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# Some Problems of the Offshore Wind Farms in Poland

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ABSTRACT: This paper presents the problems of wind power in Europe and the world, including the concept of the first location of offshore wind farms off the coast of Poland. Taking into account regulatory restrictions and technical opportunities, we can identify, evaluate and select prospective offshore wind farm locations. Obvious concerns are the depth to the sea bottom, the distance from coastline, maritime traffic and geological and climatic conditions.

## 1 INTRODUCTION

After a huge wave of interest in the construction of wind farms on land increasing interest in the construction of offshore wind farms, motivates many European countries, including Poland, to changes in the law, allowing it to such investments at sea (offshore industry). Already in the nineties of the last century began to be interested in siting offshore wind farms. Denmark, the United Kingdom, the Scandinavian countries and the United States have developed a long-term project, which aimed to analyze wind on the sea, finding a suitable location for a farm, explore the depth of water, the formation of the seabed, the routes of shipping, etc.

## 2 OFFSHORE WIND

The potential of offshore wind is enormous. It could meet Europe's energy demand seven times over, and the United States' energy demand four times over [8].

Offshore wind is a relatively new technology, so costs will reduce and the technology will advance, helping offshore wind to be more efficient and cost competitive in the near term. But this exciting technology is already being incorporated into government's energy planning around the world.

More than 90% of the world's offshore wind power is currently installed off northern Europe, in the North, Baltic and Irish Seas, and the English Channel. Most of the rest is in two 'demonstration' projects off China's east coast.

Offshore wind is an essential component of Europe's binding target to source 20% of final energy consumption from renewables, and China has set itself a target of 30 GW of installations off its coast by 2020. The United States has excellent wind resources offshore, and many projects are under development, but there is no offshore wind power installed yet.

The key benefits of offshore wind are:

- The wind resource offshore is generally much greater, thus generating more energy from fewer turbines;
- Most of the world's largest cities are located near a coastline. Offshore wind is suitable for large

scale development near the major demand centers, avoiding the need for long transmission lines;
- Building wind farms offshore makes sense in very densely populated coastal regions with high property values, because high property values makes onshore development is expensive sometimes leads to public opposition.

Figure 1. Example of an offshore wind farm [9]

Although offshore wind is often the most talked about part of the wind sector, today it represents less than 2% of global installed capacity. 2011 installations of about 1,000 MW represented ~2.5% of the annual market. Some projections show that by 2020, offshore wind will be about 10% of global installed capacity [8].

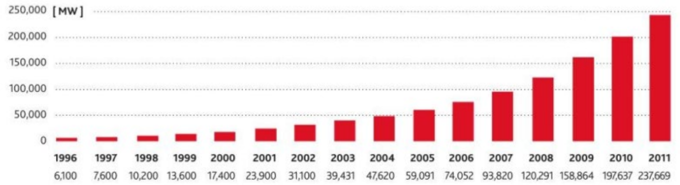


Figure 2. Global cumulative instaled wind capacity 1996-2011 [8]

The European Union has passed the milestone of 100 gigawatt (GW) of installed wind power capacity, according to the European Wind Energy Association (EWEA).

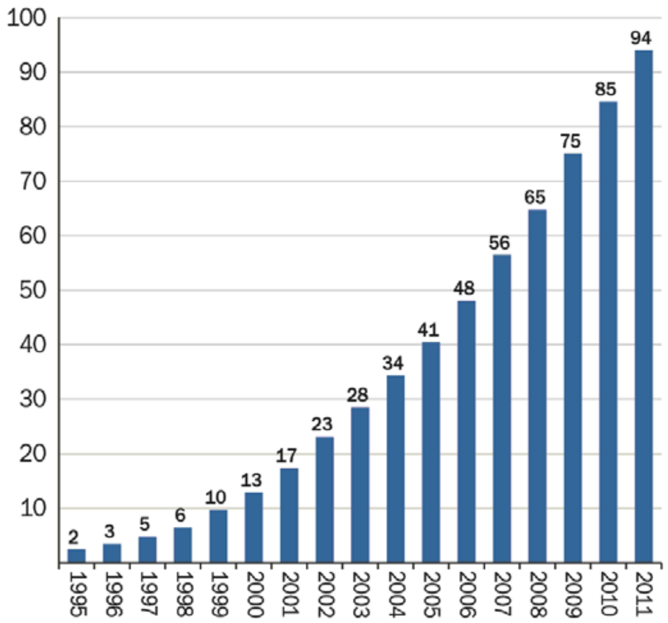


Figure 3. Graph showing progression of European wind energy (EWEA) [7]

100 GW of wind power can generate electricity over a year to meet the total consumption of 57 million households, equivalent to the power production of 39 nuclear power plants. It took the European wind energy sector some twenty years to get the first 10 GW grid connected. It only needed 13 years to add an additional 90 GW. Half of the total European wind power capacity has been installed over the past six years.

Recent wind turbine installations contributing to the 100 GW milestone include [7]:
- Anholt offshore wind farm, 400 MW developed by DONG off the coast of Denmark;
- Linowo, 48 MW developed by EDF Energies Nouvelles Polska in Poland;
- Ausumgaard, 12 MW developed by a private landowner in Denmark (West Jutland);
- Akoumia, 7.2 MW developed by Greek power company PPCR on the island of Crete.

100 GW of wind power can produce the same amount of electricity over a year as [7]:
- 62 coal power plants, or
- 39 nuclear power plants, or
- 52 gas power plants.

To produce the same amount of electricity as 100 GW of wind turbines in a year you would have to:
- mine, transport and burn 72 million tonnes of coal, at a cost of €4,983 million, and emit 219.5 Mt of CO2, or
- extract, transport and burn 42.4 million cubic meters of gas, at a cost of €7,537 million, and emit 97.8 Mt of CO2.

### 2.1 *Wind Turbine*

A wind turbine is a device that converts kinetic energy from the wind, also called wind energy, into mechanical energy; a process known as wind power. If the mechanical energy is used to produce electricity, the device may be called wind turbine or wind power plant. If the mechanical energy is used to drive machinery, such as for grinding grain or pumping water, the device is called a windmill or wind pump. Similarly, it may be called wind charger when it is used to charge batteries.

The result of over a millennium of windmill development and modern engineering, today's wind turbines are manufactured in a wide range of vertical and horizontal axis types. The smallest turbines are used for applications such as battery charging or auxiliary power on boats; while large grid-connected arrays of turbines are becoming an increasingly important source of wind power-produced commercial electricity.

### 2.2 *Wind Farm*

A wind farm is a group of wind turbines in the same location used to produce electric power. A large wind farm may consist of several hundred individual wind turbines, and cover an extended area of hundreds of square miles, but the land between the turbines may be used for agricultural or other purposes. A wind farm may also be located offshore.

As of February 2012, the Fântânele-Cogealac Wind Farm in Romania is the largest onshore wind farm in the world at 600 MW. Many of the largest operational onshore wind farms are located in the USA and China. The Gansu Wind Farm in China has over 5,000 MW installed with a goal of 20,000 MW by 2020. China has several other "wind power bases" of similar size. The Alta Wind Energy Center in California is the largest onshore wind farm outside of China, with a capacity of 1020 MW of power. As of February 2012, the Walney Wind Farm in United Kingdom is the largest offshore wind farm in the world at 367 MW, followed by Thanet Offshore Wind Project (300 MW), also in the UK.

There are many large wind farms under construction and these include Anholt Offshore Wind Farm (400 MW), BARD Offshore 1 (400 MW), Clyde Wind Farm (350 MW), Greater Gabbard wind farm (500 MW), Lincs Wind Farm (270 MW), London Array (1000 MW), Lower Snake River Wind Project (343 MW), Macarthur Wind Farm (420 MW), Shepherds Flat Wind Farm (845 MW), and Sheringham Shoal (317 MW) [7],[8],[10].

## 3 SOME PROBLEMS IN LOCATION OF OFFSHORE WIND FARMS IN POLAND

Taking into account regulatory restrictions and technical opportunities, we can identify, evaluate and select prospective offshore wind farm locations. Obvious concerns are the depth to the sea bottom, the distance from coastline, maritime traffic and geological and climatic conditions.

Table 1. Geographic coordinates determining the position of area B of offshore wind farms

| WP No. | Latitude [00°00'00,0"] | Longitude [00°00'00,0"] |
|---|---|---|
| 1 | 55°06'20,78482" N | 018°01'53,28243" E |
| 2 | 55°06'24,52209" N | 018°03'20,54312" E |
| 3 | 55°05'58,79118" N | 018°04'06,49727" E |
| 4 | 55°05'31,88721" N | 018°05'00,24074" E |
| 5 | 55°05'04,10440" N | 018°05'37,71270" E |
| 6 | 55°04'38,36006" N | 018°06'23,61878" E |
| 7 | 55°04'21,46395" N | 018°07'03,29189" E |
| 8 | 55°03'54,30525" N | 018°08'30,93288" E |
| 9 | 55°03'41,37938" N | 018°09'19,60427" E |
| 10 | 55°02'27,08108" N | 018°09'19,54662" E |
| 11 | 55°02'10,61884" N | 018°01'53,40538" E |

Table 2. Geographic coordinates determining the position of area C of offshore wind farms

| WP No. | Latitude [00°00'00,0"] | Longitude [00°00'00,0"] |
|---|---|---|
| 1 | 55°05'19,23601" N | 017°46'35,24897" E |
| 2 | 55°05'35,40626" N | 017°49'19,54800" E |
| 3 | 55°05'45,97360" N | 017°51'12,92083" E |
| 4 | 55°06'01,65557" N | 017°54'07,58456" E |
| 5 | 55°06'11,34555" N | 017°56'01,35240" E |
| 6 | 55°06'15,59407" N | 017°58'58,04276" E |
| 7 | 55°06'18,65590" N | 018°01'03,57448" E |
| 8 | 55°06'20,76941" N | 018°01'52,92250" E |
| 9 | 55°02'10,61866" N | 018°01'53,04538" E |
| 10 | 55°02'06,00000" N | 018°00'00,36000" E |
| 11 | 55°03'38,54832" N | 018°00'00,36000" E |

The proposed sample location of offshore wind farms (based on a decision of the Polish Ministry of Transport, Construction and Maritime Economy MTBiGM[1]) is described by the coordinates given in Table 1[2] and 2[3]. The first table contains data for the area B (B-Wind Company Poland), next for the area C (C-Wind Company Poland). Geographical coordinates have been plotted on electronic chart of northern coast of Poland using Transas Navi-Sailor

[1] Decision No. MFW/7/12. Minister of Transport, Construction and Maritime Economy. Warsaw, 9 May 2012.

[2] Zespół Morskich Farm Wiatrowych (MFW) o maksymalnej łącznej mocy 200 MW oraz infrastruktura techniczna, pomiarowo-badawcza i serwisowa związana z etapem przygotowawczym, realizacyjnym i eksploatacyjnym. B-WIND Polska Sp. z o.o. [1]

[3] Zespół Morskich Farm Wiatrowych (MFW) o maksymalnej łącznej mocy 200 MW oraz infrastruktura techniczna, pomiarowo-badawcza i serwisowa związana z etapem przygotowawczym, realizacyjnym i eksploatacyjnym. C-WIND Polska Sp. z o.o. [2]

4000 ECDIS simulator system, located in the Department of Navigation of Gdynia Maritime University. Wind Farm Areas are located at a distance of approximately 12 nautical miles north from the Polish coast as shown on Figure 4. West part of Area B is bordering east part of C Area.

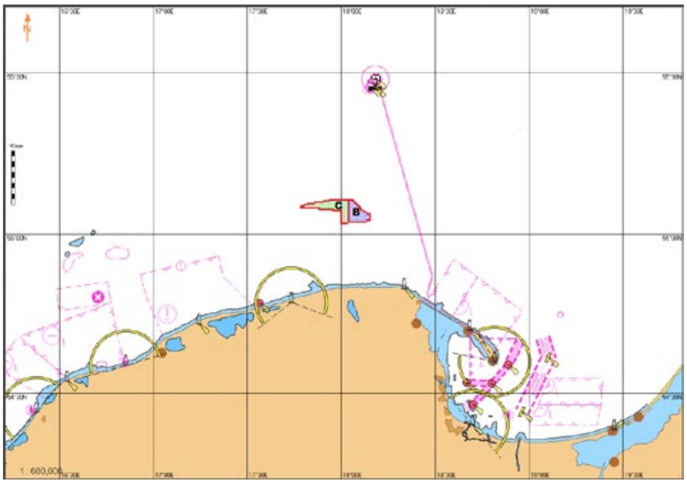


Figure 4. Location of areas B and C of offshore wind farms. Chart scale 1:600 000

The areas considered for future development like installation and operation of offshore wind farms lies on the route of the Stena ferry passenger service between the ports of Gdynia and Karlskrona. Using electronic chart application, an exemplary route (Route01), with 166.8 Nm long passing through the area for future investments has been created. The planned ships route is shown in Figure 5 and following as a continuous line.

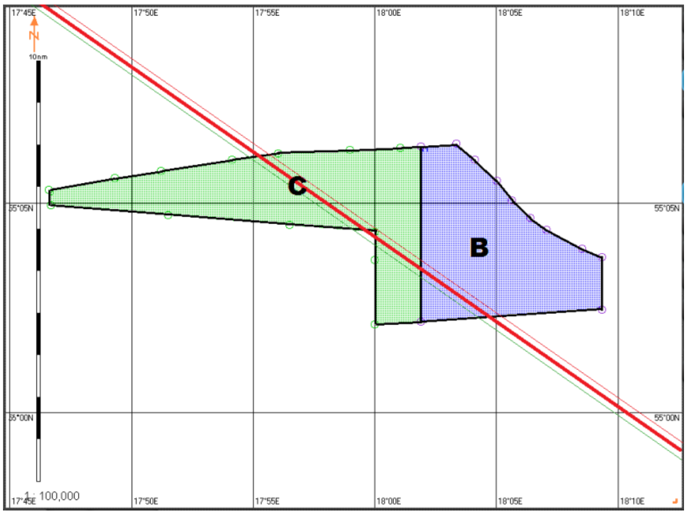


Figure 5. B and C offshore wind farms areas with marked routine route Gdynia-Karlskrona ferry. Chart scale 1:100 000

In the next step two alternative routes (Route02 and Route03) have been created in order to pass development areas at minimum required distance not less than 1 Nm, respectively north and south. Length comparison of the existing routine and alternative routes are given in Table 3.

Table 3. Length comparison of the routine and alternative routes

| Gdynia-Karlskrona | Route Length [Mm] | Length Difference [%] |
|---|---|---|
| Route01 | 166,84 | 0,00% |
| Route02 | 167,03 | 0,11% |
| Route03 | 167,45 | 0,37% |

Differences in the length of the routine and proposed alternative routes by-passing planned offshore wind farm areas are 0.19 Nm and 0.61 Nm respectively, which is less than 0.5% of total length of the route. It can be said that the route extension of a vessel sailing o Gdynia - Karlskrona caused by avoiding the areas B and C is negligible and can be omitted.

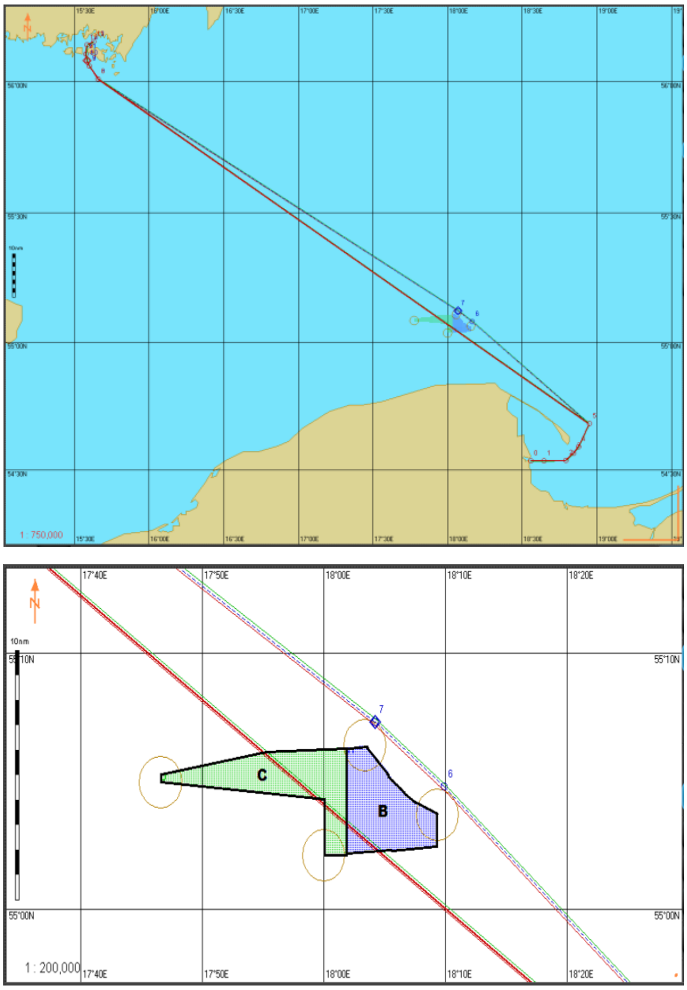


Figure 6. Karlskrona – Gdynia route and alternative route (north option). Chart scale 1:750 000 (upper part) and 1:200 000 (lower part)

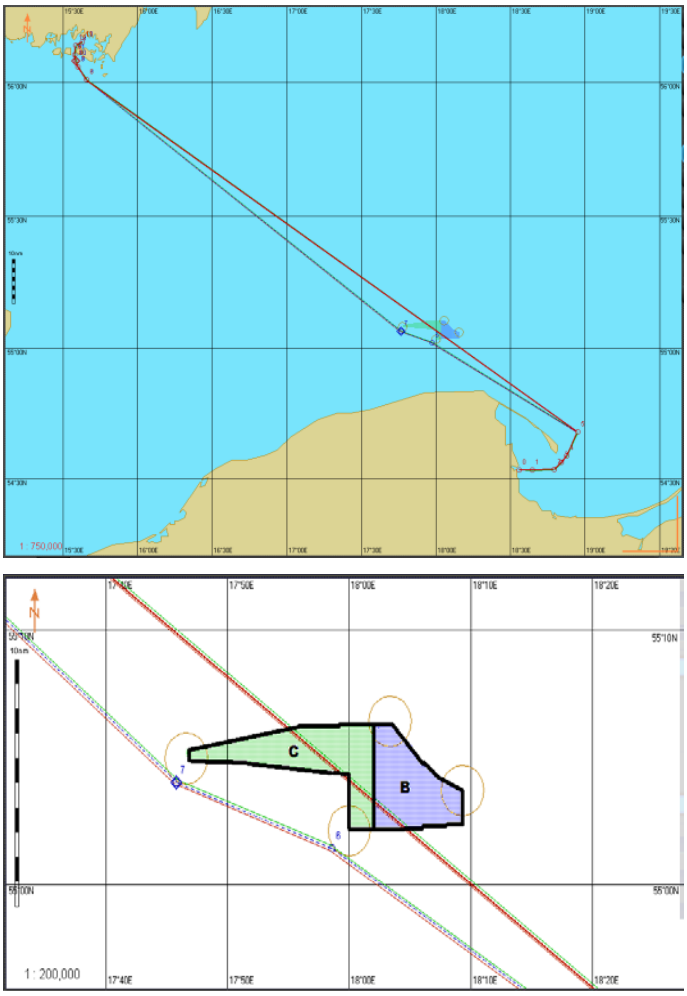


Figure 7. Karlskrona – Gdynia route and alternative route (south option). Chart scale 1:750 000 (upper part) and 1:200 000 (lower part)

It should be noted that the extension of route length is not the only problem to navigation, which faces a ship trying to avoid an not navigable area. To carry out a complete risk assessment on development areas requires to take under consideration all risks which may arise i.e. organization and ship traffic, navigational obstructions, the influence of hydro-meteorological conditions, etc. The proposed investments of offshore wind farm areas construction off the coast of Polish will require the shipping route adjustments. Location of a optimal number of wind turbines on the wind farm on dedicated area will probably cause a lot of problems.

## 4 COMPUTER APPLICATION SEEKING DISTRIBUTION OF WIND POWER STATIONS ON A DESIGNATED MARINE AREA

Based on in-depth study of incoming data, decisions are made about the wind farm concentration and optimisation, the production capacity, the cable routing and subsea crossings, the offshore grid concentration, the selection of wind turbines.

The computer program for the distribution of location of offshore wind power stations has been developed for the Windows operating system in Delphi Environment. The essence of the program is to find the best possible distribution of the points in such a way that compliance with a number of limitations. The basics are:

- the minimum distance between two locations. The assumption in the original version permanently set at 1000 m was carried out as an option to choose from a defined range of values from 500 m to 1500 m
- the arrangement of wind power station. Implemented two default construction of grids:
  - quadratic grid
  - triangular grid
- The margin area. The application assumes constant margin 500 m in size, in which it is impossible to wind the station location. The use of margin space is an option when looking for a solution.

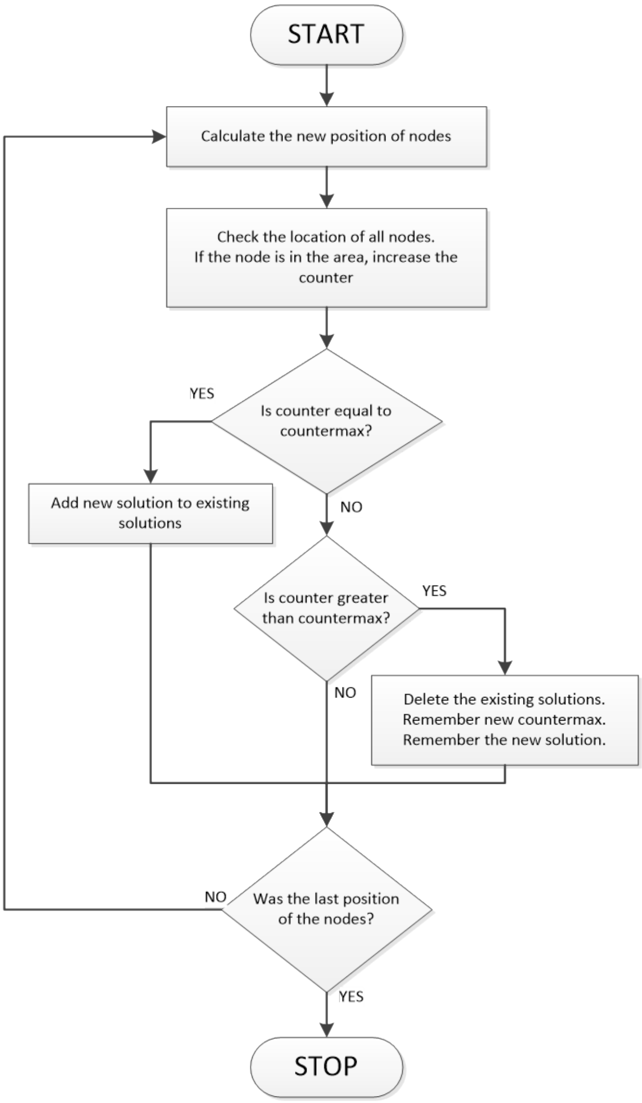


Figure 8. Iterative algorithm calculating the most favorable distribution of wind power station

To find a solution of the problem of indicating the location of wind power station to the given number of them was as large as possible an iterative algorithm proposed, whose scheme is shown in Figure 8.

In this algorithm, network nodes, which can be the location of wind power station, is moved in increments of 10 m until they reach the position of all the nodes of their successors. For each configuration, the node value is computed inside an area, having established margin and its absence. In each iteration remembered the achieved result. If there is a better than previously stored, the current solution as the best is remembered. If the number of nodes is equal to the best known value, the current solution is added to a set of best solutions. Result of the implementation of the algorithm is a set of equivalent solutions, which achieved the highest number of nodes in the search area.

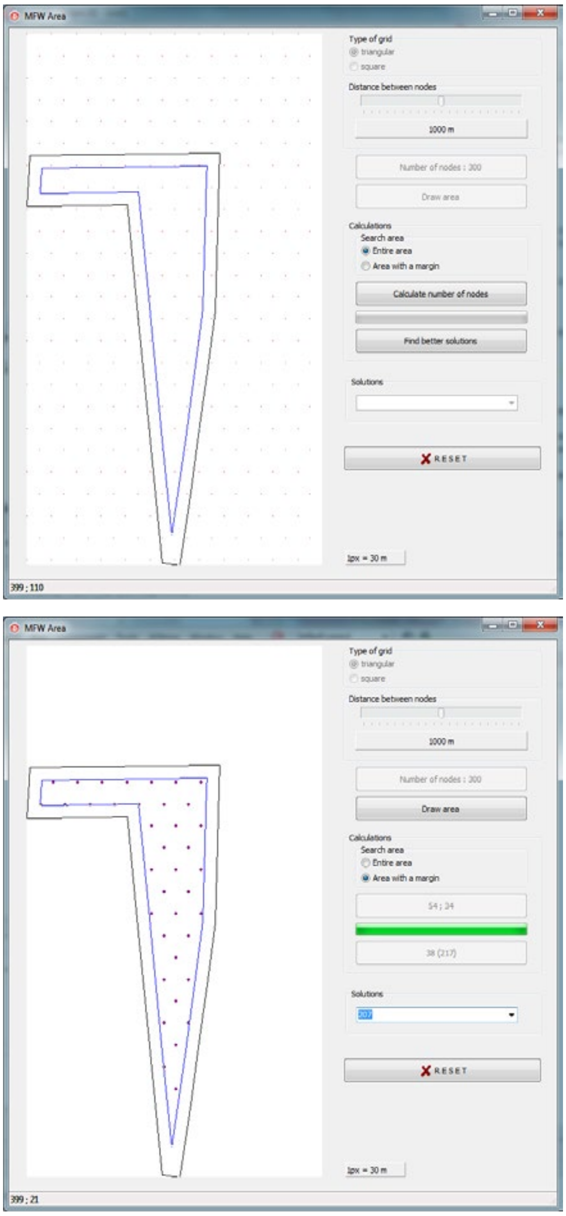


Figure 9. View of window program used for locating wind power stations in the C area (before and after the searching task)

Activity of the application is shown in a certain, irregular sea area, the shape was shown in Figure 9. outer edges of the area. Constitute a restriction on the outer edges of the area, the inner edges are extended 500 m in an internal area in which according to the restrictions.

The first stage of the calculation is to estimate the number of nodes for the proposed grid by default. The default grid is generated independently of the defined area. For this proposed grid solutions are sought in accordance with the algorithm presented a better solution, moving the entire grid of 10 m to the first node in the near future, a square area with sides equal to the minimum distance that can be reached from each other grid nodes (in this example, this distance is 1000 m).

Figure 9 shows the result in which the solution contains 54 default nodes throughout the considered grid size and 34 nodes in the area with a margin.

As a result of the search obtained 217 equivalent solutions, each of which complies with the aforementioned assumptions, the number of possible locations in the area with a margin increased to 38 nodes.

Presented application has been tested on a set area in Figure 9. At a certain fixed distance set at 1000 m analyzed area 300 nodes placed at 500 m - 1,176 nodes and 1,500 meters - 136 nodes. The maximum computation time is satisfactory and amounted to 2.5 seconds.

It is necessary to further the development of applications on adding new functionality. It seems important to implement other solve the search for a better solution. The authors want to look at algorithms to solve knapsack problem [3], namely the cutting stock problem. The use of these algorithms will allow to increase the number of nodes in a given area at the expense of introducing confusion in the structure of the grid. Knowledge on how to increase the number of wind power stations can be useful in decision-making on the implementation of the project.

## 5 CONCLUSIONS

This paper presents the problems of wind power in Europe and the world, including the concept of the first location of offshore wind farms off the coast of Poland. Currently, the role of wind energy in the Polish energy balance is small, but the situation is gradually changing. Polish territory is dominated by wind calm zones. The best wind conditions prevailing in Poland on the Baltic Sea, near Suwałki and the Carpathian mountains. Polish ‘wind basin’ is the coastal belt around Darłowo and Puck.

Unfortunately, the Polish potential development of offshore wind energy will not be used if there is no support from the government. In 2011, came into force the amended law on marine areas, to facilitate the construction of offshore wind farms. So the rules are, but for now, unfortunately, will not see the development of the energy sector. It would be afraid that if there is no clear policy statement that offshore energy is something important for the country, although there are investors and Polish companies could be financial benefits to the state without the government support the offshore wind energy in Poland will not develop.

## REFERENCES


B-Wind (2012). Zespół morskich farm wiatrowych o maksymalnej łącznej zainstalowanej mocy 200 MW oraz infrastruktura techniczna, pomiarowo badawcza i serwisowa związana z etapem przygotowawczym, realizacyjnym i eksploatacyjnym. B-Wind Polska Sp. z o.o.

C-Wind (2012). Zespół morskich farm wiatrowych o maksymalnej łącznej zainstalowanej mocy 200 MW oraz infrastruktura techniczna, pomiarowo badawcza i serwisowa związana z etapem przygotowawczym, realizacyjnym i eksploatacyjnym. C-Wind Polska Sp. z o.o.

Formela K., Neumann T., Weintrit A. (2012): Morskie farmy wiatrowe w Polsce. Technika Transportu Szynowego.

Kopits S. and Westwood A. (2009). Offshore Wind: Time for a Market Take-off? *Renewable Energy World*, 8 October.

PoweratSea (2012). Guided by the wind. Power at Sea N.V. Offshore Energy Development, Belgium.

Sawyer S. (2012): Global Offshore: Current Status and Future Prospects. Potential for mass rollaut. EAEM Guide to UK Offshore Wind, Autumn 2012 – www.eaem.co.uk

http://www.ewea.org/ - official website of the European Wind Energy Association (EWEA)

http://www.gwec.net – official website of the Global Wind Energy Council (GWEC).

http://www.thelivingocean.net/2012/04/marine-life-flourishing-beneath-off.html.

http://www.wwindea.org/home/ - official website of the he World Wind Energy Association (WWEA)