Renewable Energy 76 (2015) 494–502

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Portfolio theory application in wind potential assessment

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ARTICLE INFO

Article history:
Received 24 February 2014
Accepted 12 November 2014
Available online

Keywords:
Wind energy
Portfolio theory
Wind measurement
Energy yield assessment

ABSTRACT

Development of a wind farm project includes a lot of interconnected steps and one of the most important ones is the proper energy yield assessment. Wind energy yield assessment is typically based on wind measurements on a measurement mast that are later used in one of the wind flow software models. In cases where there are multiple wind measurements on the potential wind farm site, a question arises on how to optimally use all the available data. This paper shows a method of using such data through the application of the portfolio theory, a well-established theory in economics and frequently used in other scientific disciplines. The method shown is very flexible in terms of input data and software models, and the results of its application show that it is possible to increase accuracy and reduce uncertainty of energy yield assessment. The key result of the method is the possibility to achieve better quality of input data for the energy yield assessment without spending additional resources. The method opens up a wide space for further research and improvements, all with the objective of achieving better results of energy yield assessment and finally, better prepared wind project.

1. Introduction

Wind power is becoming increasingly important electricity source in the world. According to The Global Wind Energy Council (GWEC) the global cumulative installed capacity in 2013 in the world was 318.137 MW (Fig. 1), an increase of nearly 200 GW in the past five years [1]. This installed capacity in 2013 produce more than 580 TWh and thus meeting 2% of global electricity demand. GWEC expects a global capacity of 536 GW by the end of year 2017.

Profitability of a wind farm project depends on wind potential of the site, total investment and purchasing price of electricity. Therefore, it is important to properly estimate wind potential and select the adequate wind turbines for the site. Wind turbines usually account for 75% of total investment in a wind farm [2].

Every improvement in estimating wind potential, either by increasing accuracy or reducing the uncertainty of estimation, improves the quality of the wind project.

Wind potential is normally calculated on the basis of wind measurements on a prospective wind farm site. The objective of this paper is to demonstrate methodology for improving wind potential estimation by using portfolio theory on locations with multiple wind measurements. The described method addresses both the accuracy of estimation and the corresponding uncertainty.

2. Literature review

Accurate estimation of wind speed is critical for the assessment of wind energy potential. Usually, wind speed is modeled by using Weibull distribution [3], but there are also new methods [4]. The approach in this paper takes the existing methods into account and proposes an additional step in wind speed analysis based on the portfolio theory and normal distribution.

Modern portfolio theory was developed by Harry Markovitz in 1952 for the purpose of investing in stocks and bonds. In his paper [3], Markovitz says it is possible to find an optimal portfolio or a group of portfolios of stocks and bonds that would, given the level of expected return and correlation matrix, minimize the variance (or risk) of investment. Markovitz's theory is based on three basic variables: expected return of the portfolio E, variance (or risk) of portfolio σ and shares of individual portfolio's members within the portfolio w_i. Mathematical description is therefore the following (in today's notation) [[4], p. 131]:

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http://dx.doi.org/10.1016/j.renene.2014.11.033

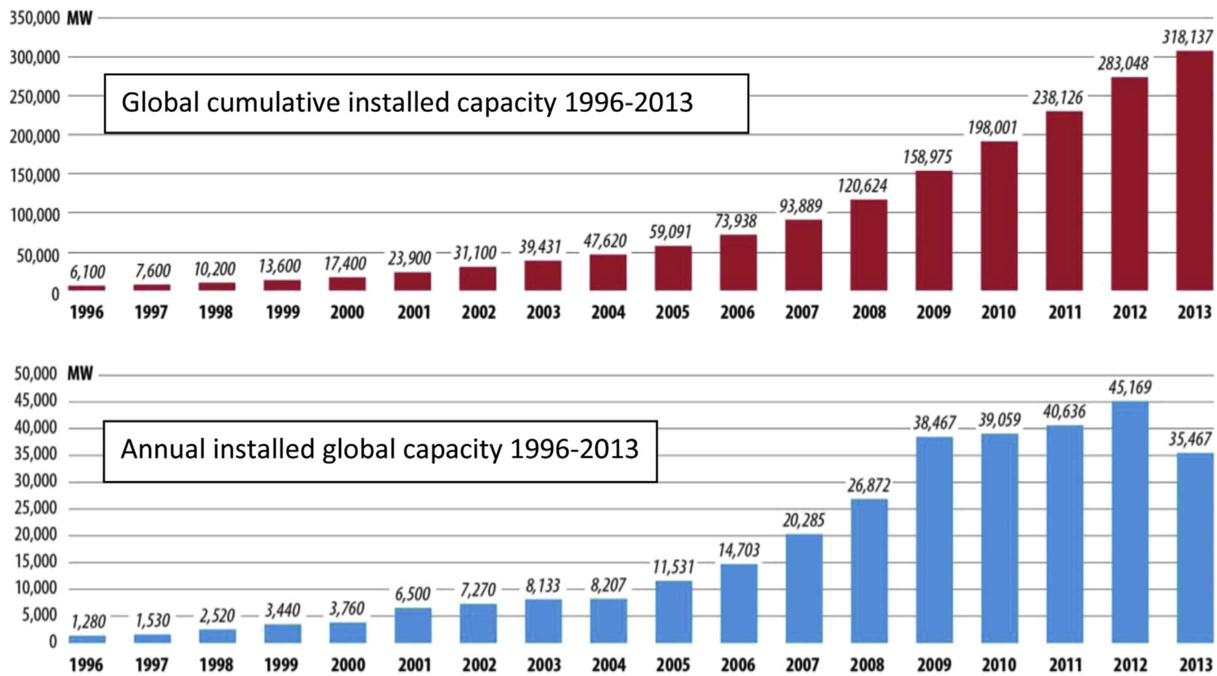

Fig. 1. Global cumulative installed capacity and annual installed global capacity 1996–2013 [1].

$$E(R_P) = \sum_{i=1}^{N} w_i E(R_i) \tag{1}$$

$$\sigma_P^2 = \sum_{i=1}^{N} w_i^2 \sigma_i^2 + \sum_{\substack{i,j=0 \\ i \neq j}}^{N} w_i w_j \mathrm{Cov}_{i,j} \tag{2}$$

$$\sigma_P = \sqrt{\sigma_P^2} \tag{3}$$

$$\sum_{i=1}^{N} w_i = 1 \tag{4}$$

N represents the number of stocks, R_i potential yield of an individual portfolio member i, and $\mathrm{Cov}_{i,j}$ is the covariance between two members of the portfolio. Covariance depends on a known correlation coefficient $r_{i,j}$ between each two portfolio members and standard deviation of individual members of the portfolio:

$$\mathrm{Cov}_{i,j} = r_{i,j} \sigma_i \sigma_j \tag{5}$$

The portfolio theory has already been applied in many scientific fields, including the energy domain, where it is used in planning of the electricity systems for policy-making purposes [5]. It was also used to combine geographically dispersed wind farms into portfolios and then evaluate their joint performance from the position of financing institutions [6]. This paper will demonstrate the application of portfolio theory in assessing wind potential based on multiple wind measurements.

Multiple wind measurements have so far been used for evaluating different wind modeling tools in complex terrain, such as the simulation done by DEWI [7] or the Bolund experiment by RISO [8]. Portfolio theory was applied in a similar simulation where the authors used WAsP model and the computational fluid dynamics (CFD) tool to assess the wind potential and then combined the results by using portfolio theory, thus reducing the uncertainty [9].

3. New methodology

3.1. Basic concept

In order to evaluate wind potential of site, we need to set up wind measurements lasting at least one year [16] on at least two heights and on a location that best represents the overall characteristics of the site [10]. Raw data is then imported into the wind modeling software to calculate the wind potential.

Wind is strongly influenced by topography, orography, roughness and obstacles [11,12]. For each of the categories a special map that describes the relevant characteristics is derived and imported into the wind modeling software.

The output from the modeling software has an uncertainty related to it [13].

The portfolio method is conceived as and additional step taken after the wind potential assessment by using any of the software models for such estimation is calculated. It can be used to calculate wind speed (m/s), wind potential (W/m^2) or electricity generation (kWh). In this paper we will use the wind speed.

Method is based on calculating wind speed in one point and one height by using wind measurement data from measurement masts on other locations or by using measurements on the same location but on lower heights. Method also takes into account the uncertainty of calculation of each estimated wind speed.

Basic scheme of input data is shown in Fig. 2 and basic scheme of forming portfolios and evaluation of results is shown in Fig. 3. Details of each step of the method are described in the following sections.

3.2. Calculating wind speed/potential

The first step is to calculate the wind speed by using a software model, such as WAsP or similar. In this paper WindPRO 2.7 with integrated WAsP 9 is used.

Wind speed is calculated for a given location and height by using wind measurements from each available instrument or data source. We “deconstruct” the mast and use each instrument separately so