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High Resolution Wind Power Models - an Irish Case Study

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Abstract

This paper focuses on high resolution wind power statistical models fitted to meteorological data for the island of Ireland. A discrete Burr model efficiently represents the number of consecutive hours of wind power availability. The models developed in this study may be most useful at time resolutions less than 6 hours to capture zero power and short bursts of wind power potential. They could serve as a useful complement to other wind power modelling approaches such as MERRA reanalysis models.

Keywords: Wind power modelling; Wind energy potential; Discrete count models;

1. Introduction

The Irish Government is aiming for 40% of electricity to be generated from Renewable Energy Sources (RESs) by 2020 in response to the EU directive on renewable energy [1]. Ireland is rich in wind resources but integrating wind power creates new operational and planning challenges for Transmission System Operators. Many of the issues particular to the Irish situation are set out in [2]. Approaches to wind power forecasting are described in [3].

Errors in wind power forecasts can cause the residual power to be over- or under-estimated. The residual power is the the power that has to be delivered from conventional generation after power from renewable sources has been committed. Improving wind modelling and forecasting has been the focus of several researchers, see [4,5,6]. A key recommendation from the European Wind Integration Study [7], is the development of pan-European models which encapsulate more detailed regional and national models.

This gives the motivation for our Irish case study. We describe a one hour resolution statistical model of the potential wind power based on historical meteorological data. This model will serve as a complement to an aggregated wind power generation model using MERRA reanalysis wind speed data [8]. The MERRA model successfully reflects the measured wind production data for the period 2001 – 2014 at greater than 6 h resolution. The correlation of the reanalysis model with actual output from 2006 onwards is 0.95 - 0.96, with RMSE between 6.5% - 8.5%. At one-

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and three-hour time-horizons, the model tends to under-estimate the magnitude of ramps in capacity factor occurring with a particular frequency (i.e., for a given ramp magnitude, the model under-predicts the frequency of wind event occurrences). At horizons greater than or equal to six hours, the differences between the reanalysis model output and actual power are very small. This is reflective of a low spatial resolution reanalysis data inadequately representing variability at smaller time-horizons but also an effect of the temporal smoothing apparent in the data.

1.1. Wind Power Integration Issues in Ireland

The Irish electricity generation system comprises of circa 7,500 MW of generation capacity and two 500 MW HVDC interconnect lines with the UK. Mains supply is offered at 50 Hz. Currently there is an installed wind capacity of circa 3,000 MW with plans for further development. Several metrics are used to quantify the productivity of a wind turbine. The *capacity factor* compares the actual power production of a turbine over a given time with the total power the turbine would have produced if it had operated at the rated power for the time frame. However, the amount of wind power that is used on the grid is limited, there are a number of reasons why wind is "curtailed". Curtailment can be due to system-wide curtailment and/or local network constraints.

Firstly, wind power may be curtailed to ensure security and stability since wind power is an asynchronous source. The limit for system non-synchronous penetration (SNSP) is set at 55%. SNSP = (wind generation + HVDC imports) / (system demand + HVDC exports). In order to meet EU targets, EirGrid (the Irish transmission system operator) aim to increase the SNSP limit to 75% by 2020. Ging et al.[9] note that such curtailment is allocated pro-rata across all wind generators with an equal bias.

As well as frequency and stability management issues, wind power may be curtailed due to operational or transmission constraints[9]. Two major geographical constraint areas in Ireland are identified in[10]: the north-west and the south-west of Ireland. These are due mainly to network congestion issues but also in some instances to system outages. They note that outages caused by storms in the south west resulted in the output of other windfarms being constrained to manage overloading lines. In addition, they note that curtailment arises mainly during the night time hours (between 11pm and 9am) due to the low overall system demand, when "must-run" conventional power plant may be able to meet the estimated residual demand.

1.1.1. Wind Power Event

Section 2 gives a brief overview of wind power modelling approaches. In this study we are particularly interested in the number of hours when power is theoretically produced (i.e., ignoring market and operational curtailment). We call this phenomenon a wind power event. We say a wind power event occurs when wind speed exceeds the cut-in threshold of a wind turbine so that power is produced. The end of the event occurs when the wind speed drops below the cut-out threshold. In this study we model X the number of consecutive hours when wind power is produced. This allows us to characterise the distribution of the wind power events and the inter-event time distribution. The system of potential wind power is characterised by intermittent switching between periods of low activity and high activity bursts of potential power production.

2. Wind Power Modelling

Analysis of long-term data on national or regional wind power output is required to understand, in particular, the variability in the production related to inter-annual and inter-decadal climatic patterns. Thirty years is generally understood to be the minimum required period in order to properly capture such fluctuations. Wind power generation has really only become a widespread contributor to power production in the last 5-10 years, with very few instances of wind farms older than 20 years, so historical records of output are not sufficient for long-term analyses, and thus simulations of such data are required.

Two main approaches are taken in the literature to developing simulations, both using wind speed data as input. The first uses *historical records* of measured wind speeds, typically held by meteorological institutions and measured at 10m above ground level. The second relies on wind speeds as represented in "*reanalysis*" datasets. Reanalysis data is that produced by running some form of a numerical weather prediction (NWP) model in *hindcast* mode, i.e. back