IJST EXPLORE International Journal of Science and Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-7318

International Journal of Science and Technology Volume 4 No. 8, August, 2015

Suitable Wind Turbine Identification Using Capacity Factor and Economic Feasibility

Ali K. Resen, Dr. Firas H. Abdulrazzaq, Jawad S. Nmr
Ministry of Science and Technology, Wind Energy Directorate, Iraq

ABSTRACT

More studies either investigated wind characteristics (wind speed and wind energy density) only, or focused on part of wind turbine characteristics of a given wind turbine generator (WTG) such as a capacity factor (CF). In this paper the properties of wind turbines and wind characteristics were studied to select the optimum wind turbines for the site. On site observation were performed this study, typical metrological data from Al-Shehabi was used to estimate various wind turbine outputs at the site. The methodology of analysis is based on the computations of annual capacity factor and economic feasibility. The computations which are done by using the Weibull distribution function and power curve model in addition to feasibility study which included payback period and cost per kilowatt hour (KWh) for each turbine. Thus, the optimum wind turbine selected depends on low cost, low payback period, and high capacity factor, and the results show that a wind turbine with 2m/s cut-in speed, 11m/s rated speed, and 25m/s cut-off speed gives highest energy production.

Keywords: *Weibull Distribution, Capacity Factor, Payback Period, Cost.*

1. INTRODUCTION

In the last decades, a growing interest in renewable energy resources has been observed. The high cost of energy from fossil fuels, as well as the decline in new coal or nuclear power plant development, has made the need for the development of renewable forms of energy extremely important. Wind energy has become competitive with conventional power generation sources and therefore the application of wind turbine generators has the highest growth among other sources.

In wind energy systems the selection of the suitable WTG for a certain site consider as difficult problem; thus, numerous criteria have been proposed for the suitability procedure. Some authors determined the wind turbine generators parameters at maximum capacity factor or at maximum density rated output power [1,2].

Most of researches have indicated that Weibull distribution function is the most commonly of various wind turbines selection studies. Weibull distribution that uses scale parameter and shape parameter to express annual mean wind speed and associated standard deviation may appropriately represent the probability distribution of wind speeds. These parameters are usually determined based on the wind distribution statistics calculated from the measured hourly time series data. The wind energy available in the wind cannot be extracted completely by any real wind turbine, as the air mass would be stopped completely in the intercepting rotor area.According to Betz's law, no turbine can capture more than 16/27 (59.3%) of the kinetic energy in wind. The factor 16/27 (0.593) is known as Betz's coefficient. Practical utility-scale wind turbines achieve at peak 75% to 80% of the Betz limit [3].The determination of a wind turbine capacity factor is a function of both the wind resource at a given location as well as the characteristics of a given wind turbine. Users should be careful to choose realistic values for capacity factor, as this parameter can have a significant impact on the overall economic feasibility of installing a wind energy system. In any case, this protocol should not be the only measure of whether erection of a wind turbine is justifiable at a given location. For wind turbine machines that operate at constant power (Pr) with maximum efficiency between rated speed and cut-out ($U_r < U < U_{off}$) and at increasing power between cut-in and rated speed ($U_c < U < U_r$), the actual wind power output from the wind turbine is determined by the turbine performance curve.

2. WIND TURBINE ENERGY OUTPUT AND CAPACITY FACTOR (CF)

Before the installation of any wind turbine, it is necessary to estimate the expected power output in order to assess the economic viability of the project, usually based on wind statistics measured over a period of at least 1 year [4]. If you were to measure the output of a wind turbine on a 24-hour basis you would not be getting an accurate account of the overall production of electricity (as this may vary from day to day, hour by hour, etc.). That being said, each wind farm is different and the output can vary from project to project depending on capacity, model of turbine, location, regional and local regulations, operations and maintenance, time of day, season, etc. Modern forecasting methods and wind resource assessment has greatly increased the predictability of wind energy output. To calculate the energy production of a wind turbine, we will need to measure the actual output by calculate the capacity factor (CF). The capacity factor is the ratio of the actual energy output and the theoretical maximum output. Capacity factors are provided for many sources of electricity, the CF usually ranges from 25 to 45 per cent for commercial-scale wind projects.Considering the capacity factor definition, the average of output energy may be expressed as product between rated power (P_r) , number of operating hours, and capacity factor (CF) value:

Actual Output = Pr x No. of operating hours x CF (MWh)

3. WIND TURBINE ENERGY OUTPUT AND ECONOMIC FEASABILITY

Wind energy costs are now lower than the costs of most new conventional sources and are close to cost-competitive with new natural gas generation due to continuing technological innovation.

The cost of energy from the wind is mostly a function of the wind resource – how fast it blows, how often, and when. Higher-speed winds are more easily and inexpensively captured. The more the wind blows, the more power will be produced by wind turbines. The term used to describe this is "average capacity," which is simply the percentage of power a turbine produces compared to what it could produce if it were always spinning. On the other hand, wind turbines operate over a limited range of wind speeds. If the wind is too slow, they won't be able to turn, and if too fast, they shut down to avoid being damaged. Ideally, a wind turbine should be matched to the speed and frequency of the resource to maximize power production.

4. STUDY AREA

The region is located in the area between Maysan province and Wasit province . It is 112 km from Maysan, 85 km from Wasit, and about 220 km from Baghdad at position 32.77°N 46.70° E; Figure. 1 shows the location of chosen site in eastern region near the border between Iraq and Iran.

5. RESULTS AND DISCUSSIONS

The methodology is applied for Al-Shehabi site Figure (1). The data were collected by Al-Shehabi metrological station at a standard height (10) m for one year.

Figure 1.Area of Study.

The modeled data provide significant additional insight regarding the wind resource at the site. Figure (2) shows the directionality of the wind resource at AL- Shehabi site.

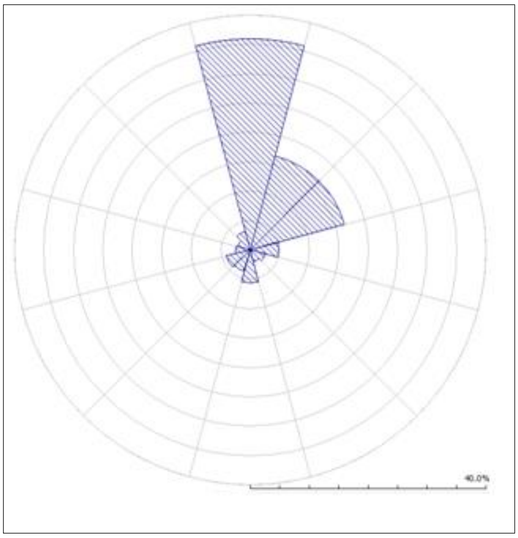

Figure 2. Wind rose at Al –Shehabi site.

Figure (3) shows the frequency of occurrence on the y-axis and the wind speed on the x-axis. This histogram illustrates the frequency of different wind speeds at the site, which is critical to turbine selection and energy production.

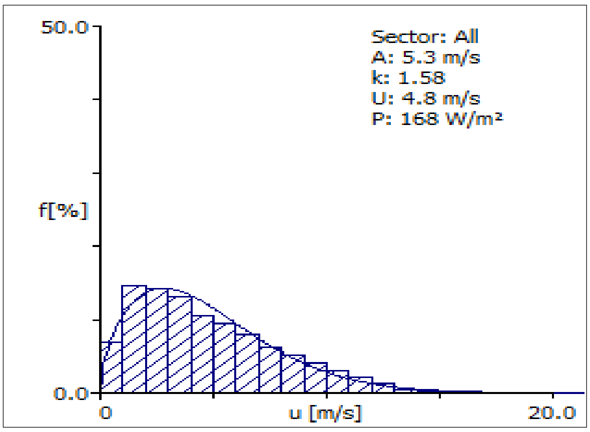

Figure 3. Wind frequency at the site and the pdf for all sectors.

Table (1) summarize the wind turbine generator properties and its capacity factor.

Table (1)- the wind turbines and site characteristics

WTG	CF (%)	$U_{c\ (m/s)}$	$U_{r\ (m/s)}$	$U_{off\ (m/s)}$
EWT (52)500KW	25	3	10	25
EWT (54) 500KW	22	3	11	25
Power Wind 500 KW	25	3	10	25
Gamesa 850 KW	16	2.5	14	21
Gamesa 850 KW	13	3	15	25
Suzlon 950 KW	26	2	11	25

The generation energy per day (hours) was calculated for each wind turbine to get more accurate for output energy production, as shown in table (2)

Table 2: Generation power per day and output energy production.

WTG	Energy per day (hours)	Energy per year (hours)
EWT (52)500KW	15	5817
EWT (54) 500KW	15	5817
Power Wind 500 KW	15	5817
Gamesa 850 KW	17.6	6440
Gamesa 850 KW	15	5817
Suzlon 950 KW	19	7050

Figure (4), represents the payback period for different WTG at the selected site.

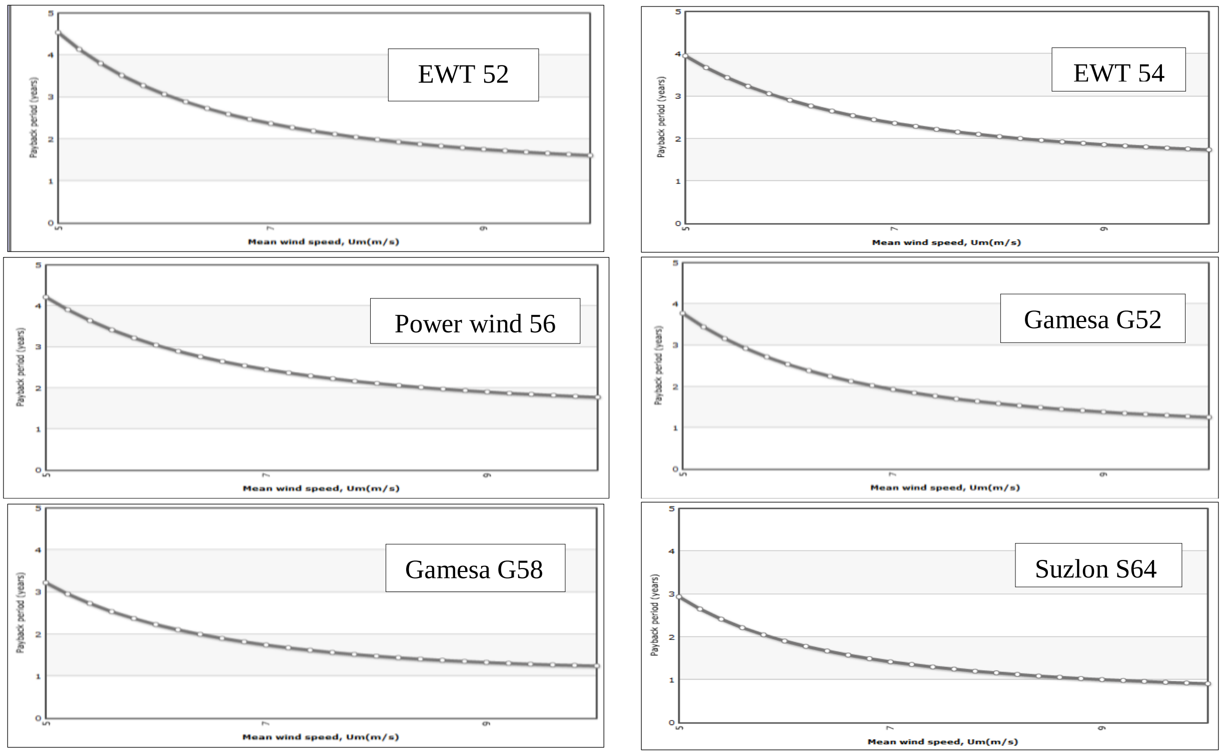

Figure 4.The payback period for different WTG at the selected site.

Figure (5), represents the cost per kilowatt hour (KWh) vs mean wind speed (U) (m/s)

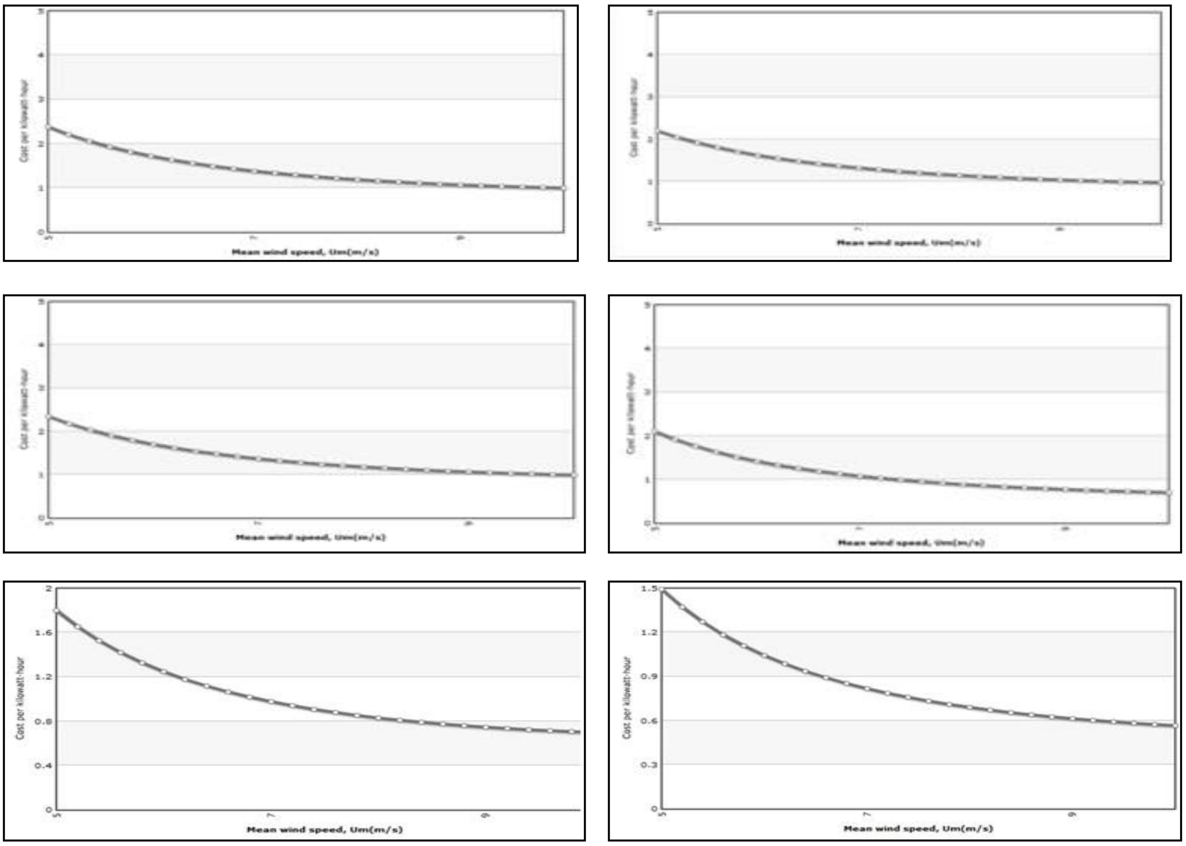

Figure (5). Cost per KWh for different wind turbines at Al-Shehabi site.

Table (3):Represent the types of wind turbines and its paybackperiod (years) for each wind speed (U) (m/s)

WTG / U(m/s)	EWT 52 500 KW	EWT 54 500 KW	Power Wind 500 KW	Gamesa G52 850 KW	Gamesa G58 850 KW	Suzlon S64 950 KW
	Payback Period	Payback Period	Payback Period	Payback Period	Payback Period	Payback Period
5	4.54	3.95	4.22	3.78	3.23	2.92
5.2	4.14	3.68	3.91	3.45	2.96	2.66
5.4	3.8	3.44	3.64	3.17	2.73	2.42
5.6	3.52	3.24	3.42	2.93	2.54	2.22
5.8	3.28	3.06	3.22	2.72	2.37	2.05
6	3.07	2.91	3.05	2.54	2.23	1.91
6.2	2.89	2.77	2.90	2.39	2.11	1.78
6.4	2.73	2.65	2.77	2.25	2	1.68
6.6	2.6	2.55	2.65	2.13	1.9	1.58
6.8	2.48	2.45	2.55	2.03	1.82	1.5
7	2.37	2.37	2.46	1.93	1.75	1.43
7.2	2.28	2.29	2.37	1.85	1.68	1.36
7.4	2.19	2.22	2.30	1.77	1.62	1.3
7.6	2.12	2.16	2.23	1.71	1.57	1.25
7.8	2.05	2.11	2.17	1.65	1.52	1.21
8	1.99	2.06	2.11	1.59	1.48	1.17
8.2	1.93	2.01	2.06	1.54	1.45	1.13
8.4	1.88	1.97	2.02	1.5	1.41	1.09
8.6	1.84	1.93	1.98	1.46	1.38	1.06
8.8	1.80	1.89	1.94	1.42	1.36	1.04
9	1.76	1.86	1.96	1.39	1.33	1.01
9.2	1.73	1.84	1.88	1.36	1.31	0.99
9.4	1.69	1.81	1.85	1.33	1.29	0.97
9.6	1.67	1.79	1.82	1.31	1.28	0.95
9.8	1.64	1.76	1.80	1.28	1.26	0.93
10	1.62	1.74	1.78	1.26	1.25	0.91

Table (4) represents the types of wind turbines and its cost per kilowatt hour (KWh) for each wind speed (U) (m/s)

WTG / U(m/s)	EWT 52 500 KW	EWT 54 500 KW	Power Wind 500 KW	Gamesa G52 850 KW	Gamesa G58 850 KW	Suzlon S64 950 KW
	Cost KWh	Cost KWh	Cost KWh	Cost KWh	Cost KWh	Cost KWh
5	2.39	2.2	2.35	2.1	1.8	1.49
5.2	2.21	2.05	2.18	1.92	1.65	1.37
5.4	2.06	1.92	2.03	1.77	1.53	1.27
5.6	1.93	1.81	1.91	1.63	1.42	1.18
5.8	1.82	1.71	1.8	1.52	1.33	1.11
6	1.72	1.62	1.7	1.42	1.25	1.04
6.2	1.64	1.55	1.62	1.33	1.18	0.99
6.4	1.56	1.48	1.55	1.26	1.12	0.94
6.6	1.5	1.42	1.48	1.19	1.06	0.89
6.8	1.44	1.37	1.42	1.13	1.02	0.85
7	1.38	1.32	1.37	1.08	0.98	0.82
7.2	1.34	1.28	1.33	1.03	0.94	0.79
7.4	1.29	1.24	1.28	0.99	0.91	0.76
7.6	1.26	1.21	1.25	0.96	0.88	0.73
7.8	1.22	1.18	1.21	0.92	0.85	0.71
8	1.19	1.15	1.18	0.89	0.83	0.69
8.2	1.16	1.12	1.15	0.86	0.81	0.67
8.4	1.14	1.1	1.13	0.84	0.79	0.66
8.6	1.11	1.08	1.11	0.82	0.77	0.64
8.8	1.09	1.06	1.09	0.8	0.76	0.63
9	1.07	1.04	1.07	0.78	0.75	0.61
9.2	1.06	1.03	1.05	0.76	0.73	0.60
9.4	1.04	1.01	1.03	0.75	0.72	0.59
9.6	1.03	1	1.02	0.73	0.71	0.58
9.8	1.01	0.99	1.01	0.72	0.71	0.57
10	1	0.98	1	0.71	0.7	0.57

6. CONCLUSIONS

The amount of electricity produced by a wind turbine at a specific site depends on many factors including the wind speed conditions at the site and the characteristics of the wind turbine generator itself, such as the cut-in , rated and cut-out wind speed. It is concluded from the preceding results that wind turbine with a specification like Suzlon S64 will has good match to Al-Shehabi site and high capacity factor.That is because this type of turbine has low of both cut-inand rated wind speeds. Also, this reason makes the number of generation hours much more than the others besides low cost of generation electricity.

REFERENCES

[1] M.H. Albadia, E.F. El-Saadanyb, " New method for estimating CF of pitch- regulated wind turbines" Electric power systems research, vol. 80, 2010, pp. 1182-1188.

[2] Ahmed R. Abul'Wafa, "Matching wind turbine generators with wind regime in Egypt", Electric power systems research, vol.81,2011, pp.894-898.

[3] Tony Burton et al., (ed), Wind Energy Handbook, John Wiley and Sons 2001 ISBN 0471489972 page 65.

[4] J. P. Hennessey, Jr., "Some aspects of wind power statistics,and performance analysis of a MWwind turbine-generator" J. Appl. Meteorol., vol. 16, no. 2, pp. 119–28, Feb. 1997.