Renewable and Sustainable Energy Reviews 52 (2015) 613–622

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Assessment of wind energy for small-scale wind power in Chuuk State, Micronesia

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ARTICLE INFO

Article history:
Received 11 December 2014
Received in revised form
27 July 2015
Accepted 29 July 2015

Keywords:
Chuuk State
Wind energy
Wind energy density
Wind energy potential
Small-scale wind turbine

ABSTRACT

The purpose of this study is to conduct a precision survey by installing a meteorological observation mast in Weno Island, Chuuk State, in order to assess the possibility of introducing a wind energy in Chuuk State, Micronesia. The meteorological data observed by the meteorological observation mast during 2013 were used to assess the wind energy density and wind energy potential. The Weibull and Rayleigh model are used to fit the distribution of wind data. Meanwhile, the annual wind energy density was recorded at about 157.08 W/m^2, while the highest wind energy density was 345.91 W/m^2 in February 2013. In addition, the annual energy generation was estimated by using the power curves of 3 kW(V), 5 kW(V), 10 kW(V), 10 kW(H) and 20 kW(H) small-scale wind turbine. The results show that the annual energy production of 20 kW(H) wind turbine is expected to be about 36,841.73 kWh/year using estimated Rayleigh distribution. It was found that the Aeolos-H 20 kW wind turbine was suitable for installation of wind power in Chuuk. Meanwhile, capacity factor of 10 kW(H) was about 23.36 % using Rayleigh distribution.

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1. Introduction

Recently, as we are confronted with environmental problems such as the depletion of fossil fuels and global warming, the development of new and renewable energy sources needs to be encouraged. There are various types of new and renewable energy sources. And among them, the wind power is a valuable future energy source. As it uses wind to induce the rotational movement of blades, generating kinetic energy, which is in turn converted into electric energy. The wind power generation is the most advanced technology among new and renewable energy sources, and many countries around the world have made great efforts to develop

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http://dx.doi.org/10.1016/j.rser.2015.07.160
1364-0321/

wind power generation technologies and to secure greater generation capacities. In some European countries, 15–30% of the total electricity generation has been replaced by wind energy [1,2]. Together with the rapid growth of the wind power market around the world, small-scale wind power generators have achieved a substantial level of development, and there are approximately 250 small-scale wind power turbine manufacturers in 26 countries around the world. The development of small-scale wind power started in the early 1980s, and the small-scale wind power is expected to double by 2015, whereas the installation capacity is expected to triple in the same period [3]. Hence small wind energy system can make a significant contribution to our energy needs. The class of the small-scale wind turbine can be divided into "micro", "small", "medium" or "mid-sized". But there is no globally unified definition of small wind size turbine. However, generally the capacity of up to 1 kW-class is categorized as "micro"; the capacity of 1–30 kW-class is classified as "small wind turbine"; the capacity of 30–300 kW is categorized as "medium" or "mid-sized" [4,5].

The small-scale wind power becomes so much closely related to the everyday life of people, as they are used for purposes of electricity generation and private household generation in small areas where wind resources are not enough to develop the wind power. Also, as they are suitable for small-scale areas and do not need transmission facilities, they are suitable for smart grid as a decentralized power supply system. In addition, as they have little noises and vibration and do not require a large installation area, the maintenance is relatively easy. What is more, in case they are used as a hybrid generation system combined with other renewable energy generation methods such as solar power, the generation efficiency is expected to be greatly increased. However, one disadvantage is that the cost of energy is relatively higher than a large-scale wind power [6].

The development of wind power requires abundant wind resources to generate electricity. However, wind power generation is not easy in the tropical regions including South Pacific, because the wind speed is not strong enough. And some developing countries have poor infrastructure for electricity generation and do not have technology and economic power, they have difficulty establishing the electricity generation system and meeting the demand and supply of energy. Given this, a small-scale wind power system needs to be introduced in consideration of the wind resource conditions and the living environment of the region, where a large-scale wind power system is not suitable.

Recently, many researchers have studied for evaluation of small wind power all over the world. In other works, feasibility study of wind energy potential in the northwest coast of Senegal be carried out. The annual mean wind speed of Senegal varies from 4.16 m/s to 4.49 m/s. Furthermore, the annual energy production varies from 635 kWh/year to 1470 kWh/year for the small wind turbine[7]. Also, in other works, the annual energy production of Hofa small wind farm located in the north of Jordan is examined. In case of Hofa small wind farm, the annual energy production varies from 2250 MWh/year to 2550 MWh/year for 6 years [8]. Through these previous studies, we can calculate with accuracy the potentials of wind energy and plan to build up wind farm optimally. Thus, this study assessed the wind energy potential by analyzing the meteorological data of Chuuk State in Micronesia, measured during 2013 for the development of small wind power.

2. Overview of Chuuk State in Micronesia

As South Pacific has a vast portion of the ocean space on the Earth and is the source area of oceanic and meteorological environments, which have influence on the climate of Earth, the ocean has been the target of many researches. Also, there is a vast quantity of untapped oceanic natural resources and its economic and industrial values are huge [9].

Those countries which belong to South Pacific can be divided into Melanesia, Polynesia and Micronesia. Among them, Micronesia consists of the Marshall Islands, Palau and the Federated States of Micronesia (FSM). The FSM is an island state that is situated on the equator in South Pacific. It is located at 6.55° North latitude and 158.10° East longitude, 4025 km from Southwest of Hawaii. In addition, it is comprised of a total of 607 small islands. The FSM consist of four states including Chuuk, Kosrae, Pohnpei and Yap and its population is estimated about 107,000 persons as of 2008. Palikir, the capital city, is located in Pohnpei state. The land size is 705 km^2 and the coastal length is 6112 km.

In the meanwhile, Chuuk lagoon, which is the longest atoll reef in the world, consists of about 290 small and large islands – 192 outlaying islands, 15 major islands and 80 islets – surrounded by an atoll, which a ring-shaped coral reef. About 40 islands are currently inhabited by people, and approximately 20,000 people live in Weno Island where Chuuk State is located. [10,11]. In Chuuk state, the energy supply mainly depends on coal energy, and the shortage of energy supply is very serious now. So, it is very urgent to resolve its power supply problem. Therefore, the studies have been actively conducted to assess the potential of renewable energy sources including wind power, solar power, and tidal current power generation. Fig. 1 shows a map of Chuuk State.

3. Analysis of meteorological data

The process that is to observe wind resources and to analyze it for assessment of wind energy potential is called precision survey. The precision survey is very important, as it assesses the possibility of wind power development and selects the optimal turbine capacity based on the results of the precision survey.

3.1. Meteorological mast description

Korea Institute of Ocean Science and Technology (KIOST) established Korea-South pacific Ocean Research Center (KSORC) in May 2000 in Weno Island located in Chuuk State of Micronesia. KSORC is observing the physical oceanographic environment, ecological changes, meteorological changes, etc. Fig. 2 shows a view of KSORC inside Chuuk State.

KIOST is reviewing the possibility for the development of new and renewable energy by observing wind conditions and marine conditions, for the purpose of eco-friendly development and to meet the electricity demand of South Pacific island states. Fig. 3 shows a view of the meteorological mast installed by the KIOST in Weno Island.

As shown in Fig. 3, the meteorological mast, which integrated the anemometer, wind vane, thermometer, hygrometer and barometer, was installed at 10 m high above the ground. Also, the observation items included the maximum gust speed and direction, 10-min average wind speed and direction, temperature, relative humidity, and atmospheric pressure. The performance of the equipment is summarized as shown in Table 1.

To calculate the potential wind energy reserve amount and to review the development possibility, at least one year of observation data was needed [12,13]. In consideration of seasonal variations, this study used the data collected for one year during 2013 at a field site in Chuuk, at an observation altitude of 10 m above the ground.