SEAI RD&D
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Analysis of local obstacle impacts on the energy performance of large scale wind autoproducers in peri-urban locations, based on multi-annual SCADA data

Summary Report- Rev 1.1

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DUNDALK INSTITUTE OF TECHNOLOGY

Contents

1.0 Background

Globally wind energy has grown substantially in recent decades with an installed capacity and the end of 2016 of 486.8GW [1]. The vast majority of this capacity is both in rural onshore wind farm developments and growing offshore developments using large scale wind turbines. There has been a relatively small contribution from small scale wind systems (i.e. systems less than 100kW) with that latest reported global capacity at end of 2015 standing at 945MW [2]. Wind autoproduction is the generation of electricity by a wind turbine(s) for onsite consumption. It is also sometimes referred to as "behind the meter" generation. It can be achieved with small medium or large scale wind turbines depending on consumer demand. The wind turbine is connected to the consumer side of the electricity meter thereby offsetting the purchase of retail electricity from the grid i.e. reducing electricity bills while only excess electricity is exported to grid. The economic advantage of wind autoproduction is that each unit of electricity (kWh) generated by the wind turbine that is consumed onsite is of a high value to the consumer compared to exporting the electricity at wholesale rates. The energy performance of any wind turbine is sensitive to a number of atmospheric parameters such wind speed, wind direction, wind shear, wind veer, turbulence and air density. These factors are influenced by local and regional features around the site such as topography, obstacles, general surface roughness and thermal effects [3]. To achieve best energy and economic performance from any wind project careful attention should be given to siting and sizing a wind turbine at the given site. This becomes even more critical for industrial wind autoproducers that have a higher likelihood of being located in peri-urban industrial areas where wind flow may be heavily influenced by building obstacles. Such installations are also likely to be at lower elevations. Staudt [4] published the economic performance of an 850 kW wind autoproducer at Dundalk Institute of Technology on the east coast of Ireland. The predicted annual energy output values were 2 million kWh while actual metered energy output was 1.5 million kWh. A further of study by Cooney et al [5] using 1 year of performance data from 2008 for the same system showed the economics of the project was on a par with a typical wind farm developments due to the offsets in purchase of retail electricity. However, the study also showed overestimates in predicted annual energy output of ~ 25% compared to measured annual energy output. Hildrith et al [6] investigated the avoidance of demand charges using a behind the meter 1.65MW wind turbine i.e. a wind autoproducer at the University of Minnesota in the USA. The focus of the study was on the economic value of power kW demand reduction from a standing charge point of view i.e. in addition to saving made as result of energy offset. Extrapolated wind speed data from a met mast to the hub height of the turbine was combined with the manufacture's power curve to estimate the power production of the turbine and concluded a potential extra 10% cost savings on demand charges. The study assumed a simple power law in the wind data extrapolation from mast height to hub height. No site description and its impact on wind turbine were given. Lantz et al [7] assessed the future market potential of distributed wind in the USA, specifically for behind the meter projects. It included small, medium scale and a large scale wind turbines. It concluded that the potential for tens of GW of capacity can be realised over time, subject to technology cost reductions and the development new business models with favourable consumer adoption mechanisms.

2.0 Introduction

This study investigates three medium to large scale wind autoproducers at separate peri-urban locations focusing on the impact of local obstacles, such as buildings and regional terrain (hills) on energy performance. The study is based on the analysis of multi-annual 10-minute Supervisory Control and Data Acquisition (SCADA) data sets for each wind autoproducer. Site descriptions of the heights and distances of local obstacles and regional terrain from the turbine are given in each case. The 10-minute SCADA data is analysed to assess the impact of these local features on the directional energy output of the wind turbines. The observed influences of local obstacles and regional terrain are discussed in the context of what potential wind autoproducer projects need to consider in siting a wind turbine at a given site to maximise energy output. Other important practical considerations such a noise, visual impact and grid connection and not covered, however, the owners experiences of local public attitudes post project installation are outlined. The study first introduces the three wind auto producers and describes the available SCADA data of interest. A common general methodology of data quality checking and analysis applied to each dataset is outlined. The three wind autoproduction project cases are then assessed individually. In each case a site description, power curves, directional energy output and turbulence is given. The observed impacts of site features on wind turbine energy performance are discussed along with feedback from each turbine owner on local public attitude towards their turbine. The report ends with a synopsis of the overall conclusions and outlines siting factors to be considered for future wind autoproducer projects along with future research needs in the area.

3.0 Wind autoproducer systems overview

Wind Autoproducer		**Rating (kW)**	**Hub Height (m)**	**Rotor Diameter (m)**
Vestas V52 (Dundalk IT)		850	60	52
Enercon E48 (UU Coleraine)		800	55	48
Enercon E48 (Bangor Town Council)		800	55	48

Fig. 1. *Three wind autoproducers at different peri-urban locations*

The full technical details and conclusions of the study are due for publication; however, summary technical conclusions and owner feedback are outlined in the next section.

5.0 Summary Conclusions

It has been shown, based on the analysis of measured multi-annual 10-minute SCADA data, that the power and energy performance of large scale wind turbine deployed in an autoproducer (behind the meter) depend on number of local site and regional factors along with the behaviour of the turbine system itself. The power curves at the sites exhibits some degree of scatter that can be attributed to turbulence and gusting and demonstrates and that these are dynamically site dependent i.e. dependent on the behaviour of the turbine systems to wind flow influenced by local physical features of the site. Use of a single manufacturer's power curve in wind project development may lead to increased error in annual energy predictions at prospective autoproduction sites. In conclusion, potential large scale wind autoproducer projects should, from a wind resource and siting point of view, consider the following:

- Allow a 2-5 year timeframe to decide upon implementing a wind autoproducer project
- Before installing a met mast become familiar/gain local knowledge of the wind resource at your site such as prevailing wind direction(s), diurnal and seasonal variations through your own observations and weather information and wind maps
- Consider regional topography in at least a 15km to 20km radius of the proposed turbine location particularly in prevailing wind directions(s)
- Consider local buildings obstacles within a 1km to 1.5km radius of the proposed turbine location
- Use as high a tower as possible (unless at very flat obstacle free site) even if planning/building code compliance becomes a greater effort

- Broad obstacles such as building or small forests, with a height of 20% of proposed turbine hub height or greater, up to 1km to 1.5km away in prevailing wind direction(s), can have a significant negative impact on energy performance
- If obstacles greater than 20% of proposed tower height occupy more than 30% of the field of view (as seen from hub height) in prevailing wind direction(s) up to 1.5km away then consider increasing tower height or reconsider the project
- Be mindful of how the site surrounding may change in the future e.g. future new building obstacles constructed in prevailing wind direction(s)
- Engage in a clear and transparent way with local residents at an early stage e.g. at the stage when initial screening of the site shows the site to be potentially a viable site for wind autoproduction

6.0 Owners' Feedback on Public attitudes

6.1 Dundalk IT

The turbine was installed in 2005 without any planning objections. Since then no complaints have been received on any aspects of the turbine or its operation. It has been and continues to be seen as a very positive piece of infrastructure in the area. There are a number of residential dwellings less than 500m of the wind turbine. The nearest residential dwelling is ~ 235m away to the northeast which is downwind of the prevailing wind (in the wake of the turbine). The nearest on campus classrooms are 110m away and the main campus library is 210m away (i.e. a quiet study zone not affected by the operating presence of the turbine). Over the year shadow flicker is observed a relatively small proportion of the time on sunny winter mornings and evenings when the sun is low in the sky. It lasts 10s of minutes in any one place with total annual cumulative time of less than 10 hours. It has not been a reported issue for this site. A key element to this has been active engagement with the local community, students and employees. Following successful public information days/evenings during the planning and leading up to the construction of the wind in 2005 the wind turbine site has remained an accessible place to visit. Many schools, industrial and public organisations and researchers have visited the turbine since 2005 and all went away with a positive experience of the turbine. In 2015, ten years after the turbine was installed, a community information event was held in Dundalk to detail; a) how the turbine had performed in the previous 10 years, b) the lessons learned from operating such as the system at DkIT, c) to give the local community a better understanding of the function of the wind turbine that exists on their doorstep and to obtain feedback on the thoughts of the local community 10 years on from installation. The event was well attended and feedback continued to be very positive. In addition to research and educational benefits other indirect ways of how the turbine of social benefit in the area include; a landmark structure used to locate DkIT, visual indicator to local farmers, boating and flying clubs on the direction and strength of the wind at any given time. Over 5000 students study every day less than 200m from the wind turbine and this from of energy has now become normalised in their lives. The turbine has also become a feature in the logos of many businesses in the Dundalk/Louth area and is also a feature in the Dundalk town logo. This has helped to distinguish the area as one committed to the overall goal of sustainability.

6.2 University of Ulster, Coleraine

The turbine was installed in 2008 as the first Enercon E48 wind turbine in Northern Ireland. Its implementation was well publicised locally at the time. The nearest dwelling is ~ 300m away to the NW of site. The nearest campus building is ~ 185m away from turbine. The turbine is power limited in some circumstance to reduce noise in the northwest, southwest and southerly directions due to proximity of student accommodation buildings and local residents within ~ 500m of turbine.

6.3 Bangor Town Council

The turbine was installed in 2008. The turbine has been received positively in the town. The nearest dwelling is ~ 250m away to the south (i.e. mostly upwind of the turbine). To the east and northeast there are dwelling houses 260m to 500m that lies in a zone a of potential shadow flicker. On a small number of occasions throughout the year the turbine is stopped due to shadow flicker occurrences, requested by one of the local residents.

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References:

[1] Global Wind Report, Annual Market Update 2016, Global Wind Energy Council (GWEC)

[2] Small Wind Report Summary 2017, World Wind Energy Association (WWEA)

[3] Wind Energy Explained: Theory, Design and Application J. F. Manwell, J.G. McGowan, A. L. Rogers, 2008

[4] L. Staudt, "Developments and Cost Benefits of the Campus Wind Turbine at Dundalk Institute of Technology," Renewable Energy in Maritime Climates, Conference Proceedings, Dublin, 2006

[5] C. Cooney et al, "Performance characterisation of a commercial-scale wind turbine operating in an urban environment, using real data" Energy for Sustainable Development 36 (2017) 44–54

[6] Laura Hildreth , Arne Kildegaard , "Avoided Demand Charges and Behind-the-Meter Wind: Insights from an Application at the University of Minnesota", Wind Energ. 2009; 12:363–374

[7] E. Lantz et al, Assessing the Future of Distributed Wind: Opportunities for Behind-the-Meter Projects, National Renewable Energy Laboratory USA, Technical Report NREL/TP-6A20-67337, November 2016