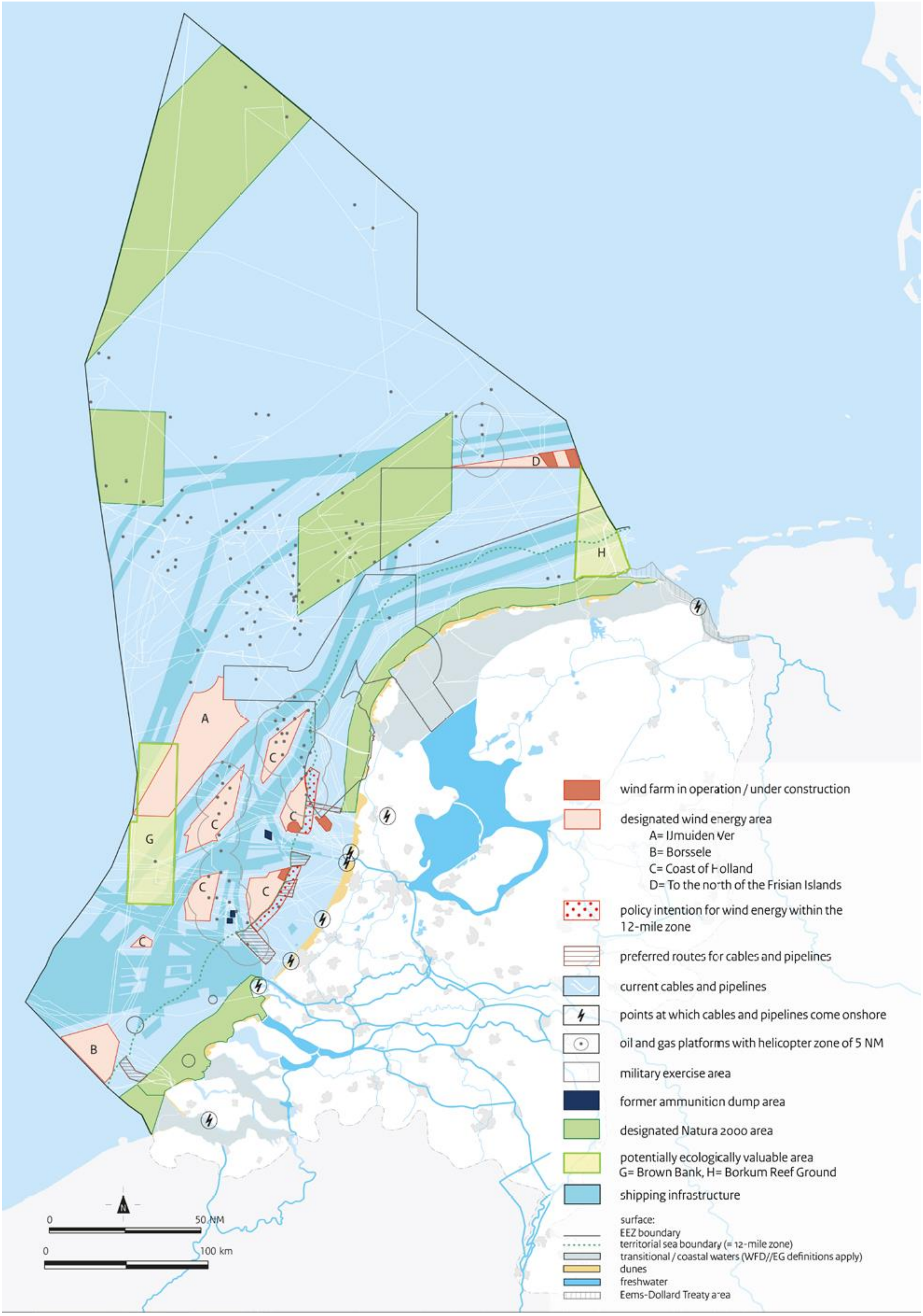


Figure 1: Dutch EEZ of the North Sea with various functions

APPENDIX E: CURRENT PRACTICE IN JAPAN

Technical Guidelines for Offshore Wind Power Generation Facilities in Ports

Introduction

In Japan, a port area is considered promising as a suitable construction site for offshore wind farms. Because a port has a water area management body and also has infrastructure necessary for the construction and maintenance of wind turbines nearby. In 2015, the Ports and Harbors Bureau of the Ministry of Land, Infrastructure, Transport and Tourism, formulated 'Technical Guidelines for Offshore Wind Power Generation Facilities in Ports' as technical advice based on the Local Autonomy Law of Japan. The guidelines propose the separation distance from an offshore wind farm area to port facilities such as shipping routes and breakwaters.

Separation from Water Area Facilities

Offshore wind farm operators shall secure the separation distance to water area facilities such as navigation routes in order to satisfy both of the followings.

- The separation distance with which the water area facilities cannot be affected by the wake behind a wind turbine.
- The separation distance with which the water area facilities cannot be directly affected by the collapse of an offshore wind power generation facility.

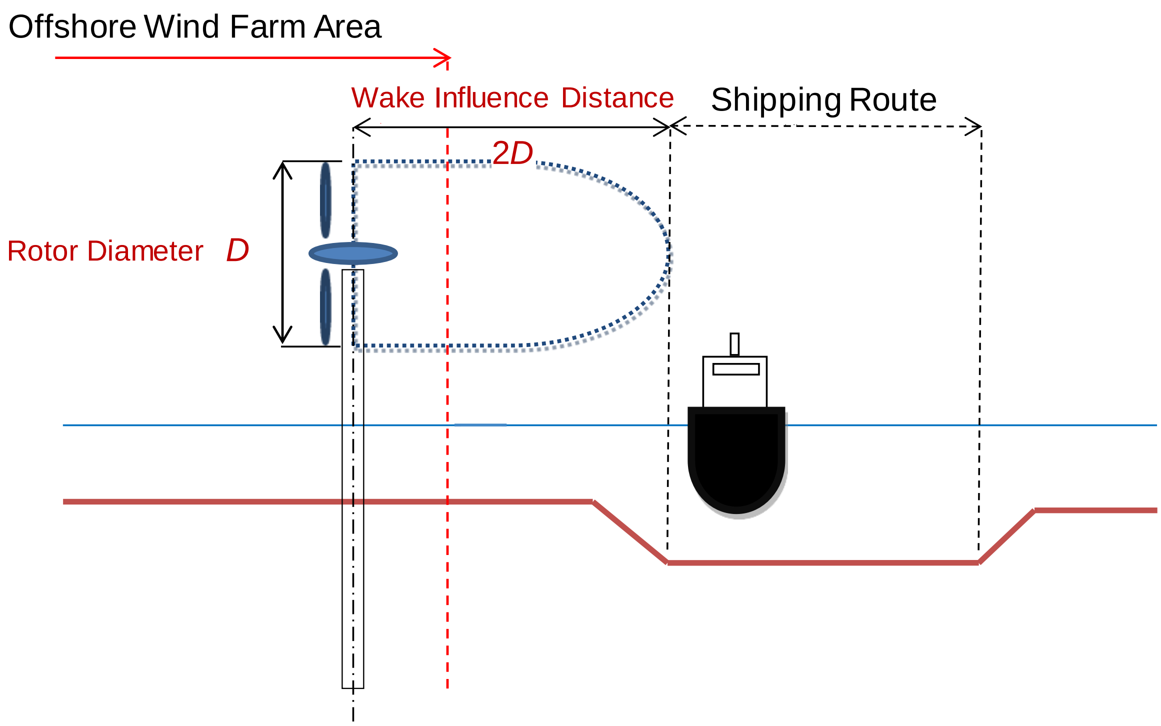


Figure1: An example of the separation distance considering the wake behind a wind turbine

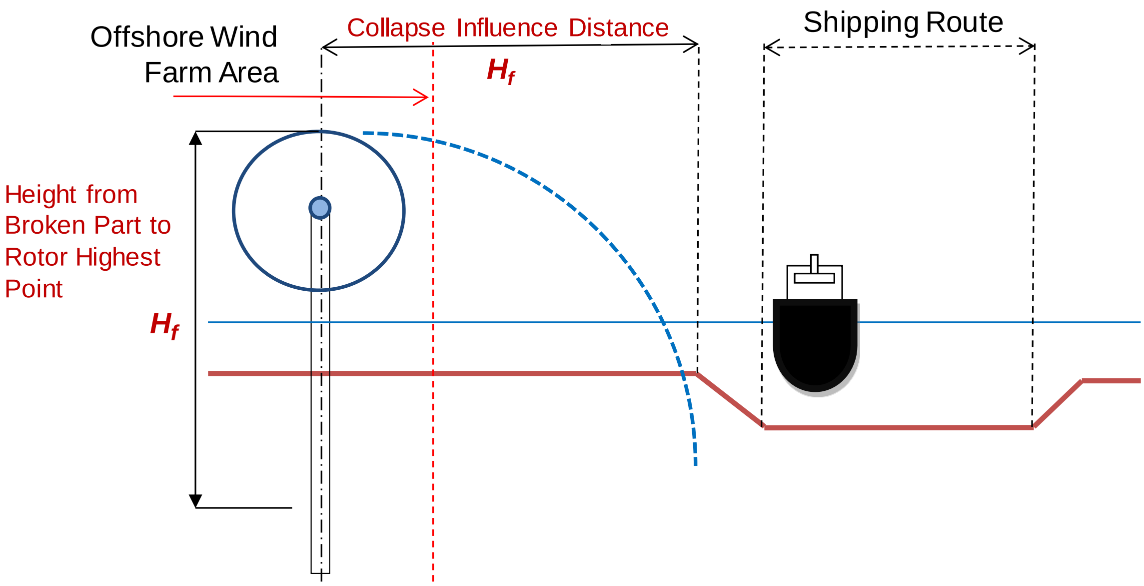


Figure 2: An example of the separation distance considering the collapse of an offshore wind power generation facility

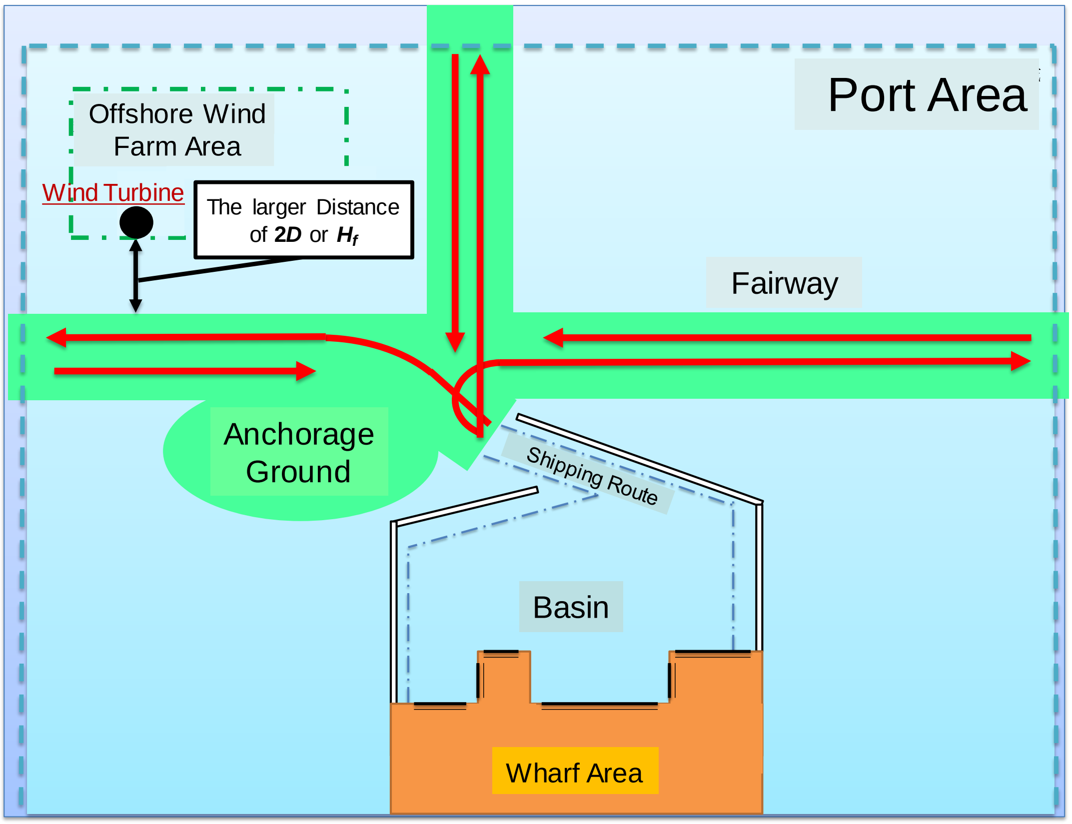
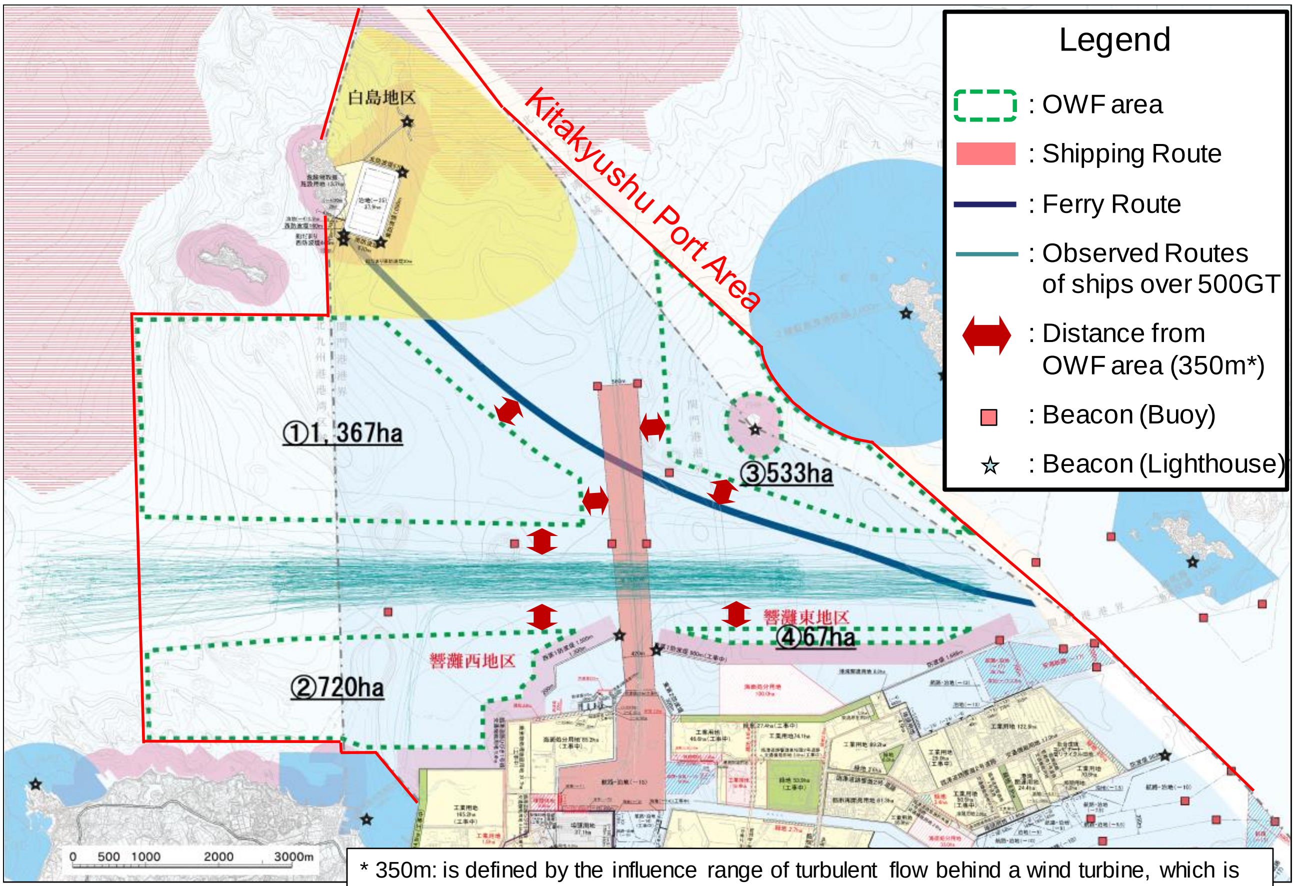


Figure 3: An example of the separation distance to a fairway (which can be considered one of the water area facilities)

Example of Project: The Offshore Wind Farms Plan in Port of Kitakyushu



* 350m: is defined by the influence range of turbulent flow behind a wind turbine, which is considered about twice the rotor diameter (D). D ≒ 164m (8MW Wind Turbine)

APPENDIX F: CURRENT PRACTICE IN FRANCE

Technical Note on Maritime Safety Measures for Offshore Wind Farm Planning

The Maritime Affairs Directorate in France, with the help of the nautical expertise of Cerema, has established a Technical Note on Maritime Safety Measures to be taken into account during the phases of defining and planning the areas suitable for the installation of offshore wind farms (OWFs).

This note, dated on 11 July 2016, defines the recommendations related to maritime safety contributing to the definition of areas suitable for the installation of offshore wind turbines and for the study of offshore wind farm (OWF) projects.

Background and Purpose of the Note

Background

The introduction at sea of a new activity must take into account the constraints of maritime transport when this zone or sector includes a shipping route, whether it is free or inscribed in compulsory traffic lanes. Indeed, it is necessary to know the subjects specific to the ship and its environment, namely in particular:

- The need to have sufficient manoeuvring space to avoid collision and to ensure compliance with the rules of navigation imposed by the International Regulations for Preventing Collisions at Sea (COLREGs). The definition of this space should take into account the density and nature of maritime traffic, the reduction of visibility, the presence of fishing vessels and pleasure craft.
- Vessel characteristics including stopping distances, radius of gyration, dynamic squatting, etc.
- The necessity, in case of bad weather, of being able to shelter from the coast in an anchorage
- Radio interference, generated by the OWFs that impact radio navigation systems, such as radar, and radio communications, in particular VHF
- Road deviations due to exceptional circumstances or cases of force majeure (damage to helms, medical evacuation, engine failure)
- Restricted manoeuvring capabilities due to, inter alia, a deep draft, transfer of a pilot, transhipment operation or towing
- The geographical specificity, current and hydrography of the area
- The nature of the cargo carried
- The necessity for rescue and assistance vessels to gain access to the area in question in case of distress or sea event
- The vessel's alertness and alert level (presence of a pilot or ready mooring arrangements)

Purpose

This note defines the maritime safety measures to implement during the phases of defining the areas suitable for the installation of OWFs as well as during the study of the projects developed by the operators. It allows the Maritime Authority to lay down provisions to ensure the safety of maritime traffic in the vicinity of an offshore, floating or laid wind farm facilities.

The note concerns ships of 300 gross tonnage or more, excluding traffic dedicated to the installation, operation and dismantling of the OWF. However, recommendations for the use of radar and VHF radio are also relevant to all other vessels.

The measures defined in this note relate to:

- The safe distance between the facilities and the vessel traffic areas
- Aids to navigation through maritime marking, vessel traffic services (VTS) and some measures to facilitate search and rescue (SAR)

Maritime Navigation: Minimum Safety Distance between an OWF and Maritime Traffic

For the purposes of this note, the right-of-way of an OWF includes, in addition to the limits of the authorisation to occupy the public maritime domain:

- The peripheral zone intended for the protection of the site defined by the Maritime Authority in territorial and inland waters
- 500 metres in accordance with Article 60 (5) of the United Nations Convention on the Law of the Sea, in the exclusive economic zone

The Minimum Distance to Stop a Vessel

Resolution MSC.137 (76) and Circular MSC/Circ 1053 set minimum standards for vessel manoeuvrability. These standards should be considered in the following two situations:

- The ship is in 'free-running' situation: the ship is underway with its machines delivering a power corresponding to about 80 % of their maximum power
- The ship is in 'manoeuvring' situation: which corresponds to a take of a pilot or entry into a port navigation channel, the stopping distances are much smaller. Indeed, the vessel reduces its speed and its manoeuvring and anchoring auxiliaries are ready to accelerate the evolution or stopping of the ship.

In the event that the OWF does not about a port entry channel and is located further offshore in the free navigation zone or in the environment of a traffic separation scheme (TSS), the ship should be considered in 'free-running' situation.

The Emergency Stopping of a Ship ('Crash-Stop')

According to international regulations, the distance recommended for the 'emergency stopping of a ship' test shall not exceed 15 times the length of the vessel; for deep draft vessels, this distance may be greater, but may not exceed 20 times their length. This test is for a vessel launched at 90 % of its maximum speed to give the order to 'reverse all', to reverse the direction of thrust of the propeller in order to stop the vessel. This total stopping distance for a large vessel is about 3 miles.

The Turning of the Ship

In addition to the 'crash-stop', a ship may make a half-turn by making a turn to avoid an obstacle. The advance is the distance travelled between the time the bar command is given and the time when the ship is heading + 90 °. This distance is at least 0.3 miles while the turning circle diameter is 5 times the length of the ship.

However, these values are variable because several ship-specific parameters are involved: ship's beam, initial velocity, draft, depth of water under the keel to take account of small radius of turning circle, weather conditions, strength and current direction. The human element should also be considered for the decision time to manoeuvre. As a result, it is reasonable to add an additional ship length.

While it is often preferable to shirk by making a turning circle, which is more effective than a 'crash-stop' for a ship on the open sea, this is not always possible in heavy traffic areas (presence of many vessels) or in danger areas (shallow water).

As an indication, the manoeuvring space of a vessel of 300 metres long in open sea and 'free-running' situation will be a turning circle with a diameter of 1 mile.

Sufficient Space to Assess Collision Risk

Given the visual impediment of an OWF, sufficient space should be maintained to allow the vessel to determine the risk of collision, in accordance with COLREGs Rule 7. The vessel shall be able to assess the possibility of crossing traffic originating from starboard in front of the OWF, crossing traffic from the OWF or crossing starboard behind the OWF irrespective of the size and type of vessels.

This assessment takes into account the distance available in front of the ship and on the sides of the vessel, which distances may vary depending on the manoeuvring space required for a vessel.

Vessels should also be given a sufficient field of view to assess the risk of collision of ships coming from the same side of the OWF (in front, inside or behind the OWF).

The distance made during the time required to assess the risk of collision is estimated at 0.5 miles.

The Distance Required to Minimise Disturbance on Ship's Radars

The presence of OWF causes disruptions to the reception of radar signals from ships sailing in or near these areas. A mirror effect of radar waves on wind turbines generates false echoes that can be confused with echoes from other ships. The accumulation of these false echoes with real echoes complicates the kinematic analysis of the routes of ships transiting near the wind farm. These false echoes constitute a disturbance or even a risk in collision course situations, especially at night and in case of poor visibility. In addition, small vessels with low radar signature are no longer systematically detected when they are sailing close to OWFs.

The recommended distance to minimise disturbance on radars in ships is 1.5 miles.

The Distance Required to Minimise Disturbances on Radio Navigation Systems

Depending on the importance of the information provided by a global navigation satellite system (GNSS) or a local radio navigation system available, it is suggested a study on the potential impact on GNSS and the local radio navigation system and its coverage is carried out during the risk analysis period of an OWF project.

Studies has been carried out in France on the disturbance generated by an OWF on the differential GPS signal (DGPS). These studies show that to maintain the accuracy of the DGPS with OWF made of 160 m high wind turbines, it is necessary to ensure a distance of 1,200 m between wind turbines and ships and between wind turbines and the DGPS reference station. The disturbance of the GPS signal affects the AIS as a GPS-related vessel identification system. The higher would be the wind turbines of the OWF, the greater would be the distance to minimize disturbance on DGPS.

Minimum Safety Distance Recommendation

The installation of an OWF must take maritime navigation into account. The definition of a safe distance between these installations and the passage of vessels is particularly important if the OWF is located close to a shipping route, in particular a TSS or a port approach channel.

The criteria for determining this minimum safety distance, which contribute to the definition of the areas suitable for the installation of OWF, are summarised in the table in annex 1.

However, the Maritime Authority may ask the operator for a formal risk assessment when the acceptable distances recommended in annex 1 cannot be met.

Even if the safety distance is observed, a formal risk assessment may also be requested when the OWF is located near a high-speed craft route, passenger ship route or a regular line of vessels carrying dangerous goods, with particularly difficult navigational conditions. This formal risk assessment is based on IMO Formal Safety Assessment (FSA). The latest IMO reference is MSC-MEPC.2/Circ.12/Rev.1 Revised guidelines for formal safety assessment (FSA) for use in the IMO rule-making process, 18 June 2015. An example of a risk analysis table for FSA is presented in Annex 2.

Aids to Navigation in the Vicinity of Offshore Wind Farms

Maritime Marking

The offshore wind farms have a maritime marking in accordance with IALA recommendation O-139.

Vessel Traffic Services (VTS)

Coastal VTS monitor maritime navigation of traffic separation schemes (TSS) and any ship routeing measures at sea. Port VTS monitor maritime navigation in and around approaches to seaport access channels. In addition, the Maritime Authority, in consultation with the Shore Authority, have defined maritime and river regulated areas for access to certain ports. Finally, naval signal stations monitor maritime approaches.

Operated independently of the monitoring of OWF, the VTS perform their missions with the use of radar, direction finder and AIS shore stations. The continuity of operation of radar, direction finder and AIS monitoring must be preserved in the VTS areas.

There is a need to provide a safety area on each side of a TSS, in order to facilitate ships safety manoeuvres in case of damage, collision or avoidance (see 2 above). In addition, a minimum distance between the wind turbines of the OWF and TSS allows to limit the areas of radar shadow and AIS frequency disturbances. To this end, a circular protection area of 5-mile radius around the VTS radar antennas must be provided. Within this protection area, the risk of disturbance of the radar is too high to allow the installation of any wind turbine.

In case of installation at a lower distance, the operator integrates this situation into the formal risk assessment (See 2.5 above) and proposes, where appropriate, measures to reduce the identified risks (e.g. additional radar capacity, pilot, tug, etc.).

The installation of an OWF in the vicinity of the equipment necessary to monitor a VTS area is likely to generate disturbances that should be assessed and compensated. All compensatory equipment must transmit the data and information in real time to the impacted VTS.

The objective is to maintain equivalent capacities not only in terms of coverage and performance but also in terms of the time between the detection of a hazardous situation and the risk of a collision with a wind turbine or between two ships in the immediate vicinity of an OWF. Consequently, the arrangements for integrating compensatory equipment are examined and analysed appropriately with the competent departments, in particular those of the relevant VTS.

VHF Radio Communications

In order to ensure the radio watch of distress calls (radiotelephony VHF 16) and alerts (digital selecting call) for distress and safety at sea and in order to coordinate the response to incidents, accidents and marine or navigation events, coastal radio stations are deployed along the coast. Their number and performance are established to ensure a consistent and permanent coverage of the areas declared on the IMO global maritime distress and safety system (GMDSS) master plan. These stations are remote controlled from the MRCC, which coordinates maritime rescue operations.

The current documentation on the presence of several dozens of wind turbines does not demonstrate any impact on VHF emissions. There are, however, several studies confirming a VHF disturbances, which, under certain conditions, may affect not only the voice but also the digital selective call and the AIS signal. It is therefore necessary to adopt a precautionary principle: within the OWF a supplementary VHF station composed of two multi-channel equipment. In the months following commissioning of the OWF, the operator shall carry out VHF propagation measurements in and near its OWF. It will communicate the results to the maritime authority, which may request any official service or a public institution for their competence or technicality to validate or invalidate the analyses presented by the petitioner. The technical characteristics of a supplementary VHF station deployed in an OWF are specified in Annex 3.

During this transitional phase and until the results of the assessment, VHF equipment can be made available to the operator by the Maritime Affairs Directorate. The operator will be responsible for the integration and installation of the latter, in particular the aerials, and the network connection to the shore. If the studies reveal VHF disturbances, the Maritime Affairs Directorate will require the operator to install and connect a VHF coastal radio station in order to comply with the GMDSS sea area A1 requirements, and operated by the competent MRCC.

If no disturbance is noted, the operational interest in maintaining the equipment will be assessed. In the event that the station should be maintained for operational reasons, the Maritime Affairs Directorate will initiate a contractual procedure with the operator to define the modalities of accommodation of the equipment and accessibility to the sites.

ANNEX 1: REQUIREMENTS FOR MINIMUM SAFETY DISTANCE BETWEEN MARITIME NAVIGATION AND OFFSHORE WIND FARMS

Distance in miles (NM) of the first wind generator row from the shipping route	Factors for consideration	risk	Tolerability
< 0.25 NM (500 m)	Inter-turbine spacing only recommended for small crafts	**VERY HIGH**	**Intolerable** unless for very small craft (small leisure craft)
0.25 NM (500 m)	X band radar interference	**VERY HIGH**	
0.45 NM (800 m)	Vessel may generate multiple echoes on VTS radars	**VERY HIGH**	
0.8 NM (1481 m)	Distance from a shipping route taken by SOLAS vessels and a wind farm	**HIGH**	**Tolerable** if As Low As Reasonably Practicable (ALARP)
1.5 NM (2778 m)	S band radar interference ARPA affected	**MEDIUM**	
2 NM (3,704 m)	Distance between a shipping route and a wind farm	**LOW**	**Acceptable** depending on traffic density
5 NM (9,260 m)	Distance between TSS and a wind farm in restricted waters	**LOW**	**Acceptable**
10 NM (18,520 m°	Ideal distance between a TSS and a wind farm	**VERY LOW**	

Note:

- No wind farm must be installed in a zone situated in the extension of a traffic lane.
- Shipping routes are routes regularly used by ships, whose definition is governed by geographical and hydrographic parameters; these routes cover long distances, particularly between two TSS. These routes concern the approaches of the channels of a port as well as travel between two ports.
- The As Low As Reasonably Practicable (ALARP) concept is part of a risk management approach which consists in reducing as much as possible the frequency and severity of hazards that may affect the wind field or ships, by compensatory measures associated with the project (traffic control, enhanced maneuvering capabilities, means of assistance, specific equipment).

ANNEX 2: EXAMPLE OF A RISK ANALYSIS TABLE FOR FORMAL SAFETY ASSESSMENT (FSA)

Summary of the main hazards relating to merchant ships near an OWF			**Effects**	**Gravity SI**	**Frequency FI**	**Risk RI=SI+FI**
Hazards	**Causes**					
Collision	Human element		founding, grounding, fire, pollution, human life lost			
	Related to the ship	Radar info lost, ME failure, steering gear failure, black-out, breaking mooring				
	External to the ship	Other ships, weather				
Grounding while underway	Human element		fire, pollution, human life lost			
	Related to the ship	Automatic positioning error, radar info lost				
	External to the ship	GNSS info lost, fixed danger, reported (wreck), weather, tide				
Grounding while drifting	Human element		fire, pollution, human life lost			
	Related to the ship	Main engine failure, steering gear failure, black-out, breaking mooring, fouled anchor				
	External to the ship	Weather, tide				
Allision with a structure at sea (wind generator) while underway	Human element		fire, pollution, human life lost			
	Related to the ship	Automatic positioning error, radar info lost				
	External to the ship	GNSS info lost, fixed danger reported, weather, state of the sea, tide				
Allision with a structure at sea (wind generator) while drifting	Human element		fire, pollution, human life lost			
	Related to the ship	Main engine failure, steering gear failure, black-out, breaking mooring				
	External to the ship	Fixed danger reported, weather, state of the sea, tide				

ANNEX 3: TECHNICAL SPECIFICATIONS OF AN EXTRA VHF STATION DEPLOYED IN AN OWF TO COMPENSATE DISTURBANCE OF MRCC VHF WATCH KEEPING

1. Objectives and Constraints

The desired continuous radio coverage is 20 NM from the OWF. This coverage corresponds to a receiver of -107 dBm on an antenna at 4 metres above water and a transmitter with a power of 25 W placed at 40 metres above water. The extra VHF station will consist of two marine VHF transmitters/receivers (Tx/Rx) which operate in multi-channel mode, that is to say, the MRCC will control remotely the Rx/Tx to change the working channel.

Two hypotheses are being considered, including:

1) A single Tx/Rx is in operation. The second Tx/Rx is the first backup activated in case of failure of the primary Tx/Rx
2) Two Tx/Rx are in operation with a clean aerial compliance vertical decoupling of at least 9 metres

The first assumption allows hardware redundancy of Tx/Rx but is not free of a damage on the aerial (connection/pulling) unlike the second. The second hypothesis is therefore sought if the implantation conditions allow the installation of two pairs of aerials.

1.1 Expected Availability

The station will operate round the clock, 7 days on 7. In case of damage incurred on an Tx/Rx, the intervention will occur within 10 business days. In case of damage on the 2 Tx/Rx or on a common aerial, the intervention must be made within 2 business days.

1.2 Maintenance Constraints

Access to the site will be the subject of an agreement between the operator and the MRCC. Equipment maintenance based on preventive visits (1 year) and corrective visits if necessary.

This maintenance will be carried out at the expense of the operator if the impacts on the MRCC communication devices are proven. Otherwise, these maintenance operations will be at the expense of the Administration.

2. Characteristics of the Station

2.1 Frequencies Used by the Tx/Rx VHF

The frequencies are spread over two frequency bands, namely 156.025 MHz to 157.425 MHz and 160.625 to 162.025 MHz. These bands consist of 25 kHz wide channels and are defined in Appendix 18 of the Radio Regulations of the ITU. They must be protected and will not be subject to interference.

2.2 Technical Area Equipment

The technical area where the equipment will be installed must be sealed against salt air and fitted with a humidity control, ideally the room must be air conditioned.

A 2-metres high bay, 19 inches wide and 80 cm deep (42U type) will contain the following:

- two Tx/Rx Built VHF and PTT relay
- an IP/analog switches and its associated power supplies
- a converter 220/24V
- a battery pack
- battery charger

- fans if the equipment room is not air conditioned

2.3 Aerials

The aerials are placed close to the outer face of the wind turbine, without obstruction by the blades. A blade passing in front of a transmitting antenna would cause a high return of energy that could quickly destroy the amplification stage of the Tx/Rx.

In addition, the mass of air pressure effects disturbed the blades passage may introduce forces on the antenna connectors and damage the seal.

Depending on the assumption chosen, the aerials will be composed of one or two pairs of aerials installed on the platform or the wind turbine tower at a minimum height of 20 metres above the highest high tide water level.

The maximum cable length between the Tx/Rx and the aerial should be 50 metres. If two pairs of aerials are installed, they must comply with a vertical decoupling of 9 metres to protect the Tx/Rx from each other.

A pair of aerials consists of two aerials located at the same height but positioned either side of the wind turbine tower in order to ensure a 360° coverage of the area. These aerials are connected to the couplers through straps 1/2".

The coaxial cable between the couplers and Tx/Rx will be of type 3/8" and 1/2" according to the cable outlet to respect cable bending radius.

The aerials have only a minimum to lightning protection since they are protected by the lightning rod of the cone of the wind turbine.

The aerials will be whips of the MAT type on the platform or will be frame of the DAPA type if placed along the wind turbine tower.

2.4 Link between MRCC and Extra VHF Station

A SDSL link will be provided by the MRCC on the shore side and delivered to an operator's premises. The transmission of signals between the link and the offshore radio station at sea will use a protected link (isolated or VPN) provided by the operator.

2.5 Power Consumption and Energy Autonomy

Overall power consumption of the station is estimated at 1,500 Watts.

The energy provided will be of type 230V/60Hz or DC 24V or 48V if necessary.

The batteries of the station will allow autonomy of 12 hours.

APPENDIX G: CURRENT PRACTICE IN SWEDEN

Regarding MSP/OWF

Introduction

Today there are no formal MSP implemented in Sweden.

The Swedish Agency for Marine and Water Management (SwAM) has been assigned the work to present a new MSP for the Swedish government, which should be in force no later than 2021.

In Sweden there are currently national interests designated for different sectors such as shipping, energy, fishing, defence etc. In the coming MSP this national interest are to be weighed against each other. The forthcoming MSP in Sweden will be developed from an ecosystem approach.

Current practice with regard to OWF.

In 2009 the Swedish Maritime Administration (SMA) and the Swedish Transport Agency (STA) together constructed a guideline for establishing offshore windfarms in Swedish waters. This guideline is mainly focusing on risk assessment. Each individual windfarm can have different safety levels (safety distances).

Therefore, no formal minimum distances are given within the guideline since this is an assessment which is done for each individual case.

The guideline is written in Swedish and can be found at the link below:

https://www.transportstyrelsen.se/globalassets/global/sjofart/dokument/vagledning_vid_proj_o_riskanalys_av_vindkraftverksetabl_svenska_kusten.pdf

The Swedish Maritime Administration submits above mentioned observations in regard to the work performed by PIANC WG 161.

Above mentioned has been handled by the Head of the Infrastructure unit Marielle Svan in participation with the senior nautical adviser at the Infrastructure unit Johan Eriksson.

APPENDIX H: CURRENT PRACTICE IN GERMANY

Marine Spatial Planning in EEZ

Introduction

In order to co-ordinate the growing conflict of maritime uses, in particular between developing and space intensive offshore wind farms and marine environmental protection goals as well as traditional maritime uses such as shipping and fisheries, an integrative and sustainable approach is needed for the development of the German Exclusive Economic Zone (EEZ).

With the Ordinances on Spatial Planning in the German Exclusive Economic Zone in the North Sea of 12 September 2009 and in the Baltic Sea of 10 December 2009, there are Spatial Plans available for the North Sea and the Baltic Sea.

The Spatial Plan sets up as a statutory ordinance due to §18a Federal Spatial Planning Act, which was introduced by the act of 24 June 2004 into the Federal Spatial Planning Act, for the first time targets and principles of spatial planning in the EEZ regarding economic and scientific uses, ensuring the safety and efficiency of navigation, as well as protection of the marine environment.The Spatial Plan also contributes to the implementation of the Federal Government's national marine strategy for sustainable use and protection of the seas (national strategy for the seas) of 1 October 2008, which is aimed at achieving sustainable development and better co-ordination of marine uses and marine environmental protection interests and which sees Spatial Planning as an important tool to solve an increasing number of conflicts in coastal and offshore waters.

A Strategic Environmental Assessment according to SEA Directive 2001/42/EC on the impact of certain plans and programs on the environment has been carried out in connection with the establishment of this Spatial Plan, in compliance with §7 para. 5 ROG 1998 (cf. §9 ROG). The objective of the SEA Directive, as stated in Art. 1, is "to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programs with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programs which are likely to have significant effects on the environment." The provisions of the Spatial Plan (see Chapter 3) have been made taking into account the results of the Strategic Environmental Assessment (see chapter 5).

Chapter 2 formulates the guidelines for spatial development.
Chapter 3 sets targets and principles, especially areas, for functions and uses.
Chapter 4 deals with other interests that need to be taken into account as well.
Chapter 5 describes the use of the results of the environmental assessment report.
Chapter 6 contains the co-ordinates concerning the regulations and maps with transnational pipelines and cables in the specific area.

The areas for wind power production have been designated in implementation of the Federal Government's strategy for wind energy use at sea, 2002, which is part of its overall sustainability strategy and is aimed at creating framework conditions allowing the offshore wind energy potential to be exploited. Also the Federal Government's Energy and Climate Programme (IEKP) of December 2007 formulates the goal of increasing the proportion of renewable energies in electricity production.

Specifics for the German EEZ in the North Sea

Figure 1: German EEZ in the North Sea

For the German EEZ in the North Sea the Spatial Plan contains provisions aimed at co-ordinating the individual uses and functions of shipping, the exploitation of resources, laying of pipelines and submarine cables, scientific marine research, wind power production, fisheries and mariculture, as well as protection of the marine environment. in the North Sea region.

The spatial planning designations of the German coastal states Lower Saxony and Schleswig-Holstein concerning the territorial sea have been taken into account. The spatial planning programme of Lower Saxony, in its revised version promulgated in May 2008, includes provisions concerning wind power production and nature conservation, offshore electricity transmission, and shipping. Relevant provisions in the spatial report coast and sea 2005 of Schleswig-Holstein, issued in February 2006, have been considered as well. The state of Schleswig-Holstein's 2009 development plan including provisions for its coastal waters is being revised currently.

The final position of point E_0 (53°43'30,8" N; 6°20'49,7" E) of the lateral boundary of the German Exclusive Economic Zone to the Kingdom of the Netherlands as well as the point's landward boundary will be determined by the Federal Government at a later time, following further consultations; cf. Proclamation by the Federal Republic of Germany concerning the establishment of an Exclusive Economic Zone of the Federal Republic of Germany in the North Sea and in the Baltic Sea of 25 November 1994 (BGBl. II, p. 3769, 3770).

Specifics for the German EEZ in the Baltic Sea

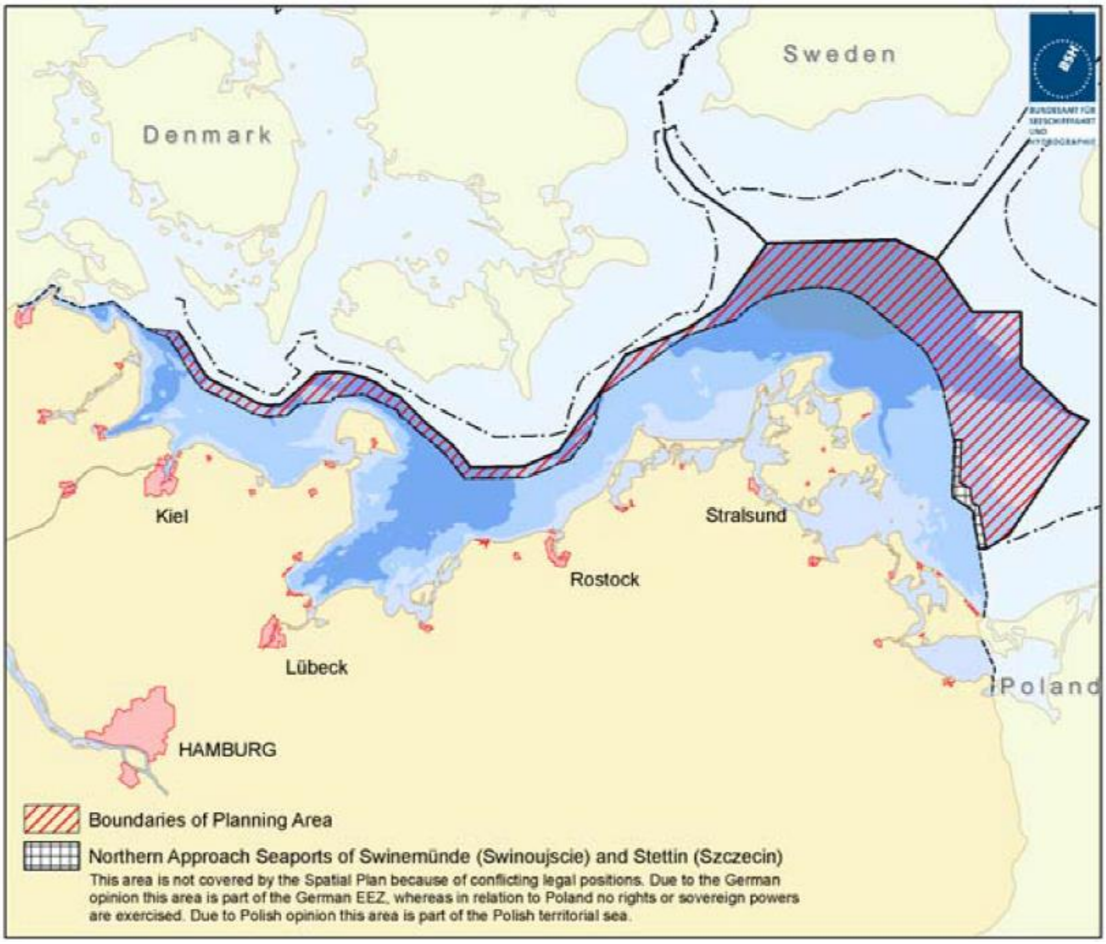


Figure 2: German EEZ in the Baltic Sea

For the German EEZ in the Baltic Sea the Spatial Plan contains provisions aimed at coordinating the individual uses and functions of shipping, the exploitation of resources, laying of pipelines and submarine cables, scientific marine research, wind power production, fisheries and mariculture, as well as protection of the marine environment.

The spatial planning designations of the German coastal states Mecklenburg-Western Pomerania and Schleswig-Holstein concerning the territorial sea have been taken into account. Relevant provisions in the spatial report coast and sea of Schleswig-Holstein, issued in February 2006, have been considered as well. The state of Schleswig-Holstein's 2009 development plan including provisions for its coastal waters is being revised currently. The spatial development programme of Mecklenburg-Western Pomerania of May 2005, which includes provisions concerning wind turbines, nature conservation, pipeline routeing and use of resources, has been considered as well.

The Spatial Plan Baltic Sea does not cover the charted area showing the northern approaches to the harbours of Świnoujście (Swinemünde) and Szczecin (Stettin) and anchorage no. 3 because of contradictory legal opinions. Due to German opinion this area is part of the German EEZ, whereas in relation to Poland no rights or sovereign powers are exercised. Due to polish opinion this area is part of the Polish territorial sea.

Spatial Plan for the German EEZ in the North Sea

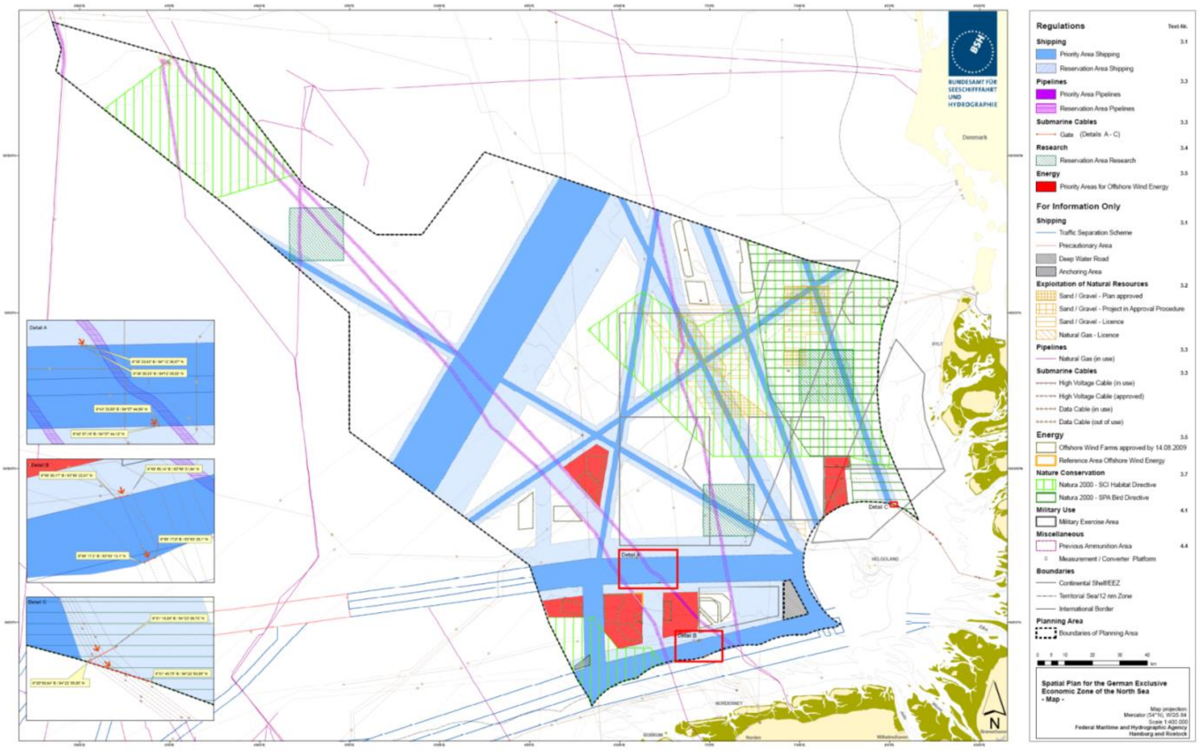


Figure 3: Spatial Plan for the German EEZ of the North Sea
http://www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/documents2/MSP_DE_NorthSea.pdf

The Spatial Plan for the German EEZ of the North See contains priority areas as well as reservation areas for shipping. According to the target 3.1.1 (1) shipping is granted priority over the other spatially significant uses in the priority areas for shipping. To the extent spatially significant planning, measures and projects are not compatible with the function of the shipping priority area in these areas they are not permitted.

The principle 3.1.1 (2) states that special consideration is given to shipping in the reservation areas for shipping. This needs to be taken into account in a comparative evaluation with other spatially significant planning tasks, measures and projects.

The Spatial Plan for the German EEZ of the North Sea also contains priority areas for energy production, wind energy in particular, as well as targets and principles (see chapter 3.5 of the Spatial Plan). According to the principle 3.5.1 (7) the safety and efficiency of navigation shall not be impaired by the construction and operation of installations for energy production.

Spatial Plan for the German EEZ in the Baltic Sea

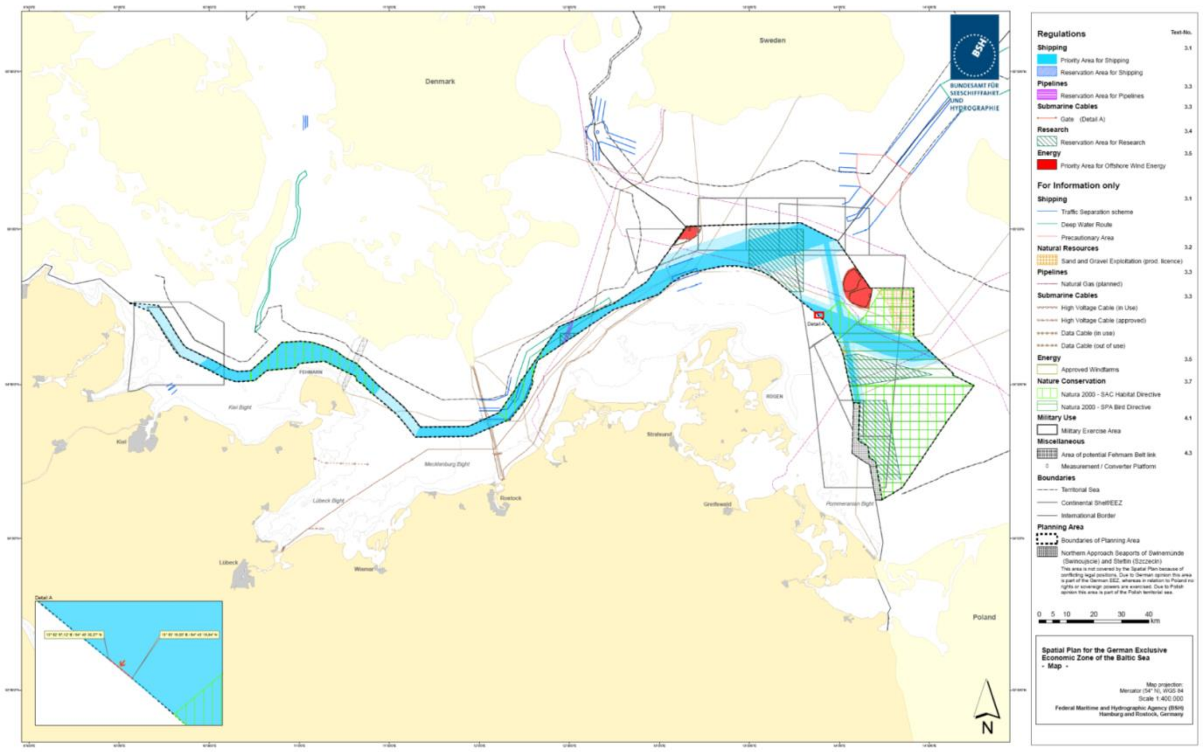


Figure 4: Spatial Plan for the German EEZ of the Baltic Sea
http://www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/documents2/MSP_DE_BalticSea_Dec2009.pdf

The Spatial Plan for the German EEZ of the Baltic See contains priority areas as well as reservation areas for shipping. According to the target 3.1.1 (1) shipping is granted priority over the other spatially significant uses in the priority areas for shipping. To the extent spatially significant planning, measures and projects are not compatible with the function of the shipping priority area in these areas they are not permitted.

The principle 3.1.1 (2) states that special consideration is given to shipping in the reservation areas for shipping. This needs to be taken into account in a comparative evaluation with other spatially significant planning tasks, measures and projects.

The Spatial Plan for the German EEZ of the Baltic See also contains priority areas for energy production, wind energy in particular, as well as targets and principles (see chapter 3.5 of the Spatial Plan). According to the principle 3.5.1 (6) the construction and operation of power production facilities in the priority areas for wind energy shall not impair the safety and efficiency of navigation.

Further information (some only in German language) can be obtained from:
http://www.bsh.de/en/Marine_uses/Spatial_Planning_in_the_German_EEZ/index.jsp
https://www.bmwi.de/Redaktion/DE/Downloads/E/windseeg-gesetz-en.pdf?__blob=publicationFile&v=9

Please note that the revision of the Spatial Plans for the German EEZ is planned from 2018 with entry into force in 2021. The revision will take into account among other things the current objectives Federal Government and the current spatial planning of the German coastal states.

Safety Zones

According to Section 11 Offshore Installations Ordinance and Section 53 Offshore Wind Energy Act the Federal Maritime and Hydrographic Agency can set up safety zones around the facilities in the exclusive economic zone where this is necessary to ensure the safety of shipping or the facilities. Where the setting up of the safety zones is needed to ensure the safety of shipping, this shall require the agreement of the Federal Waterways and Shipping Agency. Safety zones shall be areas of water which extend to a distance of up to 500 meters, measured from every point of the external edge, around the facilities. The width of a safety zone may exceed 500 meters if generally recognized international standards permit this or the relevant international organization recommends this.

Basic Design Requirements for OFW of the Federal Waterways and Shipping Agency:

- Around Offshore facilities as safety area with a radius of 500m is to be defined. For objects placed in cluster a closed safety line 500m outside of the periphery is to be defined.
- The Distance between singular offshore structures within a cluster should not be larger than 1,000 m.
- The width of the passage between two or more clusters depends on the traffic structure and density but should not be less than 2 NM with additional safety margin of 2x 500 m.
- Between Vessel separations schemes and offshore facilities a distance of 2 NM and a safety margin of 500 m is required
- The minimum distance between offshore facilities and fareways or other ways used by shipping should be 2 NN plus a safety margin of 500 m, in special cases where necessary other margins may be defined by the administration.

Further information (some only in German language) can be obtained from:
http://www.ast-nordwest.gdws.wsv.de/schifffahrt/Windparks_auf_hoher_See/index.html

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