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Renewable and Sustainable Energy Reviews

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

Evaluation of wind energy potential in province of Bushehr, Iran

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ARTICLE INFO

Article history:

Received 18 June 2014

Received in revised form

22 June 2015

Accepted 27 October 2015

Keywords:

Wind energy potential

Bushehr

Weibull distribution

Power density

Wind turbine analysis

ABSTRACT

Renewable energy is receiving increasing interest from industry and government in Iran. Among the many types of renewable energy available in the country, wind energy is currently one of the fastest growing, most commonly used and commercially attractive renewable sources for generating electricity. In this paper, the wind energy potential is assessed for four locations in Bushehr province of Iran: Asaluyeh, Bordkhun, Delvar and Haft-Chah. The analysis utilizes wind speed data measured in 2011 at heights of 10 m, 30 m and 40 m above ground level. The goal is to improve understanding of the potential of wind energy for the selected locations and to thereby improve the prospects for its usage. The Weibull probability distribution function is employed to calculate the wind power density and energy for the regions. We found that the Weibull distribution fits the experimental data well over an acceptable range. The statistical analyses of the wind data include estimations of the monthly and diurnal mean wind speed cumulative curves, and the creation of wind rose diagrams. The results indicate that Bordkhun has better potential for using wind energy than the other three areas in the province examined. The annual mean wind power density for this location is found to be about 265 W/m² for winds at a height of 40 m. Energy analyses are used to determine the best wind turbines for each location. Twelve wind turbines with generating capacities ranging from 1 kW to 100 kW are examined, and the annual capacity factor and annual energy output of the selected wind turbines are calculated. A comparison of the results for the wind turbines indicates that the Proven 15 has the highest capacity factor and economically is the best choice for all of the locations considered.

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1. Introduction

Due to concerns regarding fossil fuels, such as finite reserves and environmental impacts like climate change, and increasing electricity demands, many countries and governments are seeking to increase the use of renewable energies such as solar, wind, biomass and geothermal. Renewable energy sources are alternatives to fossil fuels and are thought by many to be sustainable, ubiquitous and essentially non-polluting [1]. Wind energy is one of the most significant renewable energy sources because of its advantages, such as clean, abundant, relatively affordable, inexhaustible and environmentally benign [2]. The use of wind turbine technology has increased rapidly over the last few decades. Many countries have tried to enhance knowledge of and technologies for wind energy generation.

An important step in the implementation of wind turbines is an assessment of the wind energy potential for relevant locations. This can be challenging because of the nature of the resource. The characteristics of wind energy, in terms of speed and direction, exhibit a high degree of temporal and spatial variability. The variability could lead probabilistic uncertainties, and these uncertainties might affect system operation significantly [3].

Over the last decade many researchers have studied the potential of wind power and wind characteristics in many regions of the world. Iran also has begun harnessing wind energy from sites with acceptable wind potential. Wind resource assessments can be divided into two main types based on area: regional assessments and micro-sitting. A regional assessment provides an overall estimation of the mean energy content of the wind over a large area. Micro-sitting is carried out to position one or more wind turbines on a land area in order to optimize the overall yearly energy output of a wind farm. During the last two years, many 40-m high towers have been installed in many provinces of Iran in order to provide wind information for an Iranian wind atlas. A precise prediction of the wind speed at a site is important for quantifying regional wind energy resources. Based on aerodynamics, the power output of a wind turbine is proportional to the third power of the wind speed. But wind energy content may nonetheless vary significantly from one region to another, especially in complex terrain.

In 1994 the first modern wind turbine was installed in Iran at Manjil [4]. Subsequent efforts, such as the construction of 25 MW and 60 MW power stations at Manjil in 2003 increased electricity generation from wind notably [5]. The Manjil and Binalood wind farms are the major wind sites in Iran. In the years 2006, 2008, 2009 and 2013, Iran was able to generate 47 MW h, 82 MW h, 91 MW h and 100 MW h of electricity from wind. Iran's power generation capacity via wind turbines is estimated to be around 15,000 MW [1]. Assessments of wind energy potential have been reported for various regions in Iran (e.g., Manjil in Guilan [6], Yazd [7], Tehran [8], north-western Iranian cities [9], Ardabil [10], Shahrabak in Kerman [11], Aligoodarz in Lorestan [12], Zarrineh in Kurdistan [13], Binalood in Khorasan [14] and Zahedan in Sistan-Baloochestan [15] provinces). Furthermore, several researchers have investigated various topics, specific to the climate of Iran, such as the feasibility of offshore wind turbine installations [16], the future of renewable energies [17], the status of wind energy [18], the development of wind energy resources [19], and the economics of hybrid renewable energy systems for rural electrification [20].

The main purpose of this article is to evaluate the feasibility of using wind energy in several areas of Bushehr province. This study focuses on determining wind power density and wind energy potential. Also, several wind characteristics are investigated for four locations of Bushehr province. Finally, the performances of several wind turbines are tested at the considered regions.

2. Regional description of Bushehr

Bushehr province, one of the 31 provinces in Iran, is located in the south of the country with a long coastline on the Persian Gulf (Fig. 1). Bandar-e-Bushehr is the center of the province, and its nine other counties are: Asaluyeh, Bushehr, Dashtestan, Dashti, Dayyer, Deylam, Jam, Kangan, Ganaveh and Tangestan (Fig. 2). With an area of 27,743 km², Bushehr is the 16th largest province in the country and is situated between N27°19'–N30°16' latitude and E50°01'–E52°59' longitude. The province of Bushehr is bordered on east by the province of Fars, on the north by Khuzestan and Kohgiluyeh provinces, on the south by Hormozgan province, and on the west by the Persian Gulf. Bushehr province can be divided geographically into two parts: the plains and the mountainous regions. The plains extend along the coast of the Persian Gulf, and are where the majority of the cities and inhabitants are located. The mountainous regions include the two mountain ranges of GachTorsh and Nokand, which run parallel to each other along the length of this province. According to the latest statistics (2012), Bushehr province has a population estimated at 1,000,000 of which nearly 68.2% are in urban areas, 30.8% are in rural regions and the remainder are non-residents [21,22]. Table 1 shows the location of meteorological sites for all studied zones.

3. Approach and methodology

For Bushehr province, the objective of investigating the feasibility of using wind energy and determining the wind power



Fig. 1. Bushehr province in Iran [20].

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