An Oral Presentation for Wind Energy International Conference

Estimation of Weibull Parameters using Maximum Likelihood Method for Wind Power Applications

Authors
K. S. R. Murthy,
Dr. O. P. Rahi,
Electrical Engineering Department,
National Institute of Technology Hamirpur (H.P), India.

Paper ID: WIND097
Venue: Hotel Ashok, New Delhi, India.

26-04-2017

Contents

- Introduction
- Problem formulation
- Objective of the research
- Solution methodology
- Results and discussion
- Conclusions
- References

Introduction

- Owing to the increasing power demand and the environmental concerns of the conventional energy sources, power generation from **wind** is receiving major attention from the power planners, engineers, environmentalist and financiers on these days.

- Since wind is an alternating energy source and to find the economic viability of wind project, a proper **wind resource assessment (WRA)** and analysis of the data collected is very important.

- The methodology includes discussions on preliminary wind survey to choose the best site for installing wind data instruments, selecting the optimum wind turbine suitable for a site and the uncertainties involved in estimating the wind speed using the different WRA techniques.

Problem formulation

- As per the analysis of Ministry of New and Renewable Energy sources (MNRE), Government of India Report, the generation cost/MW of wind power project is lesser among the other renewable energy sources such as geo-thermal, solar thermal storage, solar photovoltaic, and hydro power.
- The growth of wind power sector in India has significantly developed in the past decade, however till India has harnessed 22% of its wind power potential so far.
- The coastal, hilly, and mountainous regions are the potential locations for wind power generation worldwide, however the wind potential in hilly regions of India has not been assessed fully as yet.
- The scenario of peak power electricity shortages and average energy shortages and serious environmental risks can be circumvented by considering the wind energy power potential assessment.
- By keeping in view, this research work is carried out for the exploitation of existing wind resources to maximize the access of wind power utilization.

Objective of the research

- The main objective of the study is to focus on identifying the accessibility of wind rich sites and effective utilization of existing wind resources for the development of wind power projects based on the historical measurements.

- The Weibull shape (*k*, no units) and scale (*c*, m/s) parameters have been estimated using maximum likelihood method (MLM).

- The wind power density has been determined along with other wind characteristic parameters namely mean, maximum, maximum energy carrying, and most probable wind speeds.

Wind data and site description

- The global Modern Era Retrospective Analysis for Research and Applications (MERRA) daily data of long term period during from 1981 to 2016 (36 years) at 10 m height a.g.l has been adopted throughout the analysis for this site.

- The study utilizes the coastal site **Vizianagaram**, which is situated in northern Andhra Pradesh, India.

- The geographical coordinates of the concerning area includes latitude, longitude, and altitude from the above mean sea level are 18.12° N, 83.42° E, and 66 m, respectively.

- Also, which is located 18 km inland from the Bay of Bengal as well as 42 km away from the northeast of Vishakhapatnam.

Solution methodology

Weibull Distribution:

The Weibull $f_W(v)$ and cumulative $F_W(v)$ probability distributions are given by

$$f_W(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (1)$$

$$F_W(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (2)$$

where, k is the shape parameter which has no units and tells how peaked the distribution of the Weibull plot is, and c is the scale parameter which has the same units of wind speed as m/s and describes the wideness of the Weibull plot.

The Weibull parameters are determined based on concept of maximum likelihood estimation method.

Cont.,

Maximum Likelihood Method (MLM):

– The mean WPD calculated by using measured probability distribution for the hourly time series data is given by

$$P(v) = \frac{1}{2}\rho v^3 \tag{3}$$

$$P_T = \sum_{i=1}^{n} \left[\frac{1}{2}\rho v_i^3 f(v_i)\right] \tag{4}$$

Where P_T is the mean WPD for the measured hourly time series data. The mean WPD calculated from the probability density of WDF as given below:

$$P_W = \frac{1}{2}\rho c^3 \Gamma\left(1 + \frac{3}{k}\right) \tag{5}$$

Results and discussion

- The wind resource analysis has been done for the site Vizianagaram at 10 m height above ground level based on the NASA data during the 36 years (1981-2016).

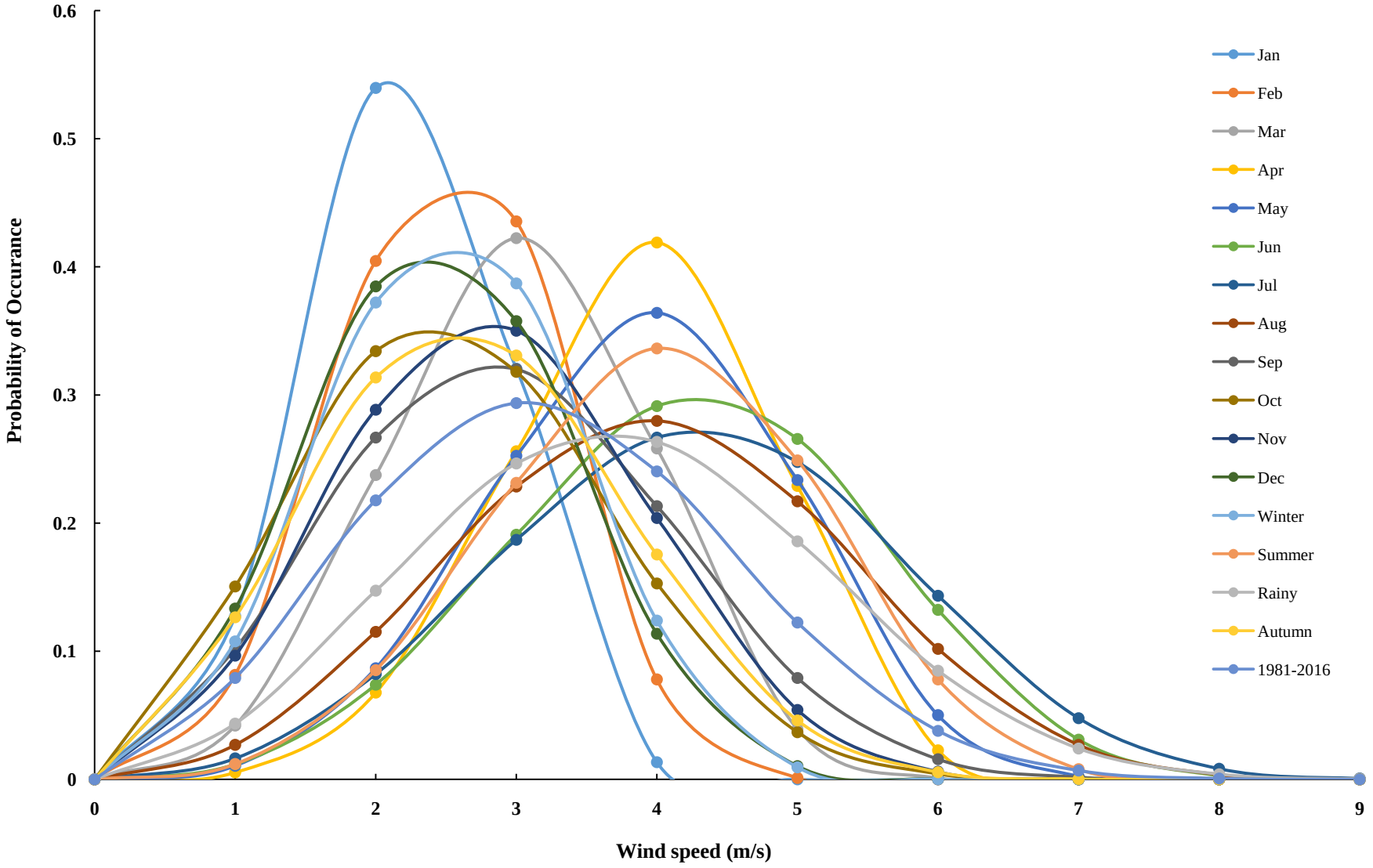
- The wind statistics are Weibull probability density distributions and cumulative of distributions have been determined using the daily data to know the wind variability at the site considered.

- The WPD has been computed using Weibull distribution and unknown Weibull parameters have been estimated by using MLM method.

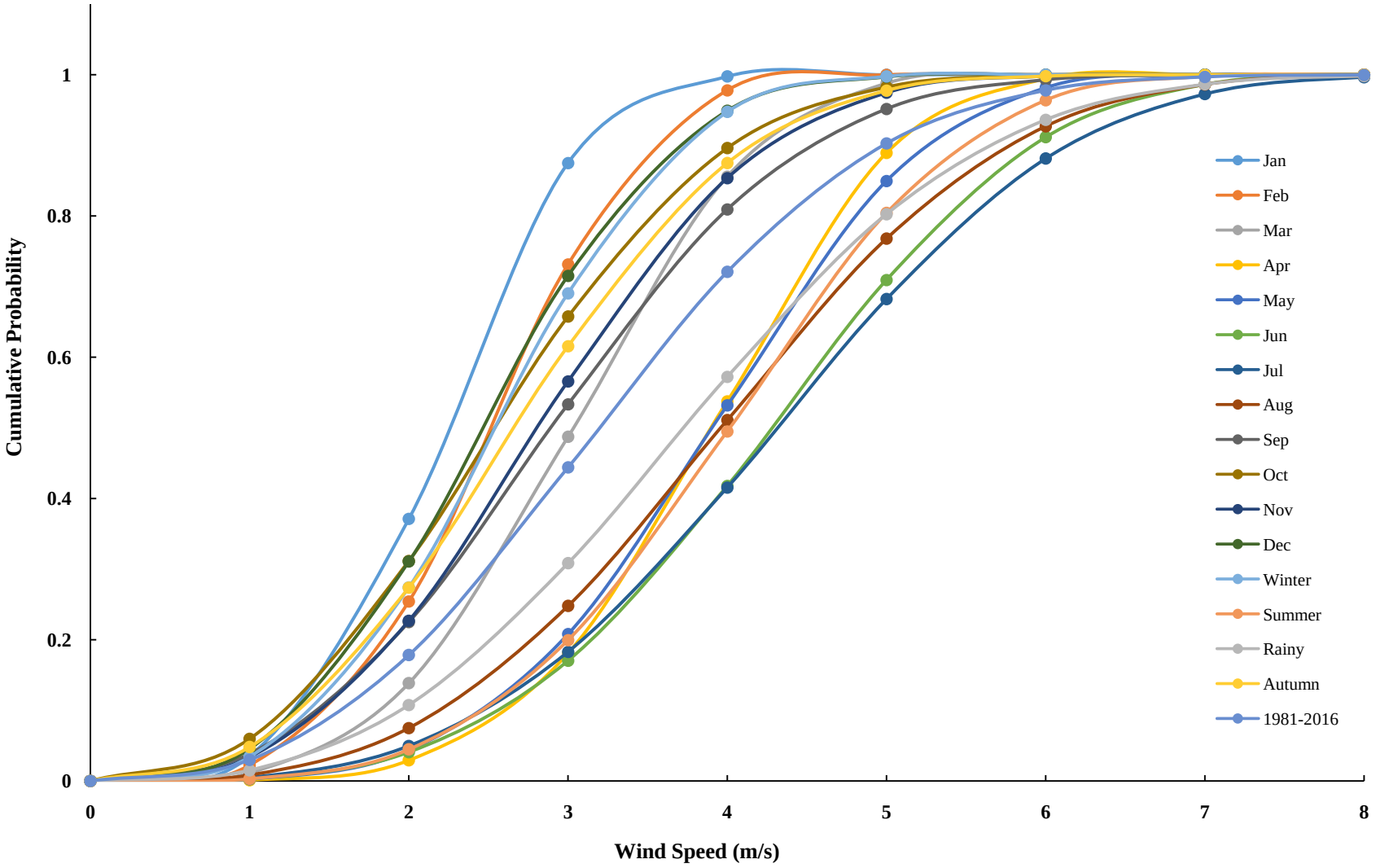
Wind characteristics obtained from the Time series data, Weibull, and Rayleigh model

S. No.	Period	V_m (m/s)	V_{max} (m/s)	k	c (m/s)	V_{mp} (m/s)	V_{me} (m/s)	Pd (W/m^2)	S. No.	Period	V_m (m/s)	Vmax	k	c	V_{mp}	V_{me}	Pd (W/m^2)
1	1981	3.40	7.62	3.00	3.82	3.33	4.52	34.04	28	2008	3.11	6.81	2.90	3.50	3.03	4.20	26.69
2	1982	3.27	7.66	2.60	3.68	3.05	4.58	32.84	29	2009	3.08	8.05	2.70	3.48	2.93	4.27	27.06
3	1983	3.53	6.89	3.40	3.94	3.56	4.52	35.89	30	2010	3.27	7.27	2.70	3.68	3.10	4.52	32.08
4	1984	3.38	7.16	2.80	3.81	3.25	4.62	34.92	31	2011	3.05	6.93	2.80	3.44	2.94	4.17	25.70
5	1985	3.36	6.33	3.00	3.78	3.30	4.48	32.96	32	2012	3.34	7.02	3.00	3.75	3.28	4.45	32.39
6	1986	3.35	9.10	2.70	3.77	3.18	4.63	34.53	33	2013	3.26	8.07	2.60	3.67	3.04	4.57	32.43
7	1987	3.44	7.50	3.00	3.86	3.37	4.58	35.24	34	2014	3.17	8.06	2.50	3.26	2.66	4.12	23.39
8	1988	3.23	6.58	2.90	3.62	3.13	4.34	29.51	35	2015	2.91	7.58	2.80	3.26	2.78	3.95	21.92
9	1989	3.13	7.33	2.90	3.52	3.04	4.22	27.16	36	2016	2.72	8.65	2.60	3.04	2.53	3.79	18.59
10	1990	3.47	8.19	3.00	3.91	3.41	4.63	36.57	37	Jan	2.22	5.15	3.70	2.46	2.26	2.77	8.53
11	1991	3.50	7.03	2.90	3.94	3.41	4.72	38.10	38	Feb	2.52	4.80	3.70	2.79	2.56	3.13	12.38
12	1992	3.26	8.40	2.80	3.68	3.14	4.46	31.45	39	Mar	3.02	5.85	3.70	3.35	3.07	3.76	21.43
13	1993	3.34	7.74	2.70	3.77	3.18	4.63	34.60	40	Apr	3.87	6.53	4.70	4.23	4.02	4.56	41.57
14	1994	3.51	8.06	2.60	3.95	3.28	4.92	40.67	41	May	3.88	8.19	4.10	4.28	4.00	4.71	43.90
15	1995	3.23	7.07	2.80	3.63	3.10	4.40	30.33	42	Jun	4.26	8.56	3.70	4.72	4.34	5.31	60.26
16	1996	3.22	7.92	2.50	3.63	2.96	4.59	32.15	43	Jul	4.32	9.10	3.40	4.80	4.34	5.50	64.86
17	1997	3.34	7.36	2.70	3.76	3.17	4.62	34.30	44	Aug	3.98	8.05	3.20	4.44	3.95	5.17	52.34
18	1998	3.23	6.31	3.00	3.62	3.16	4.29	29.07	45	Sep	2.95	7.39	2.70	3.32	2.80	4.07	23.53
19	1999	3.30	7.61	2.70	3.71	3.13	4.56	33.03	46	Oct	2.60	7.15	2.60	2.92	2.42	3.64	16.42
20	2000	3.22	7.88	2.60	3.63	3.01	4.52	31.47	47	Nov	2.84	7.50	2.90	3.19	2.76	3.83	20.25
21	2001	3.20	8.56	2.40	3.62	2.89	4.66	32.86	48	Dec	2.48	7.07	3.00	2.78	2.43	3.30	13.17
22	2002	3.24	6.90	2.80	3.66	3.12	4.43	30.90	49	Winter	2.56	7.07	3.20	2.85	2.54	3.32	13.89
23	2003	3.33	7.83	2.80	3.75	3.20	4.54	33.22	50	Summer	4.00	8.56	3.90	4.41	4.09	4.90	48.54
24	2004	3.03	7.62	2.50	3.42	2.79	4.33	27.07	51	Rainy	3.76	9.10	2.90	4.23	3.66	5.07	47.12
25	2005	3.28	7.44	2.80	3.69	3.16	4.48	31.89	52	Autumn	2.72	7.50	2.70	3.05	2.57	3.75	18.29
26	2006	3.05	7.77	2.40	3.45	2.76	4.44	28.48	53	1981-2016	3.24	9.10	2.70	3.65	3.08	4.49	31.46
27	2007	3.20	8.05	2.50	3.60	2.94	4.56	31.50									

Monthly and Seasonal Probability Distribution



Monthly and Seasonal Cumulative Distribution



Conclusions

- The average estimated WPP of 31.46 W/m^2 for the duration 36 years of studied region corresponding to the Weibull parameters of 2.7 and 3.65 m/s with a mean and maximum wind speeds of 3.24 and 9.1 m/s respectively. Also, the most probable wind speed and maximum energy carrying wind speeds have been to be 3.08 m/s and 4.49 m/s, respectively.
- The results of proposed methodology for the said wind monitoring facility shows that the particular site is not suitable for grid connected applications but this site is suitable for isolated standalone systems like rural electrification, house hold electric appliances like battery charging, mechanical applications like water pumping for irrigation.
- Finally, this research study will helps in guiding document for power and energy engineers, policy makers, as well as for researchers working in this domain for providing solution to the problem of burgeoning gap between demand and supply of energy.

References

1. H. G. M. Joselin, S. Iniyanb, E. Sreevalsanc, S. Rajapandiand, "A review of wind energy technologies," Renewable and Sustainable Energy Reviews, vol. 11, pp. 1117–1145, August 2007.
2. S. C. Bhattacharyya, "An overview of problems and prospects for the Indian power sector," Energy, vol. 19, pp. 795–803, July 1994.
3. World wind energy association is viewed on 06/07/2013 http://www.inwea.org/aboutwindenergy.html; 2013
4. Centre for Wind Energy Technology. Annual report 2011-12 Centre for Wind Energy Technology, Ministry of New and Renewable Energy, Govt. of India http://www.cwet.res.in is viewed on (27/05/2014).
5. http://en.wikipedia.org/wiki/Wind_profile_power_law (viewed on 9/06/2014).
6. N. Diwakar, S. Ganesan, S. Ahmed, V. K. Sethi, "Prediction of wind power potential by wind speed probability distribution in a hilly terrain near Bhopal, Madhya Pradesh," International Journal on Emerging Technologies, vol. 1, pp. 80-86, 2010.
7. S. S. Chandel, P. Ramasamy, and K.S.R Murthy. "Wind power potential assessment of 12 locations in western Himalayan region of India," Renewable and Sustainable Energy Reviews, vol. 39, pp. 530-545, 2014.
8. S.S. Chandel, K.S.R Murthy, and P. Ramasamy. "Wind resource assessment for decentralised power generation: Case study of a complex hilly terrain in western Himalayan region," Sustainable Energy Technologies and Assessments, vol. 8, pp. 18-33, 2014.
9. T. V. Ramachandra, G. Hegde, G. Krishnadas, "Potential Assessment and Decentralized Applications of Wind Energy in Uttara Kannada," Karnataka. International Journal of Renewable Energy Research, vol. 4, pp. 1-10, 2014.
10. B. G. Kumaraswamy, B. K. Keshavan, Y. T. Ravikiran, "Analysis of seasonal Wind Speed and Wind Power Density Distribution in Aimangala Wind form At Chitradurga Karnataka using two Parameter Weibull Distribution Function," Power and Energy Society General Meeting, IEEE, pp. 1-4. July 2011.

11. T. V. Ramachandra and B. V. Shruthi, “Wind energy potential in Karnataka India,” Wind Engineering, vol. 27, pp. 549-553, 2003.
12. G. Krishnadas and T. V. Ramachandra, “Scope for Renewable Energy in Himachal Pradesh, India - A Study of Solar and Wind Resource Potential,” Biodiversity and Climate Change, pp. 1-10, December 2010.
13. R. K. Aggarwal and S. S. Chandel, “Emerging energy scenario in Western Himalayan state of Himachal Pradesh,” Energy Policy, vol. 38, pp. 2545-2551, May 2010.
14. A.N Celik, “Weibull representative compressed wind speed data for energy and performance calculations of wind energy systems,” Energy Conversion and Management, vol. 44: pp. 3057–3072, January 2003.
15. H. Zhang, Y. J. Yu, Z. Y. Liu, “Study on the Maximum Entropy Principle applied to the annual wind speed probability distribution: A case study for observations of intertidal zone anemometer towers of Rudong in East China Sea,” Applied Energy, vol. 114, pp. 931–938, February 2014.
16. S. G Jamdade, P. G. Jamdade, “Analysis of Wind Speed Data for Four Locations in Ireland based on Weibull Distribution’s Linear Regression Model,” International Journal of Renewable Energy Research, vol. 2, pp. 451-455, 2012.
17. Z. O. Olaofe, K. A. Folly, “Statistical Analysis of the Wind Resource at Darling for Energy Production,” International Journal of Renewable Energy Research, vol. 2, pp. 250-261, 2012.
18. D. Carvalho, A. Rocha, C. S. Silva, R. Pereira., “Wind resource modelling in complex terrain using different mesoscale–microscale coupling techniques,” Applied Energy, vol. 108: 493–504, 2013.
19. L. A. Jorge, C. Kevin, S. Z. Djokic and I. H. Gil, “Performance Assessment of Micro and Small-Scale Wind Turbines in Urban Areas,” IEEE Systems Journal, 2012, vol. 6, pp.152-163, March 2012.
20. SD. Kwon, “Uncertainty analysis of wind energy potential assessment, ” Applied Energy, vol. 87, pp. 856–865, March 2010.

Thank You