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Wind Energy for Sustainable Development as Applied to the Kaliningrad Region of Russia: Technical Aspects

Abstract. Sustainable development means the shift towards the use of sustainable renewable energy sources. The development of wind energy is certainly one of the most successful examples of how to do this. Wind power engineering is the fastest developing branch of the global energy industry. In 2014, the world reached the highest level of new wind turbines installed, a capacity more than 51 GW. This means that the share of wind in total electricity production is increasing, reaching, in some countries, outstanding values (for example, 39% of total electricity consumption in Denmark in 2014). The total capacity of a new wind turbine is comparable with the biggest traditional electrical power plants and the total installed capacity of the energy system. However, it causes specific problems of interconnection, operation, and putting such installations in traditional energy systems with traditional energy sources. There are good chances that the Kaliningrad region energy system in the nearest future would have to go into isolate operation because of the disconnection of Lithuanian, Latvian, and Estonian energy systems from Russian networks. If that is the case, the development of wind energy in the Kaliningrad region could become one of the most attractive options for a sustainable future of power engineering.

Keywords: wind energy, sustainable development, energy system, mathematical model

1. Introduction

Wind power engineering – is the fastest growing sector of the world energy industry. The highest history level of the wind turbines annual installed capacity of more than 51 GW (Chart 1 and Table 1, GWEC 2015), was recorded in 2014.

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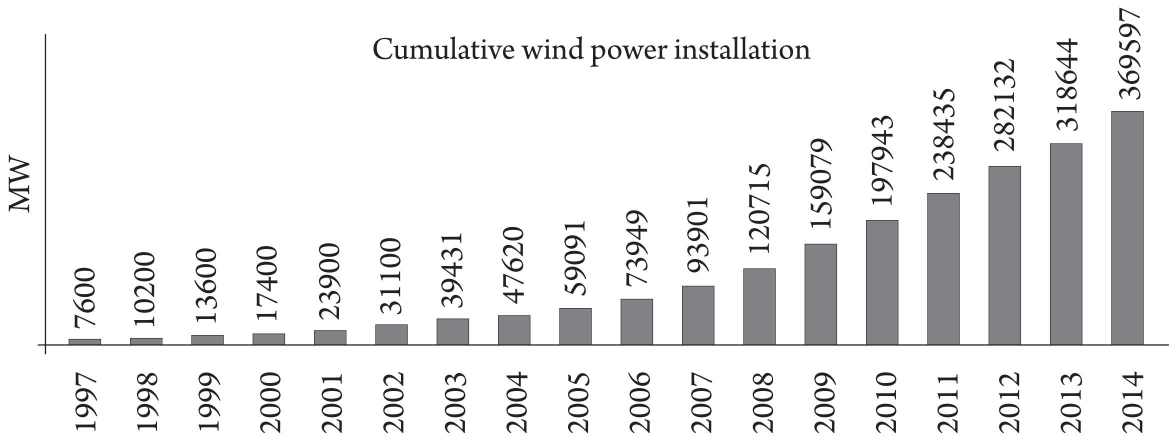
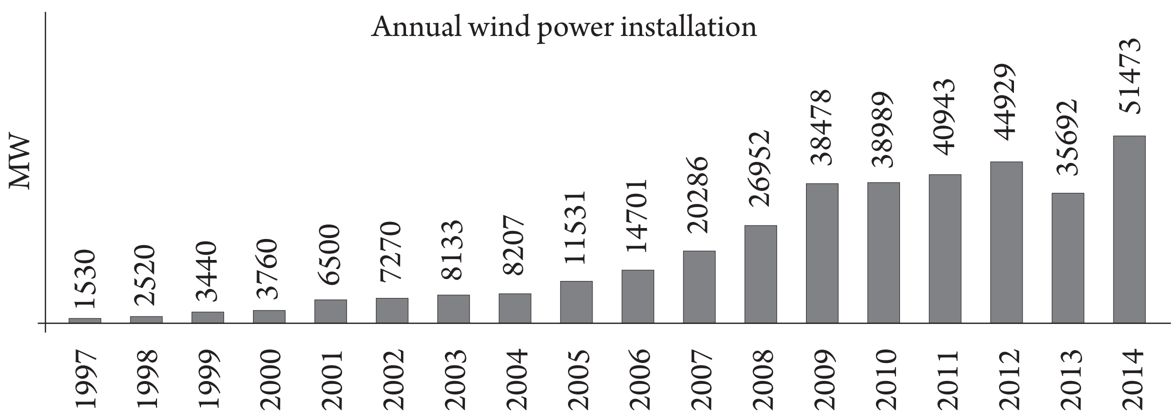
Chart 1. Global installed wind capacity in 1997-2014, cumulative and annual





Source: GWEC 2015.

Sustainable development means the shift from the use of traditional fossil fuels towards sustainable renewable energy sources for the future decrease of CO_2 emissions. The development of wind energy is certainly the most successful example of how to ensure this (Table 1).

Table 1. Development of wind energy

Year	Wind power installed capacity, MW	Wind energy share in total electricity production, %	Reducing of CO_2 emissions as a consequence of using wind energy, %
2008	120 715	1,50	2,2
2013	318 644	3,35	4,3
2018	820 000	8,00	11,0

Source: Press Release 2009.

According to the global international project Wind Force 12, by 2020 12% of global energy production will be accounted for wind energy. In the existing electrical networks this share is a theoretical allowable limit to ensure the static stability of the energy system [Larsson 2002].

It turned out that in reality the growth of installed capacity is even higher than the forecast. For example, in Denmark wind power engineering produced 33% of total energy consumption in 2013 and 39% – in 2014. In 2012 the Danish government has approved a plan to increase the share of wind energy in electricity production of Denmark to 50% by 2020 and to 84% by 2035 [The Guardian 2012]. As mentioned above, it could become a problem for static stability of the Denmark power system in isolated operation, but Denmark has strong electrical connections with European Network of Transmission System Operators (ENTSO-E). The total installed capacity of wind turbines in Denmark is 4,89 GW which only gives us about 0,7% of the ENTSO-E Continental European Synchronous Area (677 GW of total installed generator capacity), so Denmark is still far away from the theoretical limit of wind energy utilization for the purposes of energy system.

One of the main reasons of such phenomenal development of wind power in the world is a constant decrease in the cost of 1 kW of installed capacity of a wind turbine (from 823 EUR/kW in 2002 to 566 EUR/kW in 2014).

2. Collaboration of wind energy and energy systems

An individual wind turbine capacity is constantly growing (4,5-7,5 MW), capacity of a wind power plant (WPP) becomes comparable to the capacity of the power grid (the largest is Gansu WPP 7965 MW, China). Therefore, projects for new wind power plants together with such important factors as wind potential assessment and environmental requirements will need assessment of possibilities of interrelation with the electrical grid. According to PTWE [2002] the work of wind turbines and wind power plants in electrical networks are affecting:

- power quality,
- increase of electrical equipment load,
- short-circuit currents,
- power and energy balance.

Without proper assessment of connection possibilities, a project for a new wind power plant can exceed the technical capabilities of the energy system at the connection point. It could only be done using proper static and dynamic mathematical models of wind turbines and energy system, which normally consist of the models of a wind turbine, transformer substation, transmission lines, consumer loads and energy system connection (Fig. 1). As a result, the model itself must be comprehensive and need experiment data for verification.

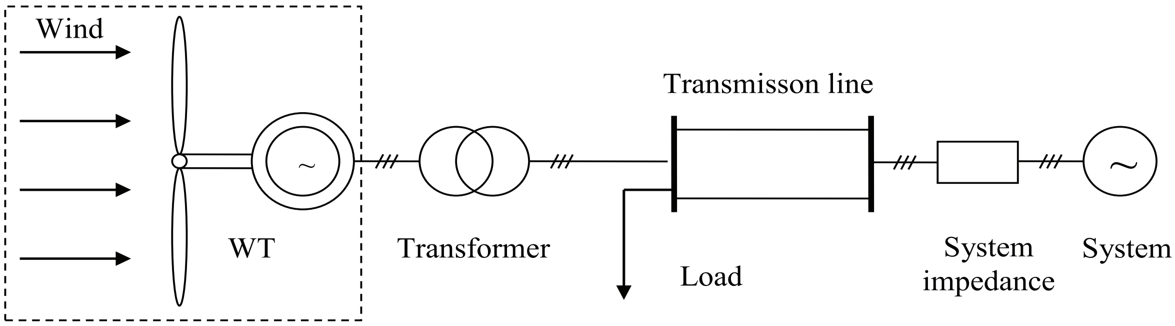


Figure 1. Block diagram of the model of the wind turbine connected to the energy system

Source: Beley & Nikishin 2011.

In Europe and North America regulations have been developed governing the procedure of such assessment. According to them, the assessment should be based on:

– ratio between the capacity of WT and short-circuit power of the energy system at the point of connection (≥ 0,02),
– complex calculation of power flows,
– voltage fluctuations in commutations,
– calculation of short-circuit currents,
– assessment of a flicker level and harmonics.

Table 2. Wind turbine and wind farm capacity limits for connection to electrical grids with different voltage levels

Voltage level of the electrical grid	Unom kV	Wind turbine (WT) capacity	Capacity limits, M
Low voltage	less than 1	small and middle capacity WT	up to 0,3
Middle voltage	from 1 to 35	middle and big capacity WT, small wind farms	2-5
Direct connection to a middle voltage grid		middle and big capacity wind farms and WPP	10-40
High voltage	more than 35	middle capacity wind farms and WPP	up to 100
Extra-high voltage	more than 220	big capacity WPP	more than 500

Source: PTD-Kompetenz 2002.

Basic recommendations on the necessary voltage level at the connection point of the energy system and capacity limits of the grid (Table 2) show us that wind farms with installed capacity comparable to the capacity of the energy system require high and extra-high voltage grids which are rarely available at the places with high wind potential.

3. Wind energy for sustainable future of the Kaliningrad region

There are no regulatory documents for connection of WTs to the energy system in Russia, but they could be developed on a basis of international standards. Total installed capacity of WT in Russia is 16,8 MW (69th in the world), but wind potential (technical capacities) is enormous: from 16 500 to 52 181 billions kWh/year.

For a variety of reasons the Kaliningrad region could be a good test site for the development of wind power engineering in our country. First of all, Russian biggest wind farm (5,1 MW, Photo 1) is situated in Kulikovo settlement of the Kaliningrad region.

Photo 1. Kulikovo wind farm in the Kaliningrad region

Source: http://golodranec.ru/gallery/album/archive/5586/IMG_2451.jpg [17.10.2015].

However, the second reason is much more important. According to the plans of ENTSO-E, within a few years the energy systems of Latvia, Estonia and Lithuania will be integrated into Continental European synchronous area ENTSO-E. It will leave the energy system of the Kaliningrad region in isolated operation (Fig. 2).

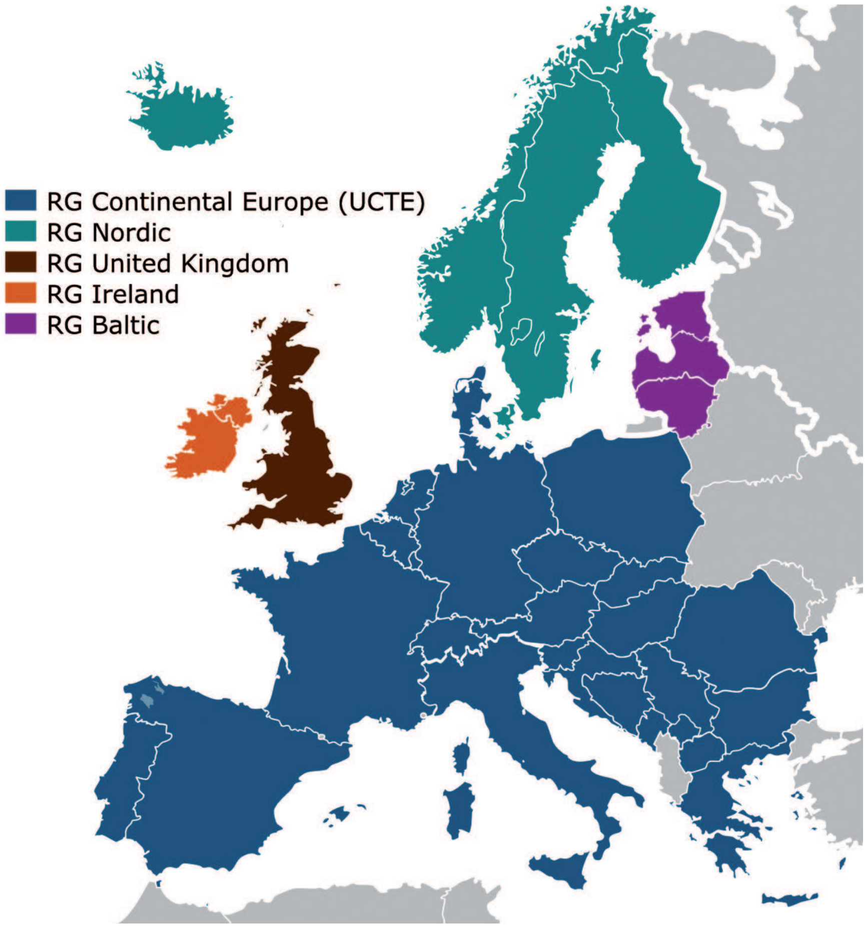


Figure 2. The Kaliningrad region in conditions of isolated operation

Source: www.snipview.com/q/European_Network_of_Transmission_System_Operators_for_Ele-ctricity [17.10.2015].

According to the long-term development programs for the electrical energy industry of the Kaliningrad region for the years 2014-2019, this problem should be resolved by means of building new power plants which will use traditional fossil fuels. At different scenarios, the installed capacity can be twice as much as the peak demand and can ensure the required control of active power.

At the same time we should mention that earlier research shows good perspectives for wind in the Kaliningrad region. During the INTERREG/TACIS project "Prospects for offshore wind energy development in marine areas of Lith-

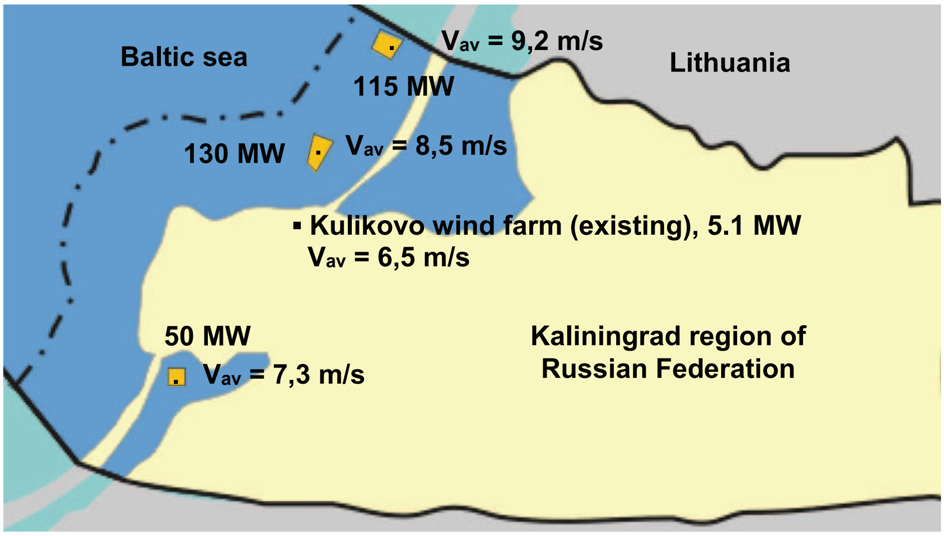


Figure 3. New installed capacities of wind turbines (orange areas) for sustainable development of the Kaliningrad region

Source: INTERREG/TACIS Project POWER 2005.

uania, Poland and Russia" (POWER) the most suitable places for wind turbines were defined (Fig. 3, orange areas)

Total electricity consumption of the Kaliningrad region in 2014 was estimated at 4531 mln·kWh. Preliminary calculations show that in order to ensure sustainable development of the region it is possible to produce almost 25% of total necessary electrical energy using new wind farms (Table 3).

Table 3. Assessment of annual average power generation of the existing and prospective wind farms in the Kaliningrad region

Wind plant capacity	Operation factor	Average wind speed, m/s	Number and type of WT	Production mln·kWh/year
50 MW (new)	0,33	7,3	25 × Vestas V-80	141,47
130 MW (new)	0,44	8,5	65 × Vestas V-80	471,01
115 MW (new)	0,49	9,2	58 × Vestas V-80	468,04
5,1 MW (existing)	0,19	6,5	20 × Vestas V-27 and 1 × Vestas W-4200/600	8,5

Source: own elaboration.

Considering that the total capacity of the energy system is expected to be less than 2200 MW by 2020, the theoretical limit of wind power utilization of 12% will not be exceeded. For preliminary calculations a math model can be used which was originally created for the assessment of Kulikovo wind farm regimes [Beley & Nikishin 2011].

4. Conclusion

The use of wind energy is the cheapest and the best known way to increase the share of sustainable renewable electrical energy sources in the Kaliningrad region, in Russia and world-wide.

It is no question that an increase of installed capacity a wind turbine creates new challenges for existing electrical energy systems, but we are still far away from possible theoretical limits of wind power utilization. Future use of new wind power plants in the Kaliningrad region can help to handle the problem of isolated operation of Kaliningrad electrical energy system, decrease of CO_2 emissions as well as increase sustainability of the region.

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Energia wiatrowa na rzecz zrównoważonego rozwoju na przykładzie Obwodu Kaliningradzkiego Federacji Rosyjskiej. Aspekty techniczne

Streszczenie. Trwały i zrównoważony rozwój oznacza przesunięcie akcentu w kierunku wykorzystania odnawialnych źródeł energii. Rozwój energii wiatrowej jest z pewnością jednym z najlepszych przykładów udanych wysiłków na tym polu. Energetyka wiatrowa jest najszybciej rozwijającą się gałęzią energetyki na świecie. W 2014 r. moc znamionowa nowych turbin instalowanych na całym świecie osiągnęła rekordową wartość 51 GW. Oznacza to, że udział wiatru w ogólnej produkcji energii rośnie, dochodząc w niektórych krajach do naprawdę znaczącego poziomu (w Danii np. w 2014 r. z wiatru pochodziło 39% łącznego zużycia energii). Maksymalna moc nowej turbiny wiatrowej jest porównywalna z mocą największych tradycyjnych elektrowni i łączną mocą znamionową systemu energetycznego. Jednak w jej przypadku występują pewne problemy związane z przyłączeniem, eksploatacją oraz funkcjonowaniem takiej instalacji w tradycyjnej sieci energetycznej bazującej na tradycyjnych źródłach energii. Jest wysoce prawdopodobne, że system energetyczny Obwodu Kaliningradzkiego będzie musiał w najbliższej przyszłości przejść na samodzielne funkcjonowanie wskutek jego oddzielenia od sieci litewskich, łotewskich i estońskich. Jeśli tak się stanie, rozwijanie energii wiatrowej w Obwodzie Kaliningradzkim może być jedną z atrakcyjniejszych opcji z punktu widzenia zrównoważonej przyszłości tamtejszej energetyki.

Słowa kluczowe: energia wiatrowa, zrównoważony rozwój, system energetyczny, model matematyczny