Sustainable Energy Technologies and Assessments 11 (2015) 17–26

Contents lists available at ScienceDirect

Sustainable Energy Technologies and Assessments

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

Original Research Article

Assessment of wind energy potential for selecting wind turbines: An application to Thailand

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ARTICLE INFO

Article history:
Received 23 January 2015
Revised 26 May 2015
Accepted 26 May 2015

Keywords:
Wind energy
Wind analysis
Economic analysis
Wind turbine
Thailand

ABSTRACT

Wind energy assessment plays a critical role on determining installation of wind turbines in many countries worldwide. Wind analysis and economic analysis are proposed to systematically assess the potential of electrical energy production for commercial wind turbines. Statistical information of wind data and power curves of wind turbines are applied for determination of factors in decision making such as annual energy production and capacity factor. Accordingly, financial indices and reductions of both fossil fuel consumption and carbon dioxide generation are examined for installing potential wind turbines. The uncertainties of financial indices are determined under variances of parametric inputs within confidence intervals. Case studies are investigated in the central region of Thailand, which has a high demand for electricity. Annual mean wind speed is between 3 m/s and 5 m/s along directions of tropical monsoons. With the proposed methodology, a wind turbine with low cut-in wind speed, such as the Vestas™ V60 850 kW, can be recommended as one of the most feasible wind turbines for electricity generation in green economy under weak and moderate wind conditions in the considered sites. The annual energy production has the most impact on the uncertainty in the net present value, among other financial parameters.

Introduction

Currently, wind energy is increasingly interesting to researchers and investors as one of the most promising renewable energy sources [1–4]. Wind energy technology, with low operating and nonfuel costs, has grown considerably in recent decades to efficiently capture the kinetic energy of wind. Commercial scale wind turbines (>500 kW) are usually installed to feed wind energy into a grid for electricity distribution. Both improvement of efficiency and reduction of unit cost of wind turbines make wind power generation competitive to other conventional energy resources. Wind resource assessment is technically required as an imperative step in estimating annual electrical energy production from wind energy at potential locations [5]. Recently, investigation and assessment of wind energy resources have been done in many countries worldwide [6–24]. Many researchers have explored wind energy resources in many potential areas such as Europe [6–12], America [13], Africa [14–17], Middle East [18–21], and Asia [22–24]. For those critical assessments of the wind energy potential, wind data at studied locations are collected for wind analysis focusing on yearly mean wind speed, wind rose, Weibull probability density function, and annual energy production. Accordingly, the financial feasibility is determined from amount of electricity generation under various situations of countries. For example, it was reported that mean wind speed and average power density were very high with magnitudes of 8.6 m/s and 458 W/m^2 at the height of 10 m, respectively, in Nigeria [17]. The levelised costs of electricity, which were generated by Bonus™ 300 kW/33 and Bonus™ 1 MW/54, were promising at 0.019 US$/kWh and 0.012 US$/kWh, respectively. On the other hand, mean wind speed of 5.65 m/s and the average wind power density of 217 W/m^2 at the height of 40 m were reported in Tunisia [9]. The vast variations of the power density in Karnataka were found from 829.73 W/m^2 in monsoon season to 186.15 W/m^2 in winter season [20]. The power density across Iceland varied between 300 and 1500 W/m^2 in winter [11]. In Hong Kong, the capacity factor was obtained with 0.35 or ever reached the maximum value of 0.50 in October [23]. The costs of electricity generation were estimated to be 0.027 US$/kWh in Turkey and 0.041 US$/kWh in Jordan [12,21]. This study is to mainly assess wind energy resources under green economy in the central region of Thailand which is located in the mid area of South-East Asia. In other words, reduction of crude oil import and carbon dioxide generation are considered for

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http://dx.doi.org/10.1016/j.seta.2015.05.002
2213-1388/

yielding economic sustainability. It is a difficult task to choose a specific site where wind turbines may be installed because many factors have to be taken into account. One of the most important factors is a feasibility study in terms of both wind analysis and economic analysis at those prospective locations [12,17,22].

In fact, the central region of Thailand is a vast plains area, which is the location of the national capital, Bangkok, and it is surrounded by high mountains along borders of northern, eastern, and western regions as shown in Fig. 1. Its area is about a quarter of Thailand's area. Its climate is mostly tropical monsoon, which consists of northeast monsoon taking place from November to March, southwest monsoon taking place from May to October, and trade winds with a short period between those. In fact, the northeast and southwest monsoon winds are caused by the temperature difference between land and sea when seasons change [25]. For example, the tilting of the earth during summer yields more solar radiation in the northern hemisphere. Therefore, the northern hemisphere gets warmed greater than the southern hemisphere. In Thailand, the southwest monsoon wind blows toward the land surface area at the northern hemisphere and the warm air rises. Unlike the southwest monsoon wind, the northeast monsoon wind strongly blows in the opposite direction in winter.

Recently, the potential of wind energy in the central region of Thailand has been an issue due to extensive accessible areas [26]. The stability of electricity in the region will be improved if the potential of wind energy can be exploited. According to the latest wind map of Thailand [27] as illustrated in Fig. 1, the average annual wind speed at 90 m from ground level is from moderate wind speed (3–4 m/s) to high wind speed (6–7 m/s) at the edge of the central region of Thailand.

In this study, the economic feasibility of wind energy in the central region of Thailand is investigated by using one-year measured data of wind at three levels: 65 m, 90 m, and 120 m. Topographical data such as height variation, roughness, and sheltering obstacles are used to develop wind resource maps at three potential areas. Mapping potential energy helps to find areas, at which wind turbines can generate maximum electricity output. In wind analysis, studies determine annual energy production and capacity factor for achievable amount of wind energy generation. Due to the low-wind speed, three small capacity wind turbines are applied at the three sites in this study. The potential of wind power generation is assessed through each scenario of current economic conditions. Also, uncertainty of financial indices in economic analysis is investigated under variances of critical parametric inputs within confidence intervals. This sensitivity analysis aims to build confidence on the level of accuracy in assessing wind energy resources. This feasibility analysis is able to determine whether the project should be invested for selected wind turbines or not. The most important concern is whether a project can generate a profit in a green economy [28].

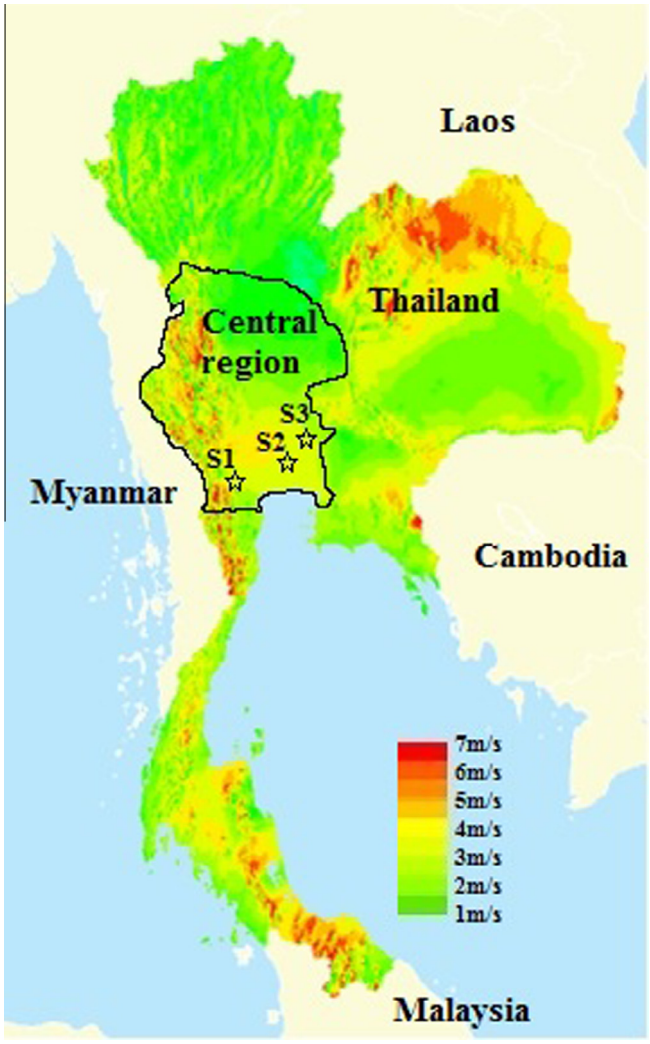

Fig. 1. Wind map and locations of wind masts in the central region of Thailand [27].

Location of wind masts and wind measurements

In this research work, a wind map of Thailand is initially investigated for finding accessible areas with high potential of wind energy. Field surveys in those areas are done by observing wind speed at ground level and personally questioning local people about wind potential during a whole year. There are many feasible locations, where it is possible to install wind masts of 120 m height as illustrated in Fig. 2. They are selected by high wind blow, wind-mast protection, and easy accessibility to existing power lines. In addition, all locations are in high demand areas of electricity. Fig. 1 provides statistical information about the yearly mean wind speed at a height of 90 m within the central region of Thailand, which is approximately bounded by the solid line. As a result of that, three suitable sites are chosen to cover the central region of Thailand; those are Ratchaburi (S1), Pathum Thani (S2), and Saraburi (S3), as shown in Fig. 1. The detailed locations of wind masts for wind measurement are listed in Table 1.

Measurement devices are mounted on wind masts for detecting wind speeds and wind directions at heights of 65 m, 90 m, and 120 m. A three-cup anemometer of NRG#40C and a wind vane of NRG#200P are used to measure wind speed and wind direction, respectively. The wind speed and wind direction are recorded by Nomad 2™ wind data loggers during the whole of 2012 at a sampling rate of 1 min with averaging of values every ten minutes. The percentages of the measurement data, which are recorded for the wind analysis, are 99.99%, 95.86% and 91.88% for the whole year at sites S1, S2 and S3, respectively.

Wind analysis of measured wind data

Wind analysis is a study on statistical information of measured wind data. It mainly focuses on identification of crucial parameters of the probability distribution function. The probability distribution function defines the occurrence frequency for each value of wind speed, which is collected for at least a year [5]. In calculating the amount of electrical energy generation from wind energy, power output functions of specific wind turbines with respect to wind speed are directly applied with the probability distribution