Wind characteristic analysis for coastal area of Pak Phanang District, Nakhon Si Thammarat Province, Thailand

Sumet Suttapukti and Nipon Ketjoy*

School of Renewable Energy Technology, Naresuan University, Phitsanulok, 65000, Thailand
Tel: 0-5596-3182 Fax: 0-5596-3182
* ***Corresponding Author:*** niponk@nu.ac.th

Abstract

Analysis and measurement of wind characteristics are essential elements for examining the potential of coastal breeze across the shore. In this paper, the daily wind data for Pak Phanang (Lon 8°18.010 N / Lat: 100°15.842 E), over a period of 12 months (Sep 2011 – August 2012), is modeled in terms of the Weibull distribution function, in order to determine wind characteristic of the location. The hourly, daily, monthly and annual wind speed probability density distributions at 100m, 80m and 60m meteorological height were focused using the data from the observation mast installed at sea level. The annual mean wind speed, air density and annual mean temperature are determined with values of 5.18 m/s, 1.165 kg/m³ and 26.6°c respectively at 100m height. The results confirm that while the wind speed is more concentrated during May to September, the distribution of turbulence occur during April and October which dramatically impact the overall wind speed that result in wind shear and gust along with major change in flow direction of wind. Further statistics suggest that this information can be used, with acceptable accuracy, for prediction of wind energy output needed for preliminary design assessment of wind turbine for the location.

Keywords: *Wind characteristic, coastal area*

1. Introduction

Nevertheless, Thailand is a country lying in the monsoon wind regime, earlier wind assessment studied has utilized meso-scale models to understand the strong local land breeze and sea breeze circulation system and their influence on the wind turbine along the shore. The contribution of the large-scale monsoonal flow, however, has not been given adequate focus in the numerical studies carried out in this area. Normal mathematic model is not enough to explain and predict such wind characteristic, patterns that occurs along the shore. Various observations were focused only on Land Breeze and Sea Breeze [1] which are the major sources of local daily wind circulation along the coastal area produced by differential heating of the land and ocean. As the land warms during the day, denser air from the adjacent ocean flows over the land. At night, the flow pattern reverses. Many researchers provide a comprehensive overview of this land breeze and sea breeze which has implications for coastal physical oceanography, coastal meteorology, and near shore wind farm development project. However across a year its pattern changes dramatically in each season influenced by monsoon that flow to Thailand in two major directions, the North-East Monsoon (From mid of June to mid of October) and the South-West Monsoon (From mid of October to mid of February).

For developing a coastal wind farm in a class three wind country like Thailand [2], one of common mistakes made during wind assessment process is that research always foresees the impact of monsoon on measurement data which cause a mistake forecast in calculation annual energy yield. Therefore research on various impacts from monsoon to local land breeze and sea breeze circulation becomes so important to enlighten further accurate coastal wind farm assessment in southern part of Thailand. This requires improved additional understanding of the surface wind field, an important variable for analysis and the influence of monsoon on land-sea breeze profile. Thus, a study has been established to investigate the characteristic features of the surface wind field along the coastal area of Pakphanang District, Nakhonsithammarat Province, Thailand through the efforts of real-time data collection and model simulation software.

2. Wind Mast site and data description

In Pak Phanang district, there were only 3 wind mast tower installed at the height of not more than 60 meters, including the government meteorological tower having a height of 25 meters. This research used lattice type higher mast tower of 102 meters installed right at the sea coast approximately about 20 meters from the sea body (Lon 8°18.010 N / Lat: 100°15.842 E). The details of the wind mast tower equipment are summarized in Table 1 where wind data being collected from 1 September 2011 to 31 August 2012. The wind anemometers were mounted at 60m, 80m and 100m height while the wind vanes were installed at 60m and 100m. Moreover all the equipment installed were with the calibration certificates from respective manufacturers [3]. Additional observation equipment such as temperature sensor (measures the difference in temperature between two heights above ground) and barometric pressure sensor were installed at 90 meters height for better understanding of surrounding climate over seasonal period of study [4].

3. Data Validation

The raw data from the mast tower were collected at the end of each month and checked for logger and sensor failures, data transmission failures and erroneous values. The report shows a smooth collection process without any fault or data error. The additional information was noted as following:

Data was recorded in 10 minutes interval without zero value offset (Industry standard recording interval). The parameters sample once every 1 or 2 second within each 10 minutes to avoid errors and this data recording was in time serial [5]. The collected wind speed data values were scrutinized for desired range (between 0 and 25 m/s), as the values above 25 m/s were not to be included in the statistical analysis. However, none of interval data go beyond 25 m/s among the whole year observation.

For further data confirmation, a time series of wind speed was generated using meso-scale simulations which were performed through WRF model to revalidate the collected data. WASP software model was also used to generate the result to avoid confusions with other sampling methodology and data sampling.

Wind direction values were checked between 0° and 360° and any value greater than 360° was rejected and not included in this analysis [6]. Temperature and pressure values were checked and compared with Thailand climate standard record. Any abnormal number due to equipment failure was supposed to be rejected and not included [7].

The standard deviation was calculated for both wind speed and direction (population standard deviation within each 10 minutes interval). This will indicate turbulence and erroneous data [8]. The maximum and minimum values of all parameters in each interval were recorded.

Table 1 Summary of equipment installed on 102 meters wind mast tower

Equipment	Manufacturer	Height	Information
Anemometer # 1	NRG Model 40	60 Meters	Measure wind speed
Anemometer # 2	NRG Model 40	80 Meters	Measure wind speed
Anemometer # 3	NRG Model 40	100 Meters	Measure wind speed
Wind Vane # 1	NRG Model 200P	60 Meters	Measure wind direction
Wind Vane # 2	NRG Model 200P	100 Meters	Measure wind direction
Barometer	NRG BP-20	90 Meters	Measure air pressure
Temperature Sensor	NRG 110S	90 Meters	Measure temperature in C°
Data Logger	NRG Symphonie Plus	Ground	Collecting digital data
Surge Protection	NRG	102 Meters	Fully equipment protection
Solar Panel	GE	30 Meters	Backup generator

4. Results and discussion

The collected 1 year (Sep 2011 – Aug 2012) observation data were analyzed statistically and the results have been presented as follows:

4.1 Diurnal and seasonal of wind data

To analyze the seasonal tread of wind data over a period of time, the monthly mean values were calculated from all recorded 10 minutes interval data at 60, 80 and 100 m height above ground level. The 10 minutes interval mean wind speeds at different heights were generated using the NRG software SDR version 7.03 through one year (Sep 2011 – Aug 2012) raw digital data (RWD). Seasonal trends of monthly mean wind speed at Pak Phanang coastal location is shown in Table 2. According to the results, the maximum monthly mean wind speed of 6.5 m/s is observed during June 2012, while minimum of 3.8 m/s in Mar and April 2012 at 100 m above the ground level. Monthly mean wind speeds of the order of 3.8 m/s and above are noticed in the summer months from March to May. Though at 80 and 100m heights, slightly higher values are observed but more or less follow the same trend as at 60 m. During March and April monthly mean wind speed for all heights was of same value (3.8 m/s at all heights) and is lowest among all months of observed year, as the south wind during that time does not accumulate additional wind speed into the coastal area. The highest 10 minutes interval wind speed recorded ever during this research was 15.5 m/s on 3 January 2012 at 3 a.m. resulted from northeast monsoon.

With the impact of Southwest Monsoon [9], wind speed shifts up from 3.8 m/s to 5.9 m/s at 100 m height from April to May and this trend continues lifting the overall wind potential with dramatic wind speeds throughout rainy season till end of September. October is the time when a change occurs from Southwest Monsoon to Northeast Monsoon resulting in high turbulence in wind speed and brings down the monthly wind speed from 5.5 m/s in September to 4.2 m/s in October as recorded at 100m height.

The diurnal behavior of 10 minutes interval mean wind speeds at the different heights is shown in Fig. 1. At 100 m height above the ground level, the higher values of wind were found from May to October.

Temperature at this location are ranging between 22°c to 32°c, the highest temperature interval was observed during April 2012, whereas the highest monthly average temperature(28°c) was observed during June 2012. It can be seen from the table 2 that rainy season has higher temperatures than winter season, thus result in greater diversification of air density.

Pressure sensor explains a higher interval during June, thus result in a great wind speed dramatically [10].

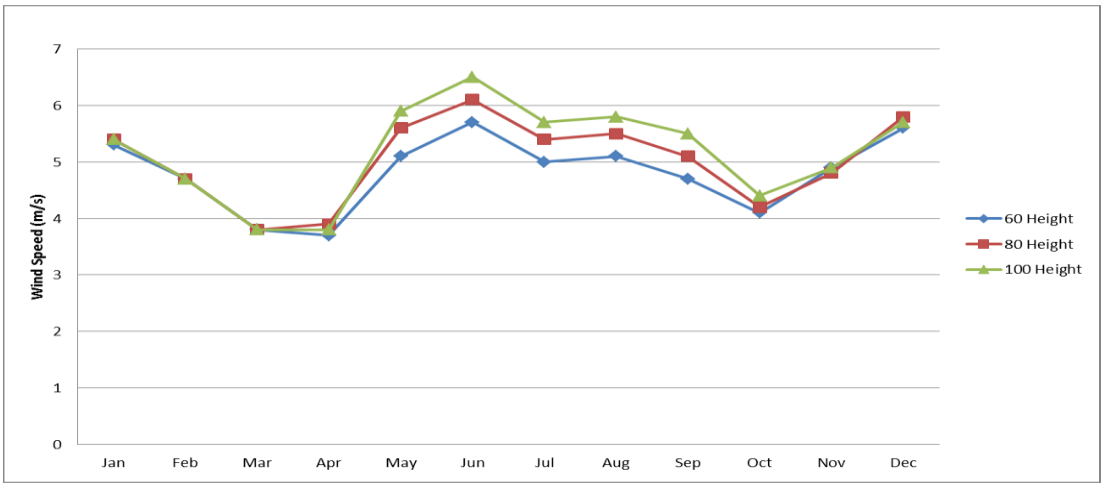


Figure 1 Comparison of monthly mean wind speed at different heights. (Sep 2011 – August 2012)

The collecting data result from using measurement tower have a similar pattern with early study which using satellite extrapolation method [2], but the monthly mean wind speed is dramatically lesser than obtain from satellite data. The collecting wind resource is still enough for developer to establish commencing wind farm meanwhile wind direction parameter is remain the same by both method with slightly differ in frequency of wind in each direction. Therefore it is always better to rely on data from wind met mast to enhance the accuracy and less aberration whereas using extrapolation method could not explain any characteristic much for this area.

Table 2 Monthly observed data at different heights over seasonal environment.

		Year 2012								Year 2011				
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average
	Wind Speed at 60 Height	5.3	4.7	3.8	3.7	5.1	5.7	5	5.1	4.7	4.1	4.9	5.6	4.81
	Wind Speed at 80 Height	5.4	4.7	3.8	3.9	5.6	6.1	5.4	5.5	5.1	4.2	4.8	5.8	5.03
	Wind Speed at 100 Height	5.4	4.7	3.8	3.8	5.9	6.5	5.7	5.8	5.5	4.4	4.9	5.7	5.18
	Temperature Observation	26.1	26.9	27.7	27.9	27.9	28	27.7	27.6	27	26.8	27.1	26.2	27.24
	Pressure Observation	1003.6	1003.2	1003.3	1003	1001.4	1001.7	1001.7	1002.6	1002.3	1002.4	1002.7	1003.5	1002.62
Natural Phenomenal During Observation	**Northeast Monsoon**	■	■								■	■	■	
	Southwest Monsoon					■	■	■	■	■	■			
	Tropical Storm from China								■	■				
	Tropical Storm Philippine										■			
	Cyclone from Andaman Sea					■								
	South Wind from Indonesia			■	■									
	Summer Season			■	■	■								
	Rainning Season						■	■	■	■	■			
	Winter Season	■	■									■	■	
	Nock Ten Storm 2011							■	■					
	Hai Tar Storm 2011									■				
	Na Gae Storm 2011										■			
	Japan Tsunami 2011			■										
	New Zealand Earthquake 2011		■											
	Flooding Thailand 2011	■							■	■	■	■	■	

4.2 Wind direction analysis

Wind vanes were installed at two monitoring levels to ensure adequate redundancy. Moreover it was not mounted at the same booms or even at the same heights as of anemometer. [6] Data obtained shows that coastal area of Pakphanang encounters wind from all directions (360°). The lowest frequency of 1.9% revises from SSE direction whereas the highest frequency of 25.4% comes from SSW direction. Southwest Monsoon show more availability than Northeast Monsoonon in this area as shown in Table 3.

Wind from the Southwest direction has the total frequency of 52.6 %, meanwhile Northeast direction has 40% in frequency. The wind directly from north direction is higher than South direction wind with Frequency of 4.3% and 3.9% accordingly.

The direction of each kind of monsoon is involved smoothly with local kind of wind such as Land Breeze and Sea Breeze. However during the seasonal change in direction, greater turbulence in direction reflects the dramatic impact of monsoon to local breeze.

Table 3 Weibull Distribution in various directions of Pakphanang Coastal wind (Sep 2011 to Aug 2012)

	A-Parameter m/s	Wind Speed m/s	K-Parameter	Frequency %
N	4.78	4.23	2.038	4.3
NNE	5.27	4.66	2.076	7.6
ENE	5.25	4.68	1.714	11
E	5.79	5.12	2.248	13
ESE	5.73	5.08	1.970	6.5
SSE	3.49	3.11	1.705	1.9
S	4.48	3.96	2.213	3.2
SSW	6.79	6.13	3.727	25.4
WSW	6.66	5.93	2.782	18.7
W	4.72	4.21	1.740	3.9
WNW	3.67	3.26	1.946	2.4
NNW	3.85	3.41	2.192	2.2
All	5.88	5.21	2.279	100

The wind speed frequency distribution by direction was stored in tabular format, which is useable as an input to wind plant design software. This Weibull Distribution represents the wind speed frequency distribution at this site.[3] The probability, that the speed will fall in a bin of unit width centered on speed “ v” (Probability Density) is given by the equation :

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

There are two parameters in this Weibull function: the scale parameter, which is of dimension speed and is related closely to the mean wind speed, and k, the non-dimensional shape parameter, which controls the width of the distribution. The values of k range from 1 to 3.5, the higher values indicating a narrower frequency distribution. A commonly observed k range is 1.6 to 2.4, within this range, the mean speed is about 0.89 times the scale factor. This Weibull data is an approximation of the true wind speed frequency distribution. While the real speed distributions at the site fit a Weibull graph very well, however this Weibull data will not be used in place of the observed speed frequency distribution during estimating energy production [7].

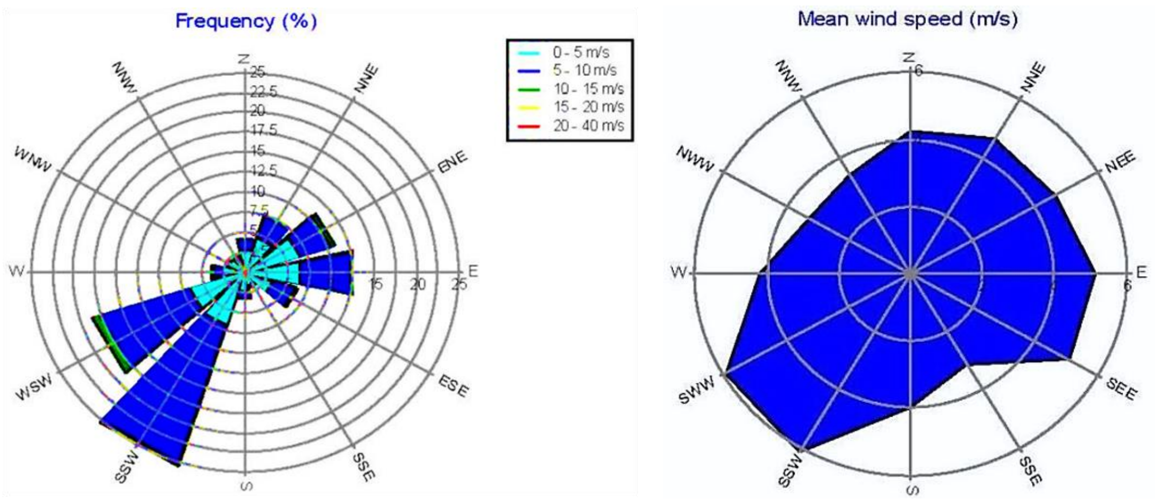
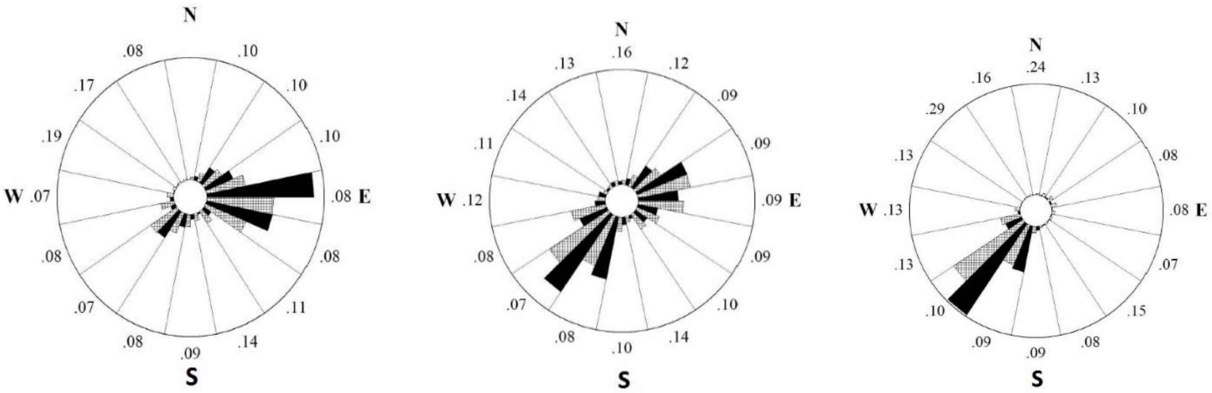


Figure 2 Wind frequency and mean wind speed graphs

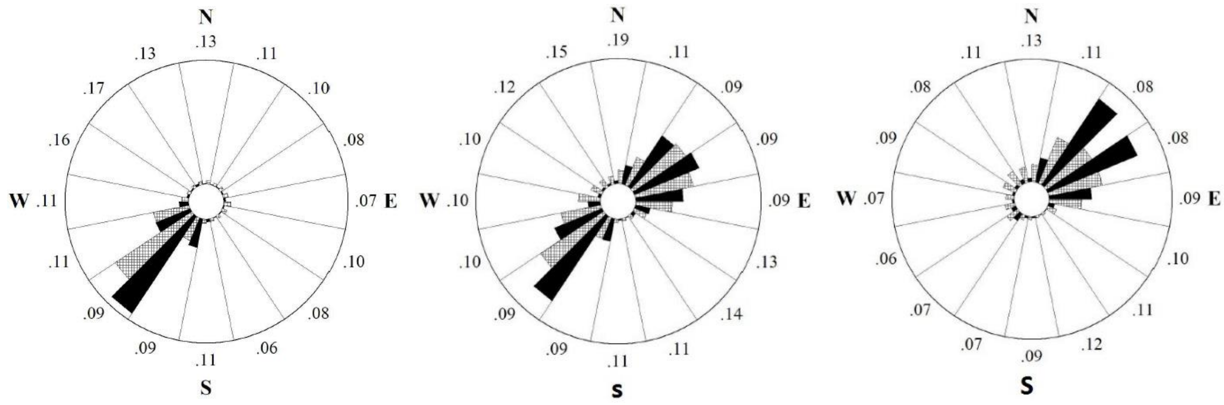
The whole period (one year), data shown in Fig. 3 explain a pattern of direction of wind changing during the months of April and October in coastal area of Pak Phanang. Wind flow from various directions at these instances results in high turbulence and affects the wind potential accordingly [11]. During March this location enjoys majority of wind from East side as Northeast monsoon is depreciated and slowly changed its direction to west side during April, whereas Southwest monsoon started to accumulate. The period of re-patterning lasts for 45 days, and increases turbulence in wind from two major directions, thus in April, this area shows the lowest wind average due to turbulence impacts on wind speed.



March April May

Figure 3 Wind direction from March to May 2012

Southwest monsoon as shown in Fig. 4 continues to flow till august and ends at the beginning of October with the exchange of wind direction to northeast monsoon, results in turbulences during the month of October, while southwest monsoon starts to decrease its potential in beginning of November.



September October November

Figure 4 Wind direction from September to November 2011

4.3 Wind availability analysis.

The wind availability analysis is performed in terms of the frequency (or number of hours) for which wind remained in a certain wind speed interval or bin [12]. The frequency is obtained by constructing a wind rose diagram using the 10 min interval wind speed and corresponding wind direction data for the entire data collection period. Generally, wind turbine generator has cut-in wind speeds of the order of 3.0 m/s [10], so that the first bin is taken as 0-2.9 m/s, the second as 2.9-4, and so on. The resulting percentage frequency distribution at 100 m height above the ground level and in different bins is shown in Fig. 5. Here the 10 minutes interval, mean wind speed remains above 3 m/s for about 87% of the time during the whole data collection period. This shows that the power of the wind speed can be harvested for 87% of time. It is also observed that mean wind speed remained above 6 m/s for 18% of the time. Moreover it shows that most of the wind speed is ranging between 5-6 m/s. The highest wind that has been observed is 15.3 m/s without any digit close to cut-out wind speed at 25 m/s (Most of wind turbine specification)

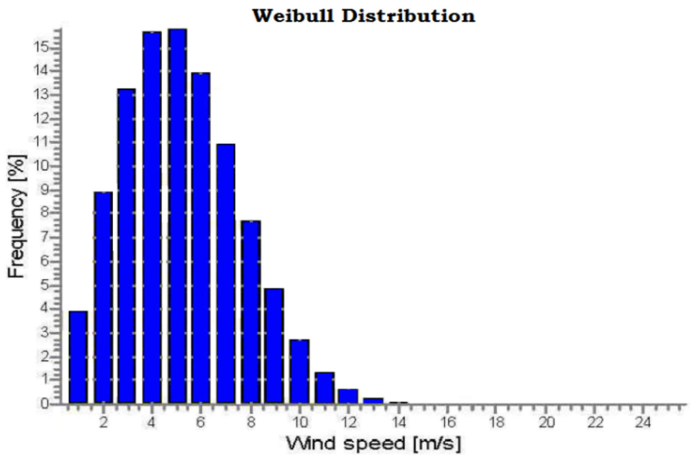


Figure 5 Frequency Distribution graph in each wind speed accumulated

5. Conclusions

The wind characteristic in Pak Phanang Coast is in circulation pattern. This area has a high potential of wind availability during rainy season in the month of June. The effect of direction change of monsoon was significant in the months of April and October resulting in turbulence which lowers down the total wind speed in the area. In the month of October highest turbulence of wind was noticed due to the impact of greater Northeast Monsoon that exists along the east coast of Thailand's Gulf. The study gives a very well conclusion that turbulence occurs along with seasonal change, from summer season to rainy season from April end till beginning of May. Another spell of turbulence dramatically occurs during seasonal change from rainy season to winter season from mid of October till beginning November. It also come to conclusion that southwest monsoon is the major wind resource for wind farm generation in this area than northeast monsoon. In summer season, this area has lowest wind speed whereas south wind does not accumulate any of its potential. Each pattern change occurs twice a year which usually takes not more than 45 days. The study also gives additional support for wind farm developer to seek advantage for applying turbine with above 100m hub height to maximize energy production. However the additional energy gains at 100m in comparison with other levels must be evaluated against the additional construction costs of hub heights.

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