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On the potential value of interval deficient wind data[☆]

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ABSTRACT

The stringent requirements of standards for wind measurements such as IEC 61400-12-1:2005(E) suggest that wind data produced by systems and procedures that do not comply with these standards are deficient and therefore not of sufficient quality for use in wind energy applications. In particular, the standard implies that data are deficient if acquired either intermittently, or continuously - but at averaging intervals exceeding the specified requirements. In order to demonstrate that certain deficient data may in fact be useful in wind energy applications, sets of interval deficient wind data of varying lengths of intermittency - and averaging interval are synthesized from ideal quality data sets produced by systems that closely comply with IEC 61400-12-1:2005(E). Weibull parameters are identified for the data sets and compared. It is inter alia shown that parameters identified from annual sets of wind data acquired at four widely dispersed compliant measurement stations in Southern Africa are remarkably insensitive to the length of intermittency interval and that the parameters can be identified with a relative error of 1% or better for intermittency intervals of up to 1 h or longer. This finding suggests that data sets acquired via historic wind measurement devices may indeed be valuable.

1. Introduction

The IEC 61400-12-1:2005(E) standard (IEC, 2005) of the International Electrotechnical Commission describes the requirements for wind measurements as it applies to the power performance evaluation of installed electricity producing wind turbines. Full compliance with this standard is also required for wind resource assessments that are specifically undertaken to provide accurate resource input data for bankable wind projects at particular sites. The standard is not strictly applicable to general wind resource assessments, but it is also often adopted for this purpose. A fundamental requirement of the standard is that wind speed data shall be acquired continuously by a digital data acquisition system (DAS) at a sampling rate of at least 1 Hz and that means -, standard deviations -, minima - and maxima shall be derived from contiguous samples for each 10 min period (1 min for the evaluation of small turbines) and then stored by the DAS. The standard further requires that wind speed inputs to the DAS shall be provided by calibrated electronic (implied) cup anemometers of known classification that are mounted at prescribed elevations relative to the hub height of the tested turbine and at prescribed locations relative to supporting structures and obstacles on the ground in order to avoid excessive interference of these objects with the free stream wind flow onto the sensors.

Wind data not acquired thus are ostensibly deficient and not of sufficient quality for use in wind energy applications. In sequence of most - to least severe in respect of non-adherence to the indicated requirements, examples of deficient data are those that are acquired :

- intermittently via mechanical anemometers and human interaction
- continuously via mechanical anemometers and human interaction
- continuously via electronic DAS served by anemometers other than the cup type and at averaging intervals exceeding those specified by the standard
- continuously via electronic DAS served by calibrated - and classified cup anemometers at the required sampling rate, but with the anemometers not mounted as specified in the standard.

Intermittent data include manual spot observations of the outputs of mechanical wind pressure sensing devices such as plate wind indicators and Dines anemometers, as well as spot evaluations of the slopes of the traces of mechanical autographic wind recorders. Fig. 1 shows a pressure plate wind indicator that was installed at the Gobabeb Research and Training Centre (GRTC), Gobabeb, Namibia in September 1962. The device is presently still used for synoptic wind observations and the output of the device is observed and recorded

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Fig. 1. Pressure plate wind indicator at Gobabeb. Photo courtesy Mr Titus Shuuya (GRTC).

three times per day at 06h00, 12h00 and 18h00 Universal Coordinated Time (UTC).

Long averaging intervals are associated with integrating devices such as mechanical wind totalizers of which the counter reading is observed once - or only a few times per day, as well as automatic weather stations (AWS) of which the averaging interval is typically set to one hour. Fig. 2 shows a mechanical wind totalizer similar to the device that was first installed at GRTC in October 1962. This type of device is presently still in use for evaporation-related wind observations at Gobabeb. The counter is read once per day at 06h00 UTC. In Namibia, the mentioned mechanical devices had been in extensive use by Namibia Meteorological Services (NMS) and its pre-independence South African predecessors as from the 1940s until the early 1990s when NMS commenced with the augmentation/replacement of the small network of these devices by a larger network of electronic AWS. Unfortunately, however, the data recovery rates (DRR) rendered by the new AWS network proved dismal in comparison to that of the old network, with the consequence that there is a lack of complete sets of compliant - or good quality long term wind data produced by NMS for the period since the independence of Namibia in 1990 to date.

The objective of the study of which the results are presented herein is to address this predicament through an empirical investigation into how interval deficiencies influence the extent to which data produced by historic devices can potentially be used to identify accurate Weibull parameters for the wind resources of Namibia in the absence of long term compliant data. Sets of interval deficient wind data of varying lengths of intermittency - and averaging interval are synthesized from ideal quality annual wind data sets produced by DAS that closely comply with IEC 61400-12-1:2005(E) (IEC, 2005). The synthesized deficient data simulate the data produced by the mentioned historic devices. Weibull parameters are identified for all the data sets and the parameters identified from the deficient data compared with those identified from the ideal data which are employed as reference values. Derived Weibull parameters and - mean wind power density are employed in the comparison rather than the measured mean wind power density, because the former can be extrapolated to higher elevations as described by amongst others Kelly et al. (2014) and Doran and Verholek (1978) who derived equations for the height variation of wind statistics.

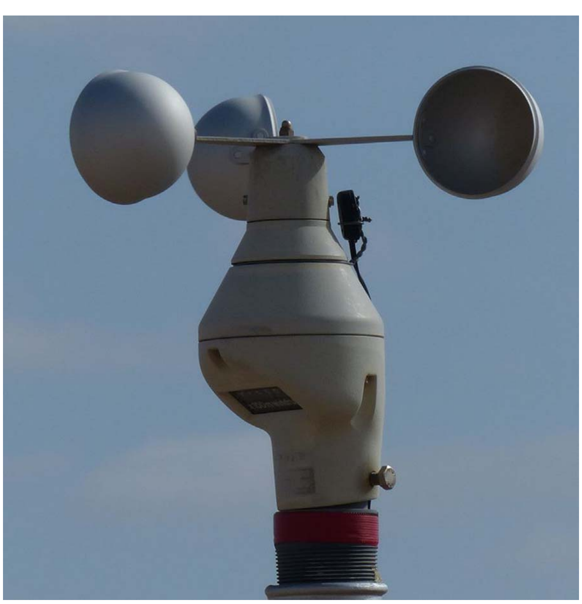

Fig. 2. Mechanical wind totalizer at Gobabeb. Photo courtesy Dr Roland Vogt (University of Basel).

No evidence could be found in literature of previous investigations into the sensitivity of annual Weibull parameters on varying lengths of intermittency - and averaging interval. Abbes et al. (2010) employed one-minute means of wind data for three stations in the United States of America to synthesize deficient data sets with intermittency intervals ranging between 2 min and 4 h. They investigated the sensitivity of the monthly electrical energy output of a wind turbine on the varying intermittency intervals and found that the outputs associated with longer intermittency intervals are less than predicted by the compliant one-minute means, the difference being less than 10% for intermittency intervals of up to one hour in all cases.

Ramírez and Carta (2005) identified Weibull parameters from a single reduced data set of which the number of data records (300) was calculated on the basis of eliminating to a selected level of significance the auto-correlations in the original data set of 52,580 data records. Using Maximum Likelihood estimation to identify the Weibull parameters from the reduced - and original data sets, they found that although the expected values of the Weibull scale parameter derived from the two data sets are virtually the same, there is considerable difference in the expected values of the Weibull shape parameter. They also found that the standard errors for the parameters identified from the reduced data set are an order of magnitude larger than those derived from the auto-correlated data of the original data set. A slightly smaller - but comparable value of the ratio of standard errors in the mean wind speed was found by Brett and Tuller (1991) who estimated the parameters of auto-correlation functions for seven stations in Canada.

Employing autocorrelation functions and the properties of Markov chains, Larsén and Mann (2006) derived theoretical expressions for the