Analysis of Wind Speed Data for Four Locations in Ireland based on Weibull Distribution's Linear Regression Model

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Abstract-Wind speed is the most important parameter in the design and study of wind energy conversion systems (WECS). The main aim of this study is to assess wind power potential of a site for wind power plant development. Availability of wind energy and its characteristics at Malin Head, Dublin Airport, Belmullet and Mullingar in Ireland has been studied based on primary data collected at these sites for a period of seven years. The wind speeds at height of 50 m above ground level were measured. Two parameter Weibull distribution's linear regression model is used for analyzing wind speed pattern variations. Weibull parameters are calculated by using Least Squares Fit Method (LSM). Our analysis shows that the coastal sites of Ireland such as Malin Head, Dublin Airport and Belmullet have good wind power potentials. These potentials if utilized they will provide solution towards power shortage problem of Ireland. Large magnitudes of winds for power generation occurred during the months of October to March and in May month.

Keywords-Wind Turbine Generator (WTG), Wind Power Plant (WPP), Weibull Distribution.

1. Introduction

Burning of fossil fuels will affect environment and will results into a] Extreme weather events like heat waves, floods, droughts and Impact on human health due increase of vector borne diseases etc. b] Significant impact on natural eco systems like wind and rainfall patterns may change, melting of polar ice caps, Sea level rise, Significant changes in agricultural productivity, Climate and Agricultural zones may shift, Recession of glaciers and Impact on water availability etc. c] Impact on human infrastructure like transportation, energy demand and tourism etc.

The solution to those problems is use of renewable energy sources e.g. Wind, Solar etc. In recent past years wind energy has emerged as clean, affordable, inexhaustible and environment friendly source of energy. So wind mills are viable option for supplying power. These wind mills should supply a power to entire city or area or district. Therefore this study aims in investigating the prospects of harnessing and useful conversion of wind energy potential for the specific areas of Ireland for setting small wind mills.

By the combinations of renewable resources sustainable energy supply can only be secured. Rapid development of wind power has aware strong public, political and scientific interest, and has triggered widespread discussion over the past few years. Power generation from wind farm projects are now becoming global concept. Those who want to become wind farm power producers are more interested in to know the characteristics of wind at the interested site and how much energy the wind farm will produce from available wind.

A proper statistical analysis of wind data is very important step performing a wind resource assessment which provides a wind energy development initiative. There are several works that deal with the use of probability density functions to describe the wind speed distribution. The Weibull Distribution is widely accepted and used in the wind energy industry as the better method for describing wind speed variations at a given sites. In this study, two parameter Weibull Distribution is used for analyzing wind speed pattern variations.

2. Data Source

In this study, data set of years 2007 to 2011 are obtained containing mean wind speed of each month in a year with observation height of 50 m above ground level. The chosen stations from Ireland are

Name	Latitude N°	Longitude W°
Malin Head Co. Donegal	55°23'N	07°23'W
Dublin Airport Co. Dublin	53°21'N	06°15'W
Belmullet Co. Mayo	54°14'N	09°58'W
Mullingar Co. Westmeath	53°31'N	07°21'W

Figure shows the locations of chosen sites in Ireland

Figure - 1, Figure - 2, Figure - 3 and Figure - 4 are showing monthly mean wind speed variations for seven years for Malin Head, Dublin Airport, Belmullet and Mullingar respectively.

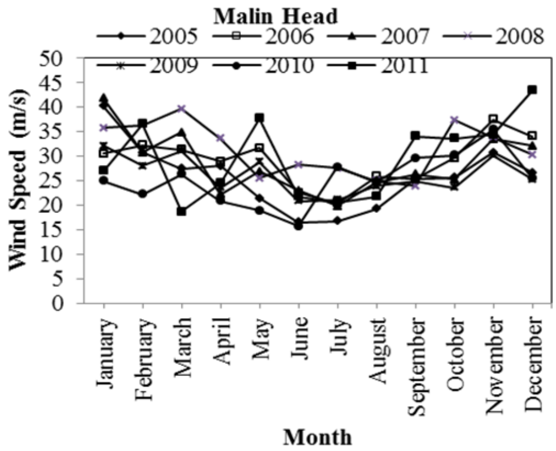

Fig. 1. Monthly Mean Wind Speed Variations for Malin Head

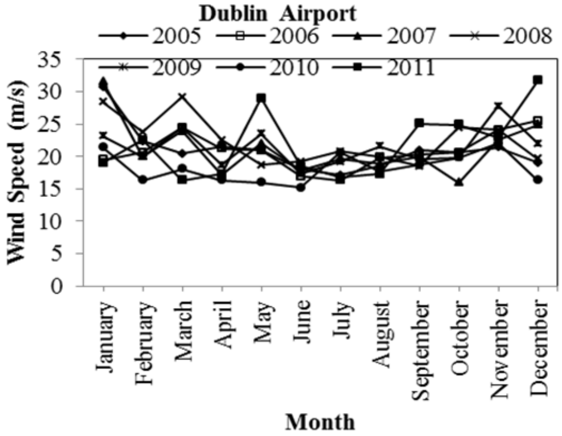

Fig. 2. Monthly Mean Wind Speed Variations for Dublin Airport

3. Statistical Model Selection

In this paper two parameter Weibull distribution is used to describe wind speed variation if wind speed variation follows Weibull probability density function. Weibull distribution is a special case of Pearson Type III or Generalised Gamma distribution with two parameters.

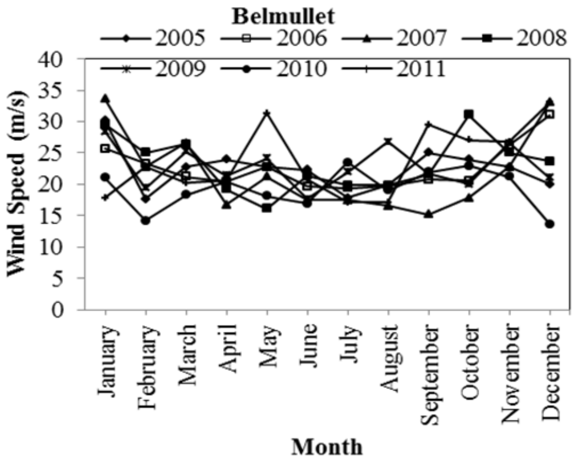

Fig. 3. Monthly Mean Wind Speed Variations for Belmullet

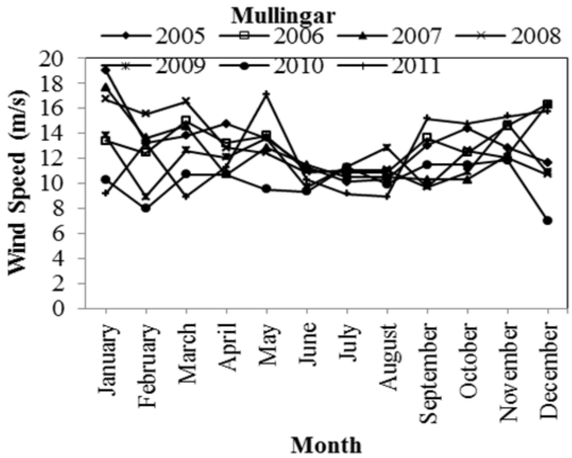

Fig. 4. Monthly Mean Wind Speed Variations for Mullingar

The Probability density function (PDF) is

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

The Cumulative Density Function (CDF) is

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

Where c is a scale parameter and k is shape parameter

There are several methods available for determining the Weibull parameters c and k out of those for calculation purpose Least Squares Fit Method (LSM) is used

By transforming in to logarithmic form equation (2) could be expressed as equation (3)

$$\ln [\ln (1 / [1\text{-}F(V)])] = k \ln V_i - k \ln c \quad (3)$$

Let $X_i = \ln V_i$

$Y_i = \ln [\ln (1 / [1\text{-}F(V)])]$

where i = 1,2,3,........,n

The linear approximation of this data is obtained using the least square method, in the form

$Y = a + b X$

Thus weibull parameters are obtained as

Shape parameter is

$$k = b \quad (4)$$

and Scale parameter is

$$c = e^{-\frac{a}{b}} \quad (5)$$

Table 1 and Table 2 are showing the Weibull parameters for locations Malin Head, Dublin Airport, Belmullet and Mullingar of Ireland for the study period of five years.

Table 1. Weibull Parameters

Year	Malin Head		Dublin Airport	
	c	k	c	k
2007	30.982	4.6	22.955	5.177
2008	33.796	5.749	24.075	6.088
2009	27.806	6.744	22.745	7.358
2010	27.423	4.612	19.249	7.821
2011	32.816	3.528	23.926	4.233

Table 2. Weibull Parameters

Year	Belmutt		Mullingar	
	c	k	c	k
2007	24.301	3.455	13.709	4.888
2008	25.139	5.269	13.722	5.345
2009	24.355	6.886	12.569	6.427
2010	20.729	5.73	10.839	6.311
2011	26.055	4.13	13.79	3.744

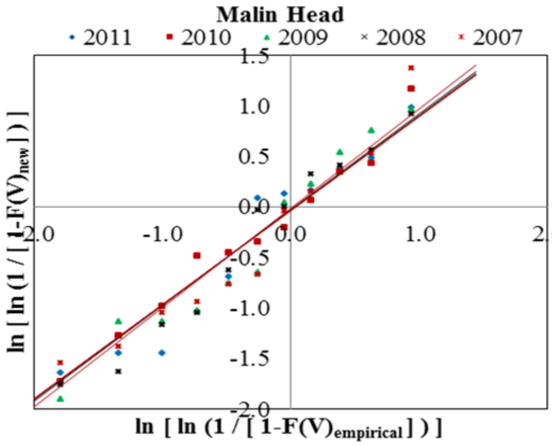

Fig. 5. Variations in ln [ln (1 / [1-F(V)$_{empirical}$])] w.r.t. ln [ln (1 / [1-F(V)$_{actual}$])] for Malin Head

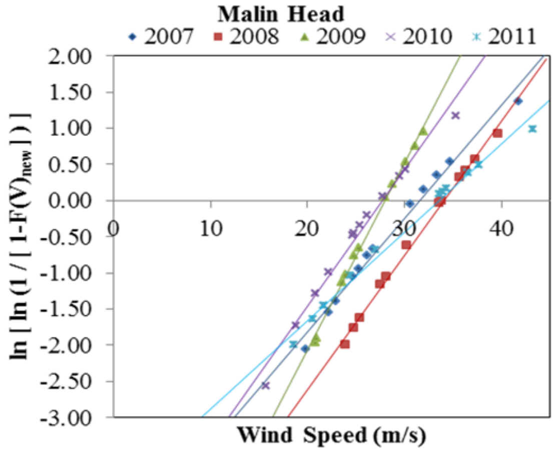

Fig. 6. Variations in ln [ln (1 / [1-F(V)$_{actual}$])] w.r.t Actual Wind Speed for Malin Head

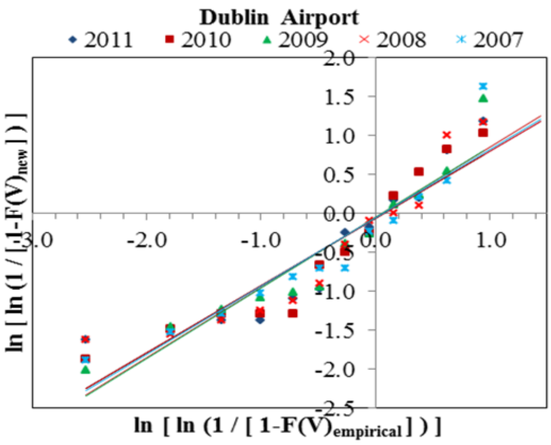

Fig. 7. Variations in ln [ln (1 / [1-F(V)$_{empirical}$])] w.r.t. ln [ln (1 / [1-F(V)$_{actual}$])] for Dublin Airport

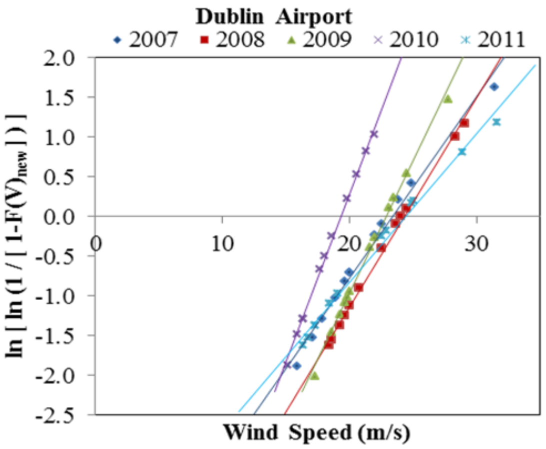

Fig. 8. Variations in ln [ln (1 / [1-F(V)$_{actual}$])] w.r.t Actual Wind Speed for Dublin Airport

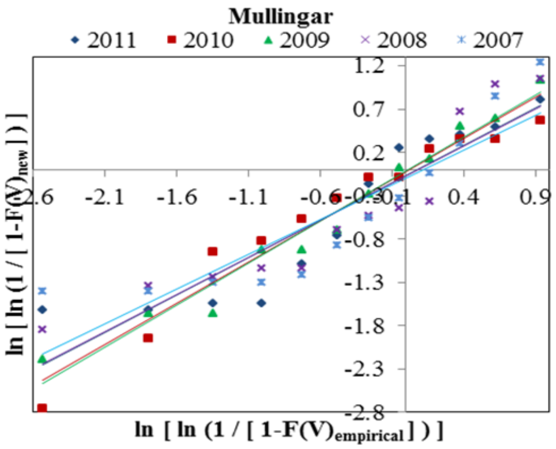

Fig. 11. Variations in ln [ln (1 / [1-F(V)$_{empirical}$])] w.r.t. ln [ln (1 / [1-F(V)$_{actual}$])] for Mullingar

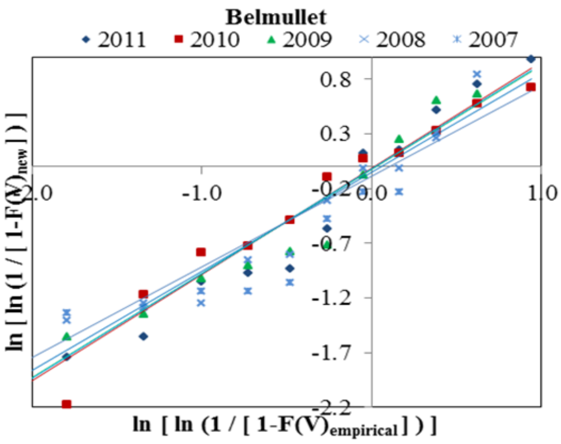

Fig. 9. Variations in ln [ln (1 / [1-F(V)$_{empirical}$])] w.r.t. ln [ln (1 / [1-F(V)$_{actual}$])] for Belmullet

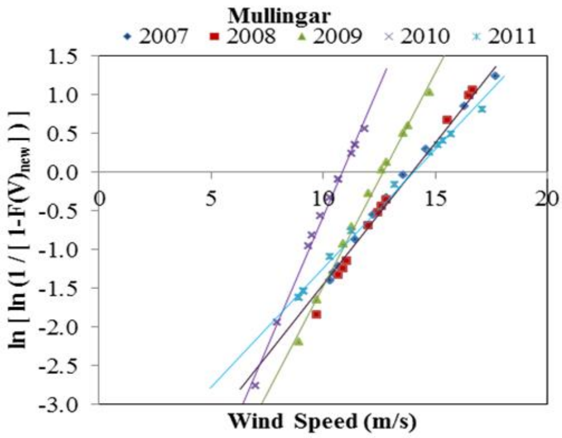

Fig. 12. Variations in ln [ln (1 / [1-F(V)$_{actual}$])] w.r.t Actual Wind Speed for Mullingar

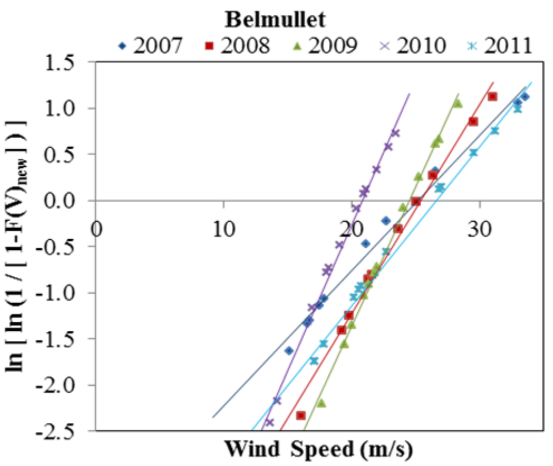

Fig. 10. Variations in ln [ln (1 / [1-F(V)$_{actual}$])] w.r.t Actual Wind Speed for Belmullet

4. Result and Discussions

Figure - 1, Figure - 2, Figure - 3 and Figure - 4 are showing the variations in monthly mean wind speed for Malin Head, Dublin Airport, Belmullet and Mullingar respectively. Seasonal changes are important considerations for applications where electricity use is time dependent for short term energy planning. Seasonal winds in Ireland are strongest in months between October to March and in May month.

Comparing Figure - 1, Figure - 2, Figure - 3 and Figure - 4, Malin Head and Belmullet locations are most suitable for establishing wind power plant as wind speed is high and more consistent throughout the year.

During the study period,

a) At Malin Head lowest wind speed is 15.73 m/s which occurs in June 2010 while highest wind speed is 23.89 m/s which occurs in December 2011,

b) At Dublin Airport lowest wind speed is 15.15 m/s which occurs in June 2010 while highest wind speed is 18.45 m/s which occurs in December 2011,

c) At Belmullet lowest wind speed is 13.59 m/s which occurs in December 2010 while highest wind speed is 19.42 m/s which occurs in January 2007,

d) At Mullingar lowest wind speed is 6.99 m/s which occurs in December 2010 while highest wind speed is 10.88 m/s which occurs in January 2005.

Table 1 is showing the Weibull parameters for four locations in Ireland for study period of five years. Figure - 5, Figure - 7, Figure - 9 and Figure - 11 are showing variations in $\ln [\ln (1 / [1-F(V)_{empirical}])]$ w.r.t. $\ln [\ln (1 / [1-F(V)_{actual}])]$. As graphs are showing a straight line variation so we conclude that Weibull distribution model is fitted well. Figure - 6, Figure - 8, Figure - 10 and Figure - 12 are showing the variations in $\ln [\ln (1 / [1-F(V)_{actual}])]$ w.r.t actual wind speed. These graphs provide us information about actual wind speed variation pattern with Weibull distribution linear regression model. From these graphs we can easily locate the data points in data set.

5. Conclusion

Based on analysis of monthly mean wind speed for Malin Head, Dublin Airport, Belmullet and Mullingar variations shows that seasonal winds in Ireland are strongest in months between October to March and in May month. This paper has presented an approach based on two parameter Weibull Distribution's Linear Regression Model for Four Locations in Ireland. Monthly mean wind speed data of Four Locations in Ireland are fitted with two parameter Weibull Distribution. Weibull Distribution parameters are calculated for Malin Head, Dublin Airport, Belmullet and Mullingar Locations in Ireland. Liner regression model helps us to directly locate the data point in a data set.

References

[1] R. C. Bansal, T.S. Bhatti and D.P. Kothari, "On some of the design aspects of wind energy conversion system" Energy Conversion Management, vol.43, No. 16, pp. 2175-2187, November 2002.

[2] A. N. Celick, "A statistical analysis of wind density based on the Weibull and Rayleigh models at the southern region of Turkey", Energy Conversion Management, vol.29, No. 4, pp. 593-604, 2004.

[3] J.A. Carta and P. Ramiez, "Influence of the data sampling interval in the estimation of the parameters of the weibull wind speed probability density distribution: a case study", Energy Conversion Management, vol.46, No. 15, pp. 2419-2438, 2005.

[4] R. C. Bansal, A.F. Zobaa and R.K. Saket, "Some issues related to power generation using wind energy conversion systems: An overview", International Journal Emerging Electrical Power System, vol.3, No. 2, pp. 1-19, 2005.

[5] T. J. Chang and Y.L. Tu, "Evaluation of monthly capacity factor of WECS using chronological and probabilistic wind speed data: A case study of Taiwan", Renewable Energy, vol.32, No. 2, pp. 1999-2010, 2007

[6] S. J. Huang and H.H. Wan, "Enhancement of matching turbine generators with wind regime using capacity factor curves stratergies", IEEE Transaction Energy Conversion, vol. 24, No. 2, pp.551-553, June 2009.

[7] R. D. Prasad, R.C. Bansal and M. Sauturaga, "Wind energy analysis for vadravadra site in Fiji islands: A case study", IEEE Transaction Energy Conversion, vol.24, No. 3, pp.1537-1543, September 2009.

[8] M.A. Alghoul, M.Y. Sulaiman, B.Z. Azmi and M. A. Wahabr, "Wind energy potential of Jordan", International Energy Journal, vol.8, pp. 71-78, 2007

[9] Gary L. Johnson, Wind Energy Systems, Prentice-Hall Inc., Englewood Cliffs, New Jercy, 1985