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SIMULATION OF A WIND POWER GENERATION SYSTEM BASED ON TECHNO-ECONOMIC ANALYSIS

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Abstract

The aim of this study is to present wind potential in Sazani Island, in southwestern part of Albania (40.50°N; 19.27°E; altitude 0 m; air density 1.225 kg/m^3). A long term data, consisting of thirty-four year (1981 to 2014) of hourly mean wind data, was adopted from Balkan Wind Atlas and analyzed. Mean wind power based on data in time series format and Weibull distribution function have been studied. Based on two methods was found that Weibull distribution was suitable for this study. Numerical values of the shape and scale parameters for Sazani Island changed over a wide range from year to year. The two parameters k and c (m/s) were 1.62 and 7.07 m/s, respectively. The mean wind speed based on measured data for whole period was 6.30 m/s at 50 m height. The predicted mean wind speed was 6.33 m/s. In addition, one 600kW wind turbine model was assessed for the site's wind characteristics using RETScreen and MATLAB software, with results suggesting economic viability.

- ***Key words:*** *Wind power, statistical assessment, Wind Turbine, RETScreen, Sazani Island*

Introduction

- Renewable energy offers a great opportunity to support sustainable development in those areas where renewable resources are accessible and hence decrease dependence on fossil fuel based energy.

  Other motivating factors:
  - rapid growth in demand for electricity,
  - rising level of carbon emissions,
  - developing of technology, etc.

- More importantly, renewable energy is believed to be a step on the ways to a healthy global environment in the future.

- Many scientific researcher reports that wind energy is being robustly investigated by several of developed and developing countries with potential of wind power, in an attempt to decrease their dependence on fossil fuels.

- Cumulative global wind energy capacity reached about 369,597 MW at the end of 2014. 2015 was a great year for the wind power industry, with 44% annual market growth and record installations of more than 51 GW.

- Typical wind power applications
  - lighting, residential/trade installations, military installations, heating, cooling, communication, electricity for remote settlements (off grid), water pumping for irrigation, etc.

- The demand for electricity in Albania is growing rapidly over the last 25 years.

  - population growth,
  - increasing standard of life,
  - rapid growth in residential, commercial, and industrial sectors.

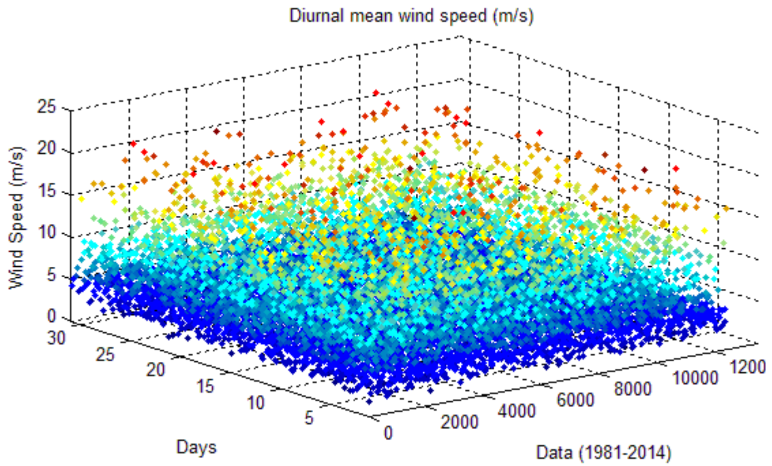
- The installed generating capacity of the conventional power plants (HPP and TPP) reached 1,823 MW and with a peak load of 1,475 MW in 2014.

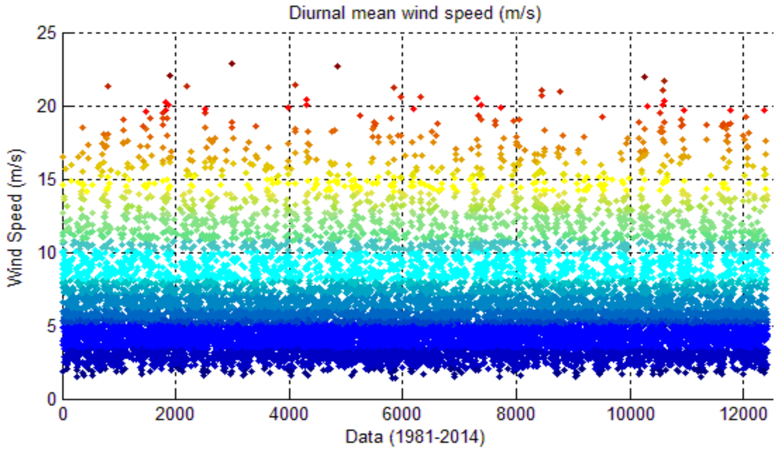
- Since, Albania has good wind potential, a considerable fraction of its energy needs maybe exploited from wind energy.

- There are few research work related to wind energy in Albania.
- In this study, long-term wind speed data (1981–2014) based on Balkan Wind Atlas of Sazani Island has been analyzed to:
  - evaluate wind power potential,
  - the techno-economic feasibility of development of a small-scale wind power plant.
- In general, long-term data indicates that the yearly average wind speeds at selected site vary from 5.63 to 6.94 m/s at 50 m height.
- Attention has been focused on the feasibility of installation of a 600 kW (50m hub height) wind turbine.
- Statistical models based on MATLAB and RETScreen Software has been utilized to carry out the techno-economic analysis.
- Moreover, the study estimates significant issues:
  - monthly variations of wind speed,
  - cumulative frequency distribution (CFD) profiles of wind speed,
  - monthly and yearly amount of energy generated,
  - cost of generating energy (COE, $/MWh),
  - capacity factor (%), etc.

Materials and Methods

- Thirty four years (1981 to 2014) of hourly wind speed records were adopted in this study. The data were recorded continuously at a height of 50 m.

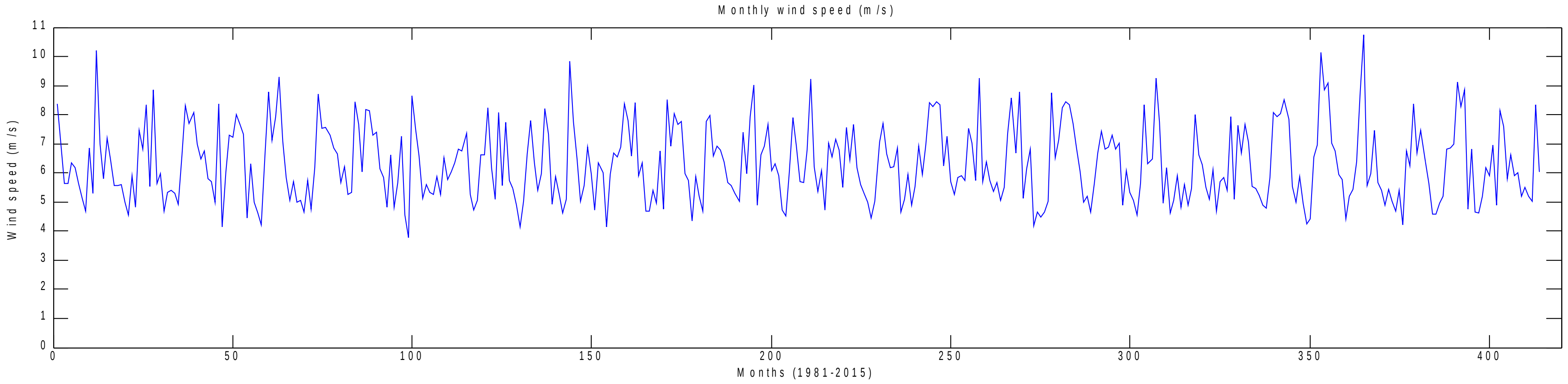




Thirty-four year daily mean wind speeds at height 50 m over the ground in Sazani Island.

- It can be showed that wind speed is relatively lower during the summer months (June to September) as compared to other months. This implies that WECS would produce less energy during summer time.

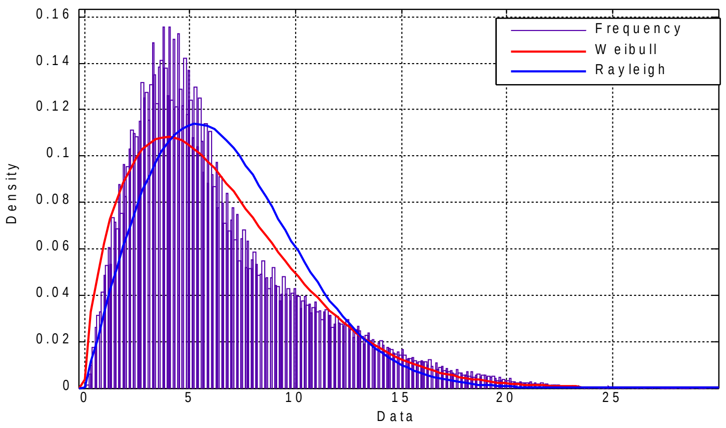
- The data also shows that there is noticeable variant in wind speed. These variations indicate that the energy output from WECS or wind farms would be subjected to considerable differences.

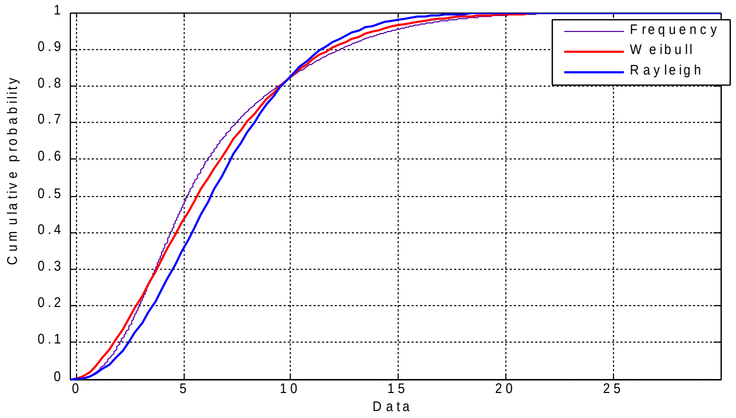


Variation of thirty-four year monthly mean wind speeds at height 50 m over the ground in Sazani Island.

- Wind is relatively faster and yields more energy at high heights above the ground.

- Fig. a) shows a histogram of wind measured data spread as a frequency density of which measured data. Also wind data are modeled using two probability density functions, Weibull and Rayleigh. Rayleigh is a special case of Weibull distribution but the shape factor is k=2.

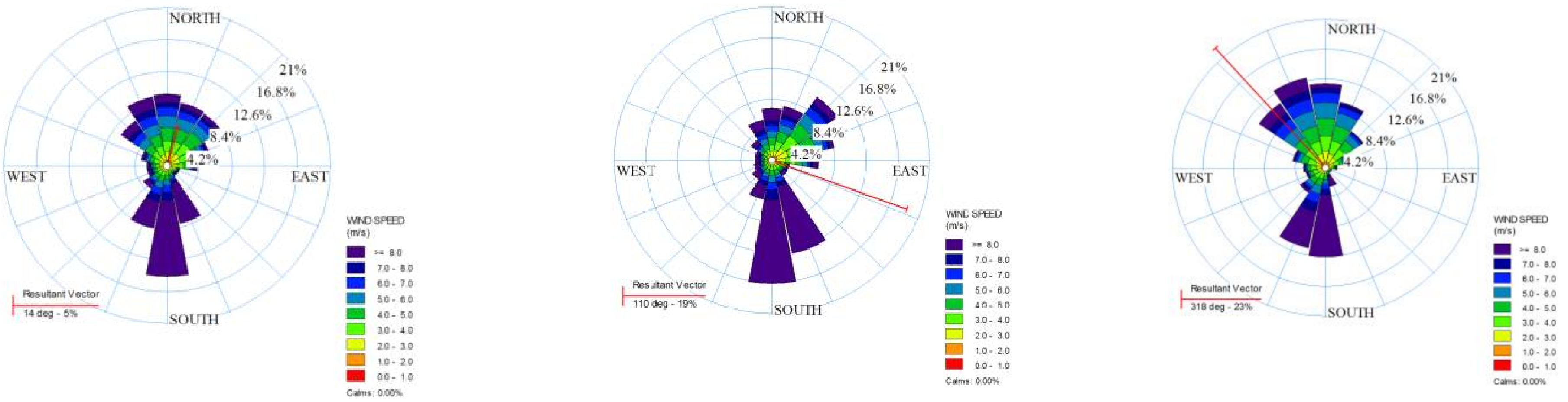




Statistical and time series analysis of measured data at the selected location, a) probability density function and b) cumulative probability distribution.

- Fig. b) shows cumulative probability functions using time series wind data, Weibull and Rayleigh models .

- The wind direction is illustrated in polar diagrams and it is measured in clockwise direction. The cycle is divided in 16 sectors, each of 22.5 degree.



Prevailing wind directions; a) whole year, b) spring-summer and c) autumn-winter wind rose analysis.

- Fig. above show the wind directions expressed with the wind rose.

- A technical and cost-effective assessment of electricity generation from a wind turbine is following discussed.

- Proposed case power system consisted in installation of VESTAS V44 wind turbine model;
  - power capacity of turbine was 600 kW,
  - 50 m hub height,
  - 44 m rotor diameter per turbine,
  - 1,521 m^2 swept area per turbine,
  - 4 m/s cut-in wind speed,
  - 15 m/s rated wind speed.

- Electricity exported rate was 80$/MWh.
- Wind shear exponent is variable related location and it is evaluated 0.17.

Wind profile assessment

- We can show that there was a constant regime in the values of the wind speed profiles across the years considered while spring and summer months appear to be the months with the least wind supply of the station.
- The magnitude of the daily mean measured wind speeds across the whole 34-year period lay within the range of 1.38 to 22.91 m/s and the monthly mean measured wind speeds from January to December across the whole 34-year period lay within the range of 3.78 to 10.76 m/s.
- Yearly, the mean measured wind speeds from 1981 to 2014 also ranged from 5.63 to 6.94 m/s.
- Moreover, we saw that up to 60% of the whole data series were values that ranged from about 0 to 6.1 m/s, 6.7 m/s 7.2 m/s using time series measurement CDF, Weibull CDF and Rayleigh CDF, respectively.
- The prevailing wind directions tend toward the east during the spring-summer period and north westerly during the autumn-winter. Since Sazani Island is an offshore site, and situated near the coastal area, wind direction changes during a day, as well. However, it was visible that wind blow from North which was most prevailing wind direction and South.

Wind energy assessment

- The assessment of wind energy is obtained by taking into consideration the effect of various losses like array, airfoil soiling, miscellaneous losses, and availability, electricity exported to grid that are listed in table below.

Wind energy related coefficients used in energy assessment

Item	Array losses	Airfoil losses	Miscellaneous losses	Availability	Capacity factor	Electricity exported to grid
Sazani 50m	0.0%	1.0%	2%	98%	33.1%	1739 MWh

Power project costs analysis

Initial costs (credits)	Amount	Relative costs
Feasibility study	$ 35,300	2.9%
Development	$ 54,900	4.5%
Engineering	$ 54,600	4.5%
Power system	$ 770,000	62.9%
Balance of system & miscellaneous	$ 308,637	25.2%
Total initial costs	$ 1,223,437	100.0%
O&M	$ 47,662	-
Periodic costs (credits)	$ 150,000	-

- It is possible to calculate the GHG emission reduction potential of proposed wind energy project by first computing baseline emission factor. The emission factor given is an output of RETScreen software, so as to calculate the amount of CO_2 reduced due to proposed case.

Power project emission analysis

GHG emission reduction summary						
	Base case GHG emission	**Proposed case GHG emission**			**Gross annual GHG emission reduction**	**Net annual GHG emission reduction**
Power project	**tCO2**	**tCO2**			**tCO2**	**tCO2**
	1,628.1	130.2			1,497.9	1,497.9
Net annual GHG emission reduction	1,498	tCO2	is equivalent to	3,484	Barrels of crude oil not consumed	

- The financial analysis is done to check whether or not the wind farm is financially available. The financial feasibility study is performed in terms of discount rate (DR), net present value (NPV), annual life cycle saving (ALCS), year to positive cash flow (YPCF), benefit to cost ratio (B-C), simple payback (SPP), equity payback (EPP) and energy production cost (COE).

Financial feasibility indicators of 600kW wind turbine

	Financial Feasibility Indicators								
Location	**Height (m)**	**DR (%)**	**NPV ($)**	**ALCS ($/yr)**	**B-C (-)**	**SPP (yr)**	**EPP (yr)**	**COE $/MWh**	**GHG Reduction tCO2 (25 yr)**
Sazan	50	9	46,103	4,694	1.09	13.4	13.8	77.17	37,447

- The cumulative cash flows are plotted versus time in cash flows graph. The graph is based on the values of the net flows accumulated from year 0.

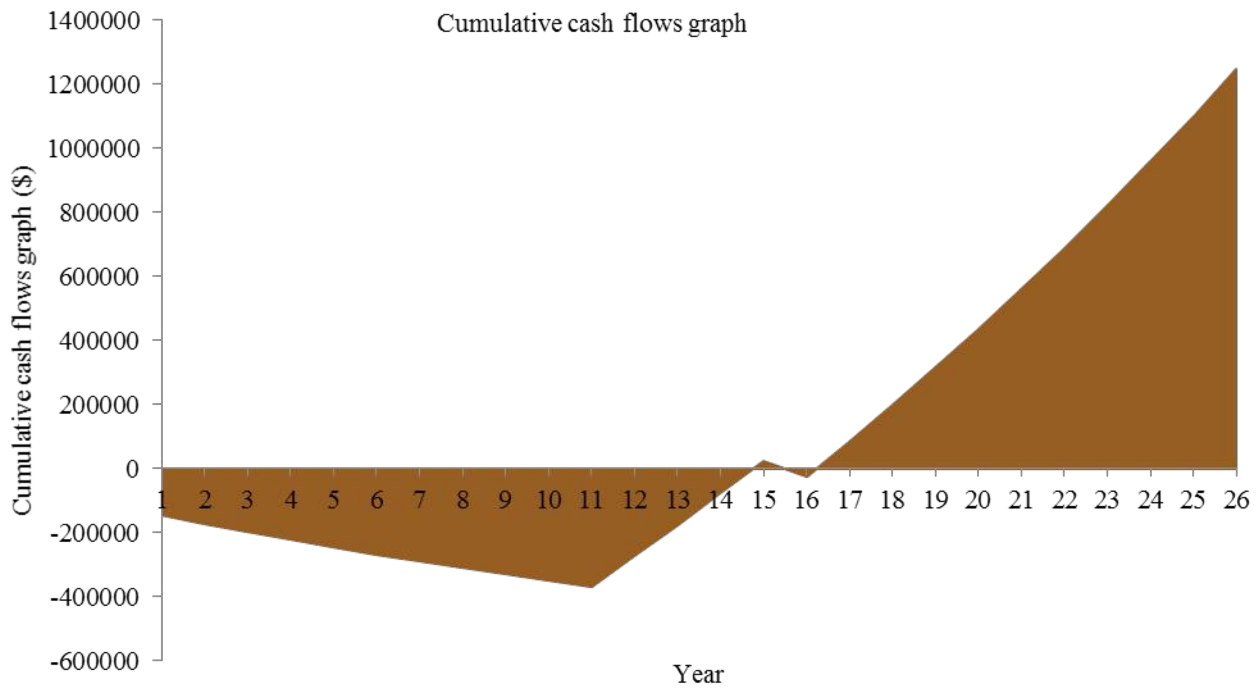


Figure 5. Cumulative Cash Flow ($) for 600 kW central-grid wind turbine installed in Sazani Island

CONCLUSIONS

- A technical and cost-effective assessment of electricity generation from a wind turbine is following discussed.
- Daily mean measured wind speeds across the whole 34-year period lay within the range of 1.38 to 22.91 m/s and the monthly mean measured wind speeds from January to December across the whole 34-year period lay within the range of 3.78 to 10.76 m/s at the 50-m height, while the average for all of the data was 6.30 m/s.
- Weibull CDF fitted more to actual data histograme than Rayleigh.
- The prevailing wind directions tend toward the east during the spring-summer period and north westerly during the autumn-winter.
- The total initial cost of all wind power systems proposed is $ 1,223,437.
- The capacity factor of our wind turbine was 33.1 %.
- The financials feasibility study made based on the assumed financial parameters showed that a positive cash flow could be obtained in 13.8 years.
- It was noticed such a development at these sites could result in avoidance of 1,497.9 tons of GHG from entering into the local atmosphere each year and about 37,447 tons of GHG in 25 years.
- Cost of energy resulted 77.17 $/MWh.

Thank you!