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Modelling of Safety Distance Between Ships' Route and Wind Farm

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Abstract

Building of the wind farms in the coastal area of the Polish maritime waters is planned in the near future. Their construction and exploitation will create new threat for safety of vessels operating in their vicinity. Paper presents different estimation methods of the risk of collision between wind turbine and sailing and drifting ships adopted in other countries and their utility assessment for estimation of threats created for safety of navigation and environment by wind farms planned for establishing in the Polish maritime areas.

Keywords: shipping safety, wind electric farm, risk estimation

1. Introduction

Wind turbine on sea is steel construction often over 100 meters high installed in shelf on shallow waters. Electric energy produced in marine farm is transported to the land used high voltage cable. Building and exploitation of wind farm creates new threats for maritime transportation. These threats can be new for this marine area or farm installation can increase and focus already existing dangers. The following risks to shipping were identified to be directly created by the wind farm development:
1. passing powered ship collision with wind farm;
2. drifting ship collision with wind farm.

The following shipping risks were identified to be potentially affected by the proposed wind farm:
1. ship to ship collision;

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2. grounding;
3. foundering;
4. fire/explosion;
5. risk caused by influence of wind farm on worst of navigational and radiocommunication equipment. Estimation of threats caused by include probability assessment of every risk with may arise or change on particular phase of farm building and exploitation and comparison of these results with results for period time before starting of this building. Additionally analyze can include:
    1. expected future dangers from increase ship traffic tension, her speed, displacement and drought;
    2. possibilities of alternation of risk level resulting from future rebuild or extension of farm or exchange of construction of wind turbines.

Poland has not experience in projecting, building and exploitation of wind generators at sea. That's why starting to solve questions connected with location of the farm and creating by its threats for shipping and environment it is necessary to base on other governments experiences. In the next part of the article experiences of other countries in analyzing methods of risk created by wind farm will be presented. Usefulness of these methods for estimation safety of shipping on Polish waters will be validated.

2. Safety Distance Between Chips Routes and Wind Generators Farm Fixing Methods

2.1. Methods choice principles

There are used a few different methods for estimation of probability and consequences of navigational accident connected by building or exploitation of wind electric farm. For areas with low ship traffic or not available sufficient information about its tension, the quantity methods are used. More complicated methods and statistic analysis are used in high traffic areas and for areas with AIS data available. Analysis of accident consequences may be provided with spectrum of statistical methods of qualitative or quantitative analyzes. For getting credible results correctness of starting data is very important. Better resultants are given by so called relative risk analyze, which is less sensitive for errors of input data and simplification of formulas.

2.2. Input data for analysis

Following input data is necessary for estimate probability of collision between ship and wind farm turbine:

1. wind farm data: wind turbines positions, distances between particular turbine, dimensions of turbine tower and marking of these tower;

2. data concerning farm location: coast line shape, depths and bathymetry of the area, sort of bottom, sea level changes;
3. information about ship movement in area around farm based on AIS reports: ships routes, traffic density, type of ships and its parameters (length, width, draft, speed), seasonal, daily and expected changes of ships traffic, standard deviation and statistic decomposition of ships flow in direction perpendicular the axis of traffic flow, and statistic decomposition of courses;
4. hydro-meteorological conditions: direction and speed of wind (on height of 10 m above sea level), height and direction of sea waves, direction and speed of current, ice reports and information about restricted visibility conditions;
5. data on: frequency of engine damage causing the losing of ship maneuver condition, time needed to repair the engine by crew, probability of false drop anchor;
6. data about possibility of tug assistance;
7. probabilities of:
   - human error during planning and providing marine voyage;
   - faults in work of navigational and radiocommunication equipment;
   - failure of farm or ship safety system damage;
   - possible lack of correcting the navigational error by the crew of the ship which is proceeding into collision with farm.

2.3. Calculation of the probability of collision between ship and wind farm used models

For probability estimation of the collision between ship and wind farm may be used detailed models below. These models were created and developed by the organizations dealing with shipping safety:

1. COLLIDE elaborated by Safetec Nordic AS for drill platform and now used for estimation of the risk level connected with wind platforms [1, 2, 3];
2. models prepared by Dutch Maritime Research Institute – MARIN [4, 5, 6, 7]:
   - SOCRA (Ship Offshore platform Collision Risk Assessment) which is a module of MANS (Management Analysis North Sea), model dedicated basely for analyses bounded with drill platform;
   - SAMSON (Safety Assessment Models for Shipping and Offshore in the North Sea) dedicated for analyses bounded with wind platform;
3. CRASH (Computerized Risk Assessment of Shipping Hazards)/MARCS (Marine Accident Risk Calculation System) prepared by Det Norske Veritas (DNV) [3, 4, 8];
4. COLWT prepared by Germanischer Lloyd (GL) [4, 5, 9, 10, 11, 12, 13, 14];
5. COLLRISK which is a property of the British company Anatec UK Ltd [4, 15];
6. DYMITRI prepared by British company British Maritime Technology (BMT) Ltd [4].

Particular above mentioned models utilize from different formulas and different assumptions. In practice more frequently Germanischer Lloyd (GL) and MARIN

– Maritime Research Institute models are used. It results of big number of wind turbines located in these countries. These companies together with Dutch University of Technology prepared studies about collision between drifting and on the way ships and wind farm. In their research three models estimation of risk of the collision were compared. These models were executed by Germanischer Lloyd, MARIN and Det Norske Veritas (DNV) [4]. In the paper these models will be signed by following abbreviations: GL, MARIN and DNV.

2.4. Modeling of collision between ship on the way and wind farm

As it was mentioned previously, models used by MARIN, GL i DNV, are in principles similar. Models GL and DNV estimate potential number of collision and multiply it by so called condition ratio. MARIN model estimates potential number of collision too, but multiply it by other coefficient – so called NER (Navigational Error Rate). Additionally particular models differ in permitted assumption for calculation of number of estimated collision. Precise definition of traffic densities in direction perpendicular to the vector of ship movement is necessary for proper estimation of the probability of collision between ship on the way and wind farm turbine. This density depends on the type of sea way (traffic separation schema, two way fairway, one way fairway, route marked by buoys, etc.). All models assume Gaussian distribution of sea traffic, but in GL and DNV models should be added 2% of uniform distribution (equal to six values of the standard deviation) as steady correction for ships not proceeding inside the sea way. In MARIN method these two groups of vessels (proceeding inside and outside the sea way) are analyzed separately. Standard deviations used in GL model are presented in Table 1. They may be changed depending on local conditions. In MARIN model distribution of ship traffic in direction perpendicular to the vector ship's movement depends on type of the sea way. For traffic separation schema it is a function of measured density of traffic, but for routes not marked by side sea buoy it is defined as normal distribution with standard deviation equal to 1 nautical mile (Nm).

Table 1

Standard deviation of Gaussian distribution of ships traffic density in direction perpendicular to the vectors of the ships movement [4]

Type of area	Standard deviation for statistic Gauss decomposition (Nm)
Port approaches	0,2 – 0,3
Ares with visible navigation marks	0,3 – 0,4
Traffic separation schemat	0,5
Way points on wide sailing routes	0,5 – 1,0
Way points at open sea	2,0

In DNV and GL models width of the zone where collision is possible is calculated as the sum of 1.2 of the ship's width and width of the wind farm element

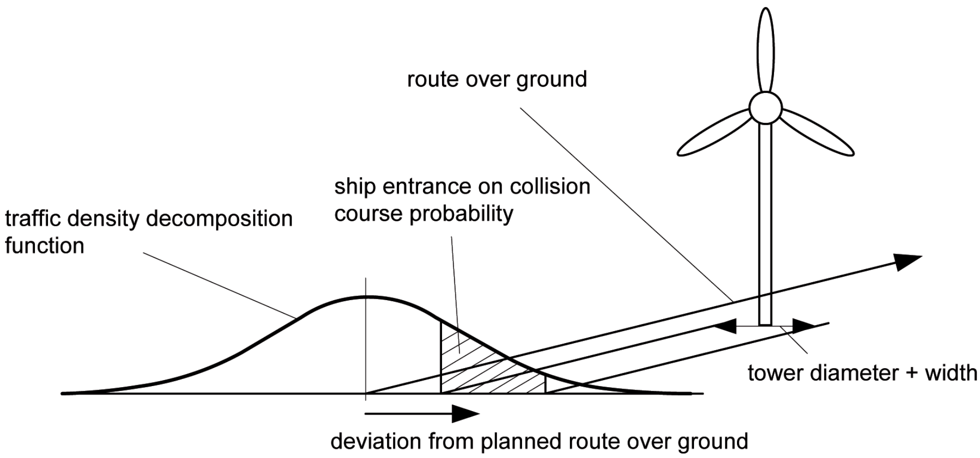

Fig. 1. Gaussian distribution of ships traffic density in direction perpendicular to the vectors of ships movement [4]

measured in direction perpendicular to the vector to vessels' movement in analyzed sea way. Coefficient 1.2 includes correction for ship's drift equal to 2°. For comparison in MARIN model used zone with breadth equal to ship's width only. DNV and GL models utilize additionally correction coefficient for not taking collision avoiding action by the ship considering technical failure and human error. In MARIN model so called navigational error ratio (NER) defined empirically on base of accidents statistics is used instead of correction coefficient utilized in DNV and GL models. Exemplary values of NER are presented in Table 2, [4].

Table 2

Parameter NER for different navigational obstacles [4]

Object	Platform	Island	Wind turbine
NER	1	6	2.5

In particular models are used different kinds of ships' division for classes and types. That is difficult to compare results of analysis conducted using these models. Generally, accounts using GL model are more sensitive to errors of centre line of traffic flow calculation and ships' division errors. The comparison shows that GL calculation is more sensitive to middle route calculation errors and for division errors. The comparison is shown in Table 3 and 4 [4].

Bayess nets are used to estimate the ratio values shown in Table 3 and 4. The aim of using these nets is aspiration to imitate of uncertainly caused by inaccuracies in estimation of the coefficients values and data available from automatic identification system (AIS) and other ships' monitoring systems. Discussed models utilize Bayess net prepared by Danish Technical University for ship's collision analysis for following assumption:

Table 3

Probability of collision between ship and wind turbine [4]

Used model	Distance between centre line of sea way and wind turbine [Nm]			Ratio to multiply by standard deviation			
	0 Nm	0.5 Nm	1.0 Nm	1.00	0.75	0.5	0.25
GL	0.148	0.0481	0.0137	0.1418	0.0542	0.0049	4.3E-08
MARIN	0.0060	0.0024	0.0009	0.0060	0.0040	0.0027	0.0019

Table 4

Sensitivity ratio [4]

Used model	Distance between centre line of sea way and wind turbine [Nm]			Ratio to multiply by standard deviation			
	0 Nm	0.5 Nm	1.0 Nm	1.00	0.75	0.5	0.25
GL	1.0	0.339	0.096	1.0	0.382	0.035	3.0E-07
MARIN	1.0	0.404	0.154	1.0	0.670	0.451	0.313

1. (s)Ships' speed is equal to 7,7 m/s in good visibility (30000 m in daylight and 20000 m during night), and 3,85 m/s in visibilities restricted below 1852 m (1 Nm);
2. 95% of the ships' crewmembers and all officers onboard know that wind farm exists.

2.5. Modeling of collision between drifting not under command ship and wind farm

The models used for analysis of collision between farm and drifting vessel not under common (comply with Colreg) are similar to described earlier models for ship under way.

There is assumed that wind and sea waves act in the same direction and on ship only. There aren't any hull resistances. Speed and drift direction are constant. Collision area is defined like the sum of ship length and wind turbine diameter. The described models differ from a few parameters and from accounting possibility dropping the anchor.

The models comparison is difficult due to different possibilities of ship's drift calculation.

GL and Marin models use different classifications of ship types and classes and that's why it is difficult to compare the analysis results achieved from these models. The GL model is more sensitive to specification of centre line of traffic and standard deviation value in direction perpendicular to the vectors of the ships movement.

3. Conclusions

1. Models presented in this article used in other countries were designated for the North Sea and utilize similar formulas known from ship maneuvering theory.

2. The most important reasons of getting different values of safe distance between ship route and wind farm are different initial assumptions and different probabilities applied in particular models.

3. In the case of Polish waters statistical data from AIS monitoring system are available for many years and due to that quality models and statistic analyses can be used.

4. The biggest problem in estimation of collision probability is lack of sufficient information about number of ship crashes and human error.

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