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Techno-economical evaluation of wind energy potential and analysis of power generation from wind at Gharo, Sindh Pakistan

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ABSTRACT

Renewable sources of energy are more favorable these days because these are environment friendly with zero emissions as compared to conventional energy sources. Wind energy is most rapidly growing, among several renewable energy sources, worldwide. The prime objective of this paper is to analyze and evaluate the wind energy characteristics and wind power potential at Gharo Sindh Pakistan. Five years wind data from Jan 2003 to Dec 2007, measured at 30 m height, has been considered in this study. The mean wind speed is more than 5 m/s for every year. The most probable wind speed is 9.356 m/s while the wind speed carrying maximum energy is 11.43 m/s. the highest value of standard deviation is 3.561 m/s and the lowest value is determined as 1.587 m/s for wind speed data at Gharo. The Weibull shape and scale parameters in the ranges from 1.291 to 4.569 and from 2.377 m/s to 9.727 m/s respectively. The wind power and energy densities are more than 260 W/m^2 and 2300 kW/m^2 respectively. The comparison of wind power densities calculated though measured wind data and calculated using Weibull and Rayleigh functions is also carried in this study. The direction of wind at Gharo is westerly for almost all five year. The assessment for power generation, from wind data collected at Gharo, through wind turbines of different manufacturers has been carried out. The GE45.7 wind turbine generates high annual energy of 11.220 GWh with capacity factor of 0.56. The economic analysis using these wind turbines, for power generation, gave an estimated cost of US$0.0255 per kWh of energy from GE45.7 wind turbine. The technical and economic analysis of wind data collected at Gharo, Sindh shows that this site has apt wind energy potential and hence is suitable for development of wind power generation projects.

Contents

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1. Introduction

The growing energy demand, increased energy prices and quest to reduce environmental impacts due to conventional sources of energy has motivated to utilize renewable energy resources worldwide. Considerable research is being done on wide range of engineering and environmental application of renewable energy. Wind energy has become promising and most valuable choice among renewable sources of energy. Being environment friendly, inexhaustible, abundant and affordable, wind energy is fast growing renewable energy source not only in developed countries but also in developing countries. After addition of 44,609 MW in 2012 (more than ever before), the global installed capacity of wind power has reached to 282,275 MW [1].

Pakistan's limited oil and gas reserves depleting rapidly, technology barrier, high cost and many other reasons are a hindrance to utilize huge coal reserves as well as nuclear energy to overcome the energy crises of the country [2]. The growing energy demand, hastily decreasing country's fossil fuel reserves, day by day increasing oil import cost and environment degradation have necessitated to utilize renewable sources of energy like wind energy to generate electricity in Pakistan. Pakistan Meteorological Department (PMD) has pointed out some potential area of about 1100 km along coastal belt of Sindh and Balochistan provinces for wind energy power projects. Studies about the wind energy potential of some of the locations have been carried out but many other locations are yet to be investigated.

The potential of wind energy for any selected site may be determined by sprouting detailed gen about the wind characteristics, like wind speed, availability, continuity and its direction [3,4]. These wind characteristics has been analyzed using different techniques, such as Weibull and Rayleigh methods, WASP (application program) and Wind Atlas analysis [3]. Also these characteristics have been evaluated at different temporal scales, like; monthly, seasonal and yearly, based on time scale of wind speed data.

The world's population is increasing day by day and the ratio of this growth is high in developing countries than developed countries. Consequently energy demand is also increasing in the same way. Keeping in view the situation of depleting local fossil fuel resources, continuous increase in fossil fuel import cost, rapid population growth and corresponding increase in energy demand many developing countries alongwith developed counties started to utilize renewable energy resources (having advantages of being sustainable, ubiquitous and essentially non-polluting) to meet the energy demand of their respective country. Studies and evaluations of wind characteristics and potential of wind power have been performed in many countries of the world. Analysis of wind power potential of Hong Kong islands using weather data has been discussed by Lu in [5]. Lin Lu also analyzed characteristics of wind turbine and selected best wind turbine based on optimum wind speed for different weather conditions. Wind energy potential and wind data analysis using Weibull probability distribution function of northern coast area of Senegal was studied in [6]. Vogiatzis et al. investigated potential of wind, by calculating average monthly and yearly wind speed, frequency distribution of wind speed and its direction, in order to evaluate capability of wind energy for the proper operation of desalination pilot unit for Mikra-Thessaloniki in North Aegean, Greece [7]. Besides mitigation of climate change, wind energy's progressive impacts on chances to reduce energy enslavement are undeniable. Assessment of wind energy and simulation of wind farm in Triunfo–Pernambuco, a state in northeast of Brazil, is presented in [8]. In this study, wind assessment was carried using wind speed, direction and temperature data and simulation for 20 MW wind farm (with 850 kW wind turbines) was done using WAsP software. It was concluded that the project would be feasible both technically and economically.

Studies and assessments of wind energy resources for some of location of Iran like; Shahrbabak in Kerman province [9], Semnan province [10], Yazd province [11], capital city Tehran [12], Zarrineh [13], Ninalood, Iran [14], etc. has been carried out in literature. Feasibility study of wind energy for Shahrbabak in the keman Province, Iran was carried out by Mostafaeipour et al. in [9]. In this study statistical analysis of power generation potential of wind was carried out. Also feasibility study, both technically and economically, of installation of wind turbine was conducted with conclusion that the Shahrbabak site is suitable for the installation of small off-grid standalone wind driven systems instead of large wind power projects. Mirhosseini et al. [10] statistically analyzed wind power generation potential for five towns of Semnan province in Iran. In this study wind data collected at 10 m is used to calculate wind speed at 30 m and 40 m heights though extrapolation. Weibull probability distribution function was used to determine statistical distribution of wind speed data collected at five towns in Semnan province. Feasibility study of wind energy for Yazd, Iran is described in [11]. Mostafaeipour analyzed wind speed of some cities in Yazd province and carried out feasibility study for implementation of wind turbines to generate wind power at the investigated sites. Keyhani et al. assessed wind energy potential as power generation source in Tehran, the capital city of Iran [12]. Wind characteristics were assessed using meteorological observed wind data and calculated though Weibull method. Though the analysis of long term wind data showed that Tehran site was not suitable for large wind power projects but wind power can be used for small non-grid application. Estimation of wind potential of Zarrineh, iran is investigated by Mohammadi et al. in [13]. In this study wind power was calculated using standard deviation and wind power density method and found that wind power density method is more accurate. Evaluation showed that the Zarrineh site is economically feasible for installation of small wind projects. Mostafaeipour et al. [14] evaluated potential of wind as source of power generation in Binalood, Iran and found that the investigated site has potential for large grid connected system. [15] investigated wind energy Characteristics for 68 locations in Iran. Wind energy resources for Yanbo, Saudi Arabia were assessed in [16]. Annual, Seasonal and diurnal variation of wind speed was analyzed in this paper. Analysis showed that small wind turbines gave high energy production than large