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Assessment of the Romanian onshore and offshore wind energy potential

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Abstract. A general assessment of the wind energy potential from the eastern part of Romania was carried out in this work by taking into account onshore and offshore wind conditions. First, a perspective of the importance of the renewable resources into the Romanian electricity system was provided, from which was noticed that the wind production cover almost 15% from the demand (reported to 2017). From the analysis of the wind data significant differences were noticed between the onshore and offshore regions, the last one presenting more important wind resources, that significantly increase during the winter time (with almost 22%). According to the performance reported by an offshore wind turbine (rated at 3 MW), such generator will operate at full capacity in a maximum 9% from the time, if we consider a hub height of 119 m.

1 Introduction

The onshore wind energy is one of the most dynamical sectors, being estimated that this is one of the cheapest renewable solutions that can compete at this moment with the conventional generation solutions in terms of the costs [1]. Definitely, the evolution of this industry will finally reach a saturation, taking into account that the suitable sites for such projects will be limited. Therefore, some new environments need to be taken into account, this being the case of the coastal and marine regions. The vast water areas allow the development of large capacity projects, being also expected more important wind resources than onshore [2–5]. In some cases, the offshore regions seem to be defined by similar wind resources as onshore, the only difference being related to the decision of the developers to assembly larger farms in order to cover the higher costs associated to such projects [6].

Europe is a leader in terms of wind electricity production, exceeding some important sectors, such as fuel oil (in 2007), nuclear sector (in 2013), hydropower (in 2015) or coal sector (in 2016). It was estimated that at the end of 2017 a total capacity of 937 GW was installed in this region, from which approximately 3.1 GW were offshore, this being related to an increase of 101% compared to 2016. Romania is defined by a wind power capacity of 3.03 GW, which increased only with 5 MW in 2017. Reported to electricity demand, was estimated that almost 12.2% is covered at this moment from the operating wind farms [7].

Regarding the Black Sea wind conditions, the previous research indicated that the western part of this basin present in general more important wind resources [8,9]. As for the Romanian coastal environment, it is estimated that the sites located on the northern areas may present interest for the development of a wind project [10,11].

In this context, the aim of the present study is to identify the differences between the Romanian onshore and offshore regions (if any) and also to estimate the performances of some offshore wind turbines that may operate in this coastal sector.

2 Methods and materials

The wind conditions used in the present work are related to the ERA-Interim database that is assembly by the European Centre for Medium-range Weather Forecast. These values are provided at 10 m height above the sea level (U10 parameter), being processed for the 20-year time interval (1999-2018). Four data per day were considered (00-06-12-18 UTC), and correspond to a spatial resolution of 0.125^o x 0.125^o, which is the finest grid available on the ECMWF server (https://www.ecmwf.int/en/forecasts/datasets/reanalysis-datasets/era-interim).

In order to assess the energy potential of a particular site, in general the wind conditions are evaluated at a hub height that starts from 80 m. A logarithmic law can be used in this case, as follows [12,13]:

$$U80 = U10\frac{\ln(z_{80}) - \ln(z_{10})}{\ln(z_{10}) - \ln(z_0)} \qquad (1)$$

where, U80 - wind speed at 80 m, U10 - initial wind speed (at 10 m), z_0 - roughness of the sea surface (0.0002 m), z_{10} and z_{80} - reference heights.

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3 Results

Figure 1 presents the share of renewable electricity in the European Union (EU) and Romania, considering the time interval from 1990 to 2017 [14]. At this point, it is important to mention that, Romania entered in the EU at the beginning of 2007. Reported on a European level, in general Romania reveals a much higher percentage share, being reported only in 2012 similar results. Definitely, there is an upward trend, more renewable sources being added to the electricity network, as we can observe in the case of the year 2016 (close to 45% for Romania). Wind and solar come together in this report, but it is important to mention that the onshore wind capacity is more relevant for this statistic. The interval from 2009 to 2017 seems to define these two sectors, being registered significant progress that is similar or exceeds the EU level (the year 2014 and year 2015).

A first perspective of the Romanian wind conditions is provided in Figure 2. From the spatial distribution of the U80 parameter, we can see that there is a clear separation between the onshore and offshore areas, the second one presenting resources that are more important. The onshore conditions gradually increase as we approach to the shoreline, being encountered areas with 5.5 m/s. As we go offshore it is possible to reach a maximum of 7.5 m/s between the 29° and 30° longitude lines. In Figure 1b, the wind conditions associated to some reference sites (onshore and offshore) is presented. In general, the onshore sites reveal values located close to 4 m/s, compared to the offshore sites (O1, O2 and O3) where an average of 6.8 m/s may be noticed. From the distribution of the wind roses reported for the site O2 (Figure 1c) we can observe that the northeast sector is the dominant one (close to 6%), where the presence of the wind conditions that exceed 12 m/s is more visible.

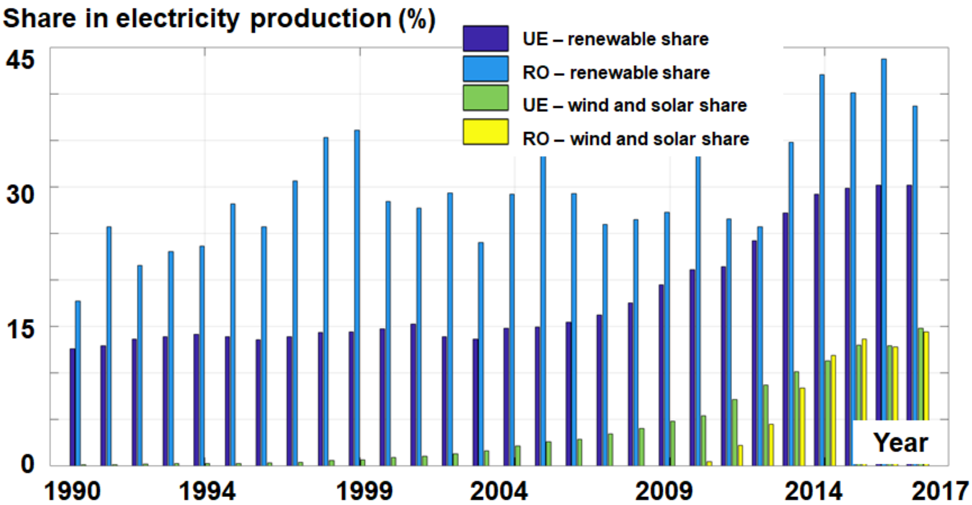

Figure 1. Share of renewable contribution to the EU and Romanian electricity production.

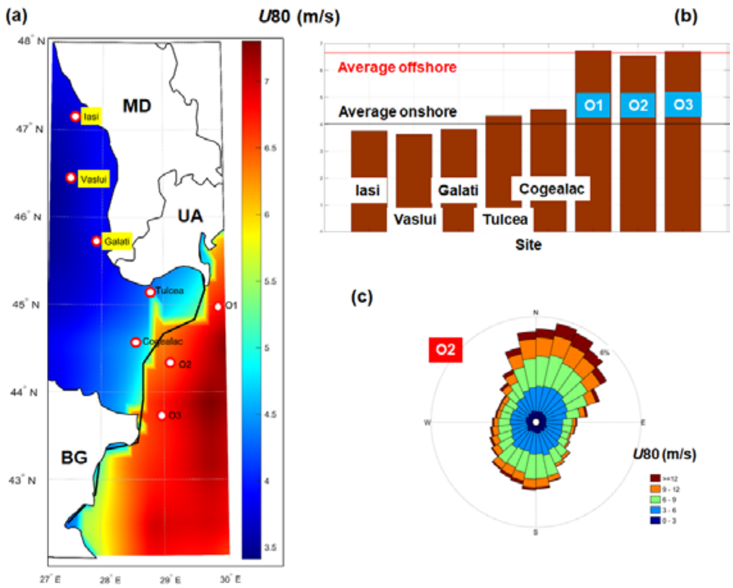

Figure 2. Distribution of the U80 parameter from the ERA-Interim data for the Romanian environment (from 1999 to 2018), where: (a) spatial distribution of the average values; (b) average values for some onshore and offshore sites; (c) wind roses for the site O2.

Figure 3 illustrates the differences between the full-time distribution (Figure 1a) and the main seasons, namely spring (March–April–May), summer (June–July–August), autumn (September–October–November) and winter (December–January–February). During the spring, we may expect an increase of the conditions with a maximum 7% onshore compared to a decrease of 8% near the Romanian coast. In the summer, all the regions show a decrease (between 8% and 19%), compared to the autumn where only the offshore regions may report an increase of 4%. A maximum increase of 22% is expected offshore during the wintertime, while only 4% is expected for the onshore regions.

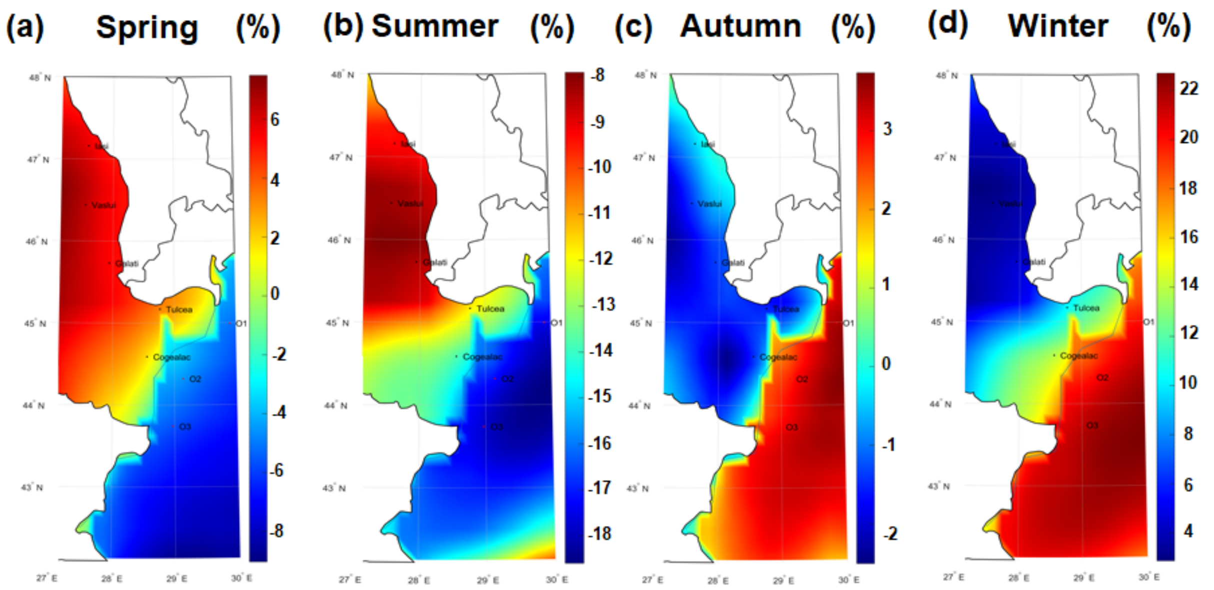

Figure 3. *U*80 differences (in %) between the average values related to the total time distribution (all the values) and the four main seasons: (a) spring; (b) summer; (c) autumn; (d) winter.

At this moment, there is no offshore wind project in the Black Sea, and therefore the next step will be to identify the performances of such system that may operate in the Romanian sector. By looking on the wind speed reported at the offshore sites O1, O2 and O3 we can see that the average wind speed (at 80 m) is located between 6.5 m/s and 5 m/s. According to the IEC recommendations these sites are related more to the C3 and C4 classes [15], and by looking on the operating turbines it seems that the system V112-3.0 [16] will be more suitable for this environment. The power curve of this turbine is presented in Figure 4, being defined by a cut-in of 3 m/s and by a rated speed of 12 m/s at which a maximum 3 MW is generated. For the hub heights, the manufacturer indicates three versions, namely: 84 m, 94 m and 119 m.

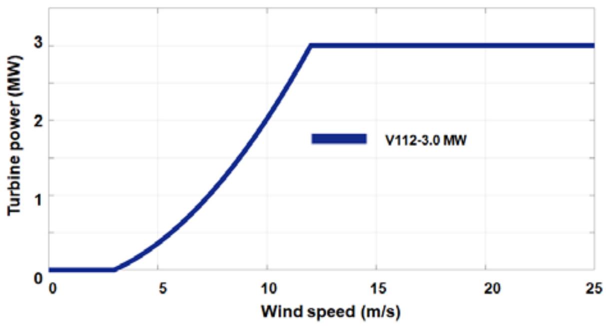

Figure 4. Representation of the V112-3.0 power curve.

The inactivity period of the selected turbine (wind speeds < cut-in) is presented in Figure 5, by taking into account various hub heights. The considered sites are representative for the Romanian coastal areas (north-centre-south) being defined at approximately 30 km offshore. As expected the downtime values decrease as the hub height increase, much higher values being accounted for the site O2 located in the center of the target area. The sites O1 and O3 reveal similar results, being reported a 12% for the hub height of 84 m, compared to a minimum of 11.3% in the case of the site O3 (hub height 119 m).

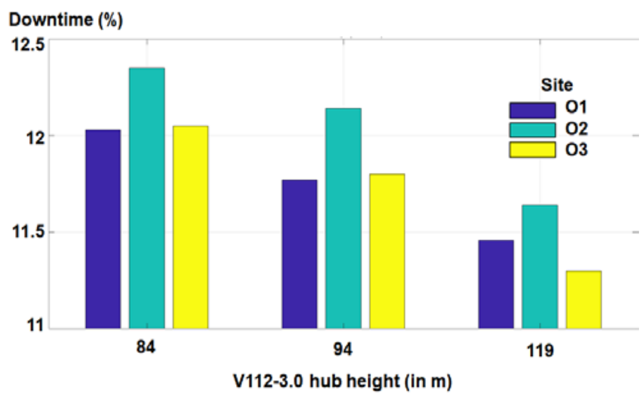

Figure 5. Downtime interval (%) reported by the V112-3.0 system for the sites O1, O2 and O3.

Figure 6 present the percentage of the time, during which the selected turbine will operate on a full capacity (3 MW). As we can notice, the values oscillate between 6% and 9%, better results being noticed for the hub height at 119 m. The differences between the sites are more visible, the site O3 reporting much better results.

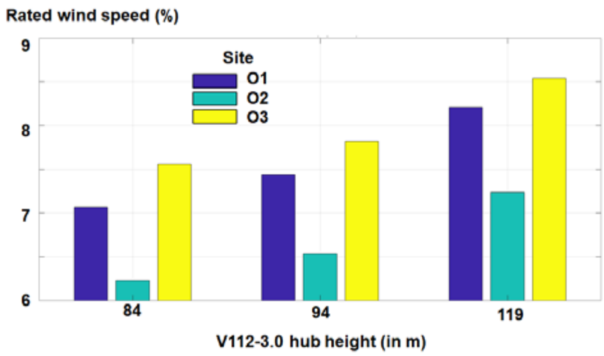

Figure 6. The efficiency of the V112-3.0 system, considering only the wind data higher than the rated speed (12 m/s).

4 Conclusions

A general assessment of the Romanian wind energy potential was provided in this work, in order to highlight the benefits coming from this energy sector. At this moment the wind projects are operational only on the Romanian onshore areas, being expected that in the near future this sector to expand to the offshore regions. By looking at the statistical data was highlighted the fact that there is interest for this type of energy, being reported an increase in the installed number of turbines.

From the analysis of the ERA-Interim was possible to highlight the spatial differences between the onshore and offshore areas, the second one presenting significantly much higher values. The accuracy of this model can be discussed in the vicinity of the coastline, since there is a sharp transition between onshore and offshore. Considering the total time values, various seasonal patterns can be noticed, better performances being expected during the winter time, when an increase with almost 22% of the wind speed is reported close to the offshore regions.

In the case of a wind turbine rated at 3 MW, we may expect downtimes periods that vary from 11% to 12.5%, while the turbine will work at full capacity at values that do not exceed 9%.

Finally, we can conclude that the Romanian coastal areas are an attractive environment for the development of a wind project (onshore or offshore). An example is the successful development of the already operational Fantanele-Cogealac project, which is one of the largest in the world (16th place – April 2019).

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References

[1] H. Klinge Jacobsen, P. Hevia-Koch, C. Wolter, Nearshore and offshore wind development: Costs and competitive advantage exemplified by nearshore wind in Denmark, Energy for Sustainable Development. 50 (2019) 91–100. doi:10.1016/j.esd.2019.03.006.

[2] J. Li, X. (Bill) Yu, Onshore and offshore wind energy potential assessment near Lake Erie shoreline: A spatial and temporal analysis, Energy. 147 (2018) 1092–1107. doi:10.1016/j.energy.2018.01.118.

[3] E. Rusu, F. Onea, Joint Evaluation of the Wave and Offshore Wind Energy Resources in the Developing Countries, Energies. 10 (2017) 1866. doi:10.3390/en10111866.

[4] F. Onea, E. Rusu, Sustainability of the Reanalysis Databases in Predicting the Wind and Wave Power along the European Coasts, Sustainability. 10 (2018) 193. doi:10.3390/su10010193.

[5] F. Onea, L. Deleanu, L. Rusu, C. Georgescu, Evaluation of the wind energy potential along the Mediterranean Sea coasts, Energy Explor. Exploit. 34 (2016) 766–792. doi:10.1177/0144598716659592.

[6] P. Enevoldsen, S.V. Valentine, Do onshore and offshore wind farm development patterns differ?, Energy for Sustainable Development. 35 (2016) 41–51. doi:10.1016/j.esd.2016.10.002.

[7] Wind in Power: 2017 European Statistics | WindEurope, (n.d.). https://windeurope.org/about-wind/statistics/european/wind-in-power-2017/ (accessed May 11, 2019).

[8] D. Ganea, E. Mereuta, L. Rusu, Estimation of the Near Future Wind Power Potential in the Black Sea, Energies. 11 (2018) 3198. doi:10.3390/en11113198.

[9] L. Rusu, D. Ganea, E. Mereuta, A joint evaluation of wave and wind energy resources in the Black Sea based on 20-year hindcast information, Energy Explor. Exploit. 36 (2018) 335–351. doi:10.1177/0144598717736389.

[10] D.M. Niculescu, E.V.C. Rusu, An overview of the wind power potential in the Romanian coastal environment - moving from onshore to offshore, in: W. Cui, E. Rusu (Eds.), 2018 3rd International Conference on Advances on Clean Energy Research (Icacer 2018), E D P Sciences, Cedex A, 2018: p. UNSP 01007.

[11] F. Onea, L. Rusu, A Study on the Wind Energy Potential in the Romanian Coastal Environment, Journal of Marine Science and Engineering. 7 (2019) 142. doi:10.3390/jmse7050142.

[12] A. Raileanu, F. Onea, E. Rusu, Assessment of the Wind Energy Potential in the Coastal Environment of Two Enclosed Seas, Ieee, New York, 2015.

[13] F. Onea, E. Rusu, Efficiency assessments for some state of the art wind turbines in the coastal

environments of the Black and the Caspian seas, Energy Explor. Exploit. 34 (2016) 217–234. doi:10.1177/0144598716629872.
[14] World Energy Statistics | Enerdata, (n.d.). https://yearbook.enerdata.net/ (accessed June 30, 2018).
[15] E. Hau, H. von Renouard, Wind Turbines, Springer Berlin Heidelberg, Berlin, Heidelberg, 2006. doi:10.1007/3-540-29284-5.
[16] Vestas V112-3.0 MW - Vestas - PDF Catalogs | Technical Documentation | Brochure, (n.d.). http://pdf.directindustry.com/pdf/vestas/vestas-v112-30-mw/20680-244373.html (accessed May 14, 2019).