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Moroccan wind farm potential feasibility. Case study

Abdellatif Nouri [a,*], Mohamed Ait Babram [b,c], Elmostafa Elwarraki [a], Mustapha Enzili [d]

[a] Laboratory of Electric Systems and Telecommunications, Cadi Ayyad University, BP 549, Av AbdelkarimElkhattabi, Gueliz, Marrakesh, Morocco
[b] Laboratoire de Mathématiques et Dynamique de populations, Université Cadi Ayyad, BP 549, Av AbdelkarimElkhattabi, Gueliz, Marrakesh, Morocco
[c] IRD, UMI 209, UMMISCO, IRD France Nord, F-93143 Bondy, France
[d] National Agency for the Development of Renewable Energy and Energy Efficiency (ADEREE), Renewable Energy Division, BP 509, Street Machaar El Haram, Issil, Marrakesh, Morocco

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ABSTRACT

The subject of this paper is the elaboration of a methodology to study the technical feasibility of a wind farm potential. The implementation of this methodology allows a comparison between the wind resources of two different sites in Morocco. One site is located in the region of Essaouira, whereas the other one is located in the region of Safi. The comparison is based on real wind data collected from two masts at the heights of 30, 50, and 60 m. Each of the masts is installed at one of the mentioned potential sites over a fixed time period, lasting fifteen months for the first site, and eight months for the second one. The aim is the determination of the most applicable site presenting a good potential for a statistical study in order to predict long-term wind behaviors. Thus, the geographical situation study of the chosen site including topography, roughness and obstacles, is carried out. Furthermore, the wind resource using data, generated by the measuring masts, is evaluated. Finally, the areas which present great wind potential are located and the wind farm turbine locations are optimized by using the WAsP software.

1. Introduction

Access to energy and energy security is a significant criterion for the social and economic development. Driven by globalization, the energy demands increase rapidly [1]. Investments in renewable energy resources have become a primary focus for the government policies, academic research, and energy industry [2], due to the effects of: (i) the gradual decrease of fossil fuel reserves in the contexts of rapid industrialization, (ii) environmental pollution and (iii) climate change due to greenhouse gas emissions [3].

Wind energy currently contributes approximately 4% of worldwide electricity consumption [4]. The Global Wind Energy Council [5] assumes that the wind power average annual rate increases around 20%. The world's total installed wind power capacity has grown surprisingly fast, from 47.620 GW to 318.105 GW during the period of 2004–2013 [6]. The global annual installed wind capacity has surpassed 35 GW since 2009. In [7] the world's total installed wind power capacity has reached 369.597 GW by the end of 2014. Concerning the total installed wind power capacity, china is leading with 114.609 GW and contributing 31% to the worldwide total, followed by the USA (17.8%) and Germany (10.6%) [7].

As part of its energy strategy, the Moroccan government supports the development of renewable energies and their energy efficiency. The Moroccan integrated wind energy project will allow the country to increase the installed electrical wind power from 280 MW in 2010 to 2000 MW in 2020 [8].

Planning a new wind farm begins with the search for a suitable location (farm setting). This is crucial to the performance and economy of the wind farm. Moreover, to ensure the effectiveness of implantations, it is also necessary to improve the wind potential simulation of a given site.

Within the last five years a lot of scientific studies about the feasibility of wind farms have been carried out worldwide. For a short overview about the so far accomplished work, and a better further understanding, some of the essential investigations are described briefly below.

Irfan et al. [9] investigated the southeastern Pakistan wind power production potential. The measurements include frequency distributions of wind speed and wind power densities, seasonal variations of speed as well as estimations of power produced by commercial turbines. Ouammi et al. [10] studied the monthly and seasonal variations of wind characteristics in relation with wind energy potential in the Liguria region, Northwest Italy. Mostafaeipour et al. [11] analyzed the wind speed of eleven cities in the

* Corresponding author.
E-mail addresses: abdellatif.nouri@gmail.com (A. Nouri), aitbabram@gmail.com (M. Ait Babram), m.elwarraki@uca.ma (E. Elwarraki), enzili@hotmail.com (M. Enzili).

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central part of Iran and reviewed the feasibility and the effectiveness of wind turbine implementation. Saleh et al. [12] used five different methods for the calculation of Weibull parameters in order to design the optimal wind farm for the Zafarana wind farm in Egypt. Boudia et al. [13] analyzed the wind characteristics of four locations in Algerian Sahara using the Weibull distribution compared to air temperature.

In addition, more recently, a significant amount of work has been done to assess the wind potential at specific locations [14–21]. Zhang et al. [14] developed a metric method, the wind power potential, to characterize and predict the quality of wind resources at a site. In the same year, Velo et al. [15] proposed another method based on neural networks-based method to determine the annual average wind speed based on short-term wind data at a complex terrain site. Tizpar et al. [16] used the Weibull distribution to evaluate the wind potential of the Mil-E Nader region in the Sistan and Baluchestan Province, Iran. Khahro et al. [17] also used the Weibull parameters in order to assess the wind power potential of Babaurband in Pakistan. Shu et al. [18] attempted to explore wind characteristics at different locations in Hong Kong, and estimated the wind energy potential using statistical analysis. Bilir et al. [19] investigated the wind energy potential using Weibull distribution parameters at two different heights of 20 m and 30 m in Ankara. Pishgar-Komleh et al. [20] made a study investigating Weibull parameters and wind power density using mean wind speed and the root mean cube of the wind speed in Firouzkooh county of Iran. In the work of Boudia et al. [21], ten years of wind data from the Oran meteorological station were used to evaluate the potential of wind power and assess the costs for wind power-produced electricity per kW h in Oran in Algeria.

In the mentioned studies, the authors made great efforts to determine the wind energy potentials in almost every country. Therefore, the most important step in the decision-making is the long-term wind resource prediction in order to evaluate the uncertainty of the wind resource. Hence, wind data of several years is needed. However, wind data from weather stations is impaired by their availability for standard levels only, missing measurements and instrumental errors. With respect to their costs, wind potential measurements at the studied sites are often limited to a minimum and a short duration. In order to undertake these forecasts scientifically, comparing with one or more nearby sites where long series of wind data measurements have been recorded is possible using statistical methods. Carta et al. [22] reviewed a wide range of measure-correlate-predict methods used for estimating long-term wind conditions for a target farm site. Furthermore, the data generated by Numerical Weather Prediction models have been widely used for wind resource assessments [23].

For the development of a wind farm and for wind resources long term predictions, knowledge about the topography is required. This includes: (i) a detailed description of the surface roughness, as well as (ii) a description of the existing obstacles and (iii) information about the topography. To gain needed data, geographic information systems (GIS) can be used. These contribute as a decision tool to identify economically functional and environmentally feasible sites, using a large amount of spatial data related to various technical, economic, social and environmental criteria. [24].

The study, presented in this paper, is carried out in this context. The data of wind measurement stations is used to assess and evaluate the wind power potential. The measurement stations are located at two different sites in Morocco and installed in heights of 30, 50, and 60 m. The first reflection axes lead to an elaboration of a wind farm development methodology. Later on, gained data are implemented in the following steps: (i) real wind data have been collected, processed and analyzed from two different wind measurement stations for a specific time period, lasting fifteen months for the first and eight months for the second station; (ii) a comparison between the parameters of the Weibull distribution, the wind direction and the wind speed is made to choose the best site for a detailed study; (iii) a new long-term evaluation method of the wind farm is performed using multivariate analysis with SPSS Software, which is utilized in statistical analyses, by comparing the relevance and coherence of the obtained data with those of neighboring port meteorological stations; (vi) the topography, roughness and obstacles at the site are described in order to implement a geographic information system; (v) a comparison is drawn between various configurations of a wind turbine in order to evaluate the electrical energy that can be produced by the wind farm. The WAsP program is used to analyze the Wind Atlas of the region to find the areas with the most appealing wind potential. These steps are leading to an optimization of the wind farm concerning characteristics, direction and location of the wind turbines, to ensure a better annual productivity. Moreover, the amount of greenhouse gases which is reduced by a 10 MW wind farm is calculated.

The remaining of this paper is organized as follows: Section 2 presents the wind farm evaluation data preparation, Section 3 reveals the obtained simulation results with the discussion, and Section 4 concludes the results.

2. Wind farm evaluating data preparation

Initially the preparation of wind farm evaluation data is presented. Thus, all following methods are used in order to put the new adopted methodology into practice.

2.1. Adopted methodology

Before focusing on the methods, a definition of the methodology which can be applied for a technical study of the feasibility of a wind farm is provided. The methods presented in this paper include:

- Gaining, processing and analyzing wind measurement data.
- Selecting the best site for a detailed study by comparing the Weibull parameters, wind speeds and wind directions.
- Comparing the relevance and consistency of the obtained data with those of neighboring meteorological stations.
- Describing the topography, roughness and obstacles.
- Determining the appropriate type of wind turbine for a particular location.
- Calculating the annual electrical production potential.
- Calculating the amount of greenhouse gases reduced by the wind farm.

The used methodology for a wind farm project simulation using WAsP software [25] is shown in Fig. 1.

2.2. Wind data measurement

The on-site wind resource characterization contains: (i) obtaining representative samples of the wind climatology at the study site, (ii) eliminating the seasonal character of the wind and (iii) identifying the conditions and constraints which are taken into account for a better exploitation of the park related to the production of electrical energy.

In this paper, the data of wind measurement stations, installed at two different sites in Morocco (Fig. 2), are used to assess and evaluate the wind power potential. The measurement stations are installed at heights of 30, 50, and 60 m. The time periods of measurement are: