Comparison of Wind Energy Potential for Coastal Locations: Pasni and Gwadar

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Abstract: A comparative study for the wind power density of the two investigated coastal sites viz. Pasni and Gwadar is presented in this paper. Pasni and Gwadar are located along the coast belt of Balochistan in Arabian Sea. Investigations are performed on daily wind speed data recorded at 12:00 UTC, obtained from Pakistan Meteorological Department (PMD) for a period five years, i.e. from 2003 to 2007. The recorded wind speed data distribution is fitted to the Weibull distribution function described by two fitting parameters i.e. scale (c) and shape (k). The Weibull parameters are numerically calculated using the Method of Moment (MoM). Monthly mean wind speeds for the two stations are predicted and wind power densities are calculated for the two stations. Comparison of the wind power densities of the investigated sites reveals a higher wind energy yield for Pasni as compared to Gwadar. The highest wind power density is predicted for the month of May.

Keywords: Weibull Distribution, Weibull Parameters, Method of Moment, Pasni, Gwadar.

INTRODUCTION

Pakistan is suffering from acute energy crises. According to 2014 energy report [1], an estimated 30,000 MWh of electrical energy is required per day in contrast the daily electrical power production of ranging between 24000 MW to 26500 MW, a daily short fall of 3500 MW to 6000 MW. Coastal belt of Balochistan presents good prospects for setting up of wind energy farms and thus reducing the energy deficit to some extent. In order to have a reliable estimates of wind energy potential for a particular site and due to a stochastic nature of wind speeds, a thorough investigation of wind parameters is required. Commonly the Weibull distribution function is employed for fitting the wind speed distribution. Additionally other distributions such as Rayleigh and Gamma distributions are also employed for fittings wind speed. A number of research groups [2-10] around the world are using the Weibull distribution function for theoretically fitting wind speed distribution. Paulo Alexandre *et al.* [11] compared seven numerical methods for the estimation of Weibull parameters for a reliable fit of the Weibull distribution function to the measured wind speed data distribution.

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Weibull Distribution

Common wind speed data distribution is modeled using Rayleigh and Weibull distribution functions [12]. The distribution function can also be used to predict wind speeds and wind power densities. The Weibull distribution in its simplest form has two parameters: the dimensionless parameter **'k'** known as shape parameter and the second parameter 'c' has the dimension of velocity and is known as scale parameter [10]. Weibull parameters are determined using various numerical methods, for example Method of Moments (MoM), Maximum Likelihood Method (MLM), Energy Pattern Factor method (EPFM), etc.

Probability Density Function (PDF)

The wind speed is used as a continuous random variable of the Weibull distribution. The mathematical form of PDF is [10]:

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} e^{-\left(\frac{v}{c}\right)^{k}} \quad (1)$$

Cumulative Distribution Function (CDF)

Cumulative distribution function for Weibull distribution is given as

$$F(v) = 1 - e^{-\left(\frac{v}{c}\right)^{k}} \quad (2)$$

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and wind power density "P' as function of wind speed is given by:

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

Here ρ is air density; the value of ρ used in the calculation is 1.225 kg/m^3. The shape parameter 'k' helps in finding how frequently wind speeds are close to some measured speed. The median value of distribution means indicates equal distribution on both the sides, i.e. 50 % wind speeds are more than the median and 50% are less than it. The value of k represents variation in mean wind speed in a given sample; higher the value of k more the stability in wind speed. The scale parameter (c) is an indicator of wind potential of a place. The large value of 'c' is an indication of more spread of wind power [10].

In the present paper we have used Method of Moments for the determination of Weibull parameters and wind power densities for Gwadar and Pasni are calculated using equation 3.

Methods of Moments (MoM)

In Method of Moment, first two moments about origin are used to determine the Weibull parameters. This method was first used by Jestus et. al [13]. Equations (4) and (5) show the first two moment of the Weibull distribution

$$\bar{v} = c\Gamma(1+1/k) \quad (4)$$

$$\sigma = c[\Gamma(1+1/k) - \Gamma^2(1+1/k)]^{1/2} \quad (5)$$

RESULT AND DISCUSSION

A comparison between wind power densities for Gwadar and Pasni is performed. The comparison is carried out through the modeling of theoretical Weibull function fitted to the actual measured wind speeds for each month for five years period.

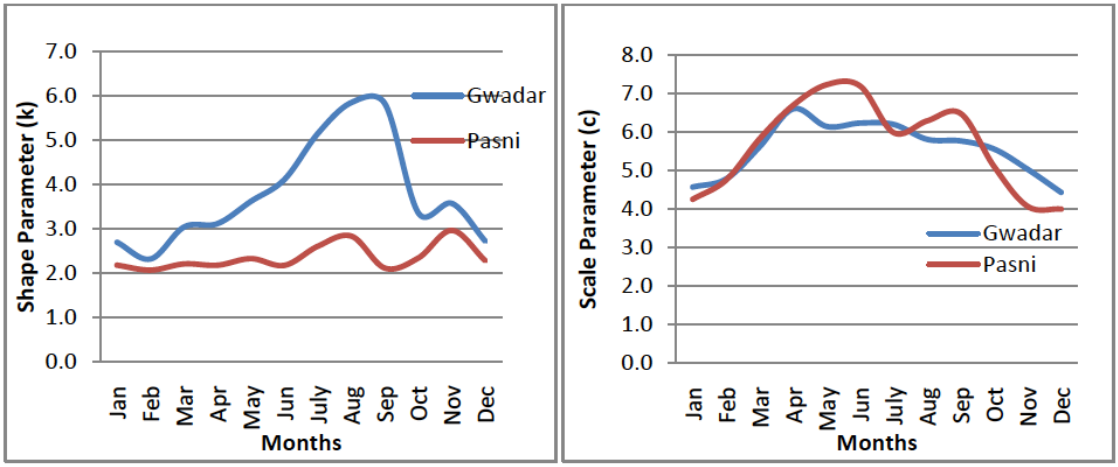


Figure 1: Plot of Shape and Scale Parameters from January to December for Gwadar and Pasni.

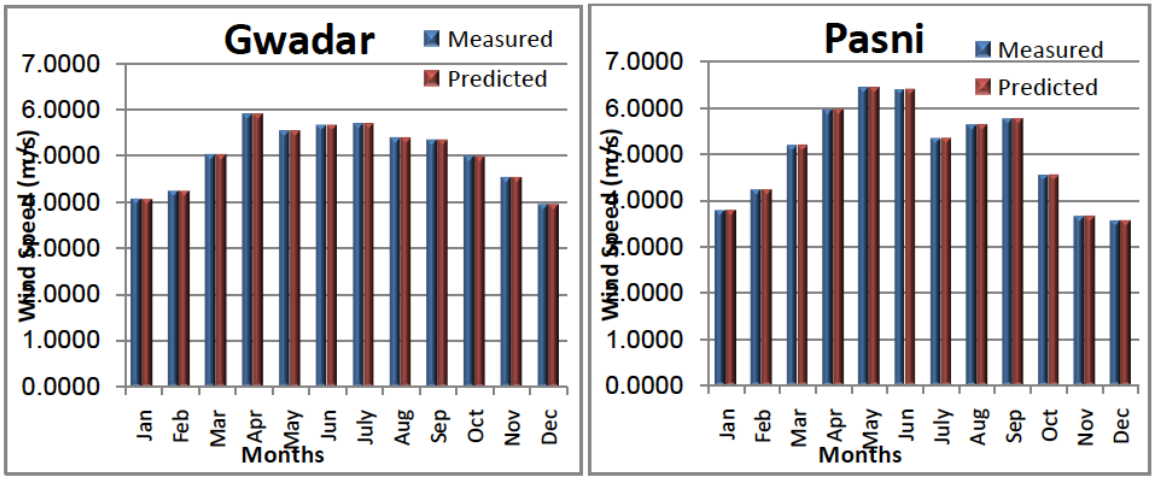


Figure 2: The measured and predicted wind speed from January to December for Gwadar and Pasni.

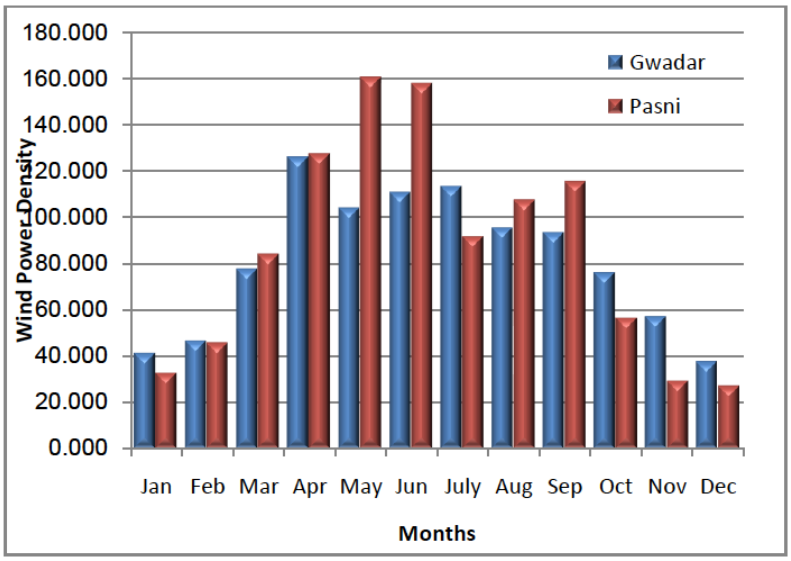


Figure 3: Comparison of available and predicted wind power densities of Gwadar and Pasni.

Table 1: The values of Scale and Shape Parameters for Gwadar and Pasni Stations for the Months January to December

	Shape Parameter (k)		Scale Parameter (c)	
Month	**Gwadar**	**Pasni**	**Gwadar**	**Pasni**
Jan	2.6942	2.1808	4.5714	4.2517
Feb	2.3189	2.0712	4.7842	4.7530
Mar	3.0380	2.2090	5.6187	5.8233
Apr	3.1147	2.1805	6.5977	6.6907
May	3.6168	2.3277	6.1414	7.2233
Jun	4.1094	2.1777	6.2292	7.1864
July	5.1468	2.6072	6.1932	5.9791
Aug	5.8395	2.8307	5.8076	6.2853
Sep	5.8095	2.1151	5.7659	6.4756
Oct	3.3520	2.3434	5.5550	5.0994
Nov	3.5703	2.9592	5.0318	4.0685
Dec	2.7169	2.2782	4.4335	3.9974

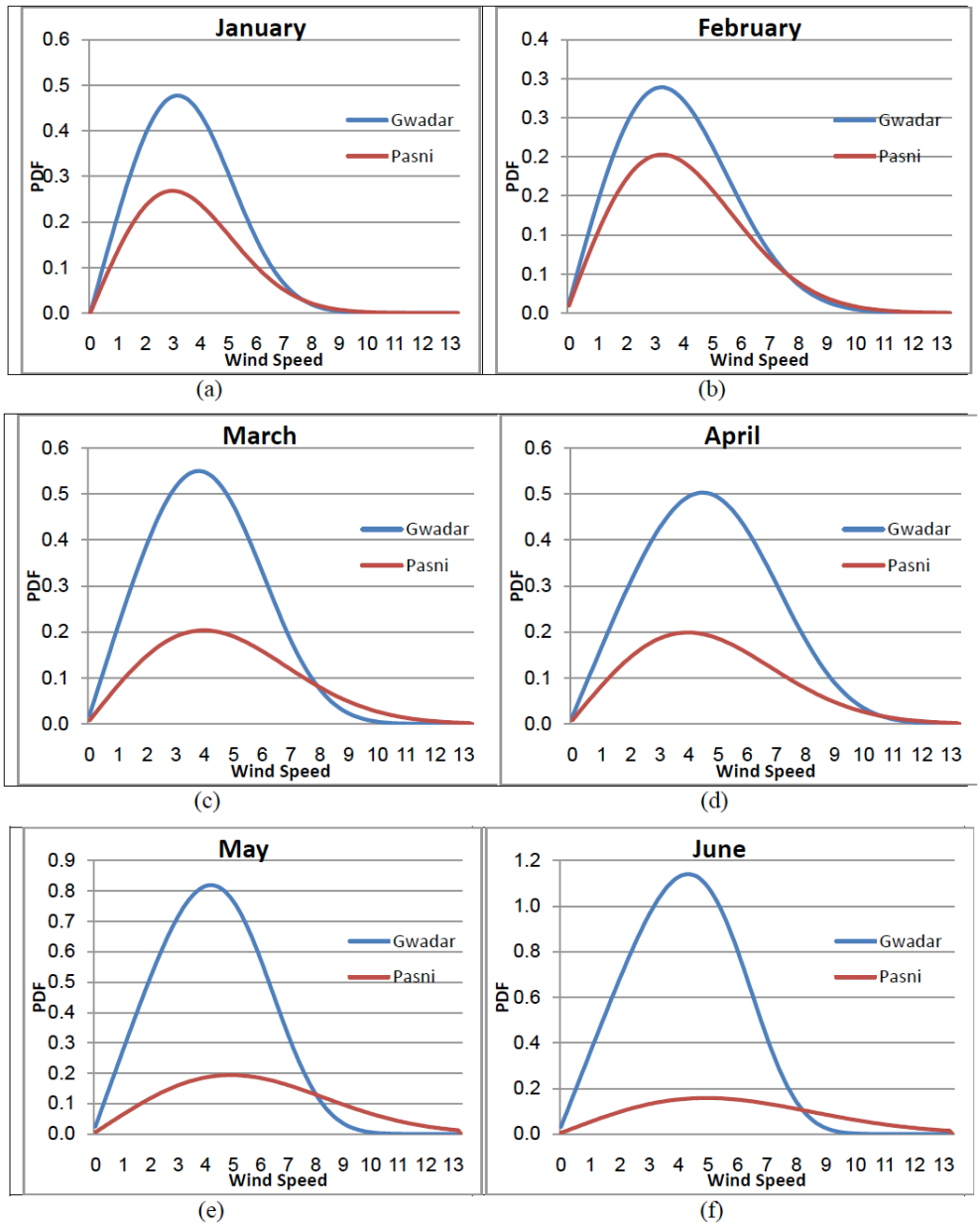
Pasni and Gwadar are two coastal areas of Balochistan, Pakistan. Their Geographical Information is as under:

	Gwadar	**Pasni**
Latitude	26° 10' 56" N	25° 16' N
Longitude	63° 30' 21" E	63° 29' E

Gwadar and Pasni are the districts of Balochistan: a province of Pakistan located near the Arabian Sea on coastal belt of Makan coast [14]. Pasni is actually 300 km from Karachi city and Gwadar is 131km from Pasni. The elevation of Makran coast varies upto around 1000 meters in which Gwadar is 0-300 meters and Pasni is 11 meters above sea level. Gwadar having an advantage of being the district headquarters of this region. As far as population is concerned Gwadar is more populated with approximately 53,000 residents as compared to Pasni having a population of around 33100 inhabitants.

Weibull parameters are estimated for each month for five years period using MoM, see Table **1**. The values listed in Table **1** indicate that the estimated values of shape parameter for Gwadar are widely spread and range from 2 to 6 whereas for Pasni shape

Figure 4: Map of Gwadar and Pasni Balochistan, Pakistan.



(Figure 5). Continued.

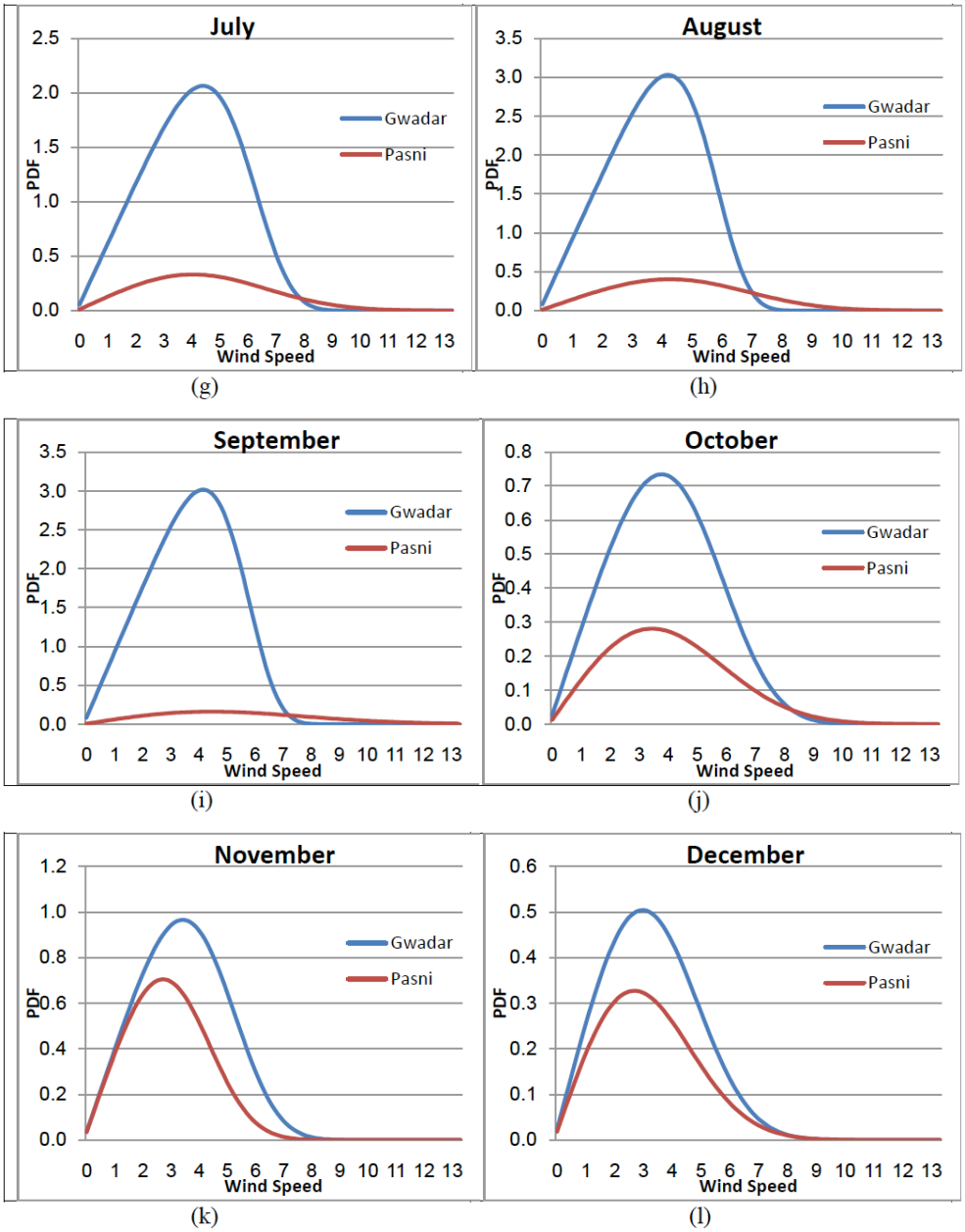


Figure 5: (**a-l**). Month-wise Plots of PDFs of Weibull distribution for Gwadar and Pasni.

parameter values for all months is ca. 2.5. This implies that in comparison to Pasni, wind speed data distribution is more stable in Gwadar having higher k values throughout the year, see Figure **1**. Therefore Gwadar is more suited for setting up of a wind farm and for the production of a stable and uninterrupted wind power. Scale parameter values for Gwadar lies betweenm 4.4 to 6.5 m/s as compared to a larger spread in c values ranging from 4 m/s to 7.5 m/s. Weibull probability density function (PDF) for Gwadar and Pasni are calculated using Weibull distribution function. The PDFs are calculated using estimated k and c values of each month for the period of five years.

The probability plots from January to December as a function of wind speeds for both stations are shown on the same graph and are given in Figure **5(a)** to **5(l)**. In general, for all months wind speed probabilities are higher for Gwadar as compared to Pasni. This implies that mean wind speeds in case of Gwadar are more probable than Pasni. The mean wind speed for each month is predicted and compared with the actual measured mean wind speeds, see Figure **2**. The agreement between the predicted wind speeds and actual mean wind speeds is excellent. Power densities for the two stations are also determined, see Figure **3**. Although higher power density is obtained for Pasni

nevertheless wind energy yield for Gwadar is more stable as compared to Pasni.

CONCLUSION

Comparison between measured and predicted wind speeds for Gwadar and Pasni have been presented and wind power densities for the two stations are given. Monthly wind speeds are predicted with the help of Weibull function and the Weibull parameters are determined by the Method of Moment (MoM). Following are the important features of the study:

1. The study reveals a good agreement between the predicted and measured monthly mean wind speeds.

2. For Gwadar highest wind power density is determined for the month of April and the wind power density remains close to 100 W/m^2 from May to September.

3. For Pasni highest wind power potential is found for the month of May.

4. The Weibull shape parameter for five year monthly mean ranges from 4 to 6 for Gwadar as compared to 2 to 3 for Pasni. This indicates wind potential is more stable in Gwadar than in Pasni.

5. The Weibull scale parameter for Pasni ranges from 4 m/s to 7.5 m/s whereas for Gwadar it is lying in the range 4 m/s to 6.5 m/s. These outcomes indicate a widely spread wind speed data for Pasni as compared to Gwadar.

6. Although higher power density is observed for Pasni, nevertheless the calculated Weibull shape parameters indicate a more stable wind pattern in Gwadar as compared to Pasni.

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