Antropogeomorphologic impacts of windfarms

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Abstract ***– During the establishment of wind farms their close environment can become altered more or less. Artificial forms and processes triggered by the construction and operation of wind turbines can be different depending on the site. There is a several decades long history of the operation of onshore wind farms, so many studies have dealt with their effects on landscape evolution. Anthropogeomorphologic issues of well planned and appropriately carried out projects are insignificant. Continental shelf areas are other sites with growing importance for the establishment of wind farms today. Conditions for offshore projects are different from those of continental ones. There is not much information on the environmental effects of offshore wind farms, since their establishment has begun just recently. Questions raised in this paper have a growing importance together with the growing investments in this field.***

Key words: wind turbines, establishment of wind farms, anthropogeomorphology, onshore and offshore wind farms, reef development

1. INTRODUCTION

The importance of renewable energy sources, thus wind energy is growing in the energy strategy of the World today. The number of wind farms has been multiplied in the past ten years in the EU. Wind energy utilization is popular, since it is clear, abundant and easy to utilize.

Opponents of wind energy utilization criticize the effects of wind turbines on birds, on the landscape and the noise of the turbines. On the contrary to those opinions, many studies have proved that noise loads of wind turbines are under the limits, there are no mass perdition of birds, while the effects on landscape are subjective issues. On the other hand there are much less research carried out on the anthropogenic forms created by the mounting of wind turbines and their impacts on the surface.

To declare that wind energy utilization is really one of the most environmental friendly technologies, every factors should be taken into consideration which can be important from the aspect of the effects of wind farms on their living and inert environment.

This paper focuses on theoretical examination of geomorphologic forms and processes connected to the construction and operation of onshore (mounted on the land) and offshore (mounted on the continental shelves) wind turbines and experimental hybrid systems.

2. DISCUSSION

A. Forms and landscape evolution processes connected to the construction and operation of onshore wind turbines

The base hills of the wind turbines are small positive or negative forms, for this reason classic geomorphic features like fluvial forms, gullies, etc. can occur on them rarely. It can be explained partly by the small size of these forms. Additionally the soil is covered with grass or crushed gravel, what protect them from the erosion of wind or water. The possibility of mass movement processes caused by the weight of the turbines can be precluded, because the construction can only be licensed in statically stable sites [1].

In connection with onshore establishment of wind turbines it can be stated that *the primary form created during the appropriate construction of the turbine do not trigger the formation of any secondary forms; new landscape evolution processes, or modifies significantly the working processes*.

B. Forms and landscape evolution processes connected to construction and operation of offshore wind turbines

There has been a tendency in the establishment of wind farms for moving from the land into the continental shelves in coastal countries recently. The part of offshore wind turbines reached only 680 MW (less 2 %) within the 40 500 MW total installed wind power capacity in Europe in 2005, but, according to the EWEA (European Wind Energy Association), their ratio can reach 30 % by 2020 and even 50% by 2030 [2].

The main reason for the investments in the field is the higher effectiveness and profit rate of offshore wind turbines. The better wind profile originated from the low roughness over the sea surface provides 40 percent more energy. There are other advantages of offshore wind farms over onshore ones: the area of individual wind farms is not limited; the environmental protection licence procedure is simpler than in the case of onshore wind farms.

Although the establishment of offshore wind farms is advantageous from the aspect of energy production, they can cost more even by 60 percent. Higher costs are originated not from laying the foundations or construction, but from the more complicated process of laying the submarine cables. Higher losses of electric power during long range transportation must be taken into account also.

Beside economic possibilities it must be taken into consideration as well that the sea bed does not remain undisturbed under offshore wind farms. Offshore wind turbines need much stronger fundamentals, since, due to its higher density, moving sea water exerts much higher pressure on the trunks of the towers of wind turbines than the flowing air. Different conditions require different building technologies, stronger concrete structures have to be used (Figure 1.)

Figure 1.
Main phases of the establishment of offshore windparks
(source: [3])

In order to decrease costs, out of the way sites with water depths between 5-10 meters are preferred, although it is possible to lay the fundamentals and cables for the turbines even into 40 meter deep waters. In the case of most of the planned German wind farms in the North Sea, water depths are between 20-40 meters, what cause high additional costs. In waters shallower than 10 meters, the base for the wind turbines is made of concrete, while in deeper waters, due to its weight, the base is made of steel. It is advantageous, since it can be put together in the land and it is adjustable to any types of sea beds. Nevertheless, it is still necessary to prepare the site: divers have to clear deposits from the seabed and a gravel bed has to be laid before the construction [4].

The huge steel-concrete base hill is much more a positive form on the sea bed, than in the case of onshore wind turbines. For the crane, which lifts the elements of the turbine a stable platform is required on the seabed. For this reason, the sea bed is disturbed not just under the fundamentals of the turbines, but under the platforms of the cranes either. Anyway, strongest disturbances of the sea bed are caused by laying the submarine cables for the turbines.

The process of the construction of offshore wind turbines does not create significant new geomorphic forms or processes. On the other hand – in the authors' opinion – mounting the fundamental structures of the wind turbines into the sea bed can affect the surface evolution processes in the shallow water environment and can lead to creation of new forms.

Towers and – depending on the depth of the water – even the base hills of the turbines can alter the dynamics of waves. On the sides of the towers of turbines facing the waves, processes characteristic for abrasion shorelines occur: waves brake on the vertical concrete and steel bodies of the towers. Braking of the waves results in much smaller "micro forms", than in abrasion shorelines at the base of the towers on the sea bed. Their small size is a consequence of the relatively small surface of the tower trunk under sea level and the diffuse spacing of the towers.

Basement embedded into the sea bed can have a significant impact on the mass movements on the sea floor. These artificial bodies do not alter the flows of the water directly but they pose as obstacles for the currents.

Coarse material rolled on the sea floor can be trapped at the base of the tower directly; or indirectly, it can loose major part of its kinetic energy in the collision with the tower body, it will be deposited in the front and along the sides of the tower. Due to water movements from the opposite direction (the soog) from the shores deposition of coarse grains can occur behind the tower as well (Figure 2). Microforms of the abrasion terrace will not affect strongly the developing form, since material transport towards the shores evens the roughness of the sea bed. The size of the new form and the time of its development is determined mainly by the amount of deposits.

Along the coast lines of North Germany the depth of water exceeds 10 meters at a distance of several hundreds of meters from the coast only. Some 10 meters wide, moving underwater bars run parallel with the coast on the abrasion terrace there. Under permanent and even winds and waves, they move towards the coast, but in a strong storm due to the violent soog, they withdraw towards the deeper waters. The process of their development is not clear in every detail, but it can be assumed that they form due to the collusion of the coastward and seaward currents [5].

It is a hard task to determine the shape of the reef formed on the sea bed on a purely theoretical base. If the strength of the two currents equals, the shape will be symmetric. However it is clear from the before mentioned facts that the strength of the currents is different, so the shape of the accumulation form will be deformed into one direction.

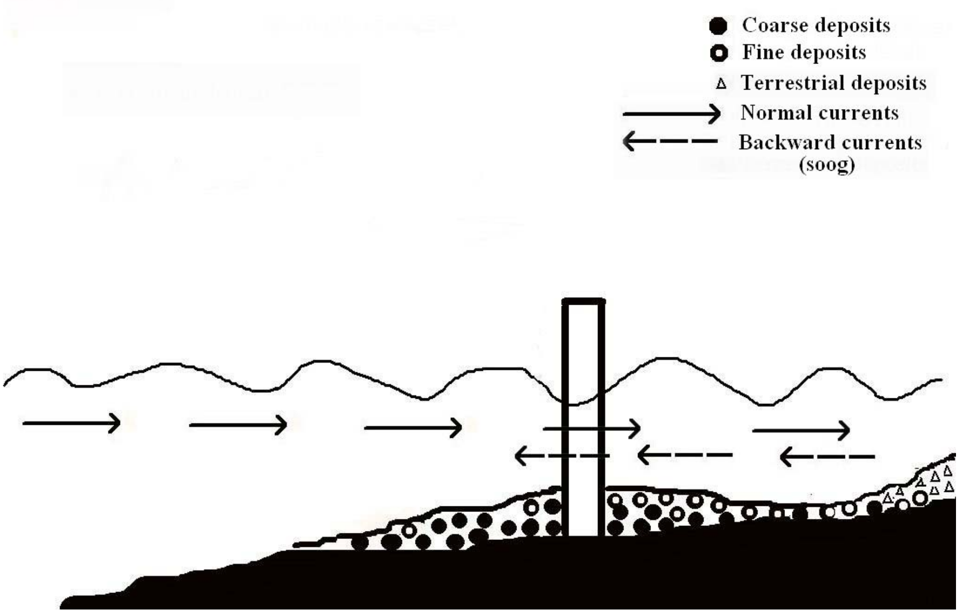


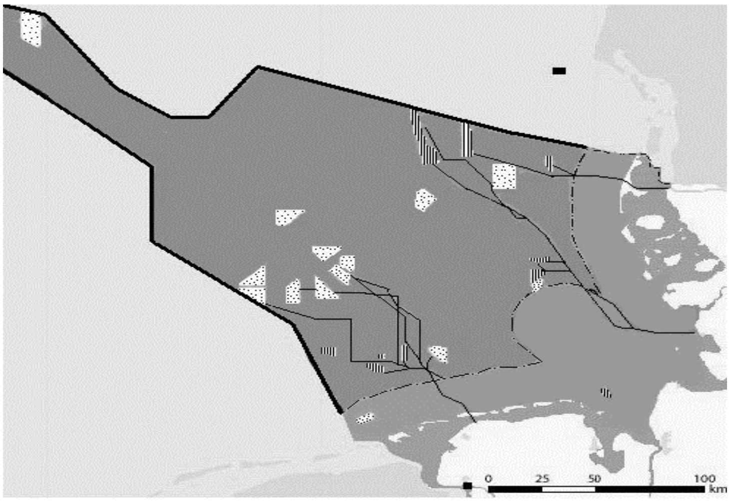
Figure 2.
Developement of accumulation forms in the environment of a wind turbine.

The role of underwater moving bars should be taken into consideration also, since the towers of wind turbines mounted on abrasion terraces can alter those unique interactions between the currents there. If there is a visible and measurable effect of the base hills and tower trunks within a short period of time, it is necessary to take into consideration that the planned life span of those objects in the seabed is 50 years.

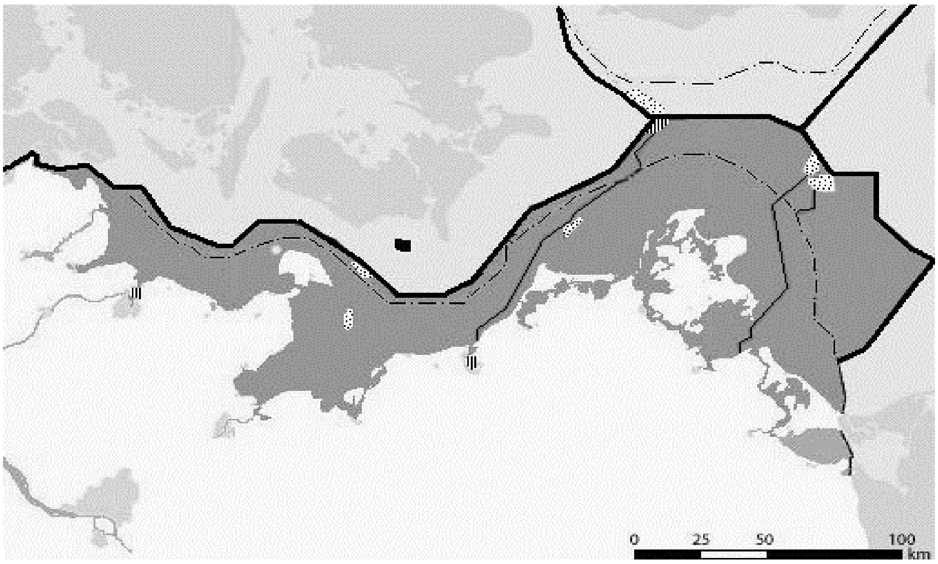
Without field measurements and experiments it is impossible to determine the parameters of the developing forms, but on the base of the before mentioned facts it seems quite probable that in the environment of the wind turbines rather special accumulation forms can develop. Those reefs can be interesting not just because of the special way of their development, but because of their potential effect on navigation. Although (anthropo-) geomorphologic concerns of this "impact assessment" are not based on measurements, but they are merely hypotheses, the authors believe that they can emphasize the importance of the issue, triggering further investigations into the topic what can prove or disprove the hypotheses.

In countries which have huge wind farms, the relatively old low capacity turbines have been being replaced by new high capacity ones, which can produce several times more energy in the same area. Cables, the fundamentals and the towers are left in the sea; new turbines are mounted on the former structures. That way, investors spare the costs of laying submarine cables, building fundamentals and towers. At the same time, the number of new offshore wind farms grows dynamically as well, together with the increasing popularity of renewable energy utilization.

First offshore wind farms were established in Denmark in the early 1990-s. Establishment of huge, high capacity offshore wind farms, like Horns Rev (80 turbines, 160 MW), or Nysted (72 turbines, 165.5 MW) have taken place since 2002. Establishment of huge wind farms is expected in the future also, since there are plans for the establishment of 4 000 WM offshore capacity by 2030 in Denmark alone. There are similar plans in Germany too: the establishment of 27 820 MW of total capacity is planned on the German seas (Figure 3.). Most of it (25 242.5 MW) will be situated in the North Sea. The greatest wind farm will have 980 turbines with a total capacity of 4 720 MW. At the same time more moderate planes are there for the Baltic Sea, where 2 577.5 MW of total capacity is planned [6].



North Sea



Baltic Sea

Border of the continental shelf
·—·— Border of abyssal zone
—— Power cables

Online (working) wind farms
:: Licenced windfarms.
‖ Windfarms under licencing procedure

Figure 3.
Offshore windparks in Germany
(source: [6] modified by the author)

For offshore wind farms those areas are suitable which are situated outside of the National parks, navigation lines and military areas. In Danemark most of these territories are situated within 7-40 kilometres off the coasts, while the before mentioned German wind farms (mainly in the North Sea) are situated at a distance between 70-100 kilometres from the coasts. Infrastructure for the transportation of electric power is very expensive and there are significant losses of power during the transportation. Additional problem for laying the submarine and ground cables is that many coastal areas belong to national parks.

Establishment of offshore wind farms is of high importance, because in the land a wind farm with 25 turbines and 50 MW of capacity, can not get licence due to environmental and landscape protection causes if its area exceeds 1.5-1.6 km^2 [7]. First offshore wind farms in Germany started operation in 2006. On the base of the plans for wind energy utilization for that region and the characteristics of the North-, and Baltic Sea coasts (water depth, development of the bars and lidos), the before mentioned hypotheses is not unfounded. It is supported by that, most offshore wind farms were established only a few years ago. They are the newest types of practical wind energy utilization. For this reason there are not any long time series of monitoring data on their impacts on the environment. Therefore it would be reasoned to carry out detailed examinations on the questions raised in this paper, since – if there are real problems – extensive research, appropriate planning and realization could prevent anthropogenic landscape evolution processes in those coastal regions.

3. CONCLUSIONS

Wind turbines produce electricity in a clear and environmental friendly way, but in the meantime they can slowly alter their environment.

Onshore wind farms do not create any significant geomorphic forms. Despite their enormous weight, turbines do not cause mass movements, since territories which are hazardous from that aspect are banned. Levelled surfaces and roads created for the construction works are small in area and later they are integrated into the road network as parking places or recreation areas, or they are recultivated.

Offshore wind turbines can alter the mass movement processes of the sea bed significantly, which can affect navigation in those areas.

The degree of the alteration of former natural processes and the extent of new effects should be determined by further detailed studies.

It can be stated that (anthropo-) geomorphologic effects of instruments of wind energy utilization are insignificant compared to those of fossil fuel exploitation or the utilization of hydropower.

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