Evaluation of Wind Energy Potential and Electricity Generation in Northern of Thailand

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Abstract

Wind energy assessment plays a vital role on determining installation of wind turbines in worldwide. Wind analysis is proposed to systematically assess the potential of electrical energy production from wind turbine. Statistical information of wind data and power curves of wind turbines were applied for establishment such as annual energy production and capacity factor. Several case studies are investigated in the northern region of Thailand, which has meteorological station (7 stations); these stations of 7 stations are applicable for wind speed and wind direction measurement at 40 meters from ground level. Direction of southwest monsoons results was revealed the annual average wind speed between 3.36-5.03 m/s. With the proposed methodology, a wind turbine with low cut-in wind speed is Fuhrländer 600kW and 1000 kW. It was found that MAEHAE station confirmed that high wind energy potential, approximately annual electricity production of 1.51 GWh and 1.72 GWh, respectively. Furthermore, the annual energy production has the most impact on financial parameters. Consequently, MAEHAE station can be recommended as one of the most feasible wind turbines for electricity generation under weak and moderate wind conditions in the considered sites in Northern of Thailand.

Keywords: Wind Energy Potential, Northern of Thailand

Introduction

Due to concerns regarding fossil fuel, such as finite reserves and environmental impacts like climate change, and increasing electricity demands, many countries are seeking to increase the usage of renewable energies such as solar, wind, biofuels, geothermal and others. Renewable energy sources are alternatives to fossil fuels and are thought by many to be sustainable and an essentially non-polluting (Alamdari et al., 2012). Wind energy is an old established source of energy which is clean and less effect for environmental assessment. The wind turbine technology has been increasing rapidly over the last few decades. Many countries have tried to enhance the knowledge of technologies for wind energy generation. An important step in the implementation of wind turbine is an assessment of the wind energy potential for relevant locations. The characteristic of wind energy is containing wind speed and wind direction. The variability could lead probabilistic uncertainties, and these uncertainties might affect the system operation significantly (Aien et al., 2014). Many researchers have been studied the potential of wind power and wind characteristics in many regions of Thailand. In northern region of Thailand has begun harnessing wind energy from sites with acceptable wind energy potential on the mountain of Chiang Mai from studies by energy organization of Thailand. Meanwhile, the wind data are feature averages of wind speed and wind directions to accumulate long term had to less, including the wind data measurements in long period time from "Meteorological Department". The data declared that surface wind speed height 10 meter above ground level. Wind energy for power generation had potential wind energy at height 40-80 meter above which the data to less at this time. In

1983, the first wind data collection of Thailand from meteorological station tower height was 10 meter above ground level between 1966-1978 and 1981-1982 (total of 15 years period). It was found that the minimum of wind speed of 5.10 km/h, available wind power of 7.60 W/m^2 in Mae Hong Son province (Kwan, 1983). In 2001, renewable and conservation energy department of Thailand and the electricity generation authority of Thailand were studied with wind potential. It found that average wind speed was 4.30 m/s at Inthanon mountain, National Park in Chiang Mai province (Department of Alternative Energy Development and Efficiency, 2001). In 2003, The renewable and conservation energy department in Thailand to study potential micrositing wind energy in Southern of Thailand at Kao Teay, Satingpra in Songkhla and Tamadeay in Phatthalung province. The wind data of wind speed and wind direction was verified at height 10, 30 and 40 meters every 10 minute for 12 month. These data are analysis by using WAsP Program for calculate wind data from measurement. It was found the high potential wind energy at height 50 meter above ground level and had a wind power class at 2 (200 W/m^2) with average wind speed between 5.67 - 7.50 m/s. The energy production from wind turbine capacity was 1 MW of 5 wind turbines about 7.359 GWh/year and cost generated energy with 4.49 Baht/kWh (Department of Alternative Energy Development and Efficiency, 2003). In 2005, the Provincial Electricity Authority (PEA) of Thailand to measurement wind data confirmed that at the height 20, 30 and 40 meter above ground level at Samoeng station in Chiang Mai province. It was found that average wind speed of 3.5, 4.0 and 4.08 m/s, respectively (Yongyut, 2005). From 2013, to studies a high resolution wind atlas for Nakhon Si Thammarat and Songkhla provinces in southern Thailand was developed using combined mesoscale, MC2, and microscale, MsMicro, modeling techniques. Results from the technical power potential at 80 m above ground level show that a total of 1,374 MW of wind farms, generating annually 3.6 TWh of electricity, could be installed; while 407 MW of small wind turbines (50 kW), generating annually 1.0 TWh of electricity, could be installed (Waewsak , Landry, Gagnon, 2013). In 2014, to assessment of the onshore wind energy potential in Thailand using the Regional Atmospheric Modeling System (RAMS). A 9 km resolution, 1,150 km by 1,750 km, wind resource map at 120 m elevation above ground level based on the NCEP reanalysis database for the three year period of 2009-2011. The Results showed that, for the study area, the annual average wind speeds at 120 m AGL are in the range of 1.60-5.83 m/s and power density at 120 m AGL is approximately 200 W/m^2 which corresponds to a wind power density of Class 2. The region has a good wind regime in the mountain areas of Western, Southern and Eastern Thailand (Chancham et al., 2014). The wind energy potential of Thailand was evaluated by using an atmospheric mesoscale model and a Geographic Information System (GIS) approach. The Karlsruhe Atmospheric Mesoscale Model (KAMM) was used to calculate the hourly wind speed in Thailand over the period of 15 years (1995-2009) with a horizontal spatial resolution of 3 x3 km^2. Thailand has high wind energy potential area of only 550 km^2 which results in a total wind turbine energy capacity of 1100 MW (Janjai et al., 2014) Nowadays, to studies in the the central region of Thailand, which has a high demand for electricity. Annual mean wind speed is between 3 m/s and 5 m/s along directions of tropical monsoons. With the proposed methodology, a wind turbine with low cut-in wind speed, such as the Vestas™ V60 850 kW, can be recommended as one of the most feasible wind turbines for electricity generation in green economy under weak and moderate wind conditions in the considered sites (Quan & Leephakpreeda, 2015). Accordingly, the main purpose of this article is to evaluate the feasibility of using wind energy (from 7 stations) in Northern of Thailand. This study focuses on determining mean wind speed, mean wind direction, Weibull distribution, wind shear coefficient and wind power generation from wind turbine of this study.

Methods and Data

Wind data collection

The installation of wind monitoring stations to collect by surveying wind energy resource in Northern Thailand surrounding 18 sources of wind data were Chiang Mai, Chiang Rai, Mae Hong Son, Phrae, Nan and Lamphun provinces. The Figure 1 and table 1 illustrated details about the location of 7 stations for measurement wind data at 20, 30, 40 meters above ground level of 6 stations, and rest of one station to measurement at 20, 40, 80 meters above ground level. The wind data collected a times period of January to December on 2008.

Figure 1 Wind data from Metrological Stations in Northern Regions of this study (https://www.google.co.th/map)

Table 1 Physical features of the metrological stations

Name of stations	Coordinates		Mean sea level	Height of tower
	Latitude	Longitude	(m.)	(m.)
ROMPOTHAI	N 19 79.377	E 100 39.920	945	40
PHATUNG	N 19 56.154	E 100 30.365	1,360	40
NORLAE	N 19 56.113	E 99 02.536	1,480	40
NONGHOI	N 18 56.225	E 95 48.948	1,304	40
KILLOM	N 19 26.011	E 98 19.007	1,668	40
MONLAN	N 19 25.821	E 99 18.310	1,573	40
MAEHAE	N 18 47.281	E 98 33.723	1,391	80

Measurement stations

Measurement devices are mounted on the meteorological station for detecting wind speeds and wind direction at heights of 40 meters and 80 meters. A three-cup anemometer of NRG 40C and wind vane of NRG 200P are used to measure wind speed and wind direction, respectively by NRG are Brand from USA. The wind data are recorded by NRG model of SymphoniePRO at a sampling rate of 1 minute with average of values every 10 minutes. The figure 2 demonstrated the wind data meteorological station of this study on 7 stations in northern region of Thailand.

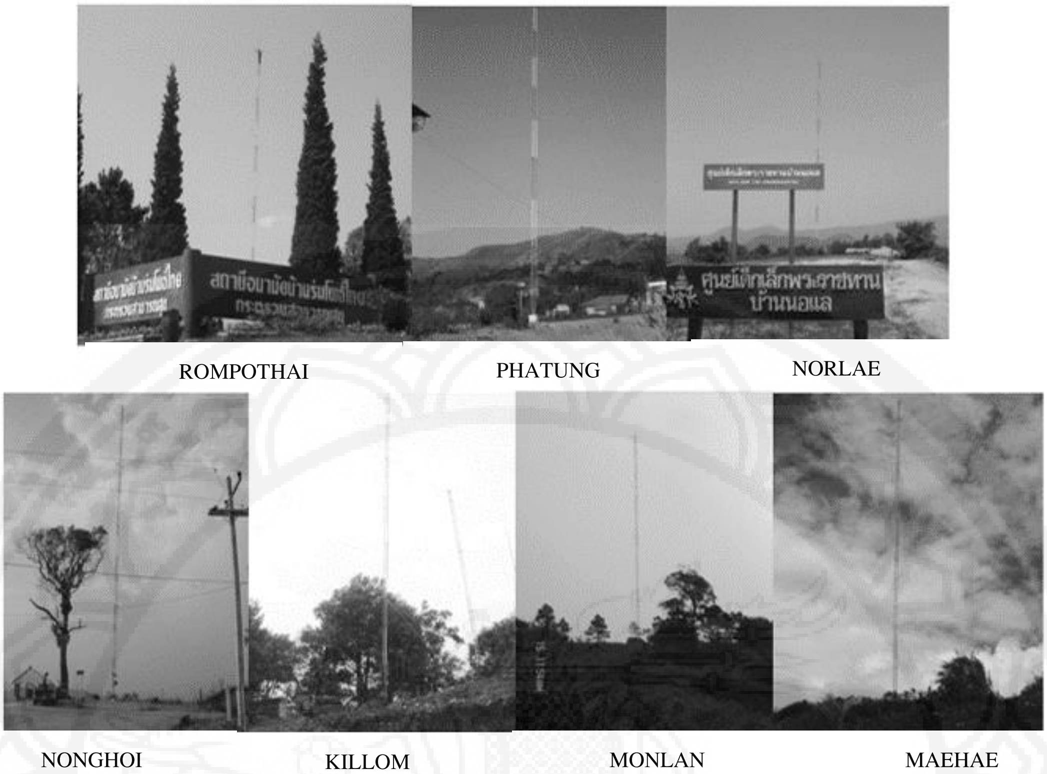

Figure 2 Wind data meteorological stations in northern region Thailand

Mean Wind Speed and Wind Direction Analysis

Statistics of wind data measured average wind speed can be calculated by frequency distribution of wind speed according to Eq. (1) (Sathyajith, M., 2006).

$$V_m = \frac{V_1 N_1 + V_2 N_2 + ...V_n N_n}{N_1 + N_2 + ...N_n} \quad (1)$$

When, V_m is mean value of wind speed over the whole measurement period (m/s), V_n is the midpoint of the wind speed bin(m/s) and N_n is the number of hours counted in the bin (hour).

Wind Speed Variation with Height

Wind speed data are normally measured at a certain height and in most cases, the wind turbine hub is placed at a different height. In order to adjust the measured wind speed data to the level of the wind turbine hub, the power law is the most common expression accepted in the literature. This law describes the vertical variation of wind speed and is formulated given by Eq. (2) (Boudia et al., 2013; Gupta, 2016)

$$\frac{V_Z}{V_{Z_r}} = \left(\frac{z}{z_r}\right)^{\alpha} \quad (2)$$

From Eq. (2) can be written as an equation to calculate the wind shear coefficient according to Eq. (3) (Baseer et al., 2015).

$$\alpha = \ln(\frac{V_Z}{V_r}) / \ln(\frac{Z}{Z_r}) \quad (3)$$

When, V_z is Wind speed at height Z (m.) and V_r is wind speed at the reference height Z_r (m.)

Weibull Distribution

Weibull distribution for wind speed can be represented as a probability density function given by Eq. (4) and as a cumulative distribution function given by Eq. (5) (Dhunny et al., 2015, Gupta, 2016)

$$f(V) = \left(\frac{k}{c}\right)\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \quad (4)$$

And cumulative distribution function by Eq. (5) Baseer et al., 2015; Dabbaghiyan et al., 2016; Dhunny et al., 2015)

$$F(V) = 1 - \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \quad (5)$$

When, V is wind speed (m/s), k is shape parameter and C is scale parameter (m/s).

Several methods are available in order to determine the two parameters of Weibull distribution. The method used in this study is graphical method. The graphical method depends on the evaluation of cumulative distribution function of wind speed. Taking double logarithmic transformation of the cumulative distribution function yields Eq. (6) (Bilir et al., 2015)

$$\ln[-\ln(1-F(V))] = k\ln V - k\ln C \quad (6)$$

When ln(-ln(1-F(V))) values are plotted against ln(V) values and a straight line is fitted to the data, shape parameter can be determined from the slope of the line. The scale parameter can be found consequently from the intercept with y-axis.

Capacity Factor

The capacity factor is one of the performance parameters of wind turbines, which both the user and manufacturer needed to know. It represents the fraction of the total energy delivered over a period, E_{out}, divided by the maximum energy that could have been delivered if the turbine was used at maximum capacity over the entire period, E_r = 8760P_r by 8760 is hours in a year. The capacity factor of a wind turbine can be calculated as by Eq. (7) (Dabbaghiyan et al., 2016)

$$C_F = \frac{E_{out}}{E_r} \times 100 \quad (7)$$

When, C_F is Capacity factor (%), E_{out} is Annual electricity production (kWh) and P_r is capacity of wind turbines (kW)

Results

In this study, the wind speed measurement data from 7 locations in northern of Thailand for a period of 12 months have been analyzed mean wind speed, mean wind direction, wind shear coefficient, Weibull distribution parameters in terms parameter of k and c. The main results obtained from the present study can be summarized as follows:

Mean Wind Speed and Wind Direction

Wind speed is the most important aspect of the wind resource. In fact the yearly variation of long term mean wind speed provides an understanding of the long term pattern of wind speed and also gives the confidence to an investor on the availability of wind power in coming years. Table 2 to 5 provides the variation of long term mean wind speed during entire data collection period at 7 stations and wind data collection period of January to December, 2008 at all stations. The table indicates that most stations have an annual mean wind speed more than 3.00 m/s of all stations. The mean wind speed has a maximum value of 5.03 m/s at KILLOM station and minimum value of 3.36 m/s at ROMPOTHAI for height of 40 meter above ground level. Among annual averages of KILLOM, MONLAN and MAEHAE show higher value of wind speed and thus can be rated a better choice for wind energy utilization when comparisons in Northern of Thailand. It will be suitable sites for installation wind turbine in the future. The direction of the wind is crucially important for the evaluation of the possibilities of utilizing wind power. The wind speed data of station were grouped into eight directional sectors: North (N), North East (NE), East (E), South East (SE), South (S), South West (SW), West (W) and North West (NW). According to figure 3 and figure 4, the prevailing wind direction from Northern are NORLAE about 43.78% and NONGHOI about 39.02% from Southern is ROMPOTHAI about 56.32% from Westerns are PHATUNG, MONLAN and MAEHAE about 49.85%, 49.02% and 394.48%, respectively and latest KILLOM the prevailing wind direction from Northwest about 43.17%. all stations showed the wind direction from between south East, West, Northwest and North directions because which under the influence of monsoon were southwest monsoon in May – October and February– May in rainy and winter seasons about 10 months.

Table 2 Monthly mean and annual mean wind speed (m/s) and wind direction at a height of 20 meter

Stations	Months												Annual mean wind speed
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
ROMPOTHAI	2.75	3.53	3.03	3.28	2.77	3.19	3.15	2.50	1.72	1.61	2.13	1.84	2.62
PHATUNG	3.57	5.14	4.43	4.19	3.85	3.88	4.02	3.05	2.52	3.35	3.35	2.97	3.71
NORLAE	1.33	0.73	0.50	2.14	4.19	1.14	1.51	1.14	0.68	0.53	1.46	0.89	1.35

Table 2 (Cont.)

Stations	Months												Annual mean wind speed
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
NONGHOI	2.84	4.02	3.91	3.30	4.53	5.95	7.12	4.76	3.42	3.03	2.00	2.06	3.91
KILLOM	4.17	5.01	4.47	4.05	4.47	5.45	6.09	3.99	3.40	3.30	3.66	2.99	4.29
MONLAN	4.03	4.88	4.31	4.05	4.33	5.28	5.97	4.50	2.92	3.28	3.60	2.84	4.17
MAEHAE	3.34	4.55	4.45	3.90	5.09	6.50	7.65	6.23	4.25	2.69	2.58	2.00	4.44

Table 3 Monthly mean and annual mean wind speed (m/s) and wind direction at a height of 30 meter

Stations	Months												Annual mean wind speed
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
ROMPOTHAI	3.16	4.10	3.54	3.84	3.22	3.57	3.51	2.84	2.11	2.09	2.65	2.24	3.07
PHATUNG	3.88	5.18	4.44	4.26	4.00	4.00	4.16	3.16	2.49	3.48	3.68	2.98	3.81
NORLAE	3.53	4.01	3.92	3.02	3.21	4.26	4.96	4.16	3.74	4.56	4.99	3.85	4.02
NONGHOI	2.84	4.06	3.94	3.35	4.57	6.00	7.16	5.16	3.47	3.06	2.04	2.00	3.97
KILLOM	4.72	5.05	4.99	4.56	4.98	5.95	6.64	4.37	4.06	4.21	4.29	3.51	4.80
MONLAN	4.33	5.27	4.63	4.40	4.91	5.81	6.54	4.98	3.66	4.07	4.34	3.34	4.69

Table 4 Monthly mean and annual mean wind speed (m/s) and wind direction at a height of 40 meter

Stations	Months												Annual mean wind speed
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
ROMPOTHAI	3.36	4.35	3.76	4.09	3.52	3.91	3.91	3.15	2.32	2.33	2.85	2.32	3.36
PHATUNG	4.08	5.50	4.56	4.40	4.13	4.17	4.42	3.28	2.59	3.60	3.68	3.01	3.95
NORLAE	3.50	3.93	3.92	3.37	4.30	3.92	4.65	3.83	3.49	4.37	4.81	3.80	3.99
NONGHOI	3.09	4.32	4.19	3.62	4.83	6.24	7.40	5.67	3.53	3.30	2.31	2.35	4.24
KILLOM	5.07	5.93	5.36	4.95	5.38	6.35	7.01	4.44	4.02	4.11	4.02	3.45	5.03
MONLAN	4.36	5.25	4.71	4.37	4.95	5.63	6.24	4.90	3.70	4.33	4.66	3.57	4.72
MAEHAE	3.50	4.69	4.45	4.02	5.12	6.48	7.60	6.17	3.24	2.62	2.50	1.95	4.44

Table 5 Monthly mean and annual mean wind speed (m/s) and wind direction at a height of 80 meter

Station	Months												Annual mean wind speed
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
MAEHAE	3.99	5.29	5.08	4.39	5.66	7.04	8.19	6.68	4.68	3.12	3.06	2.48	4.97

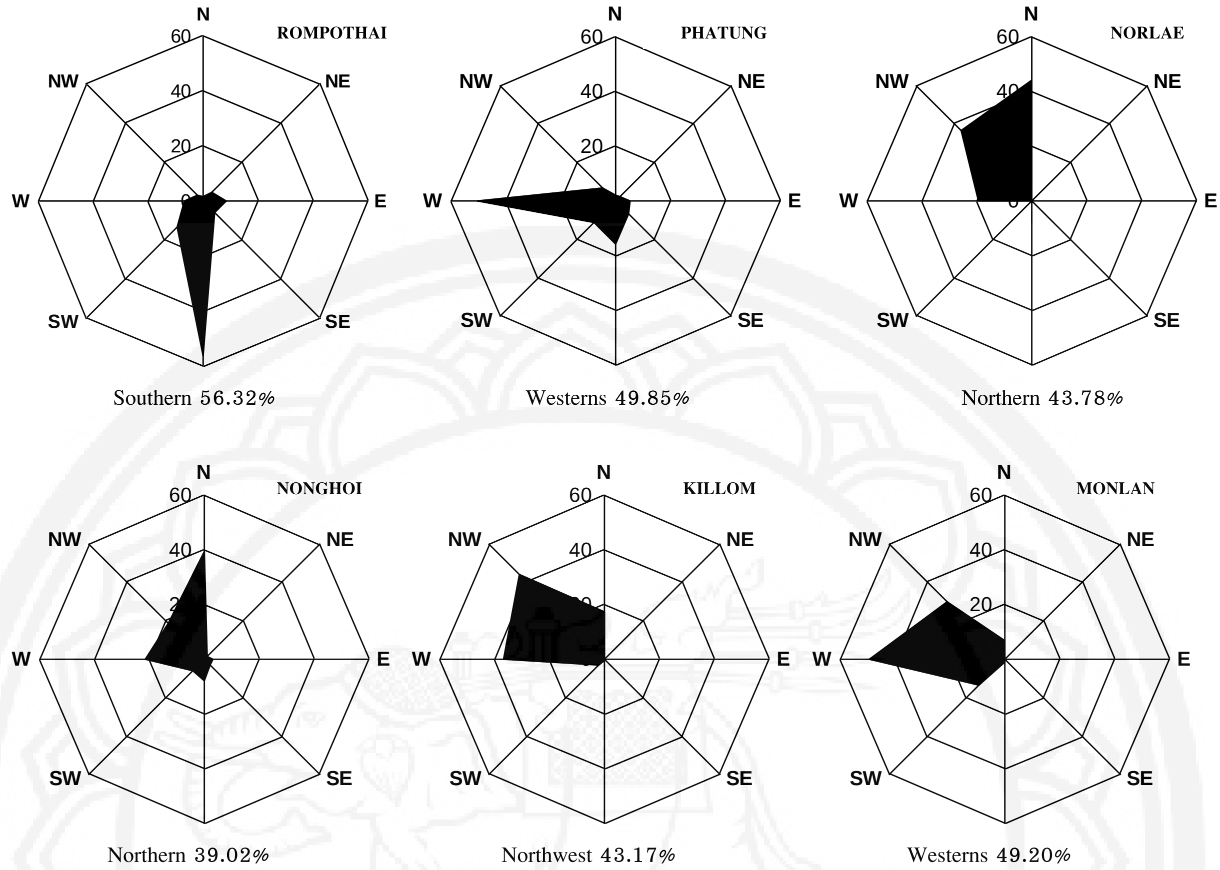

Figure 3 Wind directions at height of 40 meter above ground level

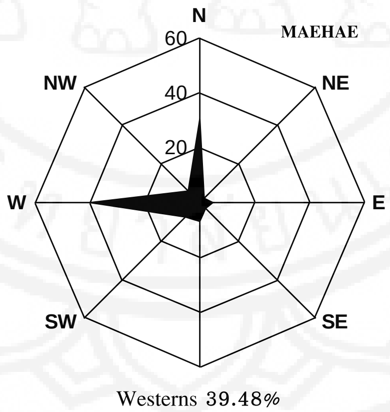

Figure 4 Wind direction at height of 80 meter above ground level

Wind shear Coefficients

The wind shear coefficient for the calculation of wind speed can be calculated at different heights if measured values are known at one height. The wind shear coefficients were calculated between 20 and 30, 20 and 40, 30 and 40 m. The long-term averages of these are summarized in Table 6. The analyses of the values were in the range of 0.117 to 0.233. The comparison of wind speed calculated using wind shear coefficient with actual wind data at

80 meters at MAEHAE station. It was found that mean wind speed average error of 3.72%. The Wind shear coefficient at ROMPOTHAI and KILLOM are the largest because these areas there are the rough terrain and a lot of around mountains. MAEHAE is small rough terrain and this area is agricultural which show in table 6. Meanwhile, in figure 5 showed the comparison of wind speed from evaluating with actual wind data at a height of 80 meters in MAEHAE station.

Table 6 Wind shear coefficient calculated using values of wind speeds at different heights

Station	Height monitoring wind data						Wind Shear Coefficient
	α_1 (20 & 30 m.)		α_2 (20 & 40 m.)		α_3 (30 &40 m.)		
	Data	α_1	Data	α_2	Data	α_3	α_{avg}
ROMPOTHAI	4,474	0.246	5,191	0.246	4,518	0.208	0.233
PHATUNG	4,910	0.136	6,105	0.143	5,420	0.186	0.155
NORLAE	873	0.180	1,014	0.146	1,656	0.128	0.151
NONGHOI	8,025	0.191	7,089	0.148	8,391	0.210	0.149
KILLOM	5,731	0.215	6,584	0.212	5,242	0.217	0.215
MONLAN	5,672	0.195	6,222	0.146	3,865	0.178	0.173
MAEHAE	4,092	0.009	6,755	0.104	6,111	0.149	0.117

Remarks : Data is number of wind shear values from wind data 8,760 hours in a year.

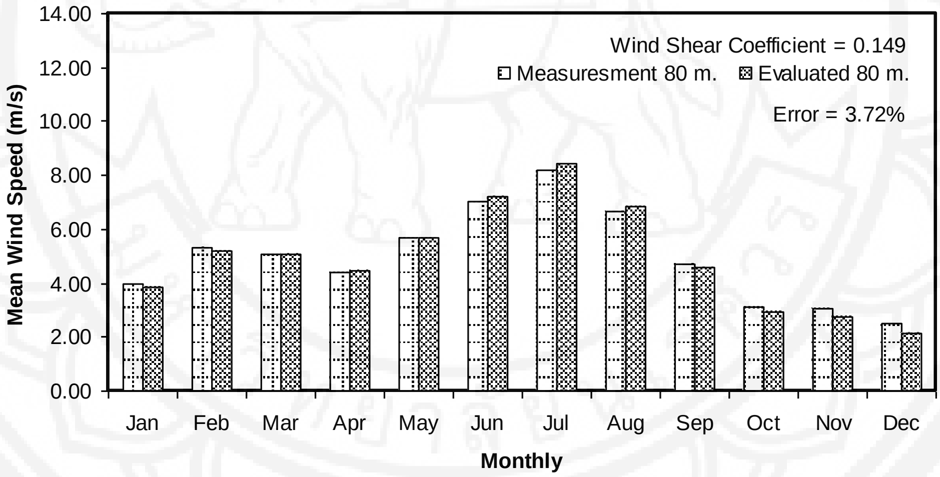

Figure 5 Compared to wind speeds from evaluate with actual wind data at height 80 m. MAEHAE station

Weibull distribution

The Weibull distribution is determined by graphical method for determining the parameter c and k and case study of KILLOM station at a height of 40 meters above ground level show in Figure 6. The maximum value of the shape parameter of 3.073, 2.489 and were found on July at KILLOM and MONLAN stations and 2.246 were found on August at MAEHAE station at the wind data calculated at 40 meter above ground level and show in Table 7. The Figure 7 shows the monthly Weibull distribution KILLOM station. The value of the scale parameter (C) was 2.89 to 4.572 m/s and shape parameter (k) were 1.432 to 1.982. The scale parameter to nearby with mean wind speed has been found difference 8.52% at height of 40 meters above ground level.

Table 7 Monthly and annual variation of Weibull parameter (k and c)

Monthly		Calculating of Weibull parameter at 40 meters above ground level						
		ROMPOTHAI	PHATUNG	NORLAE	NONGHOI	KILLOM	MONLAN	MAEHAE
January	k	1.212	1.416	1.633	1.305	1.503	1.612	1.638
	c	2.762	3.623	3.146	2.636	4.342	4.033	3.799
February	k	1.325	1.709	1.973	1.627	1.309	2.244	1.892
	c	3.843	5.269	3.792	3.956	5.845	5.032	5.074
March	k	1.435	1.616	2.248	1.541	2.028	2.412	2.111
	c	3.260	4.342	3.556	3.814	5.155	4.721	4.996
April	k	1.398	1.555	1.894	1.551	1.592	1.903	1.824
	c	3.755	4.127	3.065	3.225	4.282	4.082	4.201
May	k	1.769	1.706	2.287	1.598	1.641	2.205	1.877
	c	3.429	4.281	4.259	4.344	4.788	4.849	5.465
June	k	2.025	1.781	2.066	2.198	1.603	2.150	1.495
	c	3.504	3.812	3.628	6.145	6.112	5.426	6.363
July	k	2.234	2.151	2.018	1.803	3.073	2.489	2.019
	c	3.755	4.428	4.398	7.176	7.010	6.270	8.139
August	k	1.607	1.337	1.501	1.866	1.805	1.767	2.246
	c	2.760	2.976	3.437	5.323	3.624	4.712	6.597
September	k	1.062	1.073	1.332	1.856	1.307	1.549	0.889
	c	1.812	2.073	2.582	3.273	3.789	3.480	3.087
October	k	1.182	1.344	1.855	1.299	1.322	1.968	1.821
	c	1.836	3.103	3.977	2.628	3.661	4.185	2.958
November	k	0.926	1.168	1.477	1.349	1.209	1.480	0.899
	c	2.219	3.138	4.469	1.771	3.313	4.345	1.688
December	k	1.005	1.252	1.871	1.04	1.546	2.002	1.924
	c	1.735	2.552	3.542	1.922	2.943	3.359	2.138
Average	k	1.432	1.509	1.846	1.586	1.662	1.982	1.720
	c	2.89	3.64	3.65	3.85	4.57	4.54	4.54

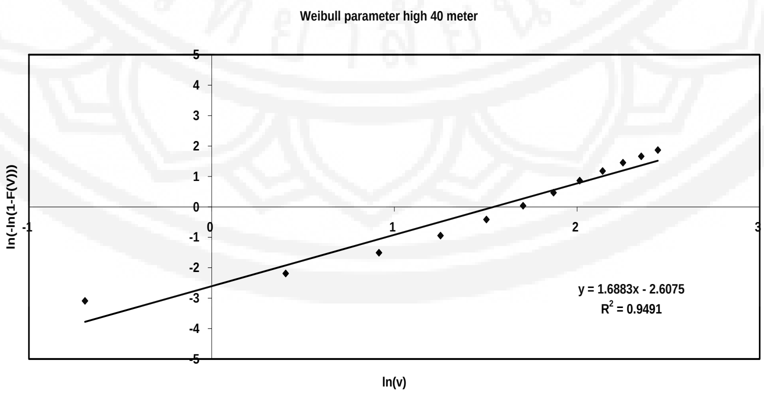

Figure 6 Weibull distribution by Graphical method on May for KILLOM station

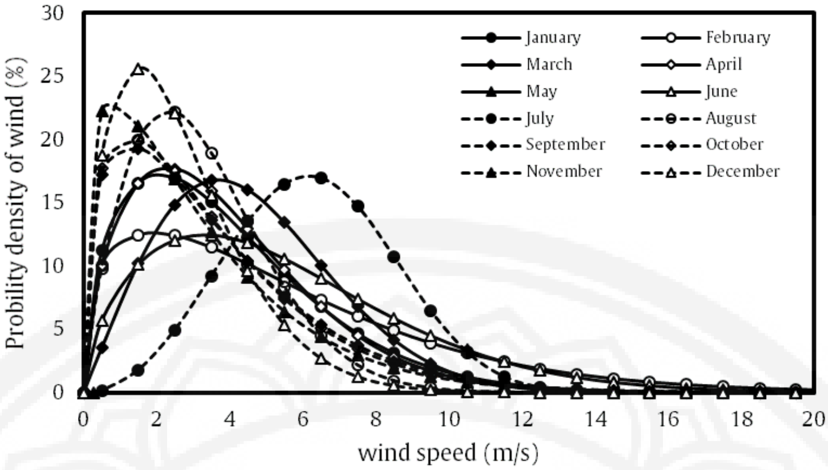

Figure 7 Monthly Weibull distribution KILLOM station at 40 meters above ground level

Electricity Generation from Wind Turbine

Wind Turbine Characteristics

The amount of power generated by a wind turbine depends on both the design characteristics of the turbine and the properties of the wind resource represented by wind speed probability density. These selected sites are suited for the generation of electricity by using wind turbines reference of this research are Fuhrländer brand from Germany with different rated power of wind turbine 600 kW and 1000 kW. The characteristic properties of the selected wind turbines are shown in table 8. The power curves for the two turbines with the different rated power are shown in Figure 8. The rated powers of these turbines were using air density standard of 1.225 kg/m^3 for calculating wind power generation.

Table 8 Characteristics of wind turbines Fuhrländer from Germany (Fuhrländer, 2015)

Characteristics	Turbine 1 (600 kW)	Turbine 2 (1000 kW)
Turbine model	FL 600	FL 1000
Rated output (kW)	600 kW	1,000 kW
Cut in (m/s)	3	4
Cut out (m/s)	20	20
Hub height (m.)	75	70
Rotor diameter (m.)	43-50	54
Swept area (m^2)	1,452-1,963	2,289
Number of blades	3	3

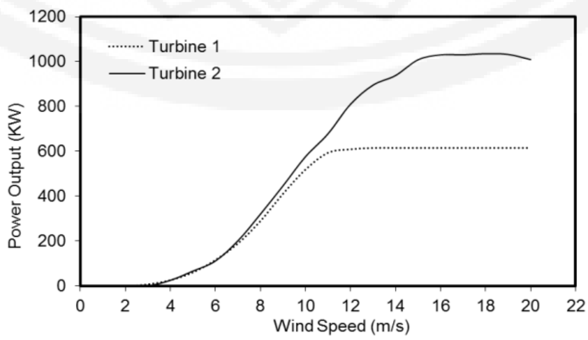

Figure 8 Power curves of FL600 and FL1000 wind turbines (Fuhrländer, 2015)

Potential of Electricity Power Generation

The table 9 to show annual energy gains and capacity factor for wind turbine power generation all stations. In case of wind turbine with a capacity of 600 kW (FL600), the annual energy output range from 656 to 997 MWh for the four stations are ROMPOTHAI, PHATUNG, NORLAE and NONGHOI. For KILLOM, MONLAN and MAEHAE stations have high potential the annual energy output range 1,432 to 1,512 MWh, respectively. In case of wind turbine with a capacity of 1000kw (FL1000), the annual energy output range from 758 to 839 MWh for the two stations are ROMPOTHAI and PHATUNG. In case NORLAE, KILLOM, MONLAN and MAEHAE stations have annual energy output range from 1,177 to 1,711 MWh. The capacity factor is performance parameters of wind turbine to calculate by equation 9. The highest capacity factor is obtained at MAEHAE station for Fuhrländer FL600 of 28.77% and Fuhrländer FL1000 of 19.54%. So, all wind sites should be installation the wind turbine capacity of 600kW because wind energy conversion (C_F) higher than wind turbine 1000kW. However, when considering power generation from wind turbine, it was found high energy more than wind turbine capacity of 600kW because at the same time the number of wind speed, which the power generation of wind turbine capacity of 1000kW to energy production higher than wind turbine capacity of 600kW. However, it should be considered in the feasibility of economic for wind turbine installation for power generation.

Table 9 Annual energy gain and capacity factor for all the stations.

Stations	FL 600		FL 1000	
	E_{out}, (kWh/year)	C_F (%)	E_{out}, (kWh/year)	C_F (%)
ROMPOTHAI	656,847	12.50	758,615	8.66
PHATUNG	726,562	13.82	839,638	9.58
NORLAE	997,766	18.98	1,177,491	13.44
NONGHOI	992,940	18.89	1,119,507	12.78
KILLOM	1,432,081	27.25	1,604,000	18.31
MONLAN	1,150,535	21.89	1,308,536	14.94
MAEHAE	1,512,210	28.77	1,711,464	19.54

Conclusions

This research has provided an assessment the wind energy and electricity generation in northern of Thailand. One year of observed wind speeds and wind direction data from 40 meters and 80 meters of meteorological station which to analysis annual mean wind speed were 3.36 – 5.03 m/s and 4.97 m/s. there are wind direction from the southwest, west, northwest and north because which under the influence of monsoon were southwest monsoon in May – October and February- May in rainy and winter seasons. The maximum energy output is found at MAEHAE station to be generated of 1,512,210 and 1,711,464 kWh/year for wind turbine capacity of 600kW and 1000kW, respectively. However, it should be considered in the feasibility of economic for wind turbine installation for power generation.

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