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Wind energy resources assessment for Yanbo, Saudi Arabia

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Abstract

The paper presents long term wind data analysis in terms of annual, seasonal and diurnal variations at Yanbo, which is located on the west coast of Saudi Arabia. The wind speed and wind direction hourly data for a period of 14 years between 1970 and 1983 is used in the analysis. The analysis showed that the seasonal and diurnal pattern of wind speed matches the electricity load pattern of the location. Higher winds of the order of 5.0 m/s and more were observed during the summer months of the year and noon hours (09:00 to 16:00 h) of the day. The wind duration availability is discussed as the percent of hours during which the wind remained in certain wind speed intervals or bins. Wind energy calculations were performed using wind machines of sizes 150, 250, 600, 800, 1000, 1300, 1500, 2300 and 2500 kW rated power. Wind speed is found to remain above 3.5 m/s for 69% of the time during the year at 40, 50, 60, and 80 m above ground level. The energy production analysis showed higher production from wind machines of smaller sizes than the bigger ones for a wind farm of 30 MW installed capacity. Similarly, higher capacity factors were obtained for smaller wind machines compared to larger ones.

Keywords: Wind; Wind farm; Frequency distribution; Wind power; Wind energy; Wind machine; Wind power curve; Wind rose; Capacity factor

1. Introduction

In this era of technological advances and materialistic life style, energy has become an essential entity for inhabitants of the planet. Sorrowfully, in this modern world, there are more than a billion people who have no access to electricity in various parts of the globe. Most of these

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unfortunate people are living in developing countries. Beyond doubt, we can and must use energy more efficiently. In the coming times the developing world will need more energy to address its essential needs. The challenge that all of us are facing is how to meet this growing demand of energy while at the same time addressing the equally urgent threat of climate change.

To address the pollution problem, green sources of energy like solar, hydropower, wind, tidal, biogas, wave energy, etc. are being encouraged. Of these green sources, the usage of wind as a source of energy is increasing in different parts of the globe due to rapid technology advancement. Wind energy utilization is also becoming competitive compared to traditional sources of energy. Other reasons that are responsible for the speedy development of wind energy utilization include its cleanliness, job creation, abundance in nature, no physical boundaries, affordability, inexhaustibility, environmentally friendly and its elegancy.

This paper presents the detailed wind data analysis and wind availability at Yanbo, an industrial city on the west coast of Saudi Arabia.

2. Motivation and objectives of the study

In this modern and materialistic life pattern, human life is increasingly dependent on energy, from powering a personal computer to cooking food. The growth in population has a direct impact on energy requirements. With respect to Saudi Arabia, there were 3,256,643 electricity consumers in the year 1997 which reached to 3,792,210 in the year 2001, an increase of about 16.44%. The number of consumers in different years is shown in Fig. 1. The consumer growth rate from year to year appears to be linear. In fact, the number of consumers increased by 3.5%, 4.4%, 3.0% and 4.6% from 1997 to 1998, 1998 to 1999, 1999 to 2000 and 2000 to 2001, respectively. The data presented in Figs. 1 and 2 is taken from the first annual report of the SEC [1].

As seen from Fig. 2, the energy growth reached 122,944 GWh in the year 2001 from 97,050 GWh in 1997. The energy increased by 8.8% from 1997 to 1998, by 4.7% and 3.2% from 1998 to 1999 and 1999 to 2000, respectively. The energy further increased sharply again from 2000 to 2001 by about 7.7% as shown in Fig. 2.

For centuries, the wind has been an important source of energy worldwide. It has been used to sail boats and ships, pump water and grind grains since medieval times. The mechanical windmill was the high technology invention of the late 1800s that allowed developing the western frontier of

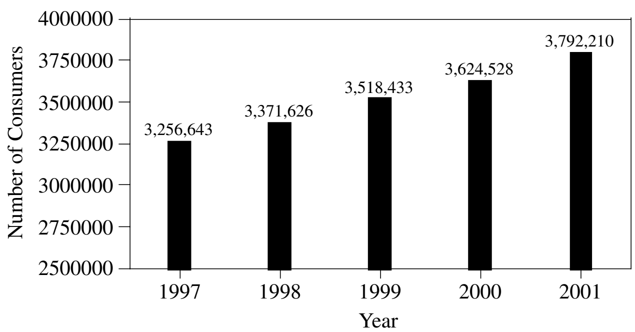

Fig. 1. Year wise growth in number of consumers.

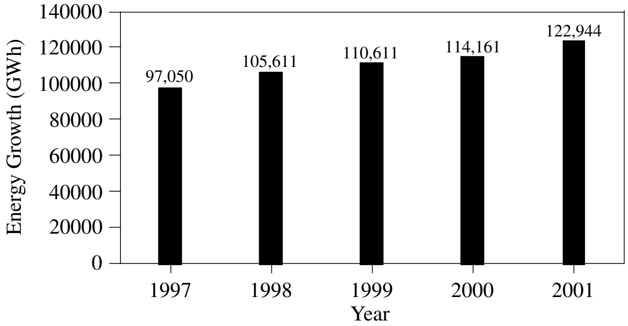

Fig. 2. Year wise energy growth.

the past [2]. With time and growing concern to reduce pollution and conserve fossil fuel, an innovative megawatt size of machine was developed during the last two decades. The big machines of today are capable of supplying enough power for 300–600 homes, which is almost 30 times more than the power produced by the wind turbines of the 1980s [3].

The cumulative worldwide wind energy generation capacity reached 31,000 megawatts (MW) in 2002 according to the global wind energy market reports [4,5]. Of this capacity, 6868 MW of new generation capacity was added during the year 2002 only, an increase of 28% compared to the previous year. As per the statistics, wind is the fastest growing source of energy with an annual rate of increase of 32% during the last five years, i.e. 1998–2002. The cumulative wind power installed capacity up to the end of years 1998–2002 is shown graphically in Fig. 3.

The major producer of wind power is the European Union (EU) countries with 75% of the total global production of wind energy, while the United States stands in second place with a 15% share of the total global production. The rest of the world only produces 10% of the total global production of wind power. With respect to the Middle East, at the end of 1995, the total wind power installed capacity was 7 MW, which increased to 192 MW at the start of 2002 [6]. Of this total, the Iran, Egypt, Morocco and Jordan shares are 11, 125, 54 and 2 MW installed capacity, respectively. Saudi Arabia with vast open flat land and with moderate winds in general and Yanbo with an annual average wind speed of 4.6 m/s at 10 m above the ground surface may be a candidate site to start wind power generation in the near future.

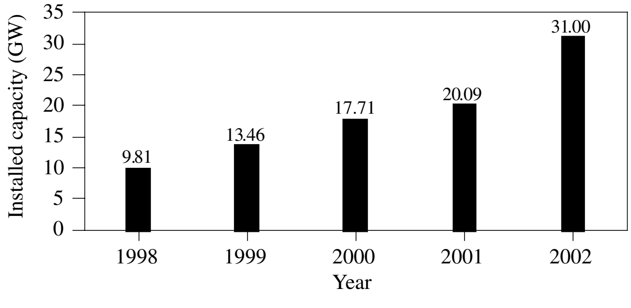

Fig. 3. Cumulative global wind power installed capacity.

In Saudi Arabia, more attention was paid to solar energy related work like establishment of solar radiation and sunshine duration recording stations, photovoltaic electric generation facility to supply power to a village on the outskirts of the capital city of Riyadh, usage of water heaters in housing complexes, photovoltaic cells to supply energy to highway telephones, remote monitoring facilities and communication towers. Meteorological data collection stations were erected in the year 1970 throughout the Kingdom in the vicinity of airports to get weather related information.

In recent years, work on wind speed data analysis such as Weibull parameter determination and distribution, wind speed prediction using different methods such as auto-regression and neural network, wind power generation cost determination and so on has been reported in the literature. The first work, in the form of a wind atlas was reported by Ansari et al. [7] in 1986. Rehman et al. [8] calculated the Weibull parameters for ten anemometer locations in Saudi Arabia and found that the wind speed was well represented by the Weibull distribution function. Rehman and Halawani [9] presented the statistical characteristics of wind speed and its diurnal variation. The auto-correlation coefficients were found to match the actual diurnal variation of the hourly mean wind speed for most of the locations used in the study. Mohandes et al. [10] used the neural networks method for prediction of the daily mean values of wind speed ahead of time. They concluded that the performance of the neural network model was much better than the performance of the traditionally used method of an auto-regression model.

Recently, Rehman et al. [11] presented the methodology for calculation of the cost of each kilowatt hour of electricity produced using long term hourly mean wind speed data at 20 locations in the Kingdom of Saudi Arabia. The authors developed wind duration curves over the entire period of data collection and used wind power curves for wind machines of 600 kW, 1.3 MW and 2.5 MW and all cost elements to calculate the cost of electricity production. Their analysis showed that the minimum cost (US$ 0.0234) of electricity production was found for Yanbo, while the next best site was Qaisumah, with electricity production cost of US$ 0.0256 per kWh.

Hence, the growing need for energy, participation of Middle East countries in wind power generation, existing long term wind speed and wind direction data at various locations in the country, globally decreasing cost of wind power generation and growing awareness of usage of green energy sources are some of the motivating factors for conducting detailed wind analyses at relatively windy sites in the country. The specific objectives of the study include seasonal and diurnal variability, wind availability in different wind speed bins, effect of hub height on energy production and capacity factor determination.

3. Site and data description

Yanbo is the second largest industrial city after Jubail in the eastern region of the Kingdom of Saudi Arabia and is situated on the west coast of the country. The latitude and longitude of the location of data collection are 24°20′ and 38°03′, respectively. It is only 6 m above mean sea level. The meteorological data collection activity was started in 1970. The measured parameters included wind speed, wind direction, temperature, relative humidity, pressure, visibility, rain and many others at 10 m above the ground surface. The data included in the study covers the period of 14 years from 1970 to 1983. The data was missing for a complete year in 1976 and partly in various months of other years. A total of 86,601 hourly records of wind speed and direction were used.

At Yenbo, like any other city in Saudi Arabia, only two seasons, viz. summer and winter are prevalent. The summer stretches between March and September, and winter starts in October and continues till February. With regard to general weather conditions, the temperature varies from a minimum of 6.8 °C to a maximum of 47.6 °C and an average of 27.09 °C. The surface pressure changes from 994.4 to 1024.1 mb with a mean value of 1008.47 mb. The relative humidity varies between 3% and 100% with an average value of 57%. The wind speed is found to reach a maximum of 25.65 m/s, while the average remained 4.63 m/s at 10 m above the ground surface.

4. Results and discussion

This section covers the long term annual, seasonal and diurnal variation of mean wind speed; the wind availability in terms of frequency distribution, energy calculations using NORDEX wind machines of different rated powers and capacity factor estimation and its variation with wind machine size and hub height. Lastly, the energy output from a wind farm of 30 MW installed capacity is discussed with wind size and hub height.

4.1. Long term wind speed variation

The long term yearly variation of wind speed provides an understanding of the long term pattern of wind speed and also confidence to an investor on the availability of wind power in coming years. In order to study the annual behavior of the wind speed, daily mean values of wind speed were used to get yearly mean values for a period of 14 years, between 1970 and 1983. The year-to-year change in the mean wind speed at 10 m above the ground is shown in Fig. 4. This figure shows that the mean wind speed was above 6.0 m/s during 1970–1972, while in decreased to about 5.0 m/s during 1973–1975. It became 5.5 m/s in 1977, while again, it decreased to 4.5 m/s and continued to be almost the same till 1980.

The seasonal change in mean wind speed provides an insight into the availability of suitable wind throughout the year. The seasonal mean wind speed values at 10 m above the ground are plotted in Fig. 5. As seen from Fig. 5, the higher winds, of magnitude 5.0 m/s or more, are

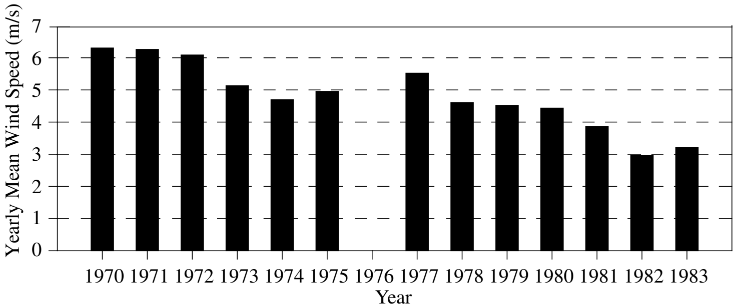

Fig. 4. Annual variation of mean wind speed at Yanbo.

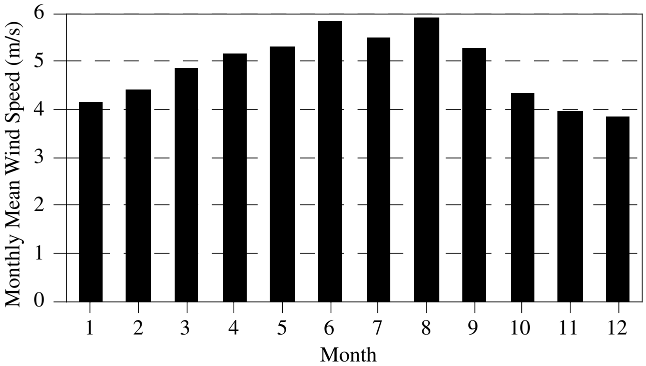

Fig. 5. Monthly variation of mean wind speed at Yanbo (average of 14 years data from 1970 to 1983).

observed during March to September, while lower values of the order of 4.0 m/s occur during the rest of the months. In general, higher wind speeds are found during the summertime and lower values during wintertime. This seasonal trend of wind speed matches the electricity load trend in the Kingdom. More electricity is required during summertime due to the increase in cooling load, while this load is minimized during wintertime.

The diurnal variation of wind speed provides information about the availability of suitable winds during the entire 24 h of the day. Hence, to study this pattern, overall hourly mean values of wind speed are shown in Fig. 6. The figure shows that the wind speed remained above 5.0 m/s during 12:00 to 21:00 h and below it during the rest of the hours of the day. In general, higher values are observed during daytime and smaller values during the evening and night hours. During the entire day, as seen from Fig. 6, the mean wind speed varies between a minimum of about 2.0 m/s at 05:00 and 06:00 h and a maximum of about 7.7 m/s at 16:00 h.

4.2. Wind availability analysis

The wind rose provides information about the occurrence of the number hours or percentage of time during which the wind remained in a certain wind speed bin in a particular wind direction.

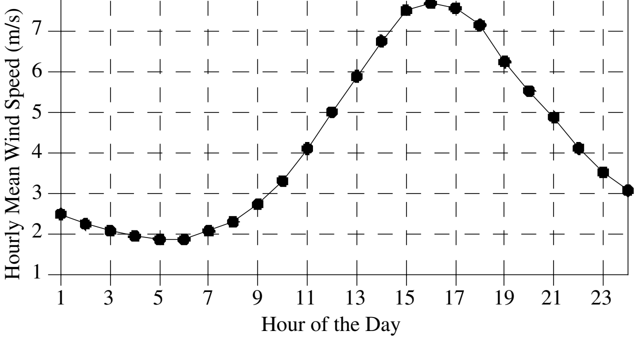

Fig. 6. Diurnal variation of hourly mean values of wind speed at Yanbo (average of 14 years data from 1970 to 1983).

Wind roses are constructed using hourly mean wind speed and corresponding wind direction values. Like wind speed, wind roses also vary from one location to another and are known as a form of meteorological fingerprints. Hence, a close look at the wind rose and understanding its message correctly is extremely important for siting wind turbines. So, if a large share of wind or wind energy comes from a particular direction then the wind turbines should be placed or installed against that direction.

In order to construct the wind rose and analyze the frequency distribution, all hourly average values of wind speed and wind direction were used, and the resulting wind rose diagram is shown in Fig. 7. It is evident from this figure that the wind blows predominantly from the W and WNW direction for about 47% of the times and about 15% of the times from the N direction. About 10% of the times, the wind blows from the NNW and about 5% from the WSW directions. Hence, wind turbines can be installed against these directions, provided there are no or a minimum number of high rise buildings and very large trees and the terrain is smooth in these directions, for optimal energy output.

The percent frequency distribution of mean wind speed in the different bins is shown in Fig. 8. Fig. 8 indicates that the wind speed remained between 0 and 1 for 11% and between 0 and 3.0 m/s for almost 32% of the times during the entire period of data collection. It is also clear from this figure that the wind remained between 4.0 and 10.0 m/s almost 60% of the times. About 8% of the times, it remained above 10.0 m/s. Since most modern wind turbines usually start producing energy above 3.5 m/s, the 60% availability of wind speed above the cut-in-speed of wind turbines is a good indication of Yanbo being a potential site for wind farm development.

In order to compare the frequency of occurrence of wind speeds at different hub heights, rose diagrams, similar to Fig. 7, were constructed and frequencies obtained. The wind speed values at different hub heights were calculated using the 1/7th wind power law. The resulting frequencies at different hub heights are compared in Fig. 9. Usually the cut-in-speed of wind energy conversion systems is about 3.0 m/s, hence the first bin is taken as >0–3.5 m/s to account for the hours during

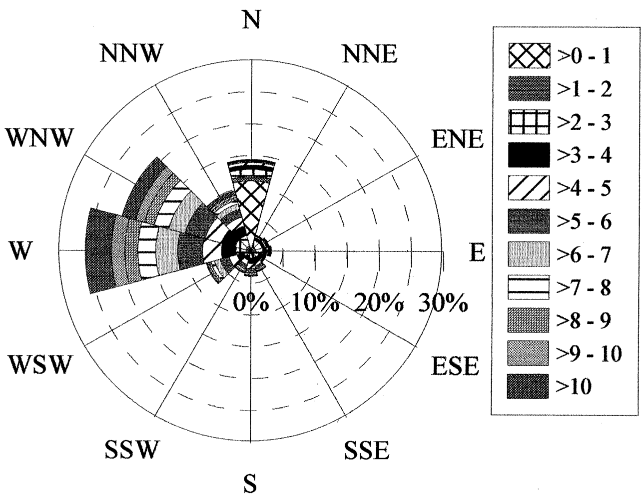

Fig. 7. Wind rose diagram for Yanbo.

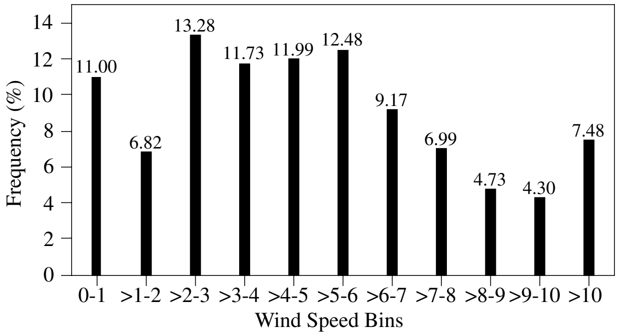

Fig. 8. Percent frequency distribution of wind speed at 10 m above ground level in different bins.

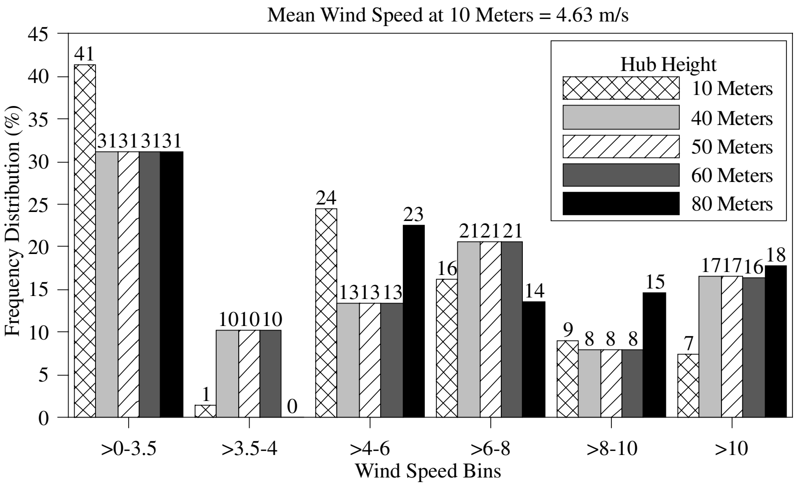

Fig. 9. Comparison of frequency distribution at different hub heights for Yanbo.

which no energy production is expected. It is obvious from this figure that wind machines can produce energy around 68% of the times during the entire year at all heights considered except at 10 m. It is also observed that higher winds, greater than 6.0 m/s and more, are prevalent for almost 46% of the times at 40–80 m hub heights. The analysis shows that wind machines with hub heights of 40–80 m can produce energy almost 69% of the times at Yanbo.

4.3. Wind energy generation analysis

To calculate the energy output from a wind machine, the wind duration availability in terms of number of hours the wind remained in a particular bin is calculated by constructing the wind rose diagram. For energy calculation purposes, the wind speed bins were taken as 0–0.5, $>0.5 \leqslant 1.5$, $>1.5 \leqslant 2.5$ and so on with centers at 0, 1, 2 and so on, respectively. The technical data of wind machines of nine different sizes is summarized in Table 1. The information summarized in Table 1

Table 1
Technical data of wind machines used in the analysis

Wind machine	Cut-in speed (m/s)	Cutout speed (m/s)	Rated speed (m/s)	Survival speed (m/s)	Rated output (kW)	Hub height (m)	Rotor diameter (m)	Expected life (yr)
Nordex N80/2500	4	25	14	65	2500	60	80	20
Nordex N90/2300	4	25	13	65	2300	80	90	20
Nordex S70/1500	3	25	13	56	1500	65	70	20
Nordex N60/1300	3	25	15	65	1300	60	60	20
Nordex N54/1000	4	25	14	65	1000	60	54	20
Nordex N50/800	3	25	15	70	800	50	50	20
Nordex N43/600	3	25	13.5	70	600	40	43	20
Nordex N29/250	3–4	26	15.5	65	250	40	29.7	20
Nordex N27/150	3–4	25	13	65	150	40	27	20

is obtained from Refs. [12–20]. The cut-in-speed or the speed at which the machine starts producing power is 3.0 m/s for four of the nine machines. The cutout speed for almost all the machines is 25.0 m/s. The wind power curves for all the wind machines are depicted in Fig. 10.

An example of the frequency distribution along with the energy output from each wind machine at 80 m hub height is summarized in Table 2. The first column lists the wind speed bins, while the number of hours per year in each wind speed bin are given in column 2. From column 2 of Table 2, it is observed that the wind speed remained above 3.5 m/s for almost 70% of the times, i.e. the wind data at 80 m above the ground, theoretically, assures availability of the wind during which the WEC (wind energy conversion) system can generate power. Similar types of wind roses were constructed at 40, 50 and 60 m above the ground level, and exercises similar to that shown in Table 2 were performed.

The total energy output per year from the wind machines of different sizes and at hub heights of 40, 50, 60 and 80 m are compared and shown in Fig. 11. The maximum energy of 5949.5 MWh is obtained from the wind machine of capacity 2300 kW (N-90) at 80 m hub height. The energy

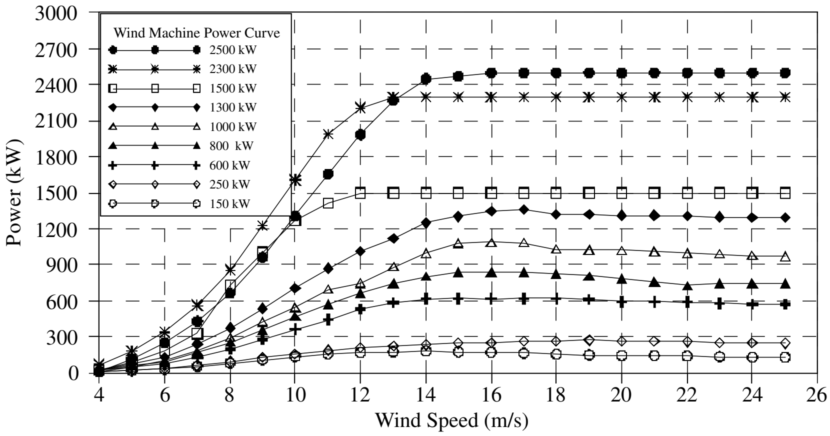

Fig. 10. Wind power curves for wind machines.

Table 2
Energy produced using WEC systems of different sizes and wind speed data at 80 m above the ground for Yanbo

Wind speed bin	Hours per year	N-80 (kWh) 2500 kW	N-90 (kWh) 2300 kW	S-70 (kWh) 1500 kW	N-60 (kWh) 1300 kW	N-54 (kWh) 1000 kW	N-50 (kWh) 800 kW	N-43 (kWh) 600 kW	N-29 (kWh) 250 kW	N-27 (kWh) 150 kW
0	964	0	0	0	0	0	0	0	0	0
1	332	0	0	0	0	0	0	0	0	0
2	269	0	0	0	0	0	0	0	0	0
3	1163	0	0	0	0	0	0	0	0	0
4	1027	13,530	63,140	21,648	26,158	12,628	20,746	15,334	10,824	7216
5	950	15,120	23,058	10,836	9198	6426	7182	5670	3024	2394
6	1113	260,648	357,340	197,588	137,681	110,355	94,590	75,672	36,785	32,581
7	81	435,435	571,445	330,890	244,615	181,685	167,475	125,860	58,870	55,825
8	803	527,614	683,029	580,216	299,672	236,709	204,829	156,212	75,715	66,151
9	612	83,868	106,575	87,522	46,632	37,149	31,233	24,099	11,136	9570
10	362	799,272	983,484	777,852	430,848	335,376	287,640	222,768	98,532	83,232
11	405	598,538	719,112	509,732	314,431	251,617	206,492	160,284	68,590	57,760
12	24	799,552	889,824	604,500	409,448	301,847	269,204	215,202	85,839	68,510
13	337	54,456	55,200	36,000	26,976	21,240	17,928	14,016	5400	4224
14	130	774,200	726,800	474,000	394,052	315,684	254,380	195,288	73,944	56,880
15	67	330,980	308,200	201,000	174,334	144,988	112,292	82,946	32,830	23,450
16	60	37,500	34,500	22,500	20,160	16,350	12,630	9270	3810	2580
17	7	235,000	216,200	141,000	128,216	102,084	78,960	58,186	24,534	15,416
18	28	80,000	73,600	48,000	42,304	33,056	26,464	19,840	8480	4960
19	19	75,000	69,000	45,000	39,570	30,750	24,240	18,300	8130	4500
20	3	10,000	9200	6000	5256	4084	3140	2376	1068	580
21	4	65,000	59,800	39,000	34,112	26,286	19,682	15,392	6838	3770
22	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0
Total	8760	5,195,713	5,949,507	4,133,284	2,783,663	2,168,314	1,839,107	1,416,715	614,349	499,599

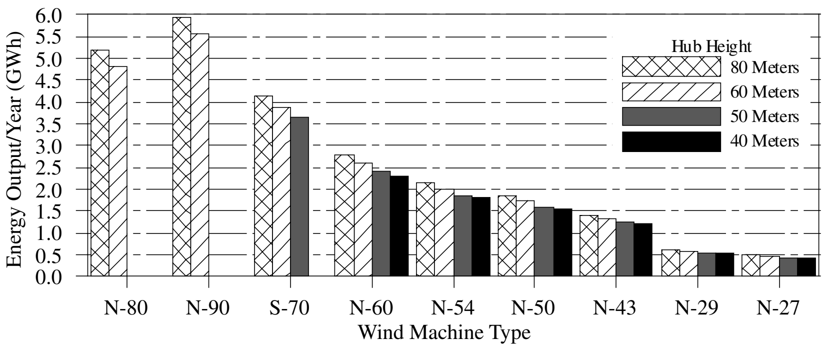

Fig. 11. Comparison of wind energy generated using WEC systems of different sizes and at different hub heights.

Table 3
Effect of decrease of hub height on the energy production from individual wind machines of different rated power

WEC type	Percent decrease in energy production with hub height for single machines					
	80–60	80–50	80–40	60–50	60–40	50–40
N-80/2500	7.26	13.76	17.15	7.01	10.66	3.93
N-90/2300	6.15	12.71	15.02	6.99	9.45	2.65
S-70/1500	6.29	11.34	13.08	5.39	7.24	1.96
N-60/1300	6.95	13.78	16.8	7.35	10.59	3.5
N-54/1000	7.19	14.06	15.98	7.4	9.47	2.24
N-50/800	6.2	12.92	15.83	7.16	10.26	3.34
N-43/600	6.21	12.38	15.66	6.57	10.07	3.75
N-29/250	5.53	11.66	14.07	6.48	9.04	2.73
N-27/150	5.36	12.11	13.65	7.13	8.75	1.74

output of wind machine N-90 decreases with decreasing hub height as shown in Fig. 11. In fact, the energy output is decreased by 6.15% at 60 m hub height compared to 80 m. This shows that hub height plays a considerable role in energy generation from the wind machines. Similar types of behavior are noticed from the wind machines of other sizes.

The percent decrease in wind energy generation with decreasing hub height is summarized in Table 3. In general, as observed from the values in Table 3, there are 5.5–7.3% energy production decreases when the hub height is changed from 80 to 60 m. In the case of a decrease of hub height from 80 to 50 m, the energy production decreased between a minimum of 11.34%, corresponding to the S-70 type of wind machine and a maximum of 14.06% for the N-54 wind machine. Similarly, changing the hub height from 80 to 40 m, the energy production decreased by 13.08% for the S-70 and 17.15% for the N-80 machines. The effect of hub height decrease from 50 to 40 m was found to be between 1.96% and 3.93%, while it varied between 5.39% and 7.16% when the hub height is decreased to 50 m from 60.

4.4. Energy output analysis for a wind farm of installed capacity of 30 MW

The theoretical yearly energy output from a single machine and from a wind farm of 30 MW installed capacity at Yanbo is summarized in Table 4. Energy calculations, presented in Table 4, are performed for nine wind machines of different sizes and having hub heights of 40, 50, 60 and 80 m. The wind farm output data shows that smaller size wind machines produce more electricity than the larger ones.

In the case of 40 m hub height, the energy output increased from 53.27 to 54.65 GWh, i.e. an increase of about 2.6% while using the 1000 kW (N-54) wind machine instead of the 1300 kW (N-60) machine. The energy output is increased by 10.44% when using the 800 kW machines (N-50) instead of the N-60 machines and 12.15% while replacing the N-60 machine by the N-43 machine of 600 kW. The increase in energy was only 3.43% while changing the wind machines from N-50 to N-43. At 50 m hub height, the energy output increased by 10.2% and 2% while using N-50 in place of N-60 and N-43 instead of N-50, respectively. More or less the same trend was observed in the case of 60 m hub height, but the magnitude of the increase of energy was less than that at

Table 4
Energy output from wind farm of 30 MW installed capacity

WEC type	Number of WECS	Wind farm output from 30 MW installed capacity (GWh)			
		40 m	50 m	60 m	80 m
N80/2500	12	–	–	57.82	62.35
N90/2300	13	–	–	72.59	77.34
S70/1500	20	–	73.29	77.46	82.67
N60/1300	23	53.27	55.20	59.58	64.02
N54/1000	30	54.65	55.90	60.37	65.05
N50/800	38	58.83	60.86	65.55	69.89
N43/600	50	59.74	62.07	66.43	70.84
N29/250	120	63.35	65.13	69.64	73.72
N27/150	200	86.28	87.81	94.56	99.92

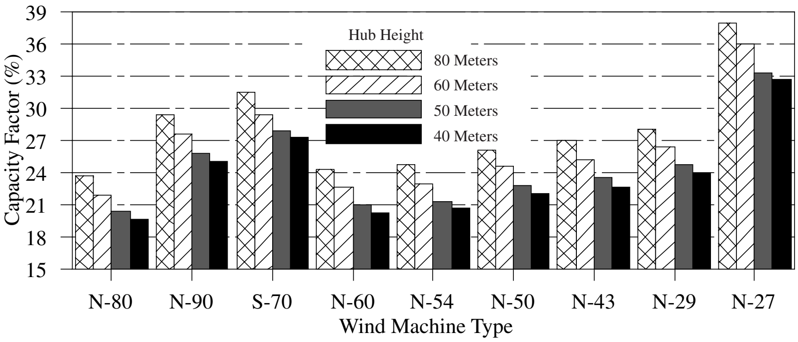

Fig. 12. Comparison of capacity factors obtained for different wind machines at four hub heights.

50 m. This analysis indicates that smaller wind machines produce more energy compared to larger ones collectively in a wind farm.

4.5. Capacity factor for wind energy conversion system

The capacity of a wind energy conversion system is obtained by dividing the actual energy produced by the rated power and number of hours in a year. The capacity factors, so calculated for different wind machines at various hub heights are compared in Fig. 12. As seen from this figure, higher capacity factors are found for wind machines of smaller sizes.

5. Conclusions

The wind data analysis presented in this paper reaches the following main conclusions:

- At Yanbo, the over all long term wind speed is found to be 4.63 m/s, which reaches more than 5.0 m/s at 50 m above ground level. This site can be further explored to find a more windy site through anecdotal information collection, study of topographical features, site visits and spot measurements of wind speed for a couple of days.

- The seasonal and diurnal trend of wind speed corresponds to the electricity demand pattern of the area and, hence, is a positive point from the wind farm development point of view.
- The seasonal trend shows higher values of wind during the summer months and smaller values during the winter months. Wind speed is observed to reach 5.0 m/s and more during the March–September months. The diurnal trend shows that wind speed of the order of 5.0 m/s and reaching 8.0 m/s were observed between 12:00 and 21:00 h.
- The frequency analysis assures the availability of wind above 3.5 m/s for 59% of the time during the entire year at 10 m above the ground surface. At 40, 50, 60 and 80 m above the ground surface, the availability of wind above 3.5 m/s is assured for 69% of the time. This encourages exploration of finding a windier site in the Yanbo region to get even better availability of wind.
- Wind energy generation was considered for nine wind machines of different sizes. It was found that the N-90 with rotor diameter of 90 m at 80 m hub height and with rated power of 2300 kW produced the maximum energy of 5949.5 MWh. The minimum energy of 499.6 MWh was obtained from the N-27 wind machine having a rotor diameter of 27 m and rated power of 150 kW.
- Higher energy output was obtained from smaller wind machines compared to larger ones for a wind farm of installed capacity of 30 MW.
- The capacity factor analysis showed that smaller wind machines have higher capacity factors than larger ones. The capacity factor was also found to increase with hub height. The highest capacity factor of 38% was obtained at 80 m hub height for N-27 wind machines.
- As per the increasing demand for electricity, increasing environmental awareness and participation of Middle East countries in wind energy production, Saudi Arabia is also looking towards the development of wind farms in the coming time.

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