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Challenges of integrating wind power plants into the electric power system: Lithuanian case

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ABSTRACT

This article reviews the technical problems which must be solved to support the development of wind energy in Lithuania. Two technical objectives were identified: determining the power transmission capacity of the electricity network, and balancing the energy generated by wind power plants related to the error control of forecasting. To complete these objectives, it was necessary to review the historical development of wind energy in Lithuania and the recent (2016) situation in accordance with statistical data. The forecast errors of the system load and generation by wind power plants, and demands of balancing and control reserves were established. The potential for connecting wind power plants to the Lithuanian power transmission network were then analysed. This article also discusses the wind energy development possibilities in Lithuania.

1. Introduction

Climate change, the increase in fossil fuel prices, and the global demand for energy security have accelerated the development of renewable energy. The traditional, fossil fuel-dependent energy sector is an anthropogenic activity that has a significant impact on the climate and average temperature [1]. To mitigate the effects of human activities on the environment, governments worldwide have promoted the use of renewable energy sources (RES), and the developing technologies that are becoming cheaper allow wider renewable energy development.

In 2009, the European Commission (EC) [2] established a goal to decrease greenhouse gas emissions by 80–95% from the 1990 levels by 2050. In support of these goals, the European Climate Foundation initiated a study to establish the main goals for the European industry and, especially, the energy sector. The results of this study were announced in April 2010 [3] and demonstrated that the set goal is technically feasible and economically achievable. On 8th March 2011, the EC confirmed this conclusion [4], forecasting the trajectories of carbon dioxide (CO_2) reduction in separate sectors and setting an intermediary goal for 2030. The EC suggested a 54–68% reduction of the 1990 CO_2 emissions for the power sector by 2030.

According to the earlier provisions of the EC Directorate-General for Energy [5], by 2030, power plants using RES should generate 32.1% of electric energy, according to the baseline scenario that states the development of the European Union's (EU's) energy system under current trends and policies. According to the reference scenario (2009), which is based on the same macroeconomic, price, technology, and policy assumptions as the baseline scenario but includes the mandatory emissions and energy targets set for 2020, RES-powered plants should produce 36.1% of electricity.

In 2011, the European Climate Foundation conducted a follow-up study called Power Perspectives 2030 [6]. The study declared that the reduction of greenhouse gas emissions should be accelerated after 2020, and investments in generation and network development should be almost doubled by 2030.

According to the On-Track Case scenario, it is deemed that the objectives of 2020 [7] have been fulfilled, and a scenario in which RES generates 50% of electricity is currently being modelled. To achieve energy supply reliability and security, RES can be diversified. Meanwhile, the More RES scenario forecasts a case in which 60% of electricity generation is fuelled by RES, which would involve increasing the development of offshore wind and solar power plants.

The annual issue of the European Network of Transmission System Operators (ENTSO-E), called the Scenario Outlook and Adequacy Forecast 2013–2030 [8], states that, to meet the EU's energy objectives for 2050, it is necessary to ensure that 51.4–59.8% of electricity is

Abbreviations: CHP, combined heat and power; EC, European Commission; EPS, electric power system; EU, European Union; HVDC, high voltage direct current; RES, renewable energy sources; WF, wind farm; WPP, wind power plant

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generated by RES power plants by 2030. According to the 2013 Reference scenario, revised by the EC Directorate-Generals for Climate Action, Energy, and Mobility and Transport [9], EU RES power plants should generate 45% of electricity by 2030. This objective applies to the entire EU; every country shall set their goals and adjust to achieve the common EU goal.

The contribution of each country to achieving these goals depends on national circumstances and the current state of their energy sources, including the manner of adjustment.

The generation of electricity using RES is one of the highest priorities of energy policy in Lithuania [10]. Priority is granted to commercial combined heat and power (CHP) plants using biomass [11] and wind energy. In 2010, the country prepared to reach a total wind power plant (WPP) capacity of 500 MW connected to the electricity network prior to 2020 [12–14]. Lithuania is the leading Baltic state in wind energy development [15,16]. This target of 500 MW was achieved in 2016 and allowed discussion on further WPP development. According to the draft act of the Republic of Lithuania Law on Energy from Renewable Sources, the country intends to increase its total installed WPP capacity to 850 MW [17].

This article reviews the wind energy situation in Lithuania, as well as the possibilities and challenges of WPP development. The article also analyses the impact of WPP on the Lithuanian electric power system (EPS). The main problems that arise as WPP development increases include the balancing of power generated by WPP and the power transmission capacity of the electricity network. Statistical data of WPP development up to the first half of 2016 are provided, and the data used to analyse different characteristics were gathered during 2009–2015. The potential for wind power plant development up to are also investigated.

2. Situation of wind power plants in the Lithuanian electric power system

2.1. Historical perspective

Wind energy development began in Lithuania in 2003 [18], when the first 160-kW WPP, which was imported from Denmark, was installed in Skuodas and connected to the electricity network (manufacturing authorisation issued on 19 November 2002).

A demonstrational WPP was installed in Vydmantai, Lithuania, in 2004 [19], which was designed and built in compliance with the recommendations of the EC Energy and Energy Network Agency for building the first WPP in any country. It was a 630 kW, Enercon E-40 type power plant. Monitoring the operational parameters of this power plant confirmed that the natural wind conditions are favourable for wind energy production and induced the development of wind energy in western Lithuania [20].

The first wind farms (WFs) in Lithuania were installed in 2007; the capacities of the first WFs were 30 MW (fifteen 2-MW Enercon E-70-type WPP) and 16 MW (six 2.75-MW Vestas-type WPP). Single WPP were also constructed [21]. WPP were actively built until 2013 [22], however, no WFs were installed in 2014 and only a few separate WPPs were connected to the separate distribution network [23,24]. In 2015–2016 WPP development continued in Lithuania with the construction of WPPs and WFs with a combined capacity exceeding 200 MW [24,25]. The chart of historical WPP development (Fig. 1) indicates intense wind energy development in Lithuania.

Wind energy development in Lithuania was behind that of Latvia and Estonia. For example, the first WPPs in Latvia and Estonia were built in 1996 and 2002, respectively. The first WFs were installed in Latvia and Estonia in 2005, which is two years ahead of Lithuania. However, wind energy development in Latvia slowed from 2012 when the total installed capacity of WPP reached 60 MW. In Estonia, the process of wind energy development was similar that of Lithuania until 2013. At the end of 2013, the total installed capacity of WPP in Estonia

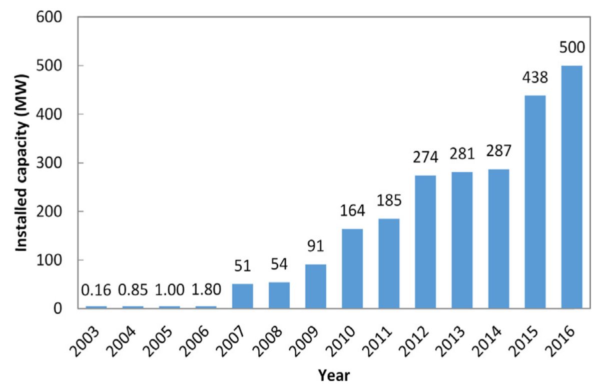

Fig. 1. Capacity of wind power plants in Lithuania.

was equal to that of Lithuania (280 MW), and WPP with a capacity of only 23 MW were installed in 2014 [22–25].

2.2. Current situation

On 1 January 2017, WPPs with a 500-MW capacity were installed in Lithuania, 412.3 MW of which were connected to the transmission network (13 WFs with capacities ranging between 12 and 73.5 MW were connected to the 110 kV electricity network, and 1 WF with a capacity of 60.0 MW was connected to the 330 kV electricity network), and 87.7 MW of which were connected to the electricity distribution network [24].

Lithuania has the highest installed capacity of WPP in the Baltic States (at the end of 2015, Estonia had an installed WPP capacity of 303 MW, while that of Latvia was 62 MW) [25]. The total demand for electricity in 2015 was 11.81 TWh [26], and WPP in Lithuania generated 0.81 TWh of electricity. This constitutes 35.4% of the electricity generated from RES and 17.6% of the total electricity generated in Lithuania [26]. 7.21 TWh or 61.0% of electricity consumed in Lithuania was imported in 2015.

The current WFs connected to the transmission network in Lithuania are listed in Table 1.

The installed WFs are located in the windiest parts of Lithuania. Fig. 2 provides a map of the wind speed in Lithuania and indicates the locations of installed WFs connected to the transmission network [24,27].

As the most favourable zone for WPP development is the coastal area (as the wind speeds are highest), the power transmission capacity of the 110 kV power lines for WPPs in western Lithuania is already exhausted. Hence, new WFs are connected in places further from the sea, such as Mažeikiai.

Table 1
Wind farms and their capacities connected to the Lithuanian 110–330 kV transmission network, 2016 (based on [24]).

Power plant name	Installed capacity in MW
Kreivėnai Wind Farm	20.0
Laukžemė Wind Farm	16.0
Mockiai Wind Farm	12.0
Benaičiai-1 Wind Farm	34.0
Kreivėnai III Wind Farm	14.9
Vydmantai Wind Farm	30.0
Čiūtėliai Wind Farm	39.1
Didšiliai Wind Farm	16.0
Šilalė Wind Farm	13.8
Sūdėnai Wind Farm	14.0
Rotoliai II Wind Farm	24.0
Pagėgiai 13	73.5
45 MW Mažeikiai Wind Farm	45.0
Šyša Wind Farm	60.0