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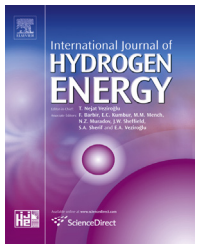

Wind characteristics and wind energy potential analysis in five sites in Lebanon

Gaydaa Al Zohbi [a,*], *Patrick Hendrick* [b], *Philippe Bouillard* [a,c]

[a] *Université Libre de Bruxelles, Building, Architecture and Town Planning, BATir, Avenue F. D. Roosevelt 50, CP 194/2, 1050, Brussels, Belgium*

[b] *Université Libre de Bruxelles, Aero-Thermo-Mechanics, Avenue F. D. Roosevelt 50, CP 165/41, 1050, Brussels, Belgium*

[c] *Nazarbayev University, School of Engineering, Kabanbay Batyr Ave., 53, Astana, 010000, Kazakhstan*

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ABSTRACT

The Lebanese electricity sector goes through a long crisis since the Lebanese civil war, marked by persistent rationing (demand is always greater than supply), mismanagement and a growing debt. This study aims at investigating the wind characteristics using actual wind data for five sites in Lebanon: Klaiaat, Cedars, Daher El Baydar, Marjyoun and Quaraoun. It was found that all sites have mean annual wind speeds greater than 3 m/s at 10 m height. The numerical values of the shape parameter k ranged from 165 to 236 in Klaiaat and Daher El Baydar for the minimum and maximum values respectively, whereas the value of the scale parameter c ranged from 407 to 630 m/s in Cedars and Daher El Baydar for the minimum and maximum values respectively. In order to verify if the wind energy could resolve or reduce the Lebanese electricity crisis, a study is elaborated on the monthly power produced by 116 wind turbines Enercon rated at a maximum 750 MW each that could be erected in five selected sites in Lebanon. The results show that the monthly based hourly electricity generated by these 116 wind turbines can cover the electricity demand during the night for whole months except August and September, and also a significant percentage of demand during daytime. Furthermore, the wind power could reduce the electricity crisis in Lebanon.

Introduction

The challenge of producing sufficient energy to meet the ever increasing global energy consumption, the rapidly depleting fossil fuel reserves, and the serious environmental problems associated with the use of fossil fuels have motivated considerable research attention on clean energy sources. Wind energy is one of the several energy sources that are both environmentally preferable and renewable. Moreover, wind energy is abundant in nature, inexhaustible, fuel-free, can generate power near load center, and thus eliminates energy losses associated with transmission network. There are, however, environmental problems

* *Corresponding author.*
E-mail address: galzohbi@ulb.ac.be (G. Al Zohbi).

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associated with wind power. Wind power has three main environmental problems that are visual impact, noise, and wild life impacts [25].

Today, wind energy is widely used to produce electricity in many countries. It is becoming the fastest growing renewable energy in the world. Thanks to the decisive improvement of technology over the past 30 years, the production of electricity by wind energy has reached a high level of technological maturity and industrial reliability [5,11]. Although wind energy is one of the most efficient energy sources, it is very variable compared to other sources of energy. It is also more sensitive to variations with topography and weather patterns compared to solar energy. Wind energy can be harvested at an economical level if the wind turbine is sited in windy area and a careful choice of the type of wind turbine that matches the wind pattern of the site is made. Thorough knowledge of the wind speed characteristics at a site of interest is very important in planning to harvest wind energy [23].

Effective use of wind energy necessitates detailed information of the wind characteristics and the distribution of wind speeds of the region. Many factors, such as the wind speed, the wind power, the generator type, and a feasibility study, have to be taken into account to install wind energy transformation system in a site. Many studies of the wind characteristics and wind power potential have been conducted in many countries worldwide by researchers. An analyze of the wind speed characteristics and wind energy potential are carried out by Emami and al. in the Firouzkouh region of Iran [13], by Ngala and al. in Maiduguri in Nigeria [24], by Bagiorgas and al. in Greece [8], by Ahmed Shata and Hanitsch on the coast of Mediterranean Sea in Egypt [3], by Keyhani and al. in Tehran in Iran [20] and by Chang and al in Taiwan [10].

Electrical energy in Lebanon is currently produced by fossil fuels (gas oil, heavy fuel oil), hydro-power and importation. The total installed capacity is 2038 MW for the thermal power plants and 2736 MW for the hydropower plants [15]. Demand always exceeds supply and outages are frequent in peak periods [28]. Lebanon suffers from a crisis in the power sector and was committed at the Copenhagen Summit to produce 12% of its energy from renewable source on the horizon of 2020. Therefore, the need of a new clean source of energy that increases electricity production from renewable source is crucial. To date, there is no record of wind power plants in Lebanon even if has fairly high wind energy potential [16].

The main purpose of this study is to investigate the wind characteristics and electrical energy produced by 116 wind turbines Enercon rated at maximum 750 MW each that could be installed in five sites in Lebanon to estimate their capacity to minimize the electricity crisis in Lebanon.

Data

Wind data measurements

The locations of the five sites considered in this study are shown in Fig. 1. The wind data were taken from the Meteorological service in Lebanon for at least one year (2 years for Klaiaat, 1 year for Cedars, 7 years for Daher El Baydar, 2 years for Quaraoun and 1 year for Marjyoun). All measurements in the wind observation station were recorded using the cup anemometer at a height of 10 m above the ground level. The measurements of the monthly average wind speed are presented in Table 1.

Fig. 1 – Location of the sites used in this study (Source: locations on google map).

Table 1 shows the monthly mean wind speeds in the sites used in this study. As can be seen in Table 1, the mean monthly wind speed varies between 205 and 678 m/s. The maximum value of the mean monthly wind speed of 678 m/s was recorded in February in Daher El Baydar while the minimum value as 205 m/s was recorded in October in Marjyoun. The maximum value of the annual wind speed of 555 m/s is recorded in Daher El Baydar whereas the minimum value 377 m/s is recorded in Cedars.

Mean monthly wind speeds for different seasons of the year are plotted in Fig. 2. During winter season, the wind speed level at two stations Klaiaat and Daher El Baydar reaches high values of 5.84–6.78 m/s. The maximum mean wind speed occurs at Daher El Baydar during February with 6.78 m/s. In spring season, the maximum value of wind speed is recorded in Daher El Baydar with 5.95 m/s during March. In summer season, the wind speed level reaches 6.28 m/s at Daher El Baydar during June. For autumn season, the maximum mean wind speed is recorded as 4.93 m/s at Daher El Baydar in October.

Fig. 2 gives the following findings:

(1) The highest values of mean monthly wind speed of all stations occurred during winter and summer seasons;
(2) For all seasons, Daher El Baydar has the maximum values of monthly wind speed.

Wind turbine characteristics

The comparison between the leading manufacturers of onshore wind turbines, Gamesa, Enercon, Siemens, Senvion, is shown in Table 2. The German wind turbine Enercon E126-7.5 is the highest powerful wind turbine with a rated power of 7.5 MW, followed by Gamesa G132-5 with a nominal power of 5.0 MW. The wind turbine Gamesa G132-5 has the lowest start-up speed, which means that the wind turbine starts at a