American Journal of Mathematics and Physics Application
ISSN: 2290-8887
Volume 01, Issue 01, April,2019

Evaluation of wind electricity ability inside the shelek corridor (Kazakhstan) the usage of weibull distribution characteristic

A. Khabensky[1,] V. Serebryakov[2]
South Kazakhstan State University, Kazakhstan[1,2]

Abstract— Kazakhstan currently has one of the maximum, according to capital, carbon footprints inside the global. there is heavy reliance (approx 85%) on coal for power manufacturing in Kazakhstan. Coal is a very carbon-in depth gas. A pressure to mild coal's contribution to power manufacturing gives a driving force for wind strength development. locating an appropriate vicinity calls for a detailed and often luxurious analysis of neighborhood wind conditions. Wind resource assessment is an important first step in gauging the potential of a domain to provide power from windmills. on this paper, the wind power ability of the Shelek hall, located inside the Almaty area in Kazakhstan changed into examine. local wind velocity distributions are represented via Weibull facts. The results display that the average annual imply wind speed version for Shelek hall tiers from 4.0 to 8.0 m/s. The wind electricity density variant based at the Weibull analysis ranges from 280.0 to 320.zero W/m2.

Keywords— Wind electricity, electricity manufacturing, renewable electricity, MERRA, Weibull distribution.

1. Introduction

For in recent times Kazakhstan is a few of the top 20 international locations which produce the very best carbon dioxide emission consistent with capital. There are several motives for this such as a small populace according to the square kilometer, a emits a very high amount of carbon dioxide to the atmosphere. It method that wind electric stations can be an appealing opportunity for authorities and the enterprise region. making an investment in such initiatives is commercially viable [1]. Kazakhstan's geographical place could be very appropriate to increase wind power stations with energy up to 760 GW. for instance; the Shelek hall has the capability to supply power from wind electricity approximately 3200 kW/h/MW [2]. The performance of the wind strength conversion system depends on an extensive variety of criteria inclusive of lots of factors [3]. The traits of the wind tendency are one of the predominant and influential parameters that aid when figuring out the suitability of a domain for using wind energy. due to the stochastic nature of the wind, numerous models were developed to analyze them to be had wind information as a way to gain the traits of any wind mode. one of these setup models operates on the idea of the Weibull distribution [3]. this article offers the info of the evaluation primarily based at the Weibull distribution of wind facts, from NASA's cutting-edge-technology Retrospective analysis for studies and programs.

2. Kazakhstan's wind energy marketplace

The Republic of Kazakhstan has the ninth biggest territory in the world. it's miles approximately 2.7 million km2. but, Kazakhstan is one of the nations with the least populace density inside the international (5.5 persons in keeping with km2). There are 3 cities with a populace of over 1 million people: Astana, Almaty, and Shymkent. Kazakhstan has large resources of fossil fuels along with coal, oil, gas, and uranium. those assets are being actively exporting. for instance, Kazakhstan produces simply much less than 100 million lots of coal and approximately 35% of this is exported to the neighboring countries. 1.5 million barrels of oil produced per day. And 75% of them bought to China and Russia.

There is no country within the global, which produces greater uranium than Kazakhstan. According to the statistics inside the 2009 year, 27.6% of the arena's uranium manufacturing turned into made via Kazakhstan.

Excess of energy assets is the main thing hindering the development of renewable electricity sources in Kazakhstan.

Based on the results of the World Summit on Sustainable improvement held at Johannesburg in 2002 Kazakh government accepted the Sustainable improvement idea for 2007-2024. That idea was dedicated to the sustainable use of renewable sources and alternative energy in Kazakhstan. efficient and sustainable use of renewable resources and alternative energy resources can be possible if:

– innovative technology in use of land, water, forestry, fishery, organic assets and renewable assets of power will be added;
– efficient use of hydropower resources, solar and wind sources and other renewable assets and opportunity power resources could be simulated;

– the centers for distribution of global enjoy in the region of energy and aid performance and use of renewable resources of energy will be set up.

considering all of the above, it's miles viable to listing the primary challenges, which can be the robust drivers for the development of wind energy in Kazakhstan:
– the old strength generation infrastructure;
– the excessive quantity of transition and distribution losses;
– the highest carbon footprints in the world. As a result, because the 2012 year, the quantity of
hooked up capacity by means of the onshore wind generators has accelerated 65 instances. it can be shown in the diagram underneath.

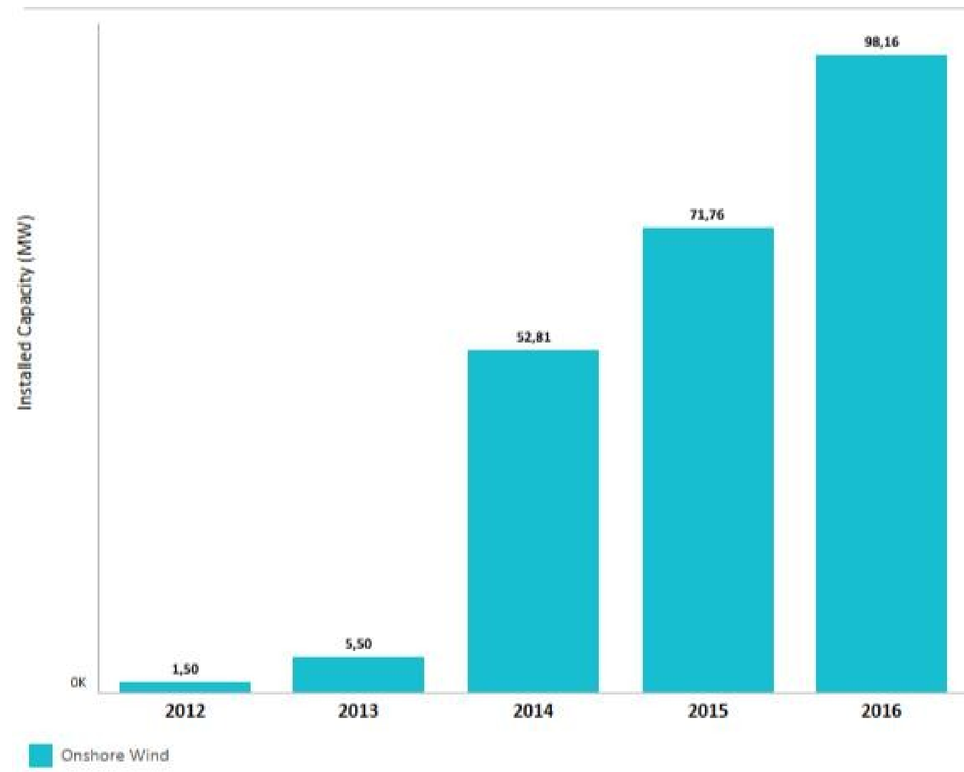

Figure 1 – Developments in renewable energy (mounted capability)

In 2012, hooked up capacity was only 1.5 MW, the primary wind power station was hooked up in Kordai, Zhambyl location. subsequent year electricity manufacturing increased 3 times. The 2014 12 months became giant for the Kazakhstan wind strength market because the second wind power station turned into an installation in Ereimentau, Akmola area. And it drove to an essential increase within the mounted potential: from 5.5 MW in 2013 to the 52.81 MW in 2014. In 2015 and 2016, there had been still fine trends in the installed capacity. as compared to the 2014 12 months, capacity electricity constructed from the wind rose by using forty% every yr. And 50 m above the floor. To cowl, all Shelek corridor grid points with latitude between 440 E and 47.50 E and longitude among 73.50 N and 77.80 N are used.

In recent years, greater attention has been paid to the Weibull distribution, as cautioned by the nearby approximation of the probabilistic legal guidelines of a number of natural phenomena and is anticipated to ensure a good correspondence to the experimental facts [7]. Mathematically, i.e. The Weibull distribution function of the 2-parameter capabilities is expressed as:

3. Strategies and materials

There are methods of acquiring data. the first manner is studying manufacturing information. The blessings of using manufacturing statistics are that they may be reflecting real fluctuations and do no longer require any additional calculations. however, this method is applicable to the places wherein a wind turbine has already been hooked up. the second manner is the use of records from the weather station. but, that way has several hazards: it isn't available; statistics once in a while now not complete. Moreover, to that, to calculate a brand new vicinity, you want to put in anemometers. This isn't economically profitable [4].

In Kazakhstan, there's no loose to be had wind speed records in the intervening time. groups must degree wind information themselves. previously a wind atlas of Kazakhstan become created inside the framework of the UNDP / GEF undertaking and the government of the Republic of Kazakhstan "Kazakhstan is an initiative to broaden the wind electricity marketplace". however, at this moment that website online isn't to be had. Ritter et al. [4], advocated an alternative dataset that is presenting wind energy evaluation and reanalysis information, which includes contemporary-era Retrospective analysis for research and programs (MERRA) statistics furnished by way of NASA [5]. MERRA gives wind facts all over the world and an hourly temporal resolution considering 1979. It consists of two additives at 3 special heights (2 m, 10 m and 50 m above ground). A northward and eastward wind element is useful to derive the wind pace and wind course at numerous turbine heights [6]. in this study the information used from “MERRA-2 inst1_2d_asm_Nx: hourly, instantaneous, single- level, Assimilations, single-stage Diagnostics V5.12.4” all through the duration from 01.01.2015, until 28.02.2018 for each day. We used the northward and eastward wind speed on the heights of two m, 10 m and 50 m above the floor. To cowl, all Shelek corridor grid factors with latitude between 440 E and 47.50 E and longitude between 73.50 N and 77.80 N are used.

In recent years, extra interest has been paid to the Weibull distribution, as counseled by means of the nearby approximation of the probabilistic laws of some of the herbal phenomena and is anticipated to make certain a good correspondence to the experimental records [7]. Mathematically, i.e. The Weibull distribution characteristic of the two-parameter functions is expressed as:

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

The integral distribution function F (x) is given by:

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

where:

v – wind speed, m/s;

k – shape factor;

c – scale parameter, m/s.

The form factor k is the principle thing in figuring out the uniformity of the wind. The uniformity of the wind adjustments courses with an exchange to i. with increasing okay, the uniformity of the wind will increase. it's been installed that the majority parameters, inclusive of wind velocity, wind velocity opportunity, should be inside a certain variety, the strength is to be had in a positive mode, and many others., are important to absolutely respect the honor of the wind regime, depend upon the difficult calculation of these values of okay and c [eight]. k and c parameters can be found with numerous methods which include the strength density method; the least square approach modified chance approach, etc. [9]. The techniques are in short discussed below

3.1 Standard deviation method

The usual deviation approach offers the ratio among the mean (v_m) and the same old deviation (σ v):

$$\left(\frac{\sigma_v}{v_m}\right)^2=\frac{r\left(1+\frac{2}{k}\right)}{r^2\left(1+\frac{1}{k}\right)}-1 \quad (3)$$

After k is determined, c is determined as:

$$c=\frac{v_m}{r\left(1+\frac{1}{k}\right)} \quad (4)$$

In a simple technique, an acceptable approximation for okay and c may be approximated:

$$k=\left(\frac{\sigma}{v}\right)^{-1.090} \quad (5)$$

$$c=\frac{2v_m}{\sqrt{\pi}} \quad (6)$$

3.2 Empirical technique (EM)

A special case of the method of moments, the empirical method determines k & c, as in equations (4), (5):

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

$$c=\frac{\bar{v}}{r\left(1+\frac{1}{k}\right)}$$

$$r(x)=\int_0^\infty t^{x-1}e^{-t}\,dt$$

3.3 Power density method (PDM)

This is one of the most crucial strategies of figuring out k and c. initially, the power sample factor E pf is calculated by way of the department of cubic wind speed to the cube of mean wind velocity [9-10]. After that k and c may be located with the aid of formulas (7, 8):

$$k = 1 + \frac{3.69}{E_{pf^2}} \quad (7)$$

$$c = \frac{\bar{v}}{r\left(1 + \frac{1}{k}\right)} \quad (8)$$

3.4 Modified likelihood method (MLM)

That technique turned into proposed by using Stevens and Smulders [10] and describes k and c via the following formulation:

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

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

4. Results and Discussion

On this observe the statistics used from 01.01.2015, until 28.02.2018 for each day. The northward and eastward wind pace on the heights of 2 m, 10 m and 50 m above the ground had been horizontally interpolated by the formula [4]:

$$c = \sqrt{u_h^2 + v_h^2} \quad (9)$$

Monthly imply values of wind pace are proven in tables 1-three. The frequency distribution of the records are proven in table 4.

Table 1 - Monthly mean velocities at height of 2 m

Month	Mean velocity m/s			
	2015	**2016**	**2017**	**2018**
January	2.7242	3.3995	2.9572	5.9183
February	3.4051	3.6068	2.8878	3.0978
March	2.2784	2.8207	3.4395	-

April	2.0906	2.2409	1.6123	-
May	1.5377	2.8716	2.6959	-
June	2.5187	1.0863	0.8440	-
July	2.4385	1.3534	2.4462	-
August	1.9352	5.6995	4.1758	-
September	2.5953	5.6995	2.6755	-
October	2.0809	2.5965	2.1037	-
November	2.2991	2.3995	2.5797	-
December	2.9105	2.5473	3.1505	-

Table 2 - Monthly mean velocities at height of 10 m

Month	Mean velocity m/s			
	2015	**2016**	**2017**	**2018**
January	3.3320	3.6725	3.3897	6.4588
February	3.8281	4.0027	3.4253	3.6344
March	2.9956	3.2741	4.0367	-
April	2.3681	2.6763	2.0381	-
May	1.8185	3.0655	2.9150	-
June	2.8588	1.2251	0.9799	-
July	3.0926	1.4276	2.9774	-
August	2.4606	6.4904	4.7401	-
September	3.0329	6.4904	3.3571	-
October	2.4876	3.0643	2.6479	-
November	2.7427	3.0442	2.9889	-
December	3.4514	2.9444	3.7378	-

Table 3 - Monthly mean velocities at height of 50 m

Month	Mean velocity m/s			
	2015	**2016**	**2017**	**2018**
January	5.4955	5.8329	5.8604	9.8087
February	5.8815	6.2380	5.3924	5.6900
March	4.3439	6.3175	6.0201	-
April	3.7365	4.8102	3.1457	-
May	2.4771	4.1304	4.5861	-
June	4.7340	4.1634	1.7987	-
July	4.9166	1.6786	4.7932	-

August	4.0327	2.2848	7.8409	-
September	4.7945	9.3863	5.1376	-
October	3.8964	9.3863	4.1561	-
November	4.6451	5.0147	4.9872	-
December	5.4955	4.5663	6.0211	-

In line with those desks the very best pace was detected in January 2018 and reached nearly 6m/s in between 2015 and 2017, and over nine m/s in 2018. Respectively inside the beginning of summer there constantly was a low wind pace. The least meaning of wind velocity for the summer season is 0.9 m/s. accumulated velocity information become additionally divided into periods to discover more commonplace velocity. It changed into determined that the most common velocity at height 2 m is 2÷3 m/s (0.58).

As for the 10 m peaks, 3÷4 m/s repeated with almost 40% frequency. The wind pace of 4-6 m/s at the peak of 50 m becomes repeated at a frequency of 0.6. As we are able to see from the table, whilst the height is growing the fee of pace is also will increase. as a result, wind pace data at these 3 heights may be vertically extrapolated to the turbine height [11].

From the above formulation and wind records, the results for form and scale parameters are calculated the usage of various strategies described above is indicated in table 4.

Table 5 – Wind velocity distribution

Methods	**Frequency**					
	2 m		**10 m**		**50 m**	
	k	c	k	c	k	c
SDM	2.74	3.14	2.93	3.66	3.10	5.74
EM	2.53	3.13	2.70	3.65	2.86	5.72
PDM	2.73	3.12	2.92	3.63	3.09	5.70
MLM	2.62	3.13	2.76	3.63	2.93	5.70

Accuracy of calculations become checked by the subsequent three strategies: RMSE, R2 and *Chi* – Square tests:

$$RSME=\left[\frac{1}{N}\sum_{i=1}^{N}\left(y_i-x_i\right)^2\right]^{1/2}$$

$$X^2=\frac{\sum_{i=1}^{N}\left(y_i-x_i\right)^2}{N-n}$$

$$R^2 = \frac{\sum_{i=1}^{N}(y_i - z_i)^2 - \sum_{i=1}^{N}(y_i - x_i)^2}{\sum_{i=1}^{N}(y_i - z_i)^2}$$

Where y_i is observed frequency and x_i Weibull's frequency, N is a number of observations, n is a number of used constants. The effects are proven in a table below

Table 6 – Wind velocity distribution

Tests	SDM	EM	PDM	MLM
RSME	0.675	0.0678	0.0692	0.0673
Chi-square	0.063	0.0063	0.0067	0.0061
R^2	0.9485	0.9469	0.9472	0.9466

As shown in Figures 1-6, all of the techniques mentioned display extra or much less comparable outcomes, despite the fact that the maximal chance approach and the electricity residences are a little more correct and, therefore, may be considered because the most appropriate.

As we are able to see from the graph, the most likely wind speed at this peak is beneath 3 m/s. And our calculations have proven the suggested price of the speed is two.seventy eight m/s.

In keeping with the Fig.4, we can see that the most in all likelihood wind speed happen at speed five m/s with an opportunity of 22.5%. this means that at Shelek hall the wind velocity that frequently arises at 5 m/s.

Typically, four-5 m/s is a really perfect wind velocity for windmills. however, the use of wind strength is commercially hooked up simplest for high (eight-9 m/s) and medium (6-7 m/s) wind conditions. If wind energy is available in low wind situations, it's miles feasible to expand mills, particularly for those regions, as a way to help to lessen dependence on fossil fuels.

To analyze the wind energy ability there may be additionally mean power density primarily based on Weibull distribution should be calculated [13].

$$P_{WD} = \frac{1}{2}\rho c^3 r\left(1 + \frac{3}{k}\right) (10)$$

In which c form elements had been calculated by means of the four methods described under. ρ is air density associated with the strain, temperature, and humidity. but, air density has no big impact on wind aid calculations, consequently, it could be taken as a regular fee of 1.225 g/cm^3.

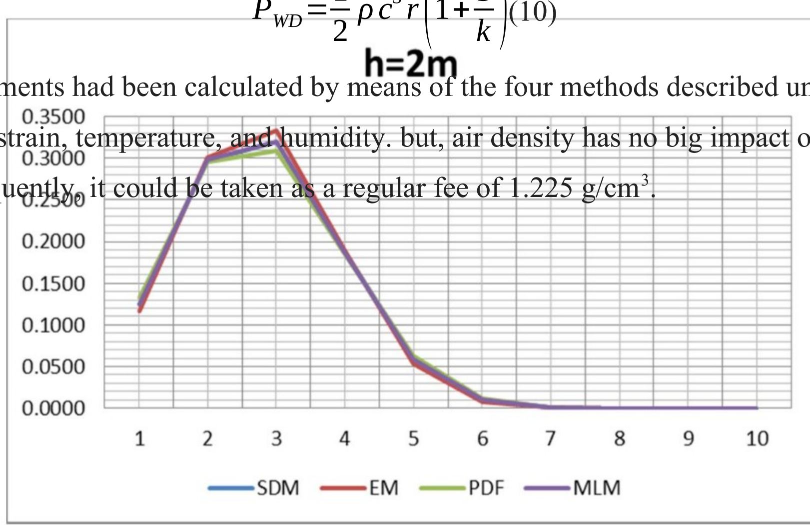

Figure 2 – Weibull distribution at the height of 2 m

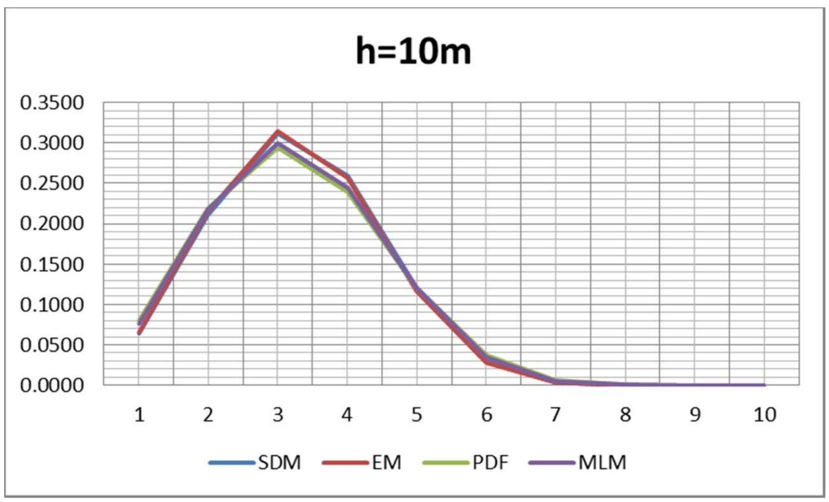

Figure 3 – Weibull distribution at the height of 10 m

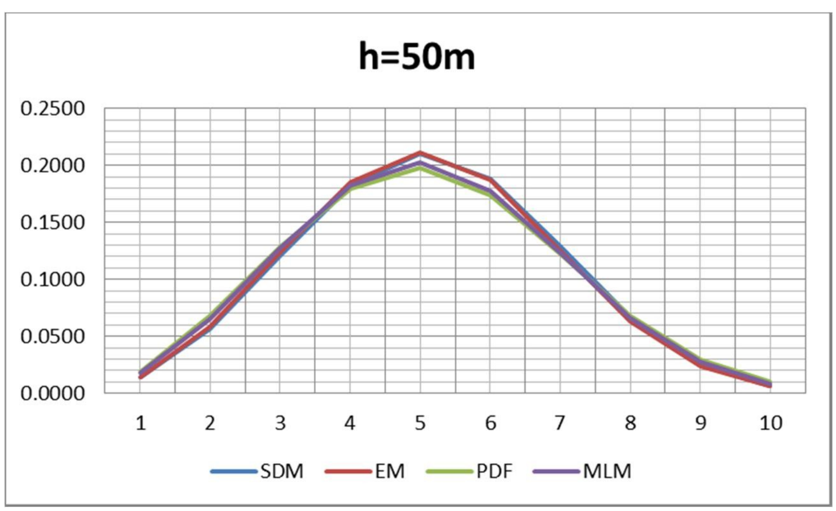

Figure 4 – Weibull distribution at the height of 50 m

However, suggest strength density can be calculated by using the formulation:

$$P_{REF} = \frac{1}{2}\rho \bar{v}^3 \quad (11)$$

6. Conclusion

The capacity of wind energy in the Shelek hall has been studied on this evaluation using the widely used Weibull distribution approach. The Weibull parameters along with shape element and scale issue had been calculated via four exceptional methods which include the least squares method, electricity density approach, empirical technique, and changed chance technique. Relative percent of errors and chi-square error have been analyzed for each technique and also calculated the efficiency of these techniques. The wind facts changed into acquired from NASA modern-day-technology Retrospective analysis for studies and packages "MERRA-2 inst1_2d_asm_Nx: hourly, on the spot, unmarried- stage, Assimilations, single-level Diagnostics V5.12.4" throughout the length from 01.01.2015 till 28.02.2018 for each day. The outcomes observed that Shelek complicated is a potential website to set up vertical axed wind turbines. The effects were confirmed by means of a Weibull distribution approach in which the Weibull shape issue and scale aspect had been calculated using 4 exceptional methods. The statistical evaluation additionally located the modified chance method is a greater green approach with minimum mistakes in the wind information analysis. The take a look at providing the capacity of the Shelek corridor to provide natural power the usage of wind electricity.

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