Comparison of Wind Potential of Ormara and Jiwani (Balochistan), Pakistan

Tariq Jamil* and G.S. Akram Ali Shah

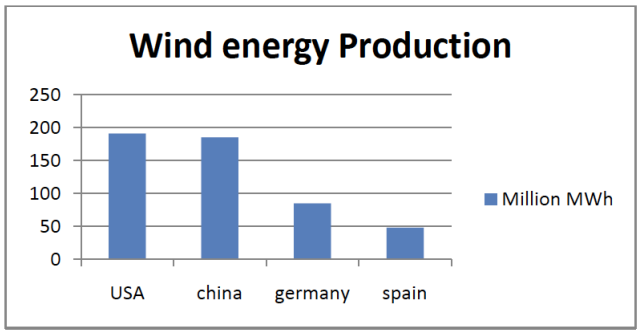
Federal Urdu University of Arts Science and Technology, Karachi, Pakistan

Abstract: This paper presents comparison of wind potential of Ormara and Jiwani and evaluation of Weilbull distribution function for two coastal areas of Balochistan. Ten years data (1998-2007) of wind speed have been obtained from Pakistan Meteorological Department (PMD) of Karachi, Pakistan. The analysis of wind data is carried out and fitted by Weibull function. The two parameters of the distribution are also evaluated. Monthly mean wind speed of two coastal locations (Ormara and Jiwan) was also predicted.

Keywords: Wind energy, Weibull distribution, Weibull Parameters, Scale Parameter and Shape Parameter.

INTRODUCTION

Pakistan is facing a serious issue of energy crises. According to the report of 2014 [1], it is estimated that 30,000 MWh of electrical energy is needed in each day. While the production is between 24000MW to 26500MW per day, and shortfall is 3500 MW to 6000 MW per day. The energy demand will be increased by two fold in the coming decade. Pakistan is one of the countries which facing a great challenge. It is important for the development of Pakistan to divert toward the renewable energy resources like wind or solar etc.



Wind is considered as an inexpensive and clean source of energy [2-4]. Worldwide, the utilization of wind power is rapidly growing up to 237016 MW. The growth rate is up to 20.3 %. Approximately 100 countries have been fulfilling their energy need by using wind. USA is among the top of the list with 190.9 million MWh followed by china with 185.1 million MWh and Germany with 84.6 million MWh.

Wind Energy Potential in Pakistan

The geographical location of Pakistan is outstanding for wind energy due to its coastal belt. This paper presents wind potential data for two coastal areas of Balochistan i.e. Ormara and Jiwani.

Geographical Location of Balochistan

Balochistan is the largest province of Pakistan with an average area of 347,190 km², situated at the eastern boundary of the Iranian terrain. Population is very small due to the mountainous topography and insufficiency of natural water resources. Makran is located at southern part whereas Kalat is the central part of Balochistan.

Geographical Location of Ormara

Ormara is located in Gawadar District in Balochistan. It is a port city 25° 16' 29 North 64° 35' 10 East situated in the Makran. Ormara is at a distance of 360 Km from Karachi in western direction and 230 kilometers away to the east of Gwadar on the Arabian Sea.

Geographical Location of Jiwani

Jiwani is situated next to bay of Oman in the Gawadar, Balochistan. It shares the boundaries of Iran at 25° 3′ 0″ North and port of Gwadar located almost 80 kilometers to east of 61° 44′ 0″.

In order to calculate and identify wind potential for the coastal areas, wind parameters are required. Weibull distribution function help to fit data of wind speed [6].

Weibull Distribution Function

The experimental data of wind speed is generally interpreted by Weibull distribution function. Researchers have been using these parameters to solve and describe the distribution.

Weibull distribution is commonly used for better fitting of experimental data. Weibull distribution function

*Address correspondence to this author at the Federal Urdu University of Arts Science and Technology, Karachi, Pakistan; Tel: +92-21- 99244141-8; Fax: +92-21-99244272; E-mail: tariqjk19@gmail.com

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Figure 1: Map of Jiwani and Ormara Balochistan, Pakistan.

is very common among researcher for the mathematical fitting of wind data. Paulo Alexandre *et al*. [4] reported the reliability of this method by the comparative study of seven different numerical methods to measure and estimate Weibull distribution function and wind speed [7].

Probability Density function (PDF)

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

Cumulative Distribution Function (CDF)

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

Where k and c are shape and scale parameter respectively, k is dimensionless, while scale parameter has dimension of velocity. It can be found by various numerical methods. For example graphical method, maximum likelihood method, moment method, empirical method, modified maximum likelihood method, and equivalent energy method [7-13].

Parameters Determination

In this section we discuss the determination of 'k' and 'c' by numerical methods:

Maximum Likelihood Method

Maximum likelihood method helps for determination of parameters k and c. For the determination of these parameters following equation can be used [14-16].

$$k = \left[\frac{\sum_{i=1}^{n} v_i^k \ln v_i}{\sum_{i=1}^{n} v_i^k} - \frac{\sum_{i=1}^{n} \ln v_i}{n}\right]^{-1}$$

$$c = \left(\frac{1}{n}\sum_{i=1}^{n} v_i^k\right)^{\frac{1}{k}}$$

Where the number of observation is n, v_i is speed of wind measure at "i" interval

Energy Pattern Factor Method

The relationship between EPM parameters and average data of wind speed is given below,

$$E_{pf} = \frac{\overline{v}^3}{\overline{v^3}}$$

$$k = 1 + \frac{3.69}{\left(E_{pf}\right)^2}$$

$$\overline{v} = c\Gamma\left(1 + \frac{1}{k}\right)$$

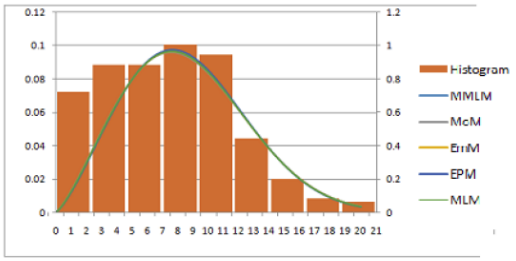
Table 1: Compersion of Scale and Shape Parameter and Predicted Wind Speed (m/s)

Omara table											PREDICTED WIND SPEED				
Months	MMLM		MOM		EmM		EPM		MLM		MMLM	MOM	EmM	EPM	MLM
	k	c	k	c	k	c	k	c	k	c					
JAN	2.286103	9.76776	2.26838	9.763395	2.288433	9.762563	2.313084	9.761369	2.286455	9.757742	8.60766	8.599681	8.603924	8.608718	8.599458
FEB	2.365714	11.54494	2.36095	11.56158	2.379283	11.56011	2.411515	11.55729	2.365418	11.55556	10.19841	10.21133	10.21439	10.21922	10.20731
MAR	2.932763	12.95069	2.92139	12.95678	2.927031	12.95574	2.829451	12.97351	2.932467	12.95987	11.55032	11.5536	11.55373	11.55088	11.55841
APR	3.22918	15.20993	3.16997	15.19145	3.169389	15.19158	2.995776	15.23089	3.228946	15.21846	13.62875	13.59992	13.59992	13.59918	13.63635
MAY	3.405083	14.43313	3.43116	14.42196	3.423985	14.42352	3.12793	14.48837	3.404687	14.44459	12.96744	12.96255	12.96254	12.96205	12.97766
JUN	3.173714	12.27636	3.23568	12.28505	3.233431	12.28547	3.009805	12.32665	3.174076	12.2677	10.99091	11.00906	11.00905	11.00859	10.98321
JUL	3.300121	12.80357	3.34371	12.79908	3.338736	12.80004	3.074598	12.85119	3.299807	12.81131	11.48488	11.48852	11.48851	11.48757	11.49177
AUG	3.493974	13.64175	3.64373	13.63262	3.631273	13.63515	3.214438	13.72143	3.493594	13.65077	12.27299	12.29248	12.29248	12.29205	12.28103
SEP	3.018446	13.11299	3.08901	13.09168	3.090463	13.0914	2.879506	13.13165	3.018795	13.10371	11.71248	11.70587	11.70587	11.70489	11.70426
OCT	2.627297	11.0958	2.62531	11.10399	2.638035	11.10232	2.603814	11.10675	2.627558	11.08856	9.85492	9.861857	9.862184	9.861241	9.84858
NOV	2.424262	9.644464	2.41467	9.640834	2.431943	9.639464	2.417594	9.640606	2.424594	9.636364	8.531961	8.527203	8.528987	8.527514	8.525086
DEC	2.116307	8.990726	2.10091	8.979345	2.123594	8.979871	2.137486	8.98008	2.116594	8.983161	7.866885	7.852571	7.86095	7.865799	7.861096

Table 2: Compersion of Shape and Scale Parameter and Predicted Wind Speed (m/s)

Jiwani table											PREDICTED WIND SPEED				
Months	MMLM		MOM		EmM		EPM		MLM		MMLM	MOM	EmM	EPM	MLM
	k	c	k	c	k	c	k	c	k	c					
JAN	1.679252	7.579552	1.60059	7.498933	1.625227	7.509114	1.567012	7.483614	1.678824	7.589094	6.508345	6.404092	6.427418	6.370103	6.514475
FEB	1.86873	9.049332	1.81398	8.992243	1.839179	8.997687	1.788752	8.986169	1.869158	9.038059	7.909972	7.715973	7.736592	7.694089	7.90148
MAR	2.015647	9.775022	1.97782	9.734178	2.001952	9.736494	1.963683	9.732637	2.015321	9.784131	8.523267	8.475038	8.487972	8.467039	8.53001
APR	2.428064	10.12141	2.4233	10.10038	2.440401	10.09893	2.37805	10.1039	2.427664	10.13094	8.964215	8.945286	8.94633	8.942021	8.972439
MAY	2.560913	10.17602	2.59197	10.16401	2.605442	10.16245	2.502468	10.17365	2.561316	10.16725	9.029624	9.023088	9.023443	9.019833	9.021977
JUN	2.499998	10.85614	2.52307	10.84223	2.538064	10.84055	2.44521	10.85023	2.499629	10.86521	9.610203	9.602904	9.604372	9.593527	9.617877
JUL	2.408445	10.97701	2.38845	10.95326	2.406244	10.95177	2.37286	10.95449	2.408141	10.98565	9.691503	9.666489	9.669832	9.663369	9.698647
AUG	2.426475	10.60765	2.41163	10.58538	2.428964	10.58388	2.386859	10.58738	2.426077	10.61825	9.383197	9.36131	9.363352	9.358108	9.392178
SEP	2.311342	8.384507	2.32567	8.371451	2.34468	8.370498	2.241092	8.374556	2.311755	8.377266	7.412121	7.402756	7.404295	7.393934	7.40597
OCT	2.233422	7.510295	2.21167	7.488822	2.232686	7.488467	2.186693	7.489075	2.233767	7.504431	6.629308	6.608204	6.610754	6.604855	6.624398
NOV	2.134975	7.010818	2.11304	6.99159	2.135553	6.991902	2.082279	6.990873	2.13459	7.016926	6.193822	6.127018	6.132715	6.118537	6.199013
DEC	1.634259	6.337035	1.54502	6.255775	1.569036	6.265816	1.511052	6.240153	1.634686	6.329584	5.481823	5.3383693	5.402635	5.354889	5.476824

omara
JANUARY



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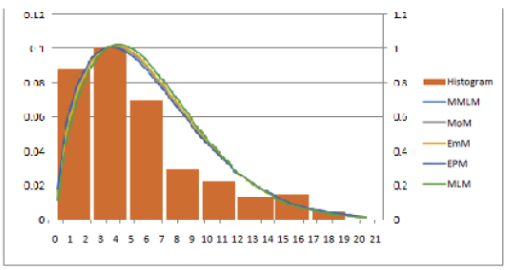

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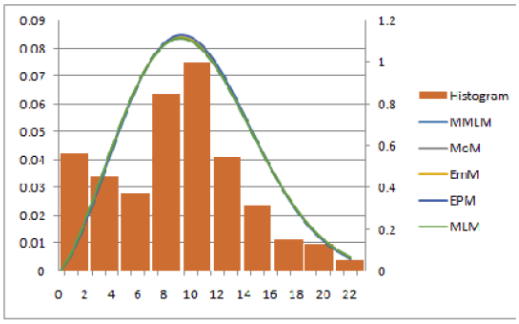

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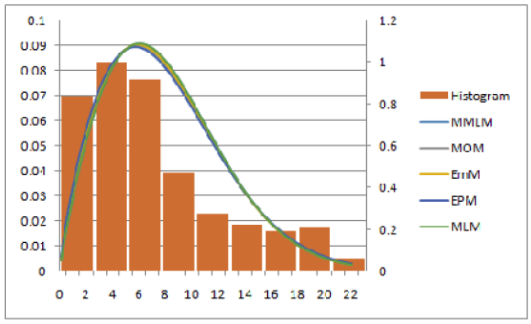

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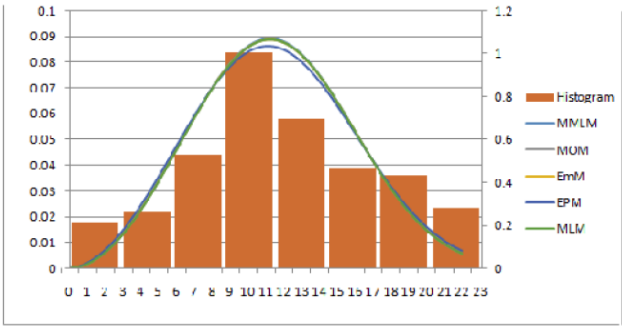

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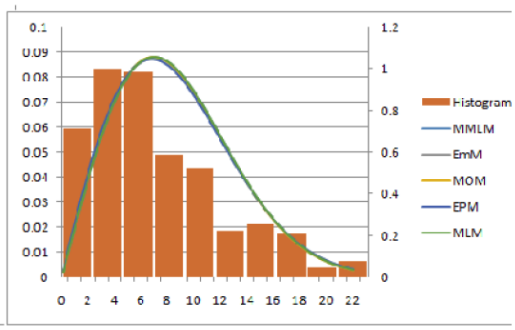

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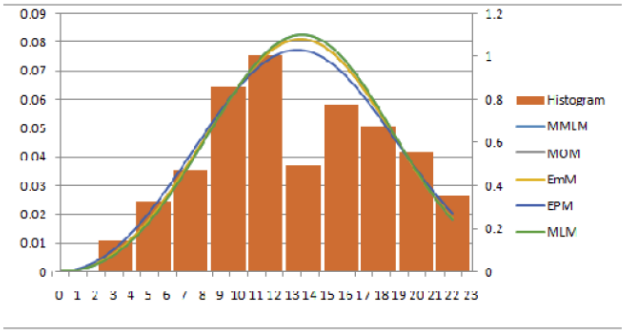

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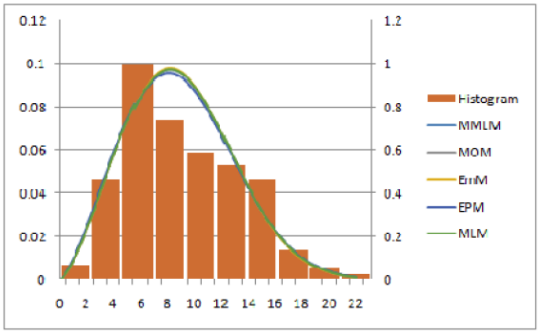

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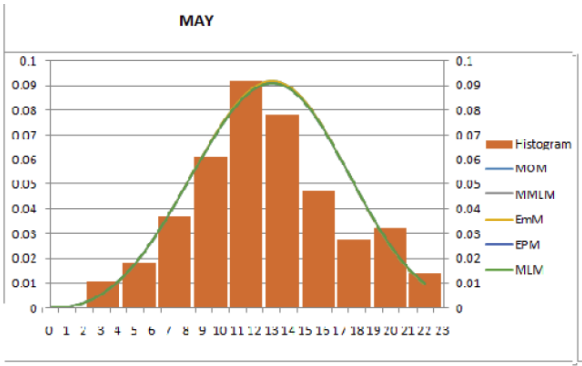

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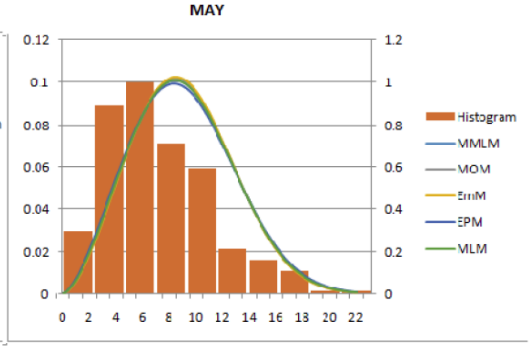

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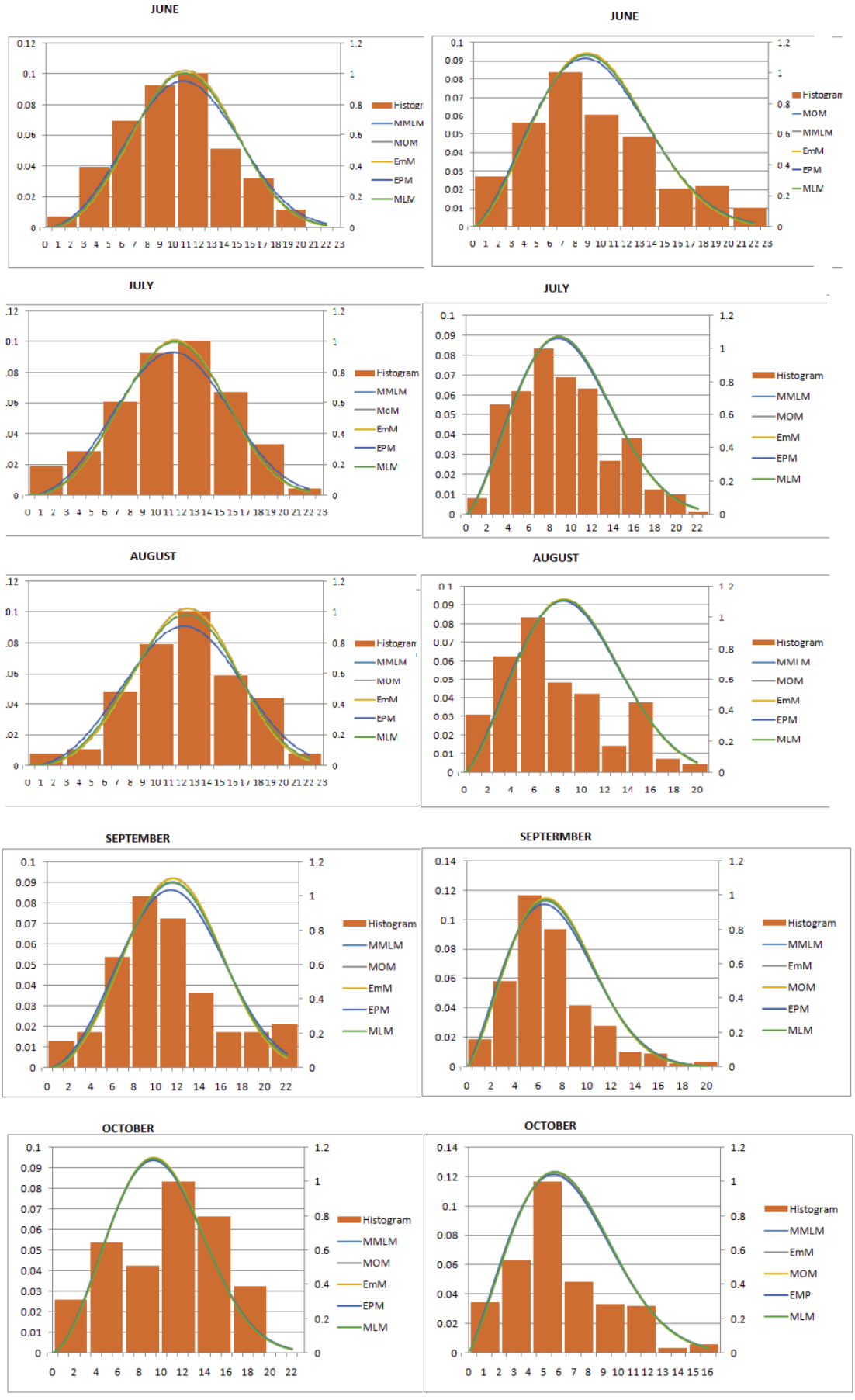

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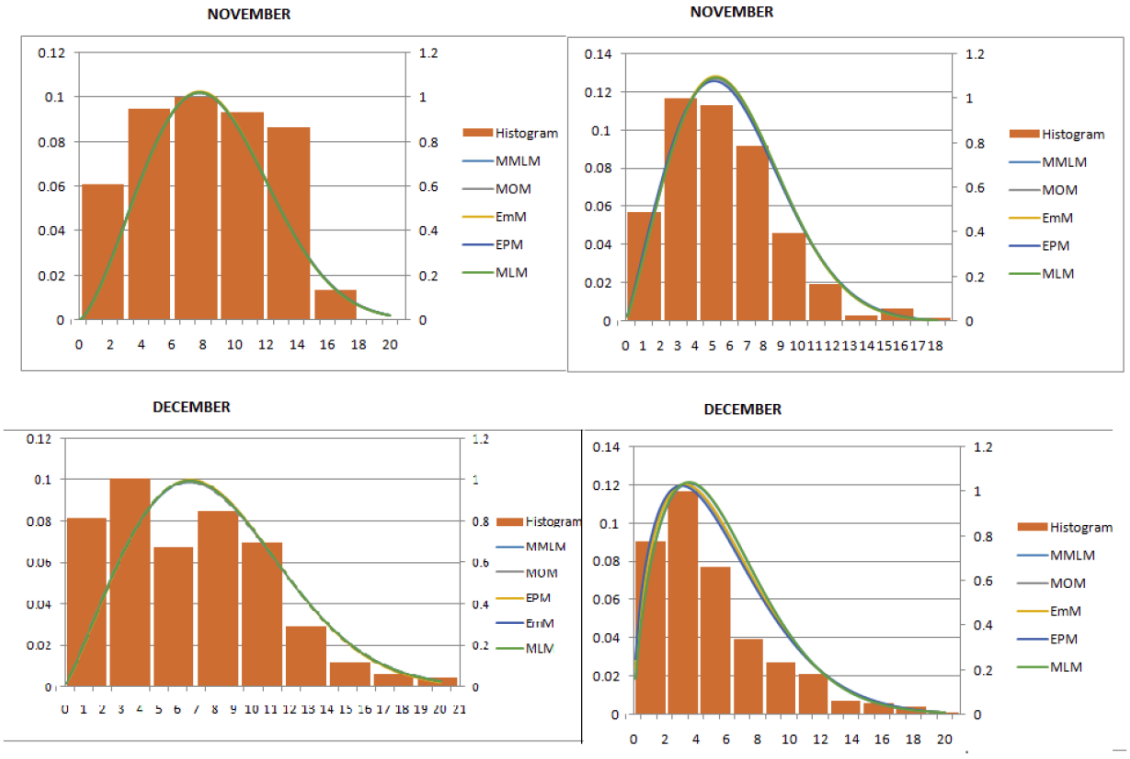

Figure 2: The compersion of month-wise plot of weibull distribution of omara and jiwani (Jan-Dec).

Modified Maximum Likelihood Method

The following equation can be used when wind data is an agreement with the Weibull distribution and following are the formulas to calculate k and c [14, 20].

$$k = \left[\frac{\sum_{i=1}^{n} v_i^k \ln v_i \; f(v_i)}{\sum_{i=1}^{n} v_i^k \; f(v_i)} - \frac{\sum_{i=1}^{n} \ln v_i \; f(v_i)}{f(v) \geq 0} \right]^{-1}$$

$$c = \left(\frac{1}{f(v) \geq 0} \sum_{i=1}^{n} v_i^k \; f(v_i) \right)^{\frac{1}{k}}$$

Method of Moment

This method was first used by Jestus *et al.* [14]. Method of moment can be used as a replacement of MLM. For this method parameter 'k' and parameter 'c' can be estimated by given equation: [14, 15], the average speed is calculated as given in EPM

$$\sigma = c \left[\Gamma\left(1 + \frac{2}{k}\right) - \Gamma^2\left(1 + \frac{1}{k}\right) \right]^{\frac{1}{2}}$$

Empirical Method

It is an exceptional case of MOM. Weibull parameters can be determined by following formula [16]. Formula for average speed is same as given in EPM;

$$k = \left(\frac{\sigma}{v} \right)^{-1.086}$$

RESULT AND DISCUSSION

The wind power potential of Ormara and Jiwani has been analyzed in this research. This compression is accomplishing and found to be fitted with the actual measured wind speed and theoretical Weibull function for each month for the period of ten years. The Weibull distribution has two parameters: the shape parameter 'k' which has no dimension while scale parameter 'c' has the dimension of velocity [9, 12, 13].

From 1998 to 2007 wind speed data of 12:00 hours have been used for this study to fit the Weibull distribution at Ormara and Jiwani. Five different methods have been used for determination of these parameters. The mean wind speed which helps to give a clue of wind potential at Ormara and Jiwani was also calculated.

Table **1** shows the estimated wind speed of Ormara and Table **2** shows the estimated wind speed of Jiwani

Table 3: Compression between Predicted and Measured Wind Speed of Ormara. Average Wind Speed (m/s) of Ormara

Months	Predicted (m/s)	Measured (m/s)
Jan	8.603888314	8.649647887
Feb	10.21013062	10.20680000
Mar	11.55338794	11.55849673
Apr	13.61282403	13.60181159
May	12.96644739	12.96410256
Jun	11.0001631	10.69615385
Jul	11.48824772	11.16354515
Aug	12.28620718	12.29387097
Sep	11.70667308	11.70753425
Oct	9.85775639	9.866981132
Nov	8.528150421	8.54869281
Dec	7.861460286	7.954198473

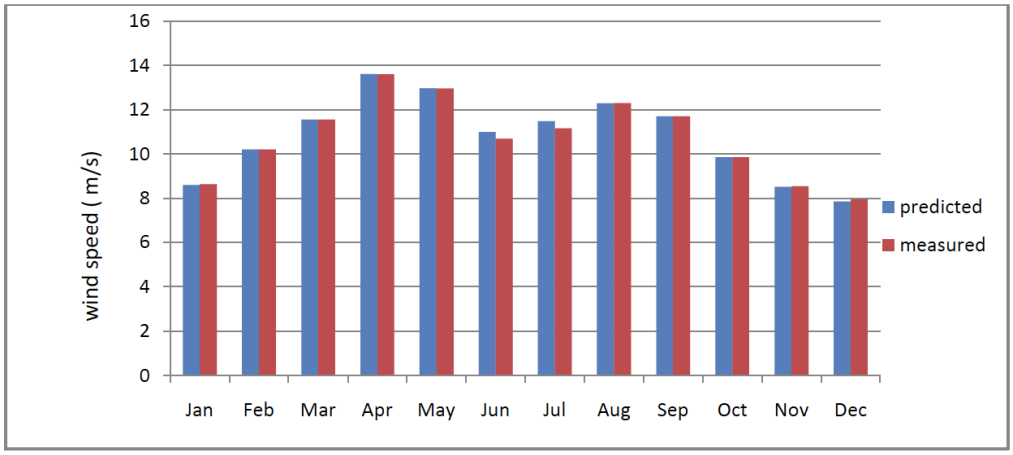

Figure 3: Compression between predicted and measured wind speed of Ormara.

by using different methods and predicted wind speed. The histogram also generated for 12:00 hours wind speed data (1998 – 2007). The PDF curves are also generated by using parameters 'k' and 'c'.

The value of wind speed lies between 7.8 m/s to 13.6 m/s for Ormara, while for Jiwani it lie between 5.4 m/s to 9.7 m/s (see Tables **3** and **4**). The mean wind speed from January to December of ten years data shown in Figure **3** and **4** for the Ormara and Jiwani. The consistency between the measured and recorded wind speeds is appreciable. According to this research wind potential of Ormara is more stable as compare to Jiwani throughout the year.

CONCLUSION

Five methods Maximum likelihood method, Modified maximum likelihood method, Energy pattern factor method, Method of moment and Empirical method have been used for the calculation of Weibull parameters 'k' and 'c' by using ten years (1998-2007) recorded data of wind speed for Ormara and Jiwani. This help to trace out the precision for the determination k and c. Comparison between measured and predicted wind speed for Ormara and Jiwani has been presented.

1. All the five method predict close values of both parameters of Weibull distribution.
2. There is slightly difference for the assessment of shape parameter which is around ca. 0.1.
3. Maximum Likelihood Methods gives better estimates of recorded wind speeds.
4. The empirical method is examined as an alternate method of moment. The shape

Table 4: Compression between Predicted and Measured Wind Speed of Jiwani. Average Wind Speed (m/s) of Jiwani

Months	Predicted	Measured
Jan	6.444886606	6.724315068
Feb	7.791621231	8.112802768
Mar	8.496665108	8.630000000
Apr	8.954058298	8.956810631
May	9.023593011	9.028253968
Jun	9.605776448	9.623548387
Jul	9.677968114	9.710476190
Aug	9.371629015	9.386006826
Sep	7.403814998	7.418543046
Oct	6.615503859	6.633450704
Nov	6.154221014	6.193165468
Dec	5.419972776	5.629343629

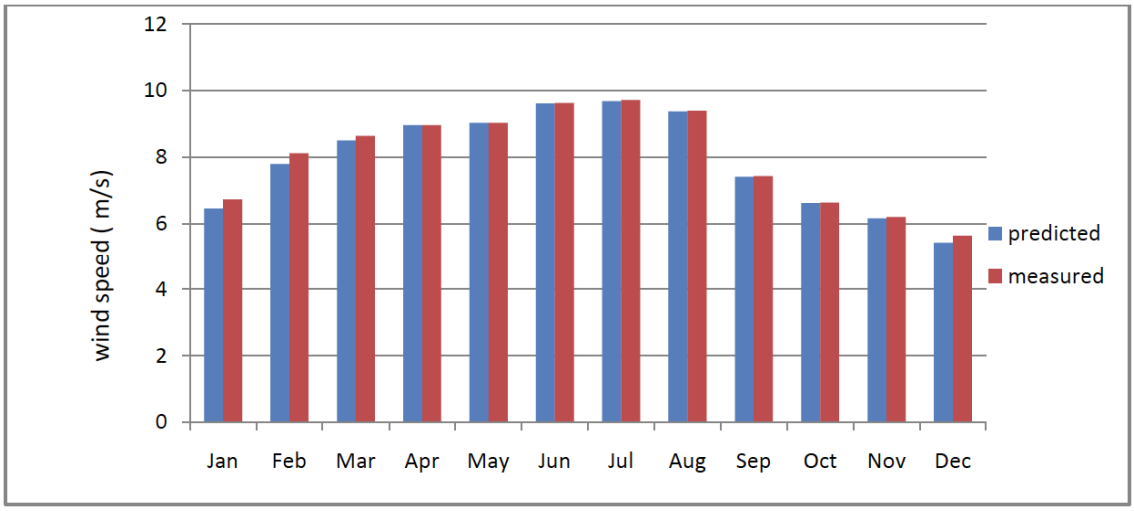

Figure 4: Compression between predicted and measured wind speed of Jiwani.

parameter and scale parameter calculated by above methods are slightly different.

5. For Ormara the highest provision of wind power is in the month of April.

6. Weibull scale parameter for Ormara lies between 7.8 m/s to 13.6 m/s while for Jiwani 5.4 m/s to 9.7 m/s. This result shows that wind potential is more stable in Ormara as compared to Jiwani.

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