ARM6-8.4.9

**Report No. 161–**

**Interaction between offshore wind farms and maritime navigation**

**Report of MarCom Working Group 161**

**Rev. 11**

**3 April 2017**

**PIANC Working Group 161**

**Table of Contents**

[1 General aspects 5](#_Toc479064763)

[1.1 Scope 5](#_Toc479064764)

[1.2 Introduction 5](#_Toc479064765)

[1.2.1 Terms of Reference 5](#_Toc479064766)

[1.2.1.1 Historical Background - Definition of the problem 5](#_Toc479064767)

[1.2.1.2 Objective and product of the study 6](#_Toc479064768)

[1.2.1.3 Method of approach 7](#_Toc479064769)

[1.2.2 Structure of Report 7](#_Toc479064770)

[1.2.3 Related PIANC Reports 7](#_Toc479064771)

[1.2.4 Members of the Working Group 7](#_Toc479064772)

[1.2.5 Meetings 8](#_Toc479064773)

[1.2.6 Acknowledgements 8](#_Toc479064774)

[2 IDENTIFICATION OF iNTERACTIONS 9](#_Toc479064775)

[2.1 Marine Spatial Planning (MSP) 9](#_Toc479064776)

[2.1.1 What is Marine Spatial Planning 9](#_Toc479064777)

[2.1.2 Which part of MSP do we cover? 11](#_Toc479064778)

[2.2 Maritime Emergency Planning (MEP) 12](#_Toc479064779)

[2.2.1 Contingency planning 12](#_Toc479064780)

[2.2.2 What kind of emergency do we cover? 13](#_Toc479064781)

[3 Legal background 15](#_Toc479064782)

[3.1 International references 15](#_Toc479064783)

[3.1.1 UN (UNCLOS) 15](#_Toc479064784)

[3.1.2 UNESCO (MSP) 15](#_Toc479064785)

[3.1.3 IMO (SOLAS, COLREGs, GPSR, ...) 15](#_Toc479064786)

[3.1.4 ITU (RR) 16](#_Toc479064787)

[3.1.5 ICAO (ICA convention annex 14) 16](#_Toc479064788)

[3.2 International recommendations 17](#_Toc479064789)

[3.2.1 UNCLOS 17](#_Toc479064790)

[3.2.2 IMO 19](#_Toc479064791)

[3.2.3 ICAO (ICA convention annex 14) and CAA 22](#_Toc479064792)

[4 Navigation constraints, collision avoidance & marine navigational marking 24](#_Toc479064793)

[4.1 Elements 24](#_Toc479064794)

[4.1.1 Ships 24](#_Toc479064795)

[4.1.2 Marine traffic 24](#_Toc479064796)

[4.1.3 Geometric configuration of the water (hydrographic) 25](#_Toc479064797)

[4.1.4 Aids to Navigation 26](#_Toc479064798)

[4.1.5 Maritime and atmospheric conditions (Hydrodynamics) 26](#_Toc479064799)

[4.1.6 Required pilotage, escorting & towing requirements 27](#_Toc479064800)

[4.2 Processes in Safety Distance Estimation 27](#_Toc479064801)

[4.2.1 Concept design 28](#_Toc479064802)

[4.2.2 Detailed design 32](#_Toc479064803)

[4.2.3 Risk Assessment 33](#_Toc479064804)

[5 Electromagnetic radiations (EMR) 37](#_Toc479064805)

[5.1 General introduction to electromagnetic radiation 37](#_Toc479064806)

[5.1.1 What is electromagnetic radiation? 37](#_Toc479064807)

[5.1.2 What do wind farms have to do with electromagnetic radiation? 37](#_Toc479064808)

[5.1.3 What are electromagnetic radiation interferences? 37](#_Toc479064809)

[5.1.4 How can electromagnetic radiation issues be managed? 37](#_Toc479064810)

[5.2 Principles to prevent radar interference 38](#_Toc479064811)

[5.2.1 Civil aviation radars and systems 39](#_Toc479064812)

[5.2.2 National Defence radars 40](#_Toc479064813)

[5.2.3 Weather radars 40](#_Toc479064814)

[5.2.4 VTS radars 41](#_Toc479064815)

[5.2.5 Ships radars 44](#_Toc479064816)

[5.3 Radiocommunications 45](#_Toc479064817)

[5.4 Radio Direction Finder (RDF) 48](#_Toc479064818)

[5.5 Others navigation systems 48](#_Toc479064819)

[5.5.1 GNSS 48](#_Toc479064820)

[5.5.2 Local radio navigation systems 49](#_Toc479064821)

[5.5.3 Magnetic compass 49](#_Toc479064822)

[6 Emergency procedures 50](#_Toc479064823)

[6.1 Introduction 50](#_Toc479064824)

[6.2 General concepts 50](#_Toc479064825)

[6.2.1 People - Search And Rescue (SAR) 51](#_Toc479064826)

[6.2.2 Planet Environment – Pollution (Planet) 54](#_Toc479064827)

[6.2.3 Property – Salvage (Materials) 54](#_Toc479064828)

[6.2.4 Professions - Social economic impact – Business 57](#_Toc479064829)

[summary of recommendations 59](#_Toc479064830)

[7.1 Important notice 59](#_Toc479064831)

[7.2 General recommendations 59](#_Toc479064832)

[7.2.1 Identification of interactions 59](#_Toc479064833)

[7.2.2 Legal background 59](#_Toc479064834)

[7.2.3 Navigation constraints, collision avoidance & marine navigational marking 59](#_Toc479064835)

[7.2.4 Electromagnetic radiations (EMR) 60](#_Toc479064836)

[7.2.5 Emergency procedures 61](#_Toc479064837)

[7.3 Extra notice 62](#_Toc479064838)

**Appendices**

Appendix A: References

Appendix B: Glossary

**List of Figures**

Figure 1. MSP Process - as envisioned by UNESCO 9

Figure 2. The 5 phases in contingency planning [adapted from FEMA] 12

Figure 3. Definitions used on turning circle, extracted from IMO resolution MSC.137(76) 22

Figure 4. Distance between wind farm and shipping route 25

Figure 5. Required space between shipping route and a starboard side wind farm 30

Figure 6. Required space between shipping route and a port side wind farm 30

Figure 7. Required room to a TSS 31

Figure 8. Safety Management System and Risk Assessment 36

Figure 9. Blind sectors generated by wind turbines 42

Figure 10. False target phenomena seen temporarily by a land based radar 43

Figure 11. Recommendation for VTS radar protection on either side of the operating area 43

Figure 12. Example of false target generated on a ship radar screen (ship is in the wind farm close to a wind generator) 44

Figure 13. Illustration of communications channels encountered in the marine environment 45

Figure 14. Fresnel zone blockage calculation for assessing wind turbine blockage 45

Figure 15. Saint-Brieuc (France) OWF project and the different VHF coverages (GMDSS sea area A1 in blue) around VHF CRS 47

Figure 16. Disruption of DGPS 49

Figure 17. Effect on sweep width of SAR lane spacing. An unswept area (red rectangular) originate due to the wind farm layout limiting available spacing [ICAO/IMO JWG, 2015] 52

Figure 18. Effect of wind on SAR helicopter following SAR lane 53

Figure 19. Effect of wind turbines blanking SAR objects – detection opportunities [ICAO/IMO JWG, 2015] 53

1. General aspects
   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 level for navigation.

This report includes,

* 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 and
* 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. Introduction
     1. Terms of Reference
        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, 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 Marime 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 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 transportation costs. For those areas which are situated between or near shipping lanes, there is a conflict between shipping and the production areas.

Then OWFs need particular attention for there are in conflict with traditional activities. One of the oldest activities is navigation, in that respect OWF are particular because:

* OWFs are situated in open sea, where mariners do not really expect obstacles on their way;
* OWFs have both parts under and above the water surface;
* OWFs have fixed parts and moveable parts with the wind turbine blades;
* OWFs are singular constructions, put in a zone configuration (single elements but also group);
* OWFs are interconnected with electrical (including data transmission) cabling;
* OWFs are crucial energy infrastructure, making them sensitive for damage and
* OWFs are visible obstacle, but also generate invisible perturbations in the form of electromagnetic radiation.

When a sea area for the production of energy of considerable size is to be located close to 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. 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, vessels in the shipping lane must give way to vessels emerging from the OWF according to the COLREGs.

* + - 1. 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 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 windfarm
* Crossing traffic emerging from the windfarm
* Crossing traffic incoming from starboard behind of a windfarm
* 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 has considered international rules such as the Collision Regulations and the General provisions on ships routeing etc.

* + - 1. Method of approach
* review of actual practice of distances between shipping and OWF 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 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 OWF, in order to ensure a minimal risk level for navigation.
  + 1. Structure of 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 & marine navigational marking

Chapter 5 – Electromagnetic radiations (EMR)

Chapter 6 – Emergency procedures

Chapter 7 – Guidelines & recommendations to assess the required safety distances in vicinity of offshore wind farms

* + 1. Related PIANC Reports

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

|  |  |  |
| --- | --- | --- |
| PIANC Report No.121 | PIANC Report 121  Harbour Approach Channels. Design Guidelines | 2014 |

* + 1. Members of the Working Group

The Working Group comprised membership from PIANC some of whom are also members of IALA. The WG161 consisted of the following members:

* Capt. Jean Charles Cornillou, WG161 Chairman, “Centre for studies and expertise on risks, environment, mobility and country planning” (Cerema), France
* Gonzalo Montero, WG161 Secretary, “Engineering, Resources & Development, S.L.” (ENRED), Spain
* Raul Atienza, WG161 Alternate Secretary, “SIPORT XXI S.L.”, Spain
* Wim Hoebee, Port of Rotterdam, 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 Research and Development Agency, National Institute of Maritime, Port and Aviation Technology, Japan
  + 1. 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. Acknowledgements

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

* Francis Zachariae, IALA Secretary General
* Capt. Phil DAY, chair IALA ARM committee, Northern Lighthouse Board, UK
* Capt. Roger Barker, chair IALA ARM committee WG1, Trinity House Ligthouse Service, United Kingdom
* David Patraiko, Nautical Institute, United Kingdom
* David Edwards, chair 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 Insitute of Telecommunications, Poland
* Matthieu Zekar, geographer, teacher in charge of research, National Maritime Academy Le Havre, France
* Jochen Ritterbusch, BSH, Germany

# 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 more detailed information and methodology.

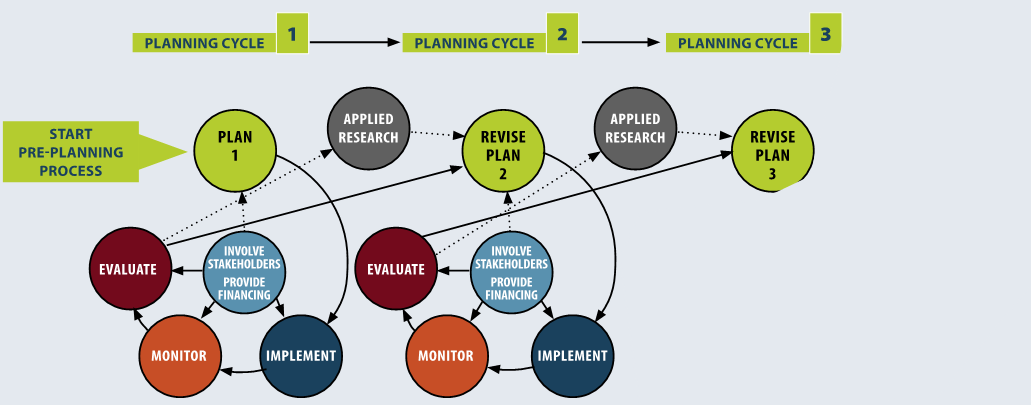
## Marine Spatial Planning (MSP)

### 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).



Therefore, MSP:

* is the responsibility of each maritime State and
* 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 31st March 2021[[1]](#footnote-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,1982 (UNCLOS) 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. The policy drivers will change the outputs of the MSP and will change over time.

### 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 finalized IALA document on this subject is the “guideline on Navigational Safety within Marine Spatial Planning” [The ARM 5 finished the development of the Guideline and Recommendation, resulting in two mature working papers to be reviewed approved at ARM 6 from 24 to 28 April 2017].

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.

## 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 Planning** (MEP).

MEP is a similar process than 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 Planning (MSP)[[2]](#footnote-2).

### Contingency planning

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

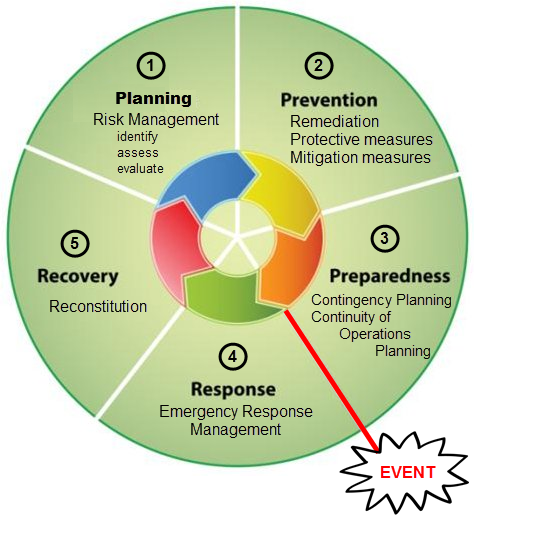


Figure 2. The 5 phases in contingency planning [adapted from FEMA]

**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 organization 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 minimize 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 emergency (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 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. Evidently recovery takes place after an emergency [FEMA, 1998].

Many of the Contingency planning phases graphics like in Figure 1 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 emphasize 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].

### What kind of emergency do we cover?

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

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

IMO adopted on 18th June 2015 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 be uses 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 SAR operation and in particular for major disaster management;
* include in emergency plan major industrial risks notion by tests involving a merchant ship in 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 identify:

**A – 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.

**B – Study of a scenario of crisis and implementation of resistance testing**

4° Simulation of emergencies situations after commissioning the OWF;

5° Identification of key operational roles of the emergency management system (Salvage and Rescue, 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 …);

7° Evaluation of the ability to contain the emergency;

8° Identification of related functions which might assist in managing the emergency (monitoring of navigation, emergency anchorage, port services, VTS, etc)

**C – Nautical recommendations**

**9a** **level 1:** Recommendations for changing operational procedures for

* emergency prevention and
* emergency management and contingency planning.

Then, if necessary:

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

1. 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.

* 1. International references
     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.

* + 1. UNESCO (MSP)

UNESCO – *the United Nations Educational, Scientific and Cultural Organization* - is responsible for coordinating international cooperation in education, science, culture and communication. Between November 2007 and May 2009, UNESCO has been developing 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.

* + 1. IMO (SOLAS, COLREGs, GPSR, ...)

*IMO – the International Maritime Organization* – is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships. As a specialized 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 1st 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)* are published by the IMO. The COLREGs set out, among other things, the "rules of the road" or navigation rules to be followed by ships and other vessels at sea to prevent collisions between two or more vessels. COLREGs will be 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 ships to determine if risk of collision exist.

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 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.

* + 1. ITU (RR)

The *International Telecommunication Union (ITU)*, based in Geneva, coordinates and standardizes 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 coordination (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.
  + 1. ICAO (ICA convention annex 14)

The*International Civil Aviation Organization (ICAO)* is an UN specialized 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 organizations 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 warms in relation to aviation.

* 1. 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 focusses on those regulations that are decisive 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 exist yet. However, the existing provisions and regulations provide sufficient guidance to argue a safe distance to such objects.

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 Organization (IMO)
* Standards for ship manoeuvrability

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

* + 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:*

1. *artificial islands;*
2. *installations and structures for the purposes provided for in article 56 and other economic purposes;*
3. *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 meter zone described in paragraph 6 is for *protection of the structure* and is not meant as a safe distance for safe maneuvering 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.

* + 1. 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 at all times: 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 taking over:

< 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

room per vessel: 2 ship lengths

Example: a traffic lane which accommodates 18,000 vessels per year with a maximum size of 400 meters should be at least 3,200 meters 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 (to be formalised in Q4 2016)*

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 (i.e. outer separation zones) 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 TSS that France proposed off Ushant, Casquets or Pas-de-Calais. TSS for the Pas-de-Calais/Dover Strait, the proposal was submitted to IMO together with the United Kingdom. Other ship’s routeing measures around OWF in high sea or next to international ship’s routeing measures already adopted by the IMO should be submitted as well 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.

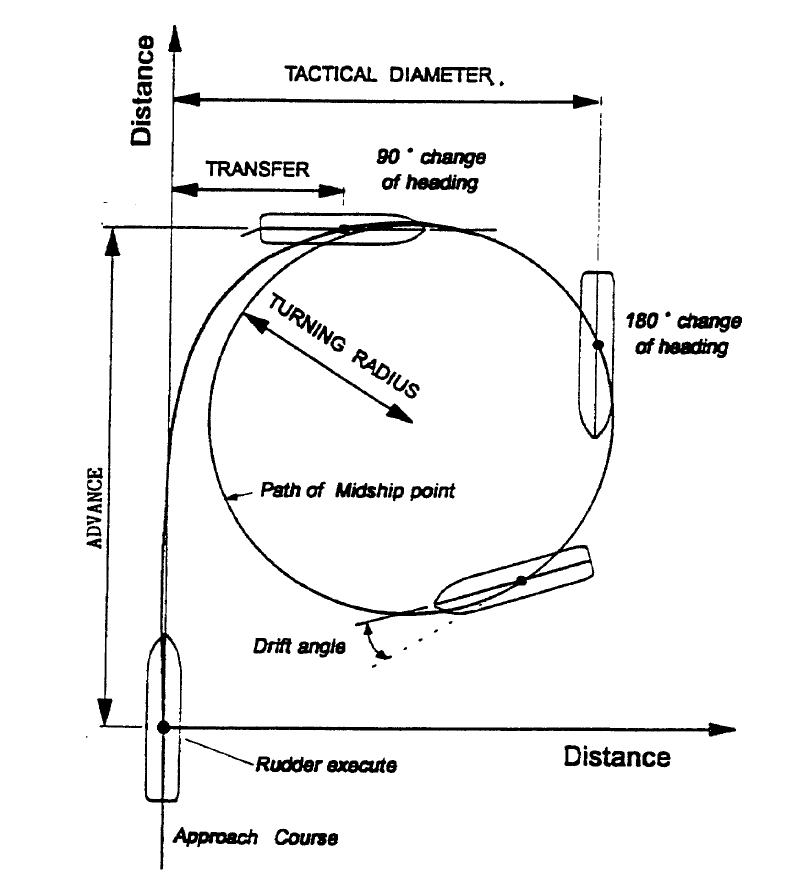


Figure 3. Definitions used on turning circle, extracted from IMO resolution MSC.137(76)

* + 1. ICAO (ICA convention annex 14) and CAA

**ICAO - International Civil Aviation Organisation**

In particular, 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 affecting the safety of operations of airplanes. Additional measures should be taken in that case. A minimum distance for wind turbines to the runway of 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 yet to date. 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 ends at 315 m. It is considered that wind turbines of more 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 web site: [www.caa.co.uk/windfarms](http://www.caa.co.uk/windfarms).

# Navigation constraints, collision avoidance & marine navigational marking

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

## Elements

### Ships

The analysis of safety distances between shipping routes and OWF require a good description of the ships that can be involved in navigation issues close to the OWF. In this way it should be considered any kind of ships in the area:

• Commercial ships (goods and passage)

• Fishing vessels

• Pleasure boats

• Supply vessels, tug boats, maintenance boats

The main characteristics of the ships must be defined in order to have a good description of the fleets. In this way, it is recommended a compilation of factors as type of ships and goods (hazard/no hazard), main dimensions (length, beam, draught), manoeuvring characteristics (manoeuvring tests, propellers, rudders and thrusters), auxiliary systems like tugs (in restricted areas or close to ports).

### Marine traffic

As a complement of the fleet description, it is important to analyze the routes and the frequencies of the ships (it is not the same a lower traffic density than a higher one). This analysis will provide information about the real navigation areas and it is an important factor for 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 to consider seasonal variations in traffic patterns and fishing operations and recreational activities. This study must be complemented with a foresight of future traffic taken into account market trends, infrastructure investments in the area or changes in traffic routes.

One of the aims of this analysis should be to get a good definition of the different shipping routes in the area. In this way, TSS or marked channels referred in Nautical Charts are the first step but also, “real” shipping lanes should be defined according with traffic statistics.

Shipping routes are routes regularly used by ships, whose definition is chaired 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.

Distance between wind farm and shipping route must be defined as the distance in between the physical boundary of the wind farm and the nearest edge of the shipping route or navigation channel.

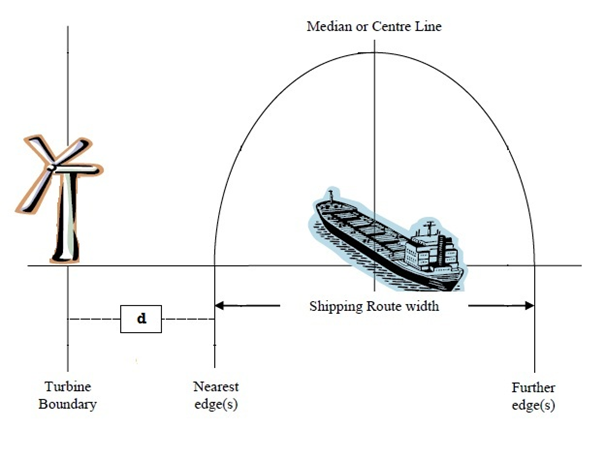


Figure 4. Distance between wind farm and shipping route

### Geometric configuration of the water (hydrographic)

A good description of the hydrographic conditions is needed in order to identify the interference areas between navigation and wind farms installations. As Nautical Charts include all the information related to the hydrographic and marine elements, it should be the first reference for the study of geometric configuration of the water. Complementary, a detailed bathymetry of the full affected area (wind farm and navigation routes identify in previous section) is also recommended.

An identification and description of navigation channels (when exists) will provide good information for the analysis of the interference areas. It is important to understand well the behaviour of the ships in the vicinity of the wind farms. TSS (Traffic Separation Schemes), marked channels, approach channels or open waters are some examples of different navigation areas that impose different behaviour to the navigation of the ships.

Combining bathymetry and navigation areas description, it is possible to identify the interference areas that should be analysed. It is important to bear in mind that these areas can be different depending on the considered ships. For example, a big vessel (with high draught) can ground out of the wind farm area while a smaller one can collide with it. In other way, TSS or marked channels impose a more accurate location of the ships and, in consequence, a lower probability of navigation out of them.

So, the analysis of the geometric configuration of the water should be done considering the previous analysis of ships and marine traffic.

### Aids to Navigation

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

A compilation of the existing AtoNs should be done in order to complement the analysis of marine traffic and to get a good understanding of the restrictions to navigation. The study of existing AtoNs should be complemented with an analysis of the future configuration of the area (when wind farm built) including a proposal of new AtoNs for OWF marking and new channels or restrictions.

There is potential for a wind turbine to actively interfere by producing its own low energy radio frequency (RF) signal. The problem at sea is sensitive because there are many radio communications and radio navigation systems dedicated for safety at sea. These systems are based on terrestrial and satellite communications. Chapter 5 relative to Electromagnetic radiation is dealing in detail about this question.

As mentioned in SOLAS V/13.2, “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”.

In this way, IALA recommendations O-139 on the Marking of Man-Made Offshore Structure should be followed.

### Maritime and atmospheric conditions (Hydrodynamics)

For a good understanding of ships 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 but also, bank effects, shallow water effects, tides. In this way, hydrodynamic studies should be performed to collect information and a good description of any factor.

Evasion manoeuvring or drifting events are very sensitive to the meteorological and ocean conditions. So, it is very important to include these factors to analyse the behaviour of the ships in the vicinity of wind farm.

It is important, not only to get a good characterization of the area, but also to identify the 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 drifting or losing control.

### Required 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 pilotage has the control of ship navigation, a more organization of marine traffic and a higher manoeuvring safety appear. In this case, recommended safety distances could be decreased taking into account that navigation conditions have a more accurate control and marine traffic interferences (ship to ship interactions) are under more specific control.

The same criterion is applicable to areas where escorting or towing is required. These factors are especially relevant in detailed design stage or, even, in risk assessment stage.

These elements also can be used as mitigation or preventive measures detected in risk assessment.

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

## Processes in Safety Distance Estimation

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

As a function of the aims and the phase of the project, different levels of detail can be performed for the analysis. In this way, if the requirements of one project are in line with a lower level analysis (concept design), it can be considered as acceptable. But, if an optimization process is required, it must be done according with higher level analysis (detailed design or risk assessment) and with a full explanation of the description of all the previous elements and an accurate description of the navigation and manoeuvring analysis in local conditions.

Taking into account PIANC WG-121 philosophy, it should be considered the following two stages of design:

* **Concept Design.** It 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. The process may include plans from rough estimates to more detailed and accurate plans. 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.** It is a more rigorous process intended to validate, develop and refine the Concept Design. The methods used in Detailed Design rely on both numerical 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.

### Concept design

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

Anyway, 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 the 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 according ordinary practice of seamen.

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

COLREG 7c) *– Risk of collision*

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

Because targets of vessels within an area with multiple structures tend to swap to the structures, a Closest Point of Approach (CPA) is hard to get. Only when the vessel departs this areas, the CPA can 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 GPS and not on water track.

In addition to the effect of swapping targets, wind farms cause radar interference. 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 minimize 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 does not act according the COLREGs, the give way vessel’s last resort is a full round turn over starboard.

The required room is for turns to starboard and port are shown in figures 2 and 3. 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 minimum 0,3 NM

2) The round turn itself is determined as explained in 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 meter distance safety zone.

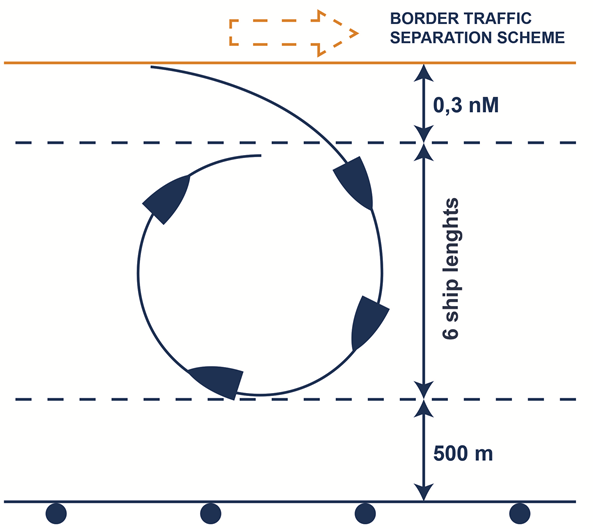


Figure 5. Required space between shipping route and a starboard side wind farm

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

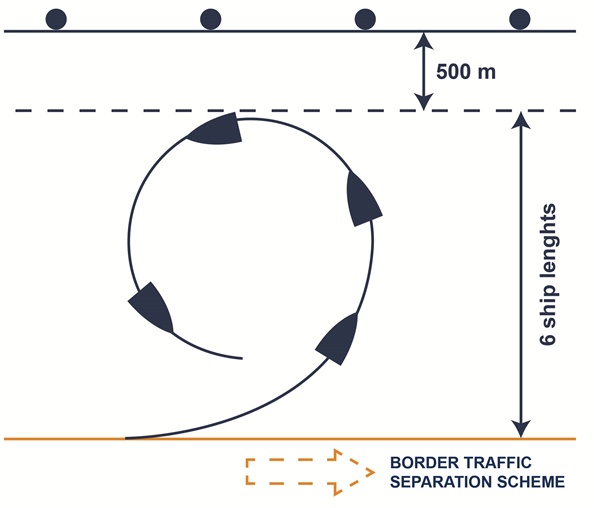


Figure 6. Required space between shipping route and a port side wind farm

Points of attention:

1. It happens quite often that after making a round turn a Not Under Command situation occurs, due to mechanical problems (e.g. low low level alarm on oil levels etc.)
2. On many vessels the Officer On Duty will hesitate to use hard rudder at once. Especially on passenger ships and container vessels one will be very cautious before starting such a turn as it can result in a lot of damage to passengers, crew and cargo.
3. 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, the Figure 7 shows that there is little room left for e.g. sailing vessels that need to beat up against the wind.

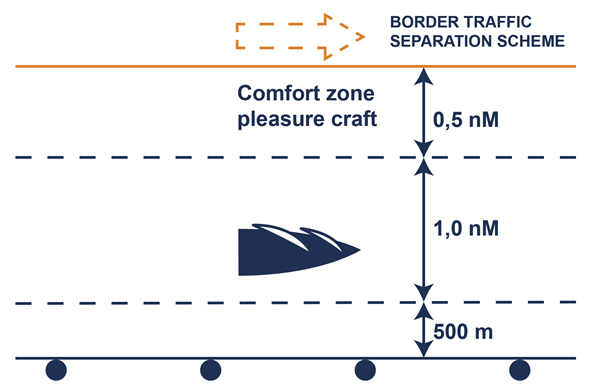


Figure 7. Required room to a TSS

Anchor areas

There are no regulations that relate to anchorages.

However, safe anchorages should provide sufficient room to manoeuvres:

a) when the anchor is dragging

b) in the approach to an anchorage

A safety study for an off shore 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 has been found to be sufficient to approach that 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 summarize***

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 meter
* Portside of any route: 6 ship lengths + 500 meter

### Detailed design

Detailed Design is a more rigorous process intended to validate, develop and refine the Concept Design. The operational aspects are checked, referred 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 PIANC WG-121 philosophy, detailed design involves the use of computer models whose type, purpose and methodology are simply outlined. 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 and

(i) detailed hydraulic modelling

* Accuracy (human factors)
* Optimisation
* Benefits
* Risk acceptance criteria

A list of tools and methods for Detailed Design is the following:

* Detailed Parametric Design and Special Formulae
* Simulation Models
  + Ship navigation/manoeuvring 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 windfarm and dimensions of manoeuvring areas, while traffic flow simulation models are used to determine safety levels and efficiency including quantitative risk assessment.

### Risk Assessment

Risk assessment comprises the first step in the development and application of the 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 at 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 barriers 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

The risk assessment process consists of five parts:

* Data gathering
* Hazard identification
* Risk analysis
* Assessment of existing measures
* Identification of risk control measures/options

Data Gathering

The Data Gathering process will aim to establish an initial list of hazards. In essence, data gathering involves familiarization 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 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.);
* Marinas;
* Fishing harbours and
* AIS data, maritime routes, etc.

Hazard Identification

The process of hazard identification attempts to list all the hazards which currently exist within the port 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 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 port). 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 will be located the OWF.

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 port’s 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 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 soft wares are 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 port 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.

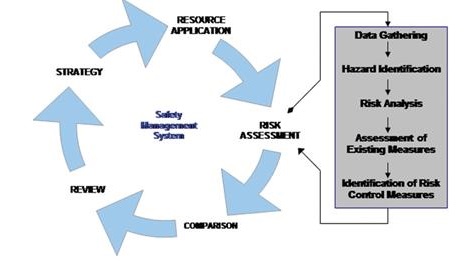


Figure 8. Safety Management System and Risk Assessment

1. Electromagnetic radiations (EMR)
   1. General introduction to electromagnetic radiation
      1. What is electromagnetic radiation?

Electromagnetic radiation (EMR) is a wavelike pattern of electric and magnetic energy moving together. Types of EMR include X-rays, ultraviolet, visible light, infrared and radio waves. As a natural phenomenon, EMR is emitted by natural sources like the Sun, the Earth and the ionosphere. 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 compensated by appropriate means.

* + 1. What do wind farms have to do with electromagnetic radiation?

From a wind resource perspective, high and exposed sites are attractive. So 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 nearby. 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 sensitive because there are many radio communications dedicated and radio navigation systems for safety at sea. These systems are based on terrestrial and satellite communications.

* + 1. 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.

* + 1. How can electromagnetic radiation issues be managed?

- Point to Point Communications: Careful sitting 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, the 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.

- Television: Interference to television signals in the wind farm area can be caused by either the reflection or obstruction of the signal by the turbine blades. With glass reinforced plastic blades, modern wind turbine generators will cause minimal television interference. It cannot however, be completely discounted for houses within a few kilometres distance of turbines. If interference does become apparent after construction, the possible mitigation techniques include:

* installation of a better quality antenna or more directional antenna,
* directing the antenna toward an alternative broadcast transmitter,
* installation of an amplifier,
* relocation of the antenna to achieve better signal to noise ratio,
* installation of a terrestrial, digital set top box for digital TV,
* installation of satellite or cable TV, or
* if a wide area is affected then the construction of a new repeater station may be considered.

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 using one of the aforementioned solutions. In the focus of Interaction between offshore wind farms and maritime navigation, we will study the different equipment: radar (in particular vessel traffic service, or VTS, radar and ship borne radar), radio communications (in particular maritime radio communications in line with the GMDSS), Automatic Identification System (AIS), shore-based radio direction finder (RDF), global navigation satellite systems (GNSS) and others navigation systems.

* 1. Principles to prevent radar interference

The wind farm developers are urged 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 to a wind farm developer. We have considered the principal radar operators: civil aviation, National Defence, weather office, and vessels traffic services. 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 be consulted as well in order to take into account the proper safe distance from wind farms for ships to use radar with no interference.

Radar operators deciding 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 area,
* constraints related to air and sea traffic,
* forecasting of weather disasters.

Each radar operator has to be consulted. There may be a competent Authority in charge to coordinate the consultation, but the rules depend on national regulations. The guidelines below are providing guidance to assist radar operators or any competent Authority if no regulations on radars protection are implemented.

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

* “**protected area**” where the risk of disruption on the radar is too high, no wind turbine can be build;
* “**regulated area**” where it is important to conduct a special study to assess the risk of disruption on the radar in coordination between the different services concerned by the wind farm. Wind turbines could be built pending to restriction or further protection required by the radar operators or, depending of the case, the option could be the prohibition of any wind turbine;
* “**authorized area**” where it is possible to build wind turbines.

The different cases below are providing the distance (d) for the area centred on the radar to be used by the different operators (civil aviation, National Defence, weather and VTS) to determine a “protected area” and a “regulated area” 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 suggested in order to organize space around a wind farm to determine whether a wind turbine is located in a “protected area” or “regulated area”.

* + 1. Civil aviation radars and systems

To protect paths approaches, Civil Aviation operates three types of equipment:

* **Primary radars** to detect aircraft. They provide monitoring without any cooperation action 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**, called VOR (Visual Omni Range), ground-based enable the aircraft to position themselves in relation to their sites. They are located at the airports and in the countryside.

*1)* Primary radars

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Recommended distance between a wind turbine and a primary radar**  **in co-visibility (d)** | | |
| **Elevation angle originating home to the radar antenna**  **(α)** | d < 5 km | 20 km ≤ d < 30 km | d ≥ 30 km |
| α ≤ 0.5° | Protected area | Authorized area | Authorized area |
| α > 0.5° | Regulated area |

The elevation angle α is the elevation angle in the vertical plane having to focus the radar antenna and passing through the tip of the blade of the wind turbine in the highest position.

*2)* secondary radar

|  |  |  |
| --- | --- | --- |
| **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 | Authorized area |

*3)* VOR

A study by the Civil Aviation showed that wind turbine 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 Doppler VOR reflections on the obstacles, it could be considered in some cases, the change of a conventional VOR into a Doppler VOR. In this case, the contribution of wind energy developers will be an agreement with the civil aviation.

* + 1. 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 distant of less than 30 km from the radar. This distance and definition of area may change depending of the national and local requirements.

* + 1. 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 distant 10 km at least 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 | | Authorized area | |
| Band S | Protected area | | Regulated area | | Authorized area |

* + 1. 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 that: “*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. The angle referred imperatively near horizontal makes inevitable confusion between the target position (ships) and wind farms, but It should be noted, that wind generators are placed in a well define structure, ships in the vicinity can be identified by breaking symmetry;
2. If no Doppler analysis and no Moving Target Indicator (MTI) is in the signal processing the rotation of the rotor doesn’t cause interference;
3. The fineness of presentation is depending for
   1. the azimuth angle of the radar beam is depending on the Antenna size of the radar.
   2. the pulse length defines the distance needed that objects behind each other are shown separately;
4. In close distance of a wind farm radars can be rendered inoperative by saturation if the power level of the received signal is too large compared to its operating range;
5. Blind sectors behind wind turbines generated by the pylons of the wind turbines and the masking blades whose attenuation is low. This average attenuation is about 0.3 dB on a round trip and
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 9*), may also generate false targets.

**In consequences these disturbances can significantly degrade the capabilities of detection, localization, identification of radar around wind turbines.**

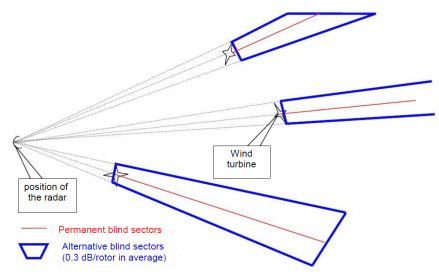


Figure 9. Blind sectors generated by wind turbines

Note: Maximum dB attenuation of the radar signal return behind a 7 m diameter pylon (radar frequency = 9.2 GHz - Iso mitigation: 1 dB)

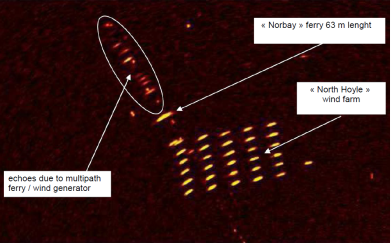


Figure 10. False target phenomena seen temporarily by a land based radar

|  |  |  |  |
| --- | --- | --- | --- |
|  | **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 | Authorized 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*).

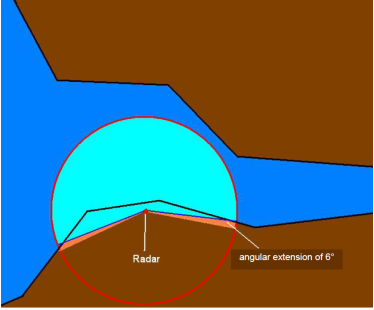


Figure 11. Recommendation for VTS radar protection on either side of the operating area

* + 1. Ships radars

Ships are using 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 Safety Of Life At Sea (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 the same way as explain above. When ARPA systems are used to track targets close to a wind farm target swops may occur. Surveys have identified that on **distance below 1.5 NM** from a wind farm special care regarding the selected range, pulse length and gain is necessary to minimize the interferences on ship born radar.

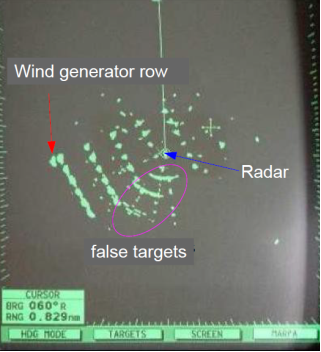


Figure 12. Example of false target generated on a ship radar screen (ship is in the wind farm close to a wind generator)

Interaction wind turbine/ship radar can generates false targets by the side lobes of the antenna. Clutter of the wind turbine is located at the same distance as the latter.

* 1. Radiocommunications

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, 1.6GHz) for navigation and Iridium (1.6GHz) and Geostationary Operational Environmental Satellite (GOES on 400MHz) for data relay by various ocean monitoring sensors, VHF (160MHz) radio for marine communications, and AIS (160MHz, automatic identification system) for vessel identification and tracking.

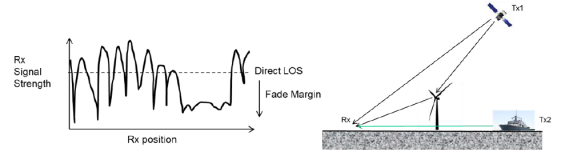


Figure 13.  Illustration of communications channels encountered in the marine environment

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.

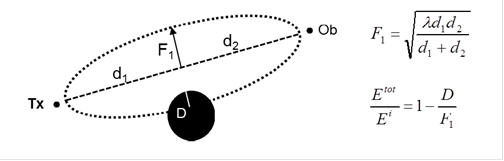


Figure 14.  Fresnel zone blockage calculation for assessing wind turbine blockage

Base on different studies in the world, we can summarize 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 6dB 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 signal fading. For example, typical GPS receivers have a fading margin of 15dB 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. The GMDSS has been internationally regulated in the ITU Radio Regulation and the related equipment on Board the vessel within IMO in chapter IV of the Safety Of Life At Sea (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 the basic principles 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 collection of all GMDSS sea areas is consolidated by the secretary of the IMO within the GMDSS master plan. This master plan helps to define the radio equipment to be carried on board ships which is depending on the radio communication infrastructures ashore in the area of operation of the ship.

VHF Radiocommunications and AIS

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

* watch keeping distress call and alert
* broadcasting maritime safety information to prevent accident,
* coordination of search and rescue operation,
* coordination for oil spill cleaning or
* coordination of salvage operation.

Automated Identification Systems (AIS) is a tracking system, which involves radio communication from ship to ship and also from ships to AIS shore based station. The VHF transmissions of the system integrates identification of the vessel, positioning, speed and heading information of the vessel. The purpose of AIS is first to identify ships in the vicinity carrying an AIS. In that respect AIS assist in collision avoidance, but it should be keep in mind AIS is not mandatory on all vessels. AIS are transceiver operating in the VHF Band. They are subject to the EMR area of the OWF 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 system of monitoring and communication. This has an impact mainly for ships in VHF range limits 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 on 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. 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 vessel traffic services (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 with the service involved (RCC, VTS or harbour masters’ office).
* During this transitional phase and until the results of the expertise, VHF equipment in the offshore wind farm may be made available to the RCC, VTS or harbour masters’ office. The operator shall bear the modalities of integration and installation of these equipment, including aerials.
* If studies reveal disturbances the RCC would require the operator that it 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 in charge of the distress watch which is the primary task of RCC.
* AIS compensatory measures are to be checked case by case depending from 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 interest to keep up the equipment should be assessed. In the event that the station should be maintained for relevant operational reasons, the RCC or any other service involved has to initiate a contractual procedure with the operator to define the modalities of lodging facilities and accessibility to the sites.

**In any case, 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 on the potential impact on radio-communication to the extent possible. Field measurements should be carried when OWF is completed in order to confirm the necessity and location of the additional VHF coastal radio station or AIS base station in the OWF or simply to check the sea area A1 coverage.**

* 1. Radio Direction Finder (RDF)

The disruption on phase due to OWF may cause some concerns on those 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.

**It is suggested to study an alternative solution for the RDF shore based station.**

* 1. Others navigation systems

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

* + 1. GNSS

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

Studies have been focus on the DGPS which is a correction signal of GPS transmitted by shore 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. The consequences are to respect a minimum distance:

* Between the reference station and wind turbine and
* Between the ship and the wind turbine.

1. A distance greater than 1200 m for a wind turbine of 160 m height and an angle of 8 ° distance above the horizon overcomes the potential impact of multi-path between satellite, ship, wind turbines and DGPS reference station.

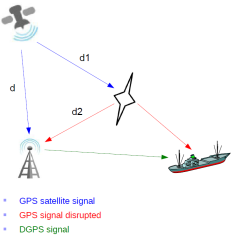


Figure 16. Disruption of DGPS

**To maintain the accuracy of DGPS, it is necessary to ensure a distance of 1.2km between wind turbines and ships, and between wind turbines and the DGPS reference station.**

* + 1. Local radio navigation systems

The hyperbolic radio navigation systems (DECCA, LORAN C) are discontinued, there may be others local systems in some harbours to give an accurate position for piloting, survey ship 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. As GNSS and DGPS, all these systems are subject to multi-path effect which hampered the accuracy of the position information.

* + 1. 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.

# Emergency procedures

## 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 as described in Section 4. Maritime Emergency Planning (MEP) for the specific interaction between OWF operations and maritime navigation should be part of a holistic Safety Management System as described in Section 4 covering both risks induced by impact from OWF towards maritime navigation and vice versa. In order to avoid a complex identification of separate risks ordered by (direct-indirect) causes, risks are more globally ordered by their nature of consequences on:

1. People (health, safety & security) with SAR as the most important respond;

2. Planet (marine environment) with pollution (oil spill) contingency as primary focus

3. Property & Assets (materials) with salvage as the main emergency respond and

4. Professions/Business (socio-economy, liability, reputation, etc).

## 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 [Extract from **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 recognized 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 categorized 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 necessary that require a substantial external response due to 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.

### People - Search And Rescue (SAR)

Maritime SAR is well 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 harmonization 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 is impacting the sea-space and it is recognized 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).

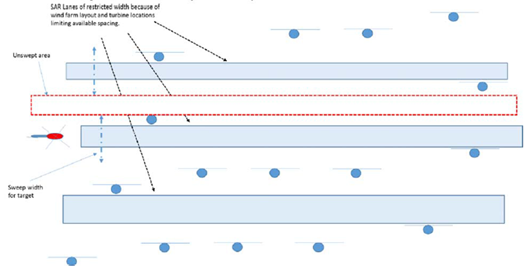


Figure 17. Effect on sweep width of SAR lane spacing. An unswept area (red rectangular) originate due to the wind farm layout limiting available spacing [ICAO/IMO JWG, 2015]

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.

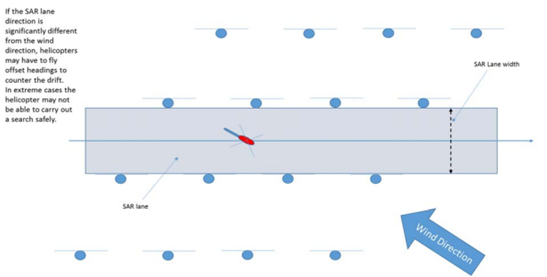


Figure 18. Effect of wind on SAR helicopter following SAR lane

[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.

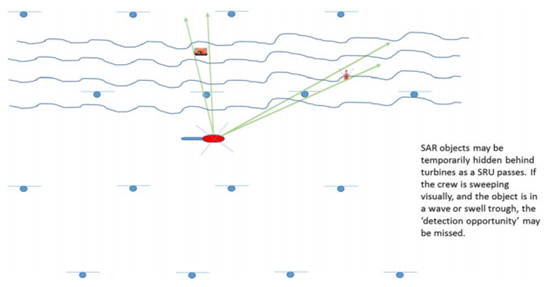


Figure 19. Effect of wind turbines blanking SAR objects – detection opportunities [ICAO/IMO JWG, 2015]

### 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 realize 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 concurred 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**].

### 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**].

There are, however, inconsistencies in the regulatory framework which governs wreck removal regulations causing uncertainty. The legal framework under which wrecks are treated has evolved over centuries. Typically, it is a blend of the coastal state’s national legal framework and international maritime law, such as relevant IMO Conventions. There is therefore a lack of uniformity or commonality in the approach to wreck removal. This can create confusion due to differences between jurisdictions and uncertainty over the geographical extent of responsibility [**Lloyd’s, 2013**].

There is considerable confusion, not least in the industry, over the use of the terms emergency response and salvage. Some evidence regarded these as two entirely separate issues, while in other cases they were regarded as a continuum of service that could not easily be split into the two aspects. The obligation of ships to go to the assistance of vessels in distress is enshrined both in tradition and in international treaties such as the International Convention for the Safety of Life at Sea (SOLAS), 1974. This shows clearly that internationally, maritime authorities recognize that salvage and emergency response are very closely linked [**Australia Parliament, 2004**].

**Types of salvage operations**

There are two types of salvage jobs: contract and pure salvage. In contract salvage the owner of the property and salvor enter into a salvage contract prior to the commencement of salvage operations and the amount that the salvor is paid is determined by the contract. This can be a fixed amount, based on a "time and materials" basis, or any other terms that both parties agree to. The contract may also state that payment is only due if the salvage operation is successful (a.k.a. [i.e.]"No Cure, No Pay") or that payment is due even if the operation is not successful. In pure salvage (also called "merit salvage"), there is no contract between the owner of the goods and the salvor. The relationship is one which is implied by law. The salvor of property under pure salvage must bring his claim for salvage in a court which has jurisdiction, and this will award salvage based upon the "merit" of the service and the value of the salvaged property [**Black Sea Diving Center LTD, 2015**].

**Regulations for salvage compensation**

The International Convention on Salvage of 1989 (Salvage 89) replaced a convention on the law of salvage adopted in Brussels in 1910 which incorporated the "'no cure, no pay" principle under which a salvor is only rewarded for services if the operation is successful. Although this basic philosophy worked well in most cases, it did not take pollution into account. A salvor who prevented a major pollution incident (for example, by towing a damaged tanker away from an environmentally sensitive area) but did not manage to save the ship or the cargo got nothing. There was therefore little incentive to a salvor to undertake an operation which has only a slim chance of success. The 1989 Convention seeks to remedy this deficiency by making provision for an enhanced salvage award taking into account the skill and efforts of the salvors in preventing or minimizing damage to the environment [**IMO, 2015**].

The 1989 Convention introduced a "special compensation" to be paid to salvors who have failed to earn a reward in the normal way (i.e. by salving the ship and cargo). Damage to the environment is defined as "substantial physical damage to human health or to marine life or resources in coastal or inland waters or areas adjacent thereto, caused by pollution, contamination, fire, explosion or similar major incidents." The compensation consists of the salvor's expenses, plus up to 30% of these expenses if, thanks to the efforts of the salvor, environmental damage has been minimized or prevented. The salvor's expenses are defined as "out-of-pocket expenses reasonably incurred by the salvor in the salvage operation and a fair rate for equipment and personnel actually and reasonably used". The tribunal or arbitrator assessing the reward may increase the amount of compensation to a maximum of 100% of the salvor's expenses, "if it deems it fair and just to do so". If, on the other hand, the salvor is negligent and has consequently failed to prevent or minimize environmental damage, special compensation may be denied or reduced. Payment of the reward is to be made by the vessel and other property interests in proportion to their respective salved values **[IMO, 2015**].

**Challenges of salvage**

All wreck removal operations are major undertakings. Some may be straightforward, but others are complex and lengthy requiring the use of heavy lifting equipment that may be scarce. Operational aspects of wreck removal start with developing an engineering methodology that considers the condition of the vessel, the site, the cargo and available equipment. Most wreck removals are variants on standard approaches. However, technological advances are enabling wreck removals to be carried out in more challenging and extreme environments [**Lloyd’s, 2013**].

In offshore salvage, vessels are exposed to waves, currents and weather and are the most vulnerable and difficult to work on. They also tend to deteriorate more rapidly than such vessels in protected harbours. Offshore salvage may provide only a short window of opportunity for the salvage team due to unusually high tide or inclement weather for instance [**Black Sea Diving Center LTD, 2015**].

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. The salvage of a vessel that is damaged but still afloat is called afloat salvage. This type of salvage is mostly unobtrusive and involves primarily damage control work such as hull welding, stabilization (rebalancing ballast tanks and shifting cargo) and structural bracing [**Black Sea Diving Center 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 …) of a wind turbine also the removal/recovery of the content might be a tough job. 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**].

**Environmental consideration**

Environmental considerations are a key factor in wreck or debris removal operations and will have significant cost impacts. Environmental impact from debris, a wreck or its cargo content is a risk, and the need to deal with pollution, or to control the potential for pollution, is central to many wreck or debris removal operations. The required approach to bunker fuel removal or handling hazardous products can have a major impact on costs. Public concern for protection of the environment appears to be greater than was the case even two decades ago, and in many parts of the world there is a zero tolerance attitude to any ship-and wind turbine sourced pollution. This applies regardless of the nature of the vessel cargo or turbine structure contents and, even if there is no risk of any noxious emissions, a wreck’s physical impact on the shore – including visual – is likely to be unacceptable to politicians and the public. News media will highlight the case, and stakeholders such as environmental protection groups may campaign for specific actions [**Lloyd’s, 2013**].

### 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.

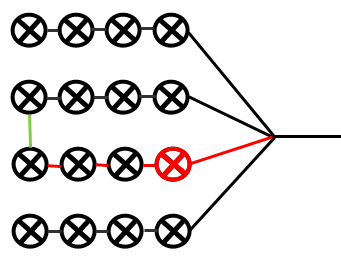
The effects and cost implications due to equipment loss are discussed in the section about salvage but there is also a large implication for the wind farm’s guaranteed energy production, transfer and delivery. Apart from the obvious costs related to the damage of property, the (re)liability of the wind 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 owner could suffer reputational damage in case an emergency occurs with - one of - his 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 followed up by an onshore control unit which checks 24 hours, 7 to 7 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 noticed and corrective actions can start up or be implemented immediately. A possible solution is described in the example below. These risks of potential loss of liability and/or reputation are recently more and more taken up in the costs estimations.

Example:

In case one of the OWF boundary is damaged to the point here it becomes idle (red circle), the other 3 windmills connected to the same connection cable will not be able to produce energy to the shore. The loss of 1 wind turbine causes the reduction of energy produced by (in this case) 4 wind turbines. To overcome this problem, a connection can be made between the blocked but working windmill chain and a fully operational chain (green line). However, such a solution should have been planned in the design phase of the wind farm as the connection cable should be able to sustain the addition energy input of extra wind turbines.

Vessel- and OWF owners take a whole list of measures and means aiming towards not needing “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 on the OWF and its respective elements (wind turbines, electrical cabling, transformation stations, export cable...) 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 minimize 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 the OWF or the reestablishment of a loss 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**].

summary of recommendations

7.1 Important notice

Due to their particular character offshore wind turbines and their positioning in an offshore wind 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 information with navigational mitigation-management and emergency procedures; in order to assure this safe and effective navigational safety and emergency response preparedness. The presented recommendations 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, the navigators also can use these guidelines for a safe and efficient practice of navigation in the vicinity of an OWF.

It is important to recognize 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 presented general guidance.

* 1. General recommendations

7.2.1 Identification of interactions

* perform a MSP & MEP (see chapter 2)

7.2.2 Legal background

* a submission to IMO, NCSR sub-committee, should be made for acceptance of general ship’s routeing provision around the OWF (see chapter 3)

7.2.3 Navigation constraints, collision avoidance & marine navigational marking

A Basic rule can be firstly implemented by navigator for OWF zones: "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 safety navigation management plan is to be established, such as:

- analysis of safety distances between shipping traffic and OWF 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 configuration of the water in consideration of the shipping traffic (see chapter 4.1.3);

- Identify local weather oceanic 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) and

- 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: 500 m + 6 ship lengths + 500 m

(i.e. for a ship of 400 m length a minimum distance of 3456 m, which is almost 2 NM)

and

* Portside of any route: 6 ship lengths + 500 meter

- in most cases additional 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 implemented 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 realization determine the risk posed by them and identify the barriers that can be put in place to control the risk by preventing the realization of the hazard and/or mitigating its effect if it does occur (see chapter 4.2.3).

7.2.4 Electromagnetic radiations (EMR)

**RADAR**

- principles to prevent shore-based radar interferences: each radar operator shall be consulted. Radar operators are civil aviation, weather office, national defence, VTS & ports. There may be a competent Authority in charge to coordinate the consultation, but the rules shall depend from the national regulations (see chapter 5.2).

Whatever the distance of vessels from OWF, 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 to its radars for this purpose.

- For ship borne radar navigator should set properly their radar equipment to prevent interferences and good operation of the ARPA.

In case of an improper setting of the radar, false targets and lost of small targets may occurred whatever the distance of the ship from the OWF.

**General guidance for precautionary use of S or X band radar**

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **On board mitigation** | **External mitigation** | **Distance where risk may be significant\*\*** |
| **False Targets** | **Adjust**  **Selected range,**  **Gain** | **Adapt design**  **(eg 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).

It should be noted that especially inside a port, since ships can recognize the range and direction of a shipping route by using marine lights etc., appropriate measures can be examined in each country against the influence on radars caused by an offshore wind farm.

**RADIOCOMMUNICATIONS**

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

* Same conclusion for RDF & others radionavigation systems (GNSS, local radionavigation systems, magnetic compass…)
* For GNSS, 0,7 NM distance to maintain accuracy of DGPS between OWF & ships and OWF and DGPS reference station

7.2.5 Emergency procedures

- 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 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 Maritime Emergency Planning (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 the other way around. In order to avoid a complex identification of separate risks ordered by (direct-indirect) causes, risks are more globally ordered by their nature of consequences. Doing so, the associated emergency management (and consequently emergency planning and response) is also categorized following the 4 basic types of consequences:

1. People (health, safety & security) with SAR as most important emergency action

2. Planet (marine environment) with pollution (oil spill) control as primary focus

3. Property & Assets (materials) with salvage as main emergency measure

4. Professions/Business (socio-economy, liability, reputation...), 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. Vessel and wind farm owners take a whole list of operational measures and means aiming towards not needing “recovery”, or at least reducing the extent of damage when an accident occurs and/or increasing the inherent capabilities for recovery – aiming a limited or very short term recovery. These operational measures and means are mainly covered in a global maintenance contract on the OWF and its respective elements (wind turbines, electrical cabling, transformation stations, export cable...) together with associated insurance coverage.

7.3 Extra notice

It is important to recognize that the table below is not 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:

1. Compliance with the best practices of seamanship and principles to be observed in keeping a navigational watch including the composition of the watch,
2. The manoeuvrability of vessels with special reference to stopping distance and turning ability in the prevailing conditions,
3. Provisions that may be required with mechanical failure of vessels involved and level of support services,
4. The state of visibility, wind, sea and tidal stream, and the proximity of navigational hazards,
5. The traffic density including concentrations of fishing vessels or any other vessels,
6. The draught in relation to the available depth of water and the existence of submarine cables and obstructions,
7. 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 and harbours 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 available for the OWF project will further specify the suggested safety distances in the table below.

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

|  |  |  |  |
| --- | --- | --- | --- |
| 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** | **Intolarable**  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**  (9260 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** |

**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 chaired 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 a port, since it is physically difficult for a ship to evacuate by 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 previous 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

Convention Law of the Sea (UNCLOS), United Nations, available from:

[www.un.org/depts/los/convention\_agreements/convention\_overview\_convention.htm](http://www.un.org/depts/los/convention_agreements/convention_overview_convention.htm)

Navigation Rules (Colregs), USCG, available from: [www.navcen.uscg.gov/pdf/navrules/navrules.pdf](http://www.navcen.uscg.gov/pdf/navrules/navrules.pdf)

Ship’s Routeing, IMO publication, The updated 2015 edition is now available; sales code IF927E (print and e-reader file formats)

Marine Spatial Planning, a Step-by-Step Approach toward Ecosystem-based Management,

Intergovernmental Oceanographic Commission, Manual and Guides No. 53, IOCAM Dossier No. 6, available from: <http://www.unesco-ioc-marinesp.be/pi_publications>

Directive 2014/89/EU, Establishing a framework for maritime spatial planning, 23rd July 2014, available from:

<http://www.eea.europa.eu/policy-documents/directive-2014-89-eu-maritime>

Marking of Man-Made Offshore Structures O-139, IALA, 13th December 2013, available from: [www.iala-aism.org/products/publications](http://www.iala-aism.org/products/publications)

Navigational Safety within Marine Spatial Planning, draft document, IALA, not publicly available yet

Marine Spatial Planning, November 2013, The Nautical Institute, available from: [www.nautinst.org/en/forums/msp](http://www.nautinst.org/en/forums/msp)

Methodology for Assessing the Marine Navigational Safety & Emergency Response Risks of Offshore Renewable Energy Installations (OREI), 2013, available from:

[www.gov.uk/government/uploads/system/uploads/attachment\_data/file/372597/NRA\_Methodology\_2013.pdf](http://www.gov.uk/government/uploads/system/uploads/attachment_data/file/372597/NRA_Methodology_2013.pdf)

Marine Guidance Note 371 (M+F) “Offshore Renewable Energy Installations (OREIs) – Guidance on UK Navigational Practice, Safety and Emergency Response Issues.” Maritime and Coastguard Agency, August 2008, available from [www.dft.gov.uk/mca/mgn371.pdf](http://www.dft.gov.uk/mca/mgn371.pdf)

Marine Guidance Note 372 (M+F) “Offshore Renewable Energy Installations (OREIs): Guidance to Mariners Operating in the Vicinity of UK OREIs” Maritime and Coastguard Agency, August 2008. Available from [www.dft.gov.uk/mca/mgn372.pdf](http://www.dft.gov.uk/mca/mgn372.pdf)

“Investigation of Technical and Operational Effects on Marine Radar close to Kentish Flats Offshore Wind Farm, BWEA (British Wind Energy Association) , April 2007, available from: [www.dft.gov.uk/mca/kentish\_flats\_radar.pdf](http://www.dft.gov.uk/mca/kentish_flats_radar.pdf)

Results of the electromagnetic investigations and assessments of marine radar, communications and positioning systems undertaken at the North Hoyle wind farm by QinetiQ and the Maritime and Coastguard Agency, 15th November 2004, Requests for further information should be sought from: Navigation Safety Branch, Bay 2/30, MCA

Radio Regulations, International Telecommunication Union (ITU) available from, <https://www.itu.int/pub/R-REG-RR>

Annexes to the Convention on International Civil Aviation Organisation (ICAO): Annex 14 Volume I — Aerodrome Design and Operations, contains Standards and Recommended Practices that prescribe the physical characteristics, obstacle limitation surfaces and visual aids to be provided at aerodromes, as well as certain facilities and technical services normally provided at an aerodrome.

Volume II — Heliports, contains Standards and Recommended Practices covering aspects of heliport planning, design and operations. Available from: <http://www.icao.int/publications/Pages/default.aspx>

*Proposals* for the amendment to annex 14, volume I and volume II, 4th June 2015, ICAO, A35 – A40. Available from the Internet

Policy and Guidelines on Wind Turbines, CAP74, Civil Aviation Authority, June 2013, available from: <http://www.caa.co.uk/windfarms/>

Appendix B: Glossary

AIS: Automatic Identification System

ARPA: Automatic Radar Plotting Assistance

COLREGs: COLlision REGulations

CRS: Coastal Radio Station

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

GPSR: General Provision for Ship Routeing

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

MEP: Maritime Emergency Planning

MSP: Marine Spatial Planning

MTI: Moving Target Indicator

NM: Nautical Miles

OWF: Offshore Wind Farm

RDF: Radio Direction Finder

RF: Radio Frequency

SAR: Search And Rescue

SOLAS: Safety Of Life At Sea

TSS: Traffic Separation Scheme

UN: United Nations

UNCLOS: United Nations convention on the law of the seas

UNESCO:United Nations Educational, Scientific and Cultural Organization

VOR: Visual Omni Range

VTS: Vessel Traffic Services

1. Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for maritime spatial planning [↑](#footnote-ref-1)
2. . The concept of MEP was generated by WG 161 [↑](#footnote-ref-2)