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Wind Turbine Optimal Selection in South Coast of Albania

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***Abstract*— In this study is presented a general method to evaluate wind power generating systems near the coast of Vlora. Different wind turbine generators were compared for a selected site in Vlora, Albania with significant wind potential. Albania has a great wind potential due to the suitable terrain. Wind turbines in general are chosen according to parameters such as size, proximity to the network and wind availability. Developing wind energy projects in Albania where the main source of energy comes from hydro sources, is to cover the meet demand. The purpose of this paper is to investigate the wind potential and the specifics of different turbines for the coast part in Vlora district. The data for wind speed are 34 years old from the Balkan Wind Atlas. The calculations were developed for the Weibull distribution, where the shape and scale parameter was calculated. The annual wind speed was calculated 7.01 at 50 m height. The turbines for the investigation are in different power. Presentation for power curve is given for turbines. Hub height characteristics have been evaluated for different commercial turbines. This study aims to help to help in characteristics of the wind potential and in the selection of suitable turbines in the selected site. Air density, power density, annual energy yield, hours of work and capacity factors for different commercial turbines are calculated. The purpose of the work is related to wind power plant performance, and problems that affect optimal power output from wind in a selected location.**

Keywords—Wind speed; wind turbine; power curve; power density; annual energy yield; capacity factor; Weibull distribution

Introduction

Albania, located on the coast of the Adriatic and Ionian Seas, has a mountainous relief in 2/3 of the territory. The coastline of the country is 345 km in the north-south direction, where a part is coastal lowland and the other part is very close to the southern mountain coast. The main wind directions are northwest-southeast and southwest-northeast, more towards the land. Beyond the territory, the direction and intensity of the wind from area to area varies specifically depending on the relief that is typical. The measurements of the Institute of Hydrometeorology have made the meteorological data on the weather available to the air and sea service. The climatic analysis carried out for the evaluation of the natural potential of the wind in the Albanian territory for energy purposes, take in consideration the observations at 22 meteorological stations distributed throughout the country. Measurements are made 10m from the surface, which varies in height. For the potential of the wind in terms of energy, it is not appropriate to use these data because the meteorological stations are positioned in non-representative sites for the energy use of wind parks. According to the National Agency of New Renewable Resources, in feasibility studies the wind speed in the hilly areas has been found to be up to 1.5 times higher than that much closer to the plain part where the stations are positioned. Also, there are very few stations near the coastal areas where the wind potential is high and the demand for wind power plant (WPP) is in the placement of turbines in hilly-mountainous areas. Besides the coastal areas, the nearby hilly areas, along the coast, places where the wind is a constant phenomenon due to the contrast of sea-land temperatures are perfect sites for installing wind turbines. Some regions of our country are being studied by some foreign companies which intend to build wind farms for the production of electricity [1]. Wind power generation projects are very complex in several aspects, the technical aspects of generation, the potential of the chosen area, the types of turbines and power, environmental but also economic aspects. Feasibility studies in the case for construction of large plants (such as the ambitious projects of the Albanian government) and very expensive, a detailed feasibility analysis should be done. The feasibility study is included in projects, and clarifies the site potential, resource assessment, preliminary project design, detailed cost estimations, greenhouse gas emission, in the base case and the design of their monitoring plan, preparation of reports , project management and total costs [2],[3],[4],[5]. The site review is done to determine the general and specific characteristics of the site and area, to identify the main data required and availability, as well as to accurately determine the most suitable place for the installation of wind turbines. Wind resources assessment requires meteorological stations or anemometric towers to measure its speed, at least for a period of one year. Environmental assessment is a very important part of the feasibility study of energy projects. Preliminary design is required in order to determine the capacity of the plant dimensions, distribution of structures and equipment, as well as the necessary amount of constructions for detailed calculation of costs. The detailed cost estimation for the proposed project is based on the preliminary design. The study of greenhouse gas emissions at the base site, a monitoring plan, is an important stage for the feasibility study in cases where the proposed wind plant will replace a conventional plant. [6], [7], [8], [9]. The preparation of the feasibility study report is calculated based on the time it takes a specialist to complete the necessary work. The purpose of this work is to determine the potential of the selected area, is it suitable, the monitoring resources in accordance with the demand charge of the network, as in order to have an intermediate balance [10], [11], [12]. The suggested method presents the different systems of wind turbines, in the selected area of Vlore coastal line, a very potential site for wind energy, near Karaburun's Peninsula.

I. METHODS OF STUDY

A. Probability distribution functions for wind

Two probability distribution functions are commonly used for wind speed, Rayleigh and Weibull distribution. The simplest is the Rayleigh distribution which has a single parameter c, the scale parameter of the distribution.

$$f(V)=\frac{2V}{c^2}e^{-(V/c)^2} \qquad 0\le V<\infty \qquad (1)$$

The Weibull distribution has two parameters k and c. The Rayleigh distribution is actually a special case of the Weibull distribution with k = 2.

$$f(V)=\frac{k}{c}\left(\frac{V}{c}\right)^{k-1} e^{-(V/c)^k} \qquad 0\le V<\infty \qquad (2)$$

The following equation for the Weibull distribution:

$$F(b)=\int_{x_{\min}}^{b} f(V)dV=\int_{0}^{b}\frac{k}{c}\left(\frac{V}{c}\right)^{k-1} e^{-(V/c)^k}dV=1-e^{-(b/c)^k}$$

(3)

If k = 2 in this result gives the Rayleigh distribution:

$$F(b)=1-e^{-(b/c)^2} \qquad Rayleigh \qquad (4)$$

B. *Cost Analysis for Wind Energy, economic evaluation*

Economic evaluations for wind energy systems are multidimensional. Various factors affect the unit cost of electricity produced by a wind turbine. The economics of a wind power system depends largely on local conditions. For a wind turbine, the fuel is free, but the capital investment is high. The initial investment for the project includes the cost of the wind turbine, investment for other essential requirements such as land, transmission lines and power conditioning systems [3]. The cost of electricity from wind turbines depends significantly on the initial capital and investment costs of operation and maintenance costs [13], [14].

The operation and energy generation of wind systems generally depends on these factors; Consumption in years of economic capital; Operation and maintenance costs; Taxes and interest on the cost estimate; Energy storage system if connected to wind.

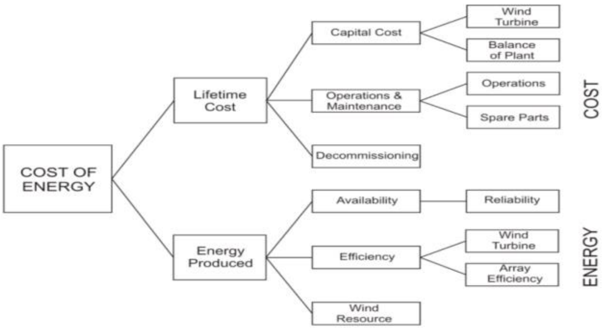


Fig. 1. Costs of energy for wind system

LCOE equation can be simplified for each technology. LCOE equation can be simplified for each technology. The following equation is more simplified:

$$LCOE=\frac{(CapEx * FCR)+}{\left(\frac{AEP_{net}}{1000}\right)} \qquad (5)$$

FCR: fixed charge rate (%), CapEx : capital expenditures , AEP net : net average annual energy production,; OpEx: operational expenditures

TABLE I. FORMULAS FOR CALCULATION THE COST OF WIND ENERGY

Levelised cost of enrgy, LCOE, simple formula	$LCOE=\dfrac{INVEST+\sum_{i=1}^{N}\frac{O\,\&\,M\ costs}{(1+r)^i}}{\sum_{i=1}^{N}\frac{E_i*(1-d)^i}{(1+r)^i}}$
Operation and maintenance costs	$P(O\,\&\,M)=nC_I\left[\dfrac{(1+I)^N-1}{I(1+I)^N}\right]$
Accumulated net present value of all costs	$NPW(C_A)_{N-1}=C_I\left[1+m(\dfrac{(1+I)^N-1}{I(1+I)^N})\right]$
The cost of operating the wind turbine (1 year)	$NPW(C_A)=\dfrac{NPW(C_A)_{1-N}}{N}=\dfrac{C_I}{N}\left[1+m(\dfrac{(1+I)^N-1}{I(1+I)^N})\right]$

The cost per kWh of electricity generated by the wind turbine:	$Cost = \frac{NPW(C_A)}{E_I} = \frac{C_I}{8760N}\left(\frac{1}{P_R CF}\right)\left[1+m(\frac{(1+I)^N-1}{I(1+I)^N})\right]$

II. RESULTS

Weibull distribution for the selected site,. The two parameters of the Weibull l $1.56 \le k \le 1.77$; $6.26 \le c \le 7.84$ m/s. The annual mean wind speed ranged between 5.58 and 7.02m/s at 50 m height . The monthly mean wind speed varies from 4.99 and 7.38 m/s at 50 m height. Results of simulations are already published in the research papers [15].

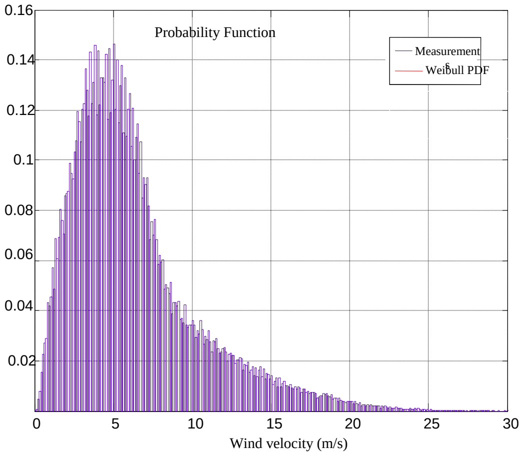
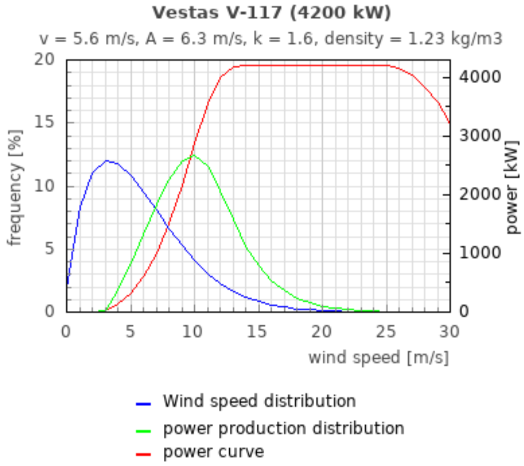
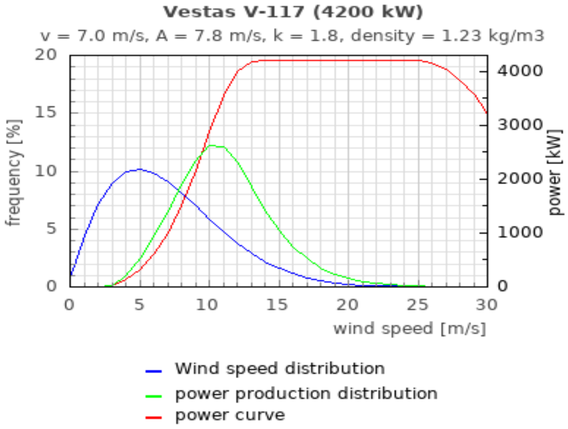
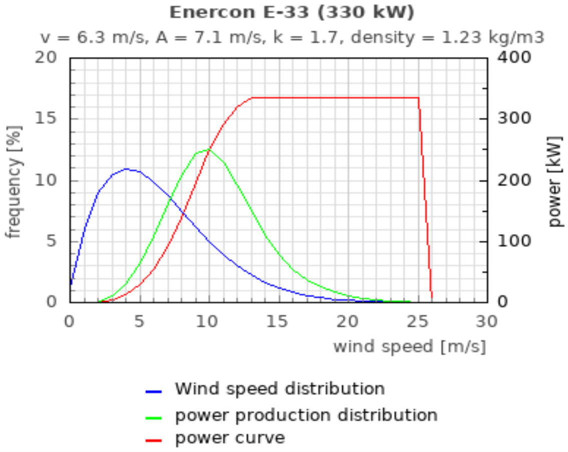
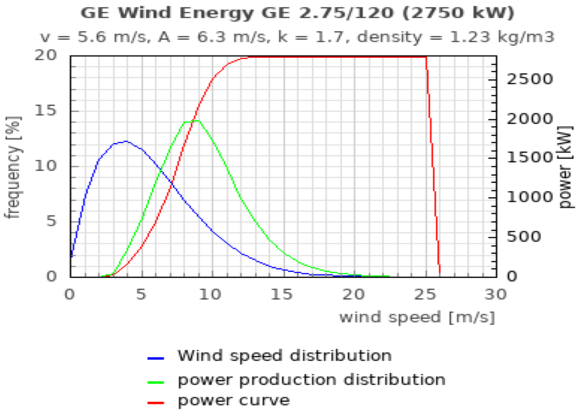


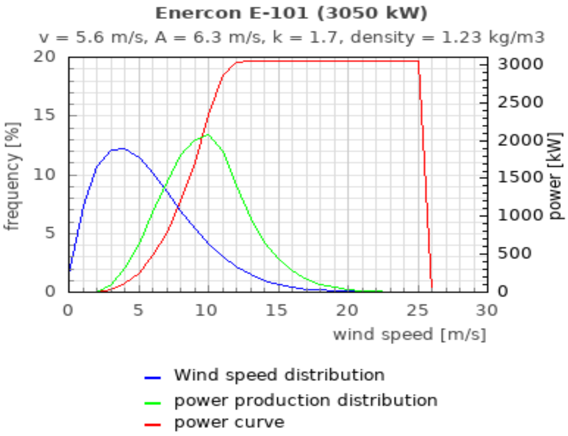
Fig. 2. Weibull probability Function and Measurements for the location [15]











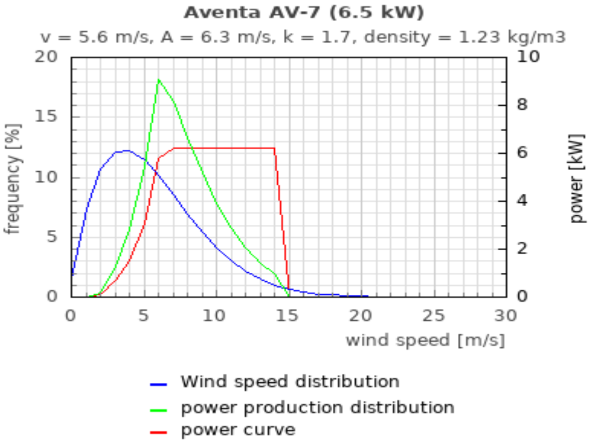


Fig. 3. For different turbines power curve, wind speed distribution and power production

The full load hours represent the capacity factor for the wind turbine. It explain the theoretical number of hours that the wind turbine generate at full load, capacity factor * number of hours in a year. Operating hours of the wind turbine during the year are the expected number of hours a year the wind turbine generate.

TABLE II. PARAMETRES FROM SIMULATION OF ONE YEAR WIND TURBINE OPERATION (1981-2014), 40.39° N; 19.34° S;

Type of Turbine	Capacity kW	Rotor diameter (m)	Power Production MW/year	Capacity Factor %	Full load hours, h/years	Operating Hours h/years
Enercon E33	330	33.4	872.447	30.2	2642	7330
Enercon E48	810	48	1954.134	27.5	2411	8117
Enercon E-58	810	53	2169.368	30.6	2676	8117
E-70 E4	2050	71	4474.639	24.9	2181	8117
Alstom ECO122	2700	122	6471.249	27.3	2395	7364
LeitWind LTW	1000	77	2504.329	28.6	2503	7364
GEVWind-E3nergy 1.7/103	1700	103	4731.247	31.7	2781	7364
Nordex N117	2400	117	5886.716	28.0	2451	7364
SenvionMM100	2000	100	4439.312	25.3	2218	7364
Vestas V100	2000	100	4505.337	20.6	1801	7364

TABLE III. MONTHLY CAPACITY FACTOR IN % FOR 4 DIFFERENT TURBINE

Turbine Type	Jan CF%	Feb CF%	March CF%	April CF%	May CF%	June CF%	July CF%	Aug CF%	Sep CF%	Oct CF%	Nov CF%	Dec CF%	Mean CF%
Vestas V47 660	28.6	30.17	18.68	20.84	20.19	11.8	14.75	12.05	11.85	7.58	41.11	35.41	20.09
Bonus B44 600	26.01	28.17	17.19	19.42	18.66	10.91	13.64	11.16	11.01	7.14	38.32	32.82	19.40
Nordex N43 600	25.94	28.36	17.03	19.43	18.57	10.78	13.54	11.06	10.97	7.15	38.67	32.79	19.40
Enercon E40 600	26.00	28.33	16.38	19.93	19.50	11.64	14.57	12.95	10.90	7.23	39.81	33.13	19.9

The model of turbine affects the production of energy from the wind at different speeds. Small size wind turbines have a low capacity factor. Different variations between rotor diameter, energy density, hub height and annual energy production are shown in the charts below.

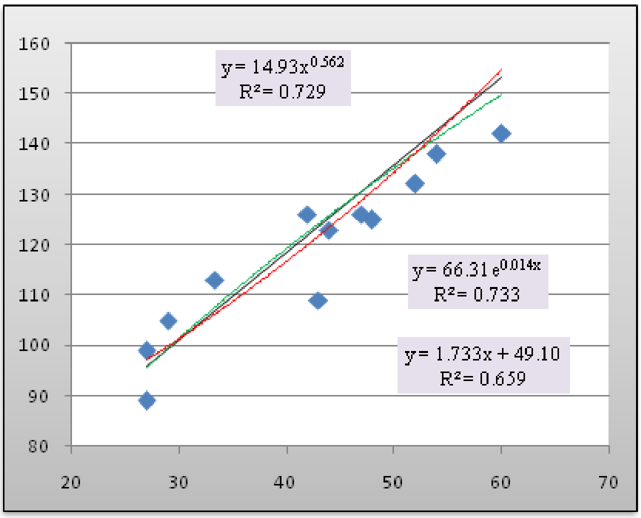


Fig. 4. Dependence of energy density on rotor diameter for different turbines

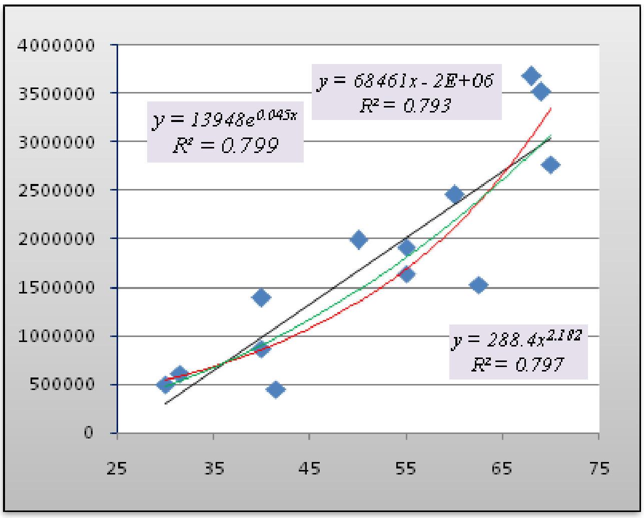


Fig. 5. Annual energy production (kWh/year) – Hub Height (m), for different turbines

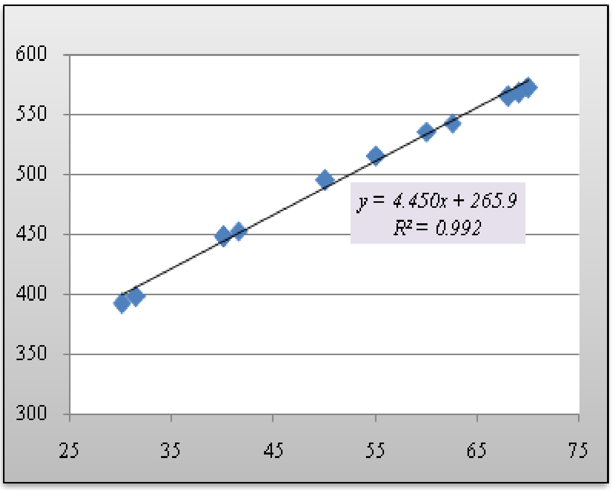


Fig. 6. Power Input (W/m$^{2)}$ – Hub Height (m)

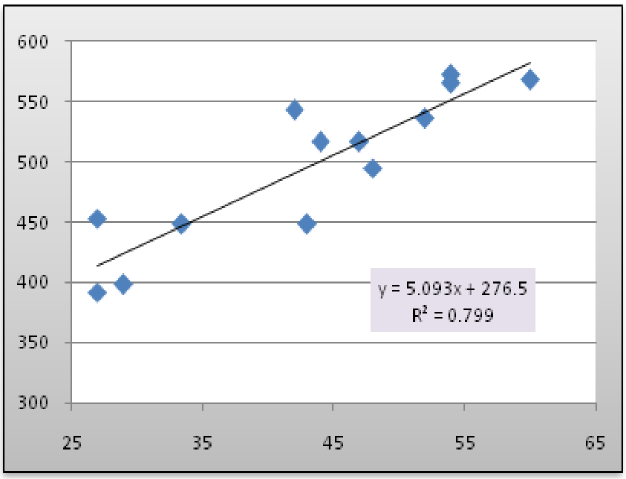


Fig. 7. Power Input (W/m$^{2)}$ – Rotor Diameter (m)

It appears from the regression analysis that there is sensitivity from the diameter of the rotor, annual energy production from hub height for different turbines. The variation power Input-hub height is in good accordance. But needs other analyzes with variable power turbines in the location to arrive at a more reliable conclusion.

LCOE assessment is done by evaluating several economic parameters, taking into account different assumptions, methods and uncertainty. Variation input data for wind energy in location and capacity factor. Financial data taking in account as discount rate, currency, taxation, risk adjustment. Simple calculation of LCOE gave the results for levelized cost of energy 0.06640 eur/kWh to 0.07536 eur/ kWh

III. CONCLUSION

In this study, the energy potential for a wind energy on the southern coast of Albania is presented, being limited to some characteristic sites for wind potential, such as the coast of Vlora. The study is focused on the area near Karaburun, as a site with a high annual wind speed potential. The main goal was to study different commercial turbines with different power in operation according to their technical characteristics. Capacity factor is higher for high power turbines, and increases with height, hub height of the turbine. For different commercial turbines but with the same power (660kW or 600kW), the facial capacity changes very little, about 0.4%. The energy performance showed that the working hours of the turbines for a year of operation are in the range of 7330 hours to 8117 hours per year. The maximum of wind turbine operation on is 83.6% to 92.6% of the year, according to the type of turbine chosen. It seems clearly that the commercial type of turbine is an important parameter in the optimal operation of the total performance, or the feasibility of the project.

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