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Velocity and power density analysis of the wind at Letšeng-la-terae in Lesotho

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ABSTRACT

The wind profile of Letšeng-la-Terae in Lesotho is analyzed using a 2-year data of 10-min averages. Wind velocity distribution data is estimated as a Weibull distribution using the Graphical Method and Method of Moments. The optimal Weibull parameters for the bi-annual data are obtained using the Method of Moments and the values of the dimensionless shape parameter, $k = 1.76$, and the scale parameter, $c = 6.71$ m/s at 10 m above ground level. The calculated air density at the site is 0.875 kg/m^3 using the temperature and the pressure measurements. The data shows that the wind is prevalently from the West. The daily wind speed trends show that the interval between 5.00 am and 3.00 pm is the windiest for every month of the year. The months with the most and the least wind speeds are August and February, respectively. Letšeng-la-Terae is a class 4 wind energy site with a 95% confidence interval of both the bi-annual mean wind speed given by 5.97 ± 0.07 m/s and the bi-annual mean power density given by 208.56 ± 7.31 W/m^2, both calculated at 10 m above the ground level. The typical turbines on the site are expected to operate 82.8 ± 6.7% of the time. The results show that the site is ideal for large-scale electricity generation.

1. Introduction

1.1. Background

The site under consideration is Letšeng-La-Terae (in short it is normally referred to as Letšeng). It is located on the North-Eastern part of Lesotho, as shown on the map in Fig. 1. Lesotho is a country of about 1.9 million citizens. The climate of Lesotho is characterized by dry and cold winters with wet and warm summers. The winters and summers are accompanied by high and low pressure systems, respectively.

Less than 20% of households are connected to the electrical grid and the majority of the rural population uses biomass fuel as the main source of energy. "Lesotho's main source of electricity is a 72 MW hydro-power station located in the North of the country at Muela". During the cold winter months or whenever there is a high demand, electricity supply is supplemented by imports from South Africa and Mozambique. Failure to meet the winter's demand, of more than 120 MW, resulted in load shedding in the winter of 2008 [1].

The goal of the Government of Lesotho (GoL) is to achieve a 35% electrification of households by 2015. Until recently, emphasis has been on solar energy as an alternative energy source and little attention has been given to the wind energy. There is currently a growing interest in wind energy [2]. There is a wide spread use and interest in the wind energy globally [3–6]. In spite of the high global interest, Africa is trailing the world with the least amount of installed wind energy capacity.

Although there might be a lot of regions on the African continent with a huge potential for producing electricity through wind, there is very little research going on and very few published literature [9]. The aim of this paper is to contribute to the global database of potential wind sites for massive electricity generation. This in turn will inform the international community of wind farm developers and equipment manufacturers with the aim of enticing them to invest in Lesotho hence generate some income and simultaneously help address the energy shortage situation of Lesotho. The results will also aid the international research community in terms of comparisons with other regions and in carrying out global wind models.

1.2. Assessment

The wind mast at Letšeng is situated at 29°01′09″S and 28°51′09″E at an altitude of approximately 3000 m above sea level.

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Nomenclature

C	Weibull scale parameter
$f(V)$	Weibull density function
$F(V)$	Weibull distribution function
k	Weibull shape parameter
m	Shear coefficient
P	Air pressure
PD	Power density
R	Dry air gas constant
RMSE	Root mean square error
T	Air temperature
V	Wind speed
V_i	Wind speed at 10 m
$\tilde{V}_i$	Mid-point of a wind speed range
$\overline{V}$	Mean wind speed
Z_0	Roughness height
Z	Height above ground level
Z_R	Reference height

Greek Symbols

ρ	Air density
σ	Standard deviation

The wind measurement site is located in the vicinity of the only operational large-scale mine in the country, the Letšeng Diamond Mine. This situation is ideal as the electricity generated could directly be used to power the mine. Moreover, since the mine is already connected to the national grid, there will be no extra costs incurred to erect the new transmission lines when the wind farm is built. Although there are no obstacles close to the measurement station, the whole area is situated on a hilly mountainous terrain.

2. Measurements

One year annual wind data is sufficient to predict long-term wind characteristics within a 10% error margin [8,10]. This paper analyzes the wind data spanning a period of 2 years, from the 1st January 2002 to 31st December 2003. This period is chosen because the equipment is currently not being serviced or calibrated so the initial data is considered to be more reliable.

The measurement station has two anemometers, one at 10 m above ground level (a.g.l.) as recommended by the World Meteorological Organization and another at 25 m a.g.l. [3,8]. The direction of the wind is also measured at 25 m a.g.l. The temperature and pressure are monitored at 2 m a.g.l. The recorded data is for 10-min intervals. A MATLAB algorithm was developed to model the wind profile at the site.

3. Results

Interruptions of the data logger caused by taking the readings and by the sensor failure resulted in the loss of some data. For the two years, 96% of the data was recovered which meets the 90% requirement of WMO [11]. For most of the results, the mean values are used to depict the results. The uncertainty is shown as error bars which are either the 95% confidence interval (C.I.) or standard mean deviation depending on which is deemed more appropriate.

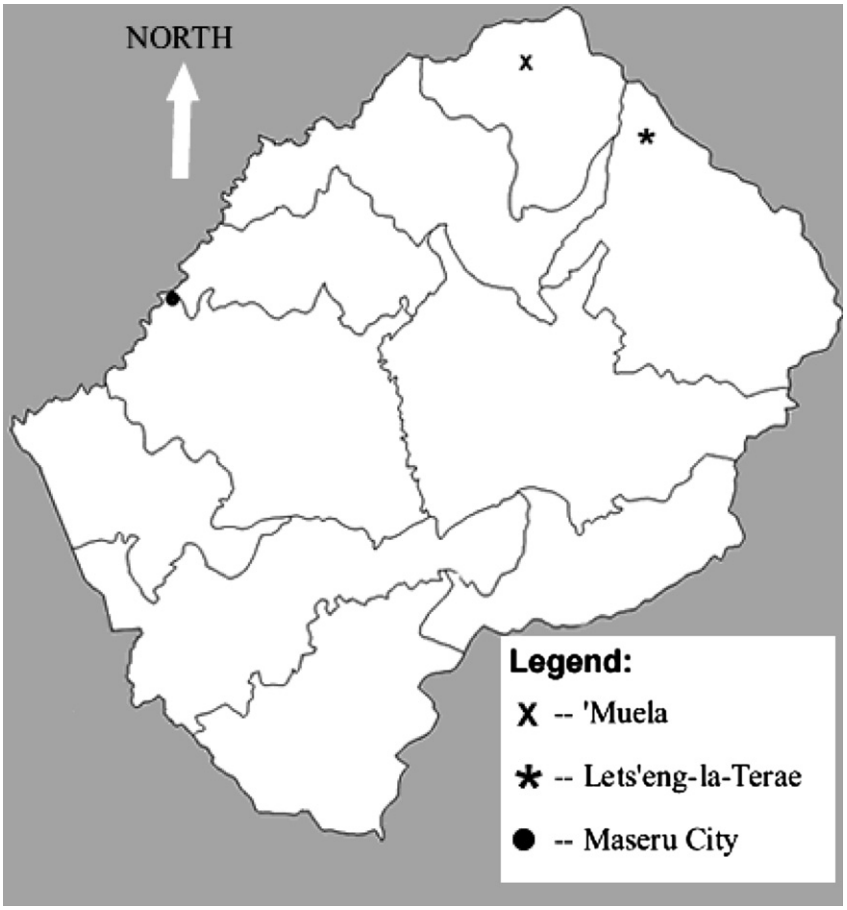

Fig. 1. Map of Lesotho.