Experience and prospects for the wind power plants constructing in the north western part of the Euro-Arctic region of Russia

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Abstract. The Murmansk region is characterized by great potential for using wind energy, whose resources are especially large in the coastal areas of the Barents and White Seas. It was found that in periphery of areas where there is a disruption to power supplies, the use of wind power plants is especially important. The paper presents a brief analysis of wind power current state and its development in the Murmansk region. Studies revealed that it is tend to be used small-power wind power plants, which are basically intended to be used for power supply to remote decentralized consumers in the region. It can be assumed that together with the construction of these wind power plants, the foundation of the Murmansk region wind energy resources development was laid. It is shown that the further wind power development of the Murmansk region is likely to have the wind farms constructing there. One of these projects found its practical application in the form of the 201 MW wind farm «Kola Wind Farm», the construction of which is scheduled to be completed by the end of 2021. The wind farm is approximately to be able to generate about 750 GWh per year.

1. Introduction
The constant energy cost escalation, the increase in the fossil fuels cost and its deficiency in some parts of the world, as well as the negative impact on the environment and human health of fossil fired power facilities, heightens an interest to the use of renewable energy sources (RES). First of all, this is conditioned by their power generating ability and thereto related environmental cleanliness, as well as the no costs concerning to extraction of primary energy resources. Therefore, the development of renewable energy sources and their involvement in the production of various types of energy are aimed at by many foreign and national researches [1], [2], [3], [4], [5].

Russia and in particular the Murmansk region is characterized by great potential for the use of RES, such as the issue of using wind energy, whose resources are especially large in the coastal areas of the Barents and White Seas, deserves special attention [6]. In these areas, for the generation of electricity and heat, there is a possibility of using wind power plants (WPPs), and that is especially true for periphery of the areas where there are power disruptions [7], [8].

2. Wind power current state and its development in the Murmansk region
Installed and commissioned indifferent places of the Murmansk region (Fig. 1) for 2000 onwards were the WPPs ranging from 1.4 to 500 kW. All WPPs total installed capacity amounted to approximately 870 kW. In most cases, WPPs are small-power installations that are used to power supply for satellite communication, as well as the ostrich farm workspace of the OOO “Severnoe Siyanie” (LLC) and the
OOO “Diving Center” (LLC) (Table 1). A number of WPPs are integrated in wind-diesel-solar power plants, which allows improving their efficiency and optimizing available resources.

Currently, there in the Murmansk region, the largest energy sources fuelled by wind energy are two WPPs. The first 500 kW one was installed at the site of the woodworking enterprise OOO “Green House” (LLC) (Kola town), and the other 200 kW WPP is operated in Murmansk for powering the “Ogni Murmanski” Hotel [9]. Thus, together with WPPs constructing, the foundation is regarded to be laid for the wind energy resources development of the Murmansk region.

3. Prospects for the wind farms constructing in the Murmansk region

Researches [10] showed that one of the promising areas for the wind energy further development in the Murmansk region may be the wind farms constructing there. One of such priority projects is a wind farm constructing near the closed administrative-territorial formation of Ostrovnoy, which is located on the Barents Sea 360 km southeast of Murmansk (Fig. 1). There is no road connection with central Murmansk region; the main track is a waterway, which is navigated by the arctic motorship from Murmansk. If the sailing cannot be performed, it became possible since the start of 2019 to get to Ostrovnoy by helicopter.

Heat supply of the closed town of Ostrovnoy is provided by the electric-heating boilers installed in each house. Their total capacity is about 8.5 MW. Electric power for the needs of the closed town, whose territory has the Northern Fleet naval base, is supplied by the substation of the Nizhne-Serebryanskaya Hydroelectric Power Station using almost 200 km length single-circuit power line (electric transmission line). Frequent breakdowns on electric transmission lines (ETL) lead to a complete blackout of urban consumers. For repair periods, the power supply of closed town is provided by 6.2 MW diesel-generating standby electric power station and 5 MW gas turbine power plant (GPP). Such difficulties with the power management, along with high costs and shipping expenses of fossil fuels for Ostrovnoy, significantly increase the cost of generated power in comparison to the central Murmansk region.

In order to improve the power supply system of the closed town, installation of 5 WPPs with a total capacity of 5 MW is suggested to be made in addition to the existing diesel station. The average annual wind speed in Ostrovnoy is of 7 m/s, an appropriate site is located 4 km southwest of the town (Fig. 1). To construct the wind farm, Enercon E-58/10.58 WPPs were chosen with a tower height of about 70 m and a wind wheel diameter of about 60 m. Grid connection of the wind farm can be performed using the located 1 km away from town substation 51.

For the North conditions, the value of the specific investment in a WPP, taking into account each cost concerning shipping expenses, customs duties, the costs of building a foundation and installing a WPP, is about 1.500 euros/kW.

To calculate the investments required for the wind farm constructing, there was used the net present value (NPV), which helps to evaluate the investment appeal of the project. The Ministry of Economic Development of the Russian Federation for 2020 reduced the inflation forecast in Russia from 3.8% to 3%, the forecast for 2021-2024 remained at around 4%. Assuming that the growth of electricity tariffs in the years to come will increase taking into account the inflation rate, then during the lifetime of WPP (20 years), the tariff will increase from 0.03 to 0.07 euro/kWh.
Figure 1. WPP arrangement in the Murmansk region: 1 – Murmansk; 2 – Kola; 3 – Molochny; 4 – Novaya Titovka; 5 – Vayda-Guba; 6 - Tsypnavolok; 7 – District 81\textsuperscript{km} of the Murmansk-Teriberka highway; 8 – Ostrovnoy; 9 - Cape Svyatoy Nos-Ostrovnoy; 10 – Pyalitsa; 11 – Mayak Nikodimsky; 12 – Chapoma; 13 – Tetrino; 14 – Chavanga; 15 – Kashkarantsy; 16 - Lovozero; 17 - Kuoloyarvi; 18 - Svetly.
Discounted cash flow analysis of the wind farm showed that the investments will be about 7.7 million euros, the payback period is about 16 years, and the income by the end of the WPP’s life time will be about 1.7 million euros.

Another worthy of particular consideration project is a wind farm around District 81st km of the Murmansk-Teriberka highway (Fig. 1). The wind farm is located on the coast 40 km from the Barents Sea and characterized by an average annual wind speed of 6.3 m/s (at a height of 10 m above ground).

The project involves the Vestas V80-2.0 WPP in the amount of 100 pieces. Each WPP provides 2 MW, and the wind wheel diameter and the tower height are 80 m and 78 m, respectively. Guide value of all project WPPs gross generation is of 750 million kWh per year. An important construction stage of the wind farm is the selection of the optimum alternative for the WPPs arrangement configuration on the ground and the infrastructure development of the designed ETLs, at that selection primary objective to minimize cash costs. Given this, WPPs were decided to be grouped together under 5 pieces, connecting them further on the major step-up substation (MSS) in order to reduce the total length of all designed ETLs. Since this project includes a large number of WPPs, it would be practical to install two MSSs, both of which should be in the center of power output, what will reduce the length of ETLs connecting the WPPs as well. Such a network infrastructure plan of the wind farm is presented in Fig. 1.

The project profitability assessment was taken applying the NPV as well, its calculation showed that investments in the wind farm constructing could total up 301 million euros and pay off after 15.5 years. After 20 years of operation of the wind farm, an income of € 62 million could be generated.

At the moment, this project is finding to some degree its practical application in the form of the 201 MW wind farm «Kola Wind Farm» being constructed by the Public Joint-Stock Company Enel Russia (PJSC Enel Russia), which is a part of the Italian Enel group. The wind farm will approximately be able to generate about 750 GWh per year. The project implementation is planned for 2019-2021 and will cost investors about 273 million euros, which corresponds to the value of specific investments in WPPs of 1.360 euros/kW.

| Locality name (Brand) | Commissioning year | Installed capacity, kW | Purpose |
|-----------------------|---------------------|-------------------------|---------|
| Kola                  | n/a                 | 2016 500                | Power and heat supply to woodworking enterprise OOO “Green House” (LLC) |
| Murmansk              | Wincon-200          | 2001 200                | Power supply to “Ogni Murmansk” Hotel |
| Chavanga Tetrino Chapoma Pyalitsa | 2014-2016 140 | Power supply to inhabited localities by wind-diesel-solar power plants |

Table 1. WPPs in Murmansk region.
4. Conclusions

At that time the most northern in Europe 200 kW WPP with a capacity of was installed and commissioned in Murmansk in 2001. After that, 670 kW WPPs were installed and put into operation in various parts of the region. Such WPPs tend to be used small-power wind power plants, which are basically intended to be used for power supply to remote decentralized consumers in the region. It can be assumed that together with the construction of these wind power plants, the foundation of the Murmansk region wind energy resources development was laid.

Further wind power development of the Murmansk region is likely to have the wind farms constructing there. That kind of priority projects are the wind farms constructing near the town of Ostrovnoy and around District 81st km of the Murmansk-Teriberka highway. The latest project has found its practical application in the form of the 201 MW wind farm «Kola Wind Farm» being constructed now by the PJSC Enel Russia. The project implementation is planned for 2019-2021. Cost of 1 kilowatt-hour of the WPPs under construction will be approximately 1.360 euros/kW. The wind farm will approximately be able to generate about 750 GWh per year.

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