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Possibilities of wind energy utilization

Introduction

The wind, the sun-transformed energy is a horizontal or vertical movement of air, which is caused by the difference in pressure, altitude or by the Coriolis force. Wind energy potential is large due to its inexhaustibility, periodicity and speed. The roughness of the terrain affects the opportunities to develop wind farms. The most profitable sites for the construction of a farm are the sea, which in comparison to the forests and urban areas has the lowest roughness and fairly smooth surface, which does not hinder the movement of the wind. The construction of wind farms is not possible in all areas of our planet. For example, more than half of the Polish areas are suitable for construction of wind farms, but the best sites for the construction of the farms are on land around the coast and beyond. The strength of the wind on the maritime areas is much higher than in other areas, and these systems give more power with comparable surface of the rotor, which is also a result of a lower roughness.

Wind contains a continuous and inexhaustible energy, and this is why people began to use it to produce electricity. It is a renewable energy source that does not have a negative impact on the environment. Advances in the technologies of energy production from wind are becoming substantial and cause a drop in energy prices. Wind turbines are involved in the conversion of wind energy into electrical energy by mechanical means.

Wind power plants can be described due to their power. We can find micro, small and large turbines.

Micro and small wind turbines are most commonly used in households. The use of micro wind turbines with power less than 100 W is usually limited to charge the batteries. Small wind turbines with outputs ranging from 100 W to 50 kW have a wider range of applications. They are able to provide energy to households. Large wind turbines with power greater than 100 kW provide the ability to sell generated energy to the power grid [1].

Another criterion for categorization is the height of the wind turbine rotor location. Wind turbines can be distinguished as small and large. Large wind turbine

rotors are placed at a height of 70 to even 120 meters. In contrast, the rotor of a small wind turbine is placed at a height from 1.5 m on the roof to 15–20 m above the ground [2].

One of the main criteria is to identify the rotation axis of the rotor. Wind power plants are divided into a horizontal rotation axis (HAWT) and the vertical axis of rotation type (VAWT). Higher efficiency and greater possibilities of utilizing wind power is seen whilst comparing horizontal axis with vertical axis wind turbines.

Wind power plants can be identified due to the number and the specific speed of rotor blades. To take into account the specific speed we can find: low, medium, and high speed rotor blades.

Wind turbines can also be distinguished on the up-wind and down-wind. Up-wind turbines are the most popular. The wind is directed to the front of the machine. According to this construction it is necessary to direct the movements of the wind. There is a need to place the rotor at a considerable distance from the tower in order not to hit it and the rigid structure of the blades. In contrast, down-wind turbines have a rotor, in which the wind falls passing through the nacelle and pole [3].

Regarding the general characteristics of selected applications of wind turbines with a horizontal axis, the most characteristic and common is a three-blade power plant. They are very quiet in their work, and are characterized by a constant moment of inertia of the rotor. The advantage of them is the strength of the structure, light weight and relatively quiet operation. Regarding a two-blade power plant, they give an excessive noise caused by the higher speed of the rotor rotation. One-blade wind turbines are not often used, and their design requires a balancing of the propeller. By contrast, turbines with multiple blades are not currently popular.

Wind turbine with diffuser is quite specific and differs in its construction from the most commonly used rotors. The operating principle is based on the Bernoulli law. The rotor of this construction is located in the tunnel. In this tunnel, the rotor spins in the air flowing faster than outside and provides a higher amount of energy. The tunnel also protects the environment from a potential destroyed rotor. The Magnus effect is utilized by another wind turbine. Force perpendicular to the direction of movement of fluid (liquid or gas) is formed on the rotating roller. Working rollers are very quiet in their work and very strong in their construction and they begin working at wind speed of 3 m/s [3].

Wind turbines can act as autonomous systems or as systems connected to the grid.

Devices that produce or consume electricity are the power system. Their function is to provide energy to customers. Power system can distinguish between power plants (manufacturing subsystem), transmission and distribution (power grids subsystem) and receiving systems. Regarding the electricity networks, there are devices that transmit, change and distribute the energy coming from the power plant to the selected areas [4].

Wind turbines in the electricity networks in Poland

The national electricity system converts electricity from large thermal power plants operating on coal or lignite, urban and industrial power plants, and from hydropower and other plants using renewable sources of energy (mostly wind energy) [5].

Power plants of the largest production capacity using non-renewable resources are power plants in e.g. Bełchatów, Kozienice, Turów, or Połaniec. Here we see the great advantage of producing electricity from coal- and lignite-fuelled power plants. Power plants of the largest production capacity using renewable resources are hydropower plants in e.g. Żarnowiec, Porąbka-Żar, or Solina-Myczkowce. You may also see an ever-growing share of energy from renewable sources, which in subsequent years can bring quite a sharp increase in energy.

Energy transmission from power plants is possible through a network and power stations. Power transmission also includes losses resulting wherefrom. We can compensate losses by regulating or increasing voltage. The values of applied voltage depends on the distance of transmission and we can find a network of highest voltage (NN: 220 kV, 400 kV and 750 kV), a network of high-voltage (HV: 60 kV and 110 kV), a network of medium voltage (MV: 3 kV 6 kV 10 kV 15 kV 20 kV 4 0 kV) and a network of low voltage (LV: 0.4 kV 0.5 kV 0.66 kV and 1 kV) [6].

The transmission network (as of December 31, 2013) consists of 246 lines with a total length of 13 519 km, including one line with a voltage of 750 kV with a length of 114 km, 77 lines of 400 kV with a total length of 5 383 km, 168 lines of 220 kV with a total length of 8 022 km, 103 stations, highest voltage (NN) and 450 kV submarine DC Poland – Sweden connection with a total length of 254 km. Due to the function one can distinguish the transmission and distribution lines. Transmission lines (NN) and 110 kV (WN) may exist as overhead transmission lines or cables. Wires in overhead lines are mounted on poles with insulators, while cables are installed under the ground or water. Transmission networks draw power from power plants, provide it to a variety of audiences and deal with the exchange of power between the states [6].

Distribution networks are used to separate energy and to collect the power points. Distribution networks are: municipal electricity networks (MSE), all-terrain electric power networks (TSE), industrial electricity networks (PSE), interior power networks (SEW) [6].

Super Grid is an international network of High Voltage Direct Current (HVDC) networks, which enables the transmission and production of energy in the very long distances with little loss of power. The aim is to create a network of shared energy between the member states of the European Union and produce clean energy from, inter alia, offshore wind farms. The European Union is trying to cope with the energy policy aims and create a common energy market and give competition to other countries on the international arena. The network is quite an expensive and long-term investment, but it has the potential to bring great influence on the

development of the energy sector around the world [7]. Super Grid allows for the use of offshore wind energy, which depends on the weather conditions. When adverse weather happens in a given location, it is possible to draw energy produced elsewhere in the grid so Super Grid provides a continuously reliable power. Quite smaller than the Super Grid concept but using the same technology is the transmission by nodes. It is an idea significantly cheaper than the individual connection to the power grid, which is usually used in the construction of offshore wind farms. The principle of operation of this type of solution is to join a couple of connections into a single network node, which as the only one is connected with electricity network [8].

The European Union faces the challenge of filling the principles of the Climate Package. It foresees the reduction in greenhouse gas emissions by 20%, an increase of renewable energy by 20% and increase of the energy efficiency by 20%. In addition to these principles of the EU, member states are required to bring smart grid and metering systems in general. Smart grids with communication between the different modes of the energy market supply energy at lower costs, increase efficiency, and gather all renewable sources. This results in reducing carbon dioxide emissions and air pollution. Smart grids bring the reliability of supply to customers, and elimination of electrical losses. They help produce the right amount of energy in a continuous population growth. As regards the benefits for power plants from the construction of smart grids, this gives the ability to anticipate the needs for energy and eliminates the power outage. Consumers will feel the effects of smart grid through smart meter that will send customers information about current energy prices, which will give a discount and show electricity consumption. The consumer will get the information when it is best to perform daily activities [9].

Wind farms

In areas of good weather conditions many units of turbines that produce energy, i.e. wind farms, are built. Onshore wind farm is built no closer than about 300–350 meters from built-up areas and no less than 1 km from Nature 2000 sites.

Wind Power took the lead in the Polish market for renewable energy in 2011, before the forefront of hydropower. The number of installed capacity in Poland on September 30, 2014 amounted to 3 668.277 MW and the number of working installations was 902. Production of electricity with wind power in 2014 is above 4 529 344.790 MWh (Table 1).

Tab. 1. Production of electricity with wind power in the years 2005–2014 (Based on Certificates of Origin issued by the President of the ERO, September 30, 2014) [6]

Year	Amount [MWh]
2005	135 291.630
2006	257 037.412
2007	472 116.429
2008	806 318.563

2009	1 045 166.230
2010	1 823 297.061
2011	3 126 526.394
2012	4 524 473.670
2013	6 073 903.230
2014	4 529 344.790

It is, however, one of the lowest in Europe, as the installed capacity and power unit per capita is only about 0.106 kW. The largest wind farm in Poland is Margonin with 120 000 kW, which consists of 60 wind turbines [10].

Table 2. Top ten wind turbine suppliers

No.	Supplier	Country	Percentage of the market share
1.	Vestas	Denmark	13.2%
2.	Goldwind	China	10.3%
3.	Enercon	Germany	10.1%
4.	Siemens	Germany	8.0%
5.	Sulzon Group	India	6.3%
6.	GE	U.S.	4.9%
7.	Gamesa	Spain	4.6%
8.	United Power	China	3.9%
9.	Ming Yang	China	3.7%
10.	Nordex	Germany	3.4%

Offshore wind farms develop at a rapid pace from year to year. Despite the large investment of costs, this is one of the most cost-effective and developing renewable energy sources in the world. Offshore wind farms are based on the experience of onshore wind farms. A very important part of an offshore wind farm operation is its connection to the network. The infrastructure is located inside the open farm, in which the cables run with current generator through the tower to the main point of power supply substation. Current is converted there to a higher voltage and goes to the national power system (NPS).

As regards the variety of wind turbines, we can say that each company has individual models. Worldwide turbine manufacturers are companies such as Vestas, Goldwind, Enercon or Siemens. The list of top ten wind turbine suppliers indicates that five suppliers cover the needs of almost half of the wind turbine market (Tab. 2) [11].

Comparison of offshore and onshore

Offshore wind farms in comparison with onshore one have, in addition to the differences in the construction of foundations, disparities in the conditions of placement. The best use of the wind is possible in areas with minimal roughness of the

terrain. So it is at sea where wind farms are located, far from land and so to a lesser extent contribute to the impact on the environment and acoustics.

Wind blowing over the sea is stronger than that on the mainland. Distance of about 40 km from the shore results in an increase of the wind speed by up to 25%. The advantage of the construction of offshore wind farms is the production of energy. During the operation of the farm with a capacity of 1 GW, it is able to produce more than 80 TWh, while onshore farms produce only 50 TWh. Offshore wind farms have also a couple of significant disadvantages compared to onshore wind farms. They have high construction costs, because they are much higher than conventional land-based structures. High maintenance costs and transport of heavy parts of the structure also contribute to the disadvantages of these investments. The disadvantages include the substantial costs of underwater transmission cables and disorder in the environment, like barriers to fish migration or negative effects on fishing and shipping. The advantages and disadvantages will not change the fact that both wind energy locations contribute to improving the lives of societies. Wind power plants contribute to the reduction of greenhouse gas emissions and do not increase emissions of carbon dioxide into the atmosphere. They are an inexhaustible source of energy and able to develop new construction technologies [12].

Energy from offshore wind farms becomes nowadays more and more profitable. Investments are quite large but very rewarding, too. Offshore wind energy has become a kind of connection between the countries of the European Union. As we know, the EU countries aim to obtain the substantial expansion of energy from renewable sources and to create a single energy market. The creation of offshore wind farms in the Polish economic zone of the Baltic Sea would bring many ecologic, economic, and social benefits to our country. Polish wind farm potential by year 2020 may reach up to 1 GW. According to the forecast, by the year 2030 the potential of Polish farms can achieve up to 10 GW. This sector size would bring great opportunities for employment, up to 9000 new workplaces (based on UK and Germany data). So far in Poland there are no offshore wind farms or there is no advanced stage of development investment. However, since 2009, there are already investments of all kinds planned and they estimate the creation of the first Polish farms before the year 2020. Relatively shallow and not far away from the shore regions are best areas suitable for the construction of wind farms. The availability of land for building farms in Polish economic zone is approximately 3500 km^2, however, taking into account the economic conditions (bottom depth and distance from shore); surface is within the range of a little more than half of it.

Conclusion

Poland is expected to reach 15% of energy from renewable sources by 2020, but the objective will be achieved probably only by cheaper sources and will be supplemented by more expensive ones. It is planned after reaching 15% from renewable energy to terminate the assistance to fund green energy. The construction of

offshore wind farms can provide Poland many ecologic, social, and economic benefits. Offshore wind farms are a stimulus for the development of coastal regions nearby of ports. The demand for port services in these places will be significant. This will be a chance to stimulate the Polish steel industry and shipbuilding. One will need to supply large-scale structures, cables and electrical equipment. We will need equipment to move the construction over long distances and we will need technicians to repair equipment and the construction. All this needs its warehouses, offices and manufacturing.

Harbour town will expand not only in the neighbourhood of ports and shipyards, but will be expanded throughout the cities. More tourists will frequently use the services on the sea and in the vicinity of offshore wind farms. Farms can bring many benefits to the public finance sector, the impact on the labour market or regional development. Building of farms will bring many new jobs in various positions. The work will get people connected with energy, tourism and construction sector. Poland can also expect with great possibility an increase in the security of the state by entering the European Super Grid project. We will also increase our share in the production of energy from renewable sources and significantly expand our efficiency in the implementation of the climate package 3x20.

We have enough great potential; we have some major investors that specialize in wind energy. I think the wind energy sector will bring us many benefits and will also be very profitable for investors.

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Abstract

The continuous increase in the concentration of carbon dioxide and rising energy prices due to depletion of non-renewable energy sources is forcing in many countries of the world exploration of new sources of energy. One of the most utilized sources is wind. Wind energy sector is one of the leading global manufacturers of green energy. Wind energy sector is developing very well in terms of technology and is still moving forward. It is a leader technology to fight against global warming. Wind power can be used on- and offshore. So far, onshore structures are the most popular forms of transforming power of the wind, but offshore technology for a few years has been standing out in a high speed. The paper points to the technologies and capabilities of wind energy development.

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