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An extensive evaluation of wind resource using new methods and strategies for development and utilizing wind power in Mah-shahr station in Iran

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ABSTRACT

In this study, the 10-min period measured short-term wind speed data at 10 m and 40 m heights for Mah-shahr station in Iran was statistically analyzed to determine the potential of wind power generation. In addition in this paper different distribution functions are compared to each other in order to find the best distribution in Mah-shahr which is compatible with the wind data. It is found that the Weibull distribution is the best function to model the wind data in Mah-shahr. It should also be mentioned that the different methods for calculating Weibull parameters were used and compared to each other. Moreover an extreme analysis of wind data in Mah-shahr was carried out to determine the maximum gust wind speed over a 50-year return period (Ve50). Using the method of "periodic maxima" for analysis of extreme winds, it was revealed that the 50-year wind speed at 80 m in Mah-shahr which is 39.5 m/s is lower than usual values of Ve50 limits for different wind turbines. This means that the risk of extreme wind gusts in Mah-shahr might not be a problem for installation of wind turbines. From the primary evaluation of wind data in Mah-shahr it is found the studied site has an acceptable potential of wind power for electricity generation. Energy production of different wind turbines at different heights is determined. Then a simple economic evaluation carried out to determine whether studied site is suitable for development of commercial or small and residential wind turbines. It became clear that the "Nordex N100/2500" with a rated power of 2500 kW has the lowest price of electricity and has a high level of capacity factor. Thus in the second phase of the study an extensive economic evaluation of installing 10 MW wind park using 4 Nordex N100/2500 wind turbines was performed on the RETScreen® international simulation software. For this purpose, four main scenarios have been taken into consideration. It was revealed that in the second scenario by assumption of the new proposed feed-in-tariff rate (4400 rials), the return period of investment was significantly reduced. It has been demonstrated that the government's new policy for increasing the feed-in-tariff rate has been very effective for improving the financial viability of the proposed wind farm. In the final steps, effects of the clean development strategies have been taken into account.

1. Introduction

Climate change, global warming, and the recent nuclear plant disasters (e.g. Fukushima in Japan, Marcoule in France, Forsmark in Sweden and etc.) warn the earth about having a safe, reliable and economically sounded source of energy. Currently, the demand for fossil fuel is increasing, but its price is increasing sharply. It goes without saying that carbon emission must be decreased too. Utilization of renewable energy resources like wind is viable way towards a clean environment, sustainable and secure energy future in the world. The fastest growing renewable energy source in the world is wind which has been rapidly used in many countries. By the end of June 2012 the world wide wind capacity reached 254 GW, which the most contribution belongs to China and USA with an overall installed capacity of 67.77 GW and 49.80 GW, respectively [1].

Using wind energy is an important parameter which affects daily life of people in developing countries, where almost one third

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of the world's people live without electricity. Developing countries must expand their knowledge toward renewable sources of energy to meet the demand for energy [2]. Developed countries have paid more attention toward wind as a source of clean energy. Most of the European countries showed stronger growth in the first half of 2012 than in same period of 2011: The top markets in Europe continue to be Germany with a new capacity of 941 MW and a total of 30,016 MW, Spain (414 MW, 22,087 MW in total), Italy (490 MW, 7280 MW total), France (650 MW, 7182 MW total), the United Kingdom (822 MW, 6480 MW) and Portugal (19 MW, 4398 MW) [3]. USA added 2883 MW between January and June 2012, about 28% more than in the same period in previous year, while Canada installed 246 MW during the first half of 2012 [3]. Global warming, fossil fuel diminishing, climate change disaster, along with more energy demand underscore the increasing value of renewable energy implementation [4]. Wind is an alternative clean source of energy compared to fossil fuel, which pollutes the lower layer of the atmosphere. It can be harnessed on a local basis for application in rural and remote areas [5]. The main advantage of wind is that, like the hydropower, it doesn't need fuel. The only costs therefore come from building and maintaining the turbines and power lines. Turbines are getting bigger and more reliable. The development of technologies for capturing the wind at high altitudes could provide sources with small footprints capable of generating power in a much more sustained way.

The technology improvement is a major key element to the growth of wind turbine industry. Development of more efficient generators and power electronics, along with high strength fiber composites improvement are the main contributors to growth of wind turbine sector. Clearly, lower cost and efficiency of wind turbines urge countries to use the wind power instead of other conventional sources of energy [6]. In spite of the fact that the wind turbine price is decreasing recently, improper sitting for installation of the wind turbines results in loss of huge amounts of money [7]. On this account, precise assessment of wind potential along with economic evaluation play significant role in wind energy utilization for any location. Scanning the literatures indicate an extensive research works on wind power development and feasibility study in the whole world:

1.1. Wind resource assessment review

The wind characterization in terms of speed, direction and wind power is the first step to obtain the initial feasibility of generating electricity from the wind power through a wind farm, in a given region. Many relevant works have been developed in this aim:

1.1.1. Recent studies in the world

Wua et al. [8] employed three probability density functions, i.e., Weibull, Logistic and Lognormal for wind speed distribution modeling using data measured at a typical site in Inner Mongolia, China, over the latest three year period from 2009 to 2011. It has been demonstrated that the Logistic function provides a more adequate result in wind speed distribution modeling in the studied site. Adaramola et al. [9] studied the wind power generation along the coast of Ghana. The energy output and unit cost of electricity generated from medium size commercial wind turbine models with rated powers ranging from 50 kW to 250 kW were determined. It was found that the wind resource along the coastal region of Ghana can be classified into Class 2 or less wind resource which indicate that this resource in this area is marginally suitable for large scale wind energy development or suitable for small scale applications and be useful as part of hybrid energy system. Khahro et al. [10] analyzed Weibull scale and shape parameters 5 numerical methods in Babaurband, Sindh, Pakistan. Economic evaluation, to exemplify feasibility of installing wind turbines, was also done. The estimated cost of per kW h of electricity from wind was calculated as 0.0263 US$/kW h. Thus the candidate site is recommended for some small stand-alone systems as well as for wind farm. Akorede et al. [11] investigated the wind energy potential for production of electric power in the Peninsular Malaysia. Wind speed data of six selected sites across the country collected over a period of 10–20 years are employed for the study. Overall, the results obtained from this investigation show that the large-scale wind energy is not viable in Malaysia due to weak wind regimes; however, small-scale wind energy system may be economically viable in a few regions most especially when the recently launched feed-in tariff in the country is extended to wind energy. This study also showed that the standard deviation of the average monthly wind speeds is a better factor than the average annual wind speed for ranking of selected sites in terms of annual energy production. Boudia et al. [12] presented a statistical analysis of wind characteristics of four locations situated in Algerian Sahara, namely Bordj Badji Mokhtar, Djanet, Illizi and Tamanrasset, using Weibull distribution function on wind speed data at 10 m height. Wind speeds at 50 m were assessed by extrapolating the 2-parameter Weibull using the power law. In addition, the analysis of energy efficiency for wind turbine of 600 kW rated capacity was made for calculating electricity generation and capacity factor for all periods. Sunderland et al. [13] investigated if a viable wind resource, worth exploiting, exists at an accessible height above a city (Dublin, Ireland). The analysis showed that in conjunction with urban surface roughness, the urban frictional velocity must also be considered for urban wind resource modeling. The research is provided a renewable energy context by considering the productivity of a commercially available wind generator. The results show that the wind resource available at roughly twice the average building height at either an urban and suburban location is worth harnessing, but within a very short height reduction, the wind resource depletion renders the consideration economically unviable. Janajreha et al. [14] assessed the wind energy potential of Masdar City in United Arab Emirates using Weibull distribution function. In addition, the power curves of two sizes of horizontal axis wind turbines were coupled with the Weibull distribution. Chen et al. [15] first investigated the effect of using different hub height wind turbines in a small wind farm on power output. Three different wind conditions are analyzed using nested genetic algorithm, where the results show that power output of the wind farm using different hub height wind turbines will be increased even when the total numbers of wind turbines are same. Different cost models are also taken into account in the analysis, and results show that different hub height wind turbines can also improve cost per unit power of a wind farm. At last, a large wind farm with commercial wind turbines is analyzed to further examine the benefits of using different hub height wind turbines in more realistic conditions. Islam et al. [16] carried out a study of wind resource assessment in two regions in Malaysia using Weibull distribution. They found that that the selected regions are suitable for small-scale wind turbines. Lima et al. [17] analyzed wind characterization and wind power potential in Brazilian northeast region based on Weibull distribution function and showed the wind map and the wind power density map using WAsP program. Bekele et al. [18] studied wind potential assessment at four locations in Ethiopia using Weibull distribution function. The study showed that, three of four locations have the average wind speed of 4 m/s whereas another one has the mean wind speed of less than 3 m/s. Ouammi et al. [19] carried out a study about monthly & seasonal assessment of wind energy characteristics at four locations in Liguria region in Italy using Weibull distribution function. It was found, capo vado is the best site. The highest energy produced may be reached in December with a value of 3800 MWh. Fyrippis et al. [20] studied the wind energy potential assessment in Naxos island, Greece