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Assessment of wind energy potential and economics in the north-western Iranian cities of Tabriz and Ardabil

Farivar Fazelpour [a], Nima Soltani [b,*], Sina Soltani [b], Marc A. Rosen [c]

[a] Department of Energy Systems Engineering, Faculty of Engineering, Islamic Azad University-South Tehran Branch, Tehran, Iran
[b] Young Researchers and Elite Club, South Tehran Branch, Islamic Azad university, Tehran, Iran
[c] Faculty of Engineering and Applied Science, University of Ontario Institute of Technology, Oshawa, Ontario, Canada

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ABSTRACT

In recent years, wind energy utilization has become increasingly attractive on economic grounds. Wind turbines for electricity generation employ a proven technology, supply energy on a reliable and sustainable basis, and at good, windy sites may even be competitive with conventional sources of energy. In this paper, the statistical results are reported of an investigation of the potential of wind energy as a power source for the Iranian northwestern cities of Tabriz and Ardabil. A number of different methods were explored as well. In this study, the Weibull probability distribution function is employed using mean meteorological wind data measured at three-hour intervals. These data have been measured at a height of 10 m above ground level and gathered over a six-year period. Furthermore, the hourly, diurnal, seasonal, monthly, and annual wind speed variations are analyzed and the economics of the wind turbines is evaluated. The yearly values of the Weibull shape parameter vary from 1.81 to 2.13 m/s with a mean of 1.99 m/s for Tabriz and from 2.62 to 2.98 m/s with a mean of 2.86 m/s for Ardabil. Also, yearly values of the Weibull scale parameter vary from 3.35 to 4.45 m/s with a mean of 4.18 m/s for Tabriz and from 3.68 to 4.55 m/s with a mean of 4.16 m/s for Ardabil. The results show that the highest wind power potential occurs during months of August and July in Tabriz and during months of October and September in Ardabil. The results indicate that the monthly mean price of electricity generated from the 25 kW wind turbine in Tabriz and Ardabil, for most of the months of the year, are less than or approximately equivalent to the current purchase tariff of renewable energy in Iran.

Contents

* Corresponding author. Tel.: +98 9141008507.
E-mail addresses: f_fazelpour@azad.ac.ir (F. Fazelpour), nima_soltani@yahoo.com (N. Soltani), Sina_soltani@engineer.com (S. Soltani), marc.rosen@uoit.ca (M.A. Rosen).

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1. Introduction

Due to increasing industrialization, world population and electricity demand in recent years, utilization of natural resources such as oil, gas and coal have raised. Increasing utilization of hydrocarbon-based fuels leads to increasing environmental emissions of various forms of air pollution, greenhouses gases such as carbon dioxide, and other substances. Also reserves of fossil fuels are limited. Therefore, initiatives have begun to substitute renewable energies such as solar, wind, biomass, tidal and wave for fossil fuels. Global warming phenomena and environmental pollution considered are serious global threats by many researchers [1].

Renewable energy sources have gained in popularity in recent years because they are effortlessly and widely available and relatively benign environmentally. Use of wind energy has been used in many countries to helps to reduce dependence on fossil fuels and to enhance sustainability [2]. Wind energy has become an increasingly important resource for power generation globally, and its application is increasing annually [3]. This trend has been reinforced because, since the oil crises in the 1970s, fossil fuel prices have increased and the costs of renewable energy technologies have significantly declined [4]. Studies on renewable energy applications have increased dramatically since 2000 [5].

Effective use of wind power requires a detailed knowledge of the wind characteristics at the application location [6]. The European Wind Energy Union classifies wind energy as follows: approximately good ($\overline{V}$=6.5 m/s), good ($\overline{V}$=7.5 m/s), and very good ($\overline{V}$=8.5 m/s) [7], where $\overline{V}$ denotes the mean wind speed at a given height. Unlike estimating solar energy, potential wind energy and wind speed are not easily estimated because they greatly depend on the features of the site and location [8].

On a worldwide basis, the cumulative installed wind generation capacity increased between 1996 and 2012 (Fig. 1), and during the period of 2007 and 2012, it increased by more than a factor of three. A wind power capacity of 44.7 GW was operational in 2012, representing an annual increase of about 19%. In 2011, the wind power capacity increased by 20% worldwide relative to that in 2010, representing a higher annual growth rate on average as it compared with most other renewable energy sources.

Approximately 10 million MW of wind energy is continuously accessible in the world [10] and the maximum global wind potential is around 35% of the total global energy consumption. But the global installed capacity only reached 282,430 MW in 2012, as seen in Fig. 1 [9].

As shown in Fig. 2, the countries with the most installed wind power capacity are China, United States of America (U.S.A), Germany, Spain, India, England, Italy, France, and Canada, accounting for over 80% of the global total renewable energy resources. China, U.S.A, and Germany account collectively for almost 60% of the total electricity generated from wind.

The worldwide wind turbine capacity connected to the grid was approximately 2000 MW in 1990, mainly in the U.S.A and Denmark [11]. The Netherlands, England, Italy, Germany, and India have began using wind energy since 1990 [11]. But the usage of wind power generation remains relatively small, despite advancement in technology, which helped to reduce the cost of electricity generation from wind turbines.

The use of wind energy for the six regions for the period of 2004–2012 is shown in Fig. 3. China and India account for 27% and 6%, respectively, of wind energy usage, while the corresponding values for U.S.A and Canada are 21% and 2%, respectively [9].

The International Energy Agency predicts that by 2030 wind power will be the second largest source of renewable energy, right

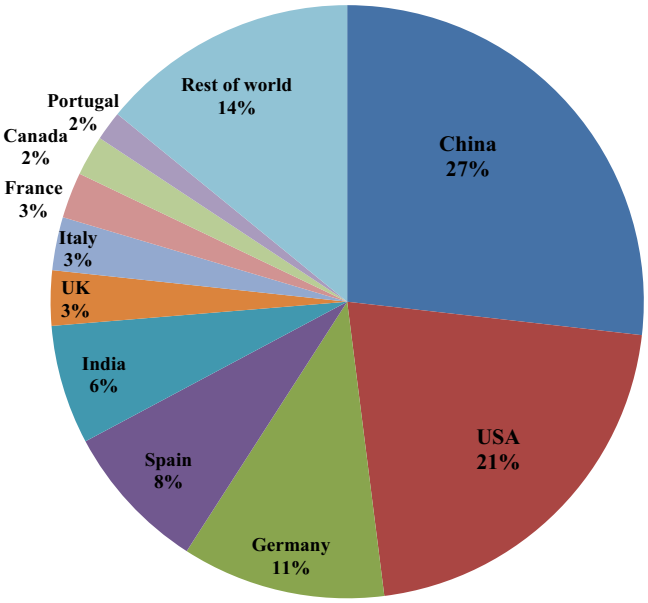

Fig. 2. Leading countries in installed wind power plants capacity as of Dec 2012. *Data source*:[10].

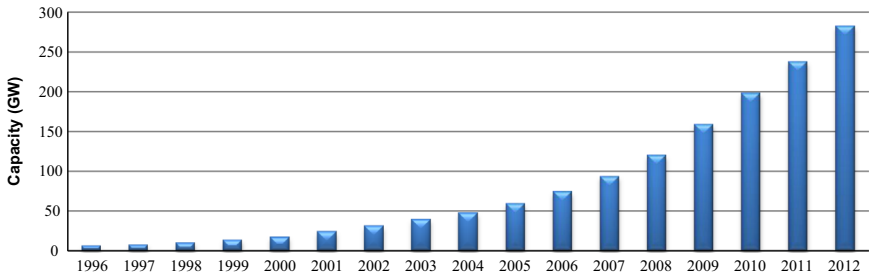

Fig. 1. Global annual installed wind power generation capacity for 1996–2012. *Data source*:[10].