Feasibility Analysis of Wind Power Plant in South East Region, Vietnam

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ABSTRACT

The wind power market is expanding quickly and the cost of wind power equipment is decreasing, making wind power technology a key player in the world's energy transition. Assessing wind potential and selecting the right wind turbine site are crucial parameters for developing a wind farm. Vietnam focuses on onshore and nearshore wind power projects due to its promising wind power potential and supportive policies. However, Vietnam has diverse climate characteristics and wind patterns. Therefore, initial basic research is necessary to evaluate the feasibility of investing in wind power projects. This study examines the technical feasibility of a typical wind power project in the Southeast region of Vietnam using Wind Atlas Analysis and Application Program (WAsP) software. The results indicate that the wind turbine's type and installation location significantly affect wind power plants' efficiency. The total power output of the wind power project after factoring with losses at a rate of 17%, is 304,149 MWh.

Keywords-wind power; wind energy potential; WAsP

I. INTRODUCTION

Wind energy is seen as an important means to reduce the dependence on fossil fuels and promote a carbon zero economy [1]. Transitioning to clean and renewable energy is necessary to achieve the Sustainable Development Goals (of clean and affordable energy) by 2030 set by the United Nations [2, 3]. The wind power market is rapidly growing, and the decreasing cost of wind power equipment makes it the key to the world's energy transition [4-6]. Assessment of wind potential and wind turbine site is very important to develop a wind farm [7], since the former highly impacts a wind farm's electricity output and economic efficiency [8, 9]. The WAsP method has been widely used to assess the potential for wind power development [10, 11]. It considers the influencing factors of terrain elevation and terrain surface cover (roughness) [12, 13]. Vietnam is implementing onshore and nearshore wind power projects due to its strong wind power potential and support policies [14-20]. The government approved new price caps for transitional projects in 2023, adding 822 MW of capacity. The country aims to have 21.8 GW of onshore and 6 GW of offshore wind capacity by 2030, according to the Power Development Plan VIII (PDP 8). However, further research is needed to assess the feasibility of wind power projects, especially in the Southeast region, which is believed to have high wind energy potential [21, 22].

The study examines the technical feasibility of a typical wind power project in the Southeast region of Vietnam with the help of WAsP software.

II. METHODOLOGY

The process of calculating electricity for a project as it can be seen in Figure 1 includes the following steps:

A. *Raw Data Analysis*

A statistical summary of the wind climate at a particular location is provided by analyzing a time series of measurements performed using anemometers at the project area. Data are statistically analyzed to find parameters according to the Weibull distribution at different altitudes and main directions. Additionally, the particular data can be compared with long-term data obtained from other meteorological stations in the area.

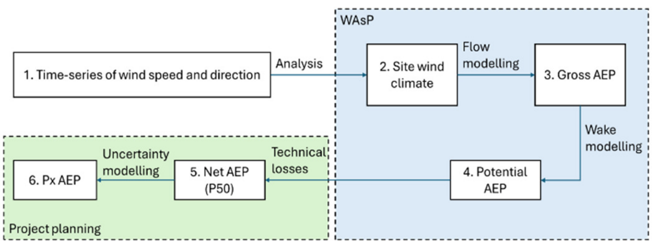

Fig. 1. Steps in the wind farm energy yield assessment procedure.

B. *Forecast Wind Data at Any Point in the Project Area*

Statistical summary results are available for one location within the project. These results include characteristics of the project area, such as terrain, roughness, and obstacles. The WAsP software can predict climate characteristics at any point within the project area. Utilizing the climate characteristics and the turbine characteristic curve (Power curve), the annual power output at any location can be calculated (Gross Annual Energy Power - AEP). However, this does not include all actual losses. To calculate the actual power output for the plant, the considered losses are:

- Wake loss: includes actual wake loss and future wake loss (due to shielding by later stages and neighboring projects) estimated at an additional 3%.
- Availability of wind turbines: wind turbines may be required to stop operating for periodic maintenance or for damaged equipment to be replaced. The availability of the turbine loss is estimated at 6% of the theoretical electricity production.
- Loss of turbine capacity characteristics is estimated at about 3%.
- Loss in the process of power conversion and transmission is 2%.
- Loss due to environmental effects such as temperature increase is about 1.0%.
- Losses due to curfew: noise, visibility, net are 2%.

The aforementioned losses are real losses calculated using the software, as well as some assumptions derived from global experience, such as those from the European Wind Energy Association. In the upcoming phase, the loss coefficients will be adjusted based on the equipment parameters supplied by the contractor. The wind speeds at various altitudes are listed in Table I and Figure 2. The average wind speed at a 100 m altitude is approximately 6.1 m/s.

Wind speed remains relatively consistent throughout the day and year. Wind energy generation is feasible, accounting for 90.29% of the year's production. The dominant wind directions are East (E) and East Southeast (ESE) from October to April, and West Southwest (WSW) from April to September.

Thus, the total technical loss is: 3+6+3+2+1+2 = 17%. After deducting technical losses, the average annual electricity output is:

$$P50 = \text{Potential AEP} - \text{technical losses} \quad (1)$$

III. CASE STUDY

The project is located in the southeastern region of Vietnam. It has been equipped with automated instruments to measure various factors, such as wind speed, wind direction, temperature, and air pressure and it is programmed to record data every 10 min on a datalogger.

TABLE I. AVERAGE MONTHLY WIND SPEED IN YEAR

Height	1	2	3	4	5	6	7	8	9	10	11	12	Avg
120m	7.65	8.85	6.48	7.22	4.45	4.55	5.61	7.69	6.33	5.04	6.00	6.98	6.40
100m	7.25	8.47	6.28	6.97	4.23	4.20	5.34	7.46	6.09	4.62	5.63	6.66	6.10
80m	7.08	8.25	6.09	6.76	4.13	4.00	4.99	7.02	5.82	4.45	5.42	6.47	5.87
60m	6.90	8.05	6.06	6.70	4.09	3.80	4.74	6.59	5.45	4.27	5.19	6.23	5.67

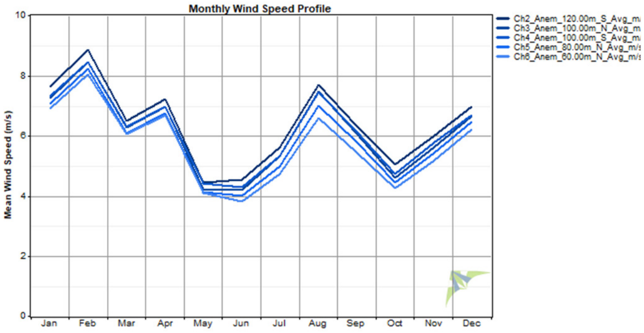

Fig. 2. Average monthly wind speed.

IV. RESULT AND DISCUSSION

The project begins by analyzing the area's wind potential and importing weather data and other characteristics into the WAsP software. Once the turbine data are imported, WAsP calculates theoretical and potential power output. This information is used for project analysis. To maximize power output, the project selects suitable turbines and arranges them to minimize wake losses. They are arranged based on wind energy distribution and terrain conditions.

This study utilized the Envision EN-156-3.0 turbine (Table II and Figure 3) installed at a height of 140 m to calculate plant energy. Figure 4 presents a wind profile graph according to the altitude at the measuring station. There are 3 proposed turbine layout plans as it can be seen in Figures 5-7.

Table III displays the power output calculations from wind turbine layout plans. Turbine distribution significantly impacts the wind farm's power output. Plan 3 was chosen because it offers a maximum equivalent of 3755 full load hours, the highest power output of 366,445 MWh, and a total power output of 304,149 MWh after deducting losses at a 17% rate. The plan has taken into account issues such as preventing encroachment from other projects and ensuring a distance from residential areas. In general, the true value cannot be accurately known, even if there is a measuring device or wind turbine to measure wind speed or output because these values themselves are determined with a certain degree of uncertainty. However, these measured values were quite close to the real ones.

TABLE II. PARAMETER OF WIND TURBINE

Parameter	Unit	Value
Rated power	kW	3000
Rotor diameter	m	156
Swept area	m^2	19113
Class (IEC)	-	S
Rated wind speed	m/s	9.1
Turbulence intensity (IEC)	-	C
Cut-in wind speed	m/s	3
Cut-out wind speed	m/s	20
Hub height	m	95/100/110/130/140

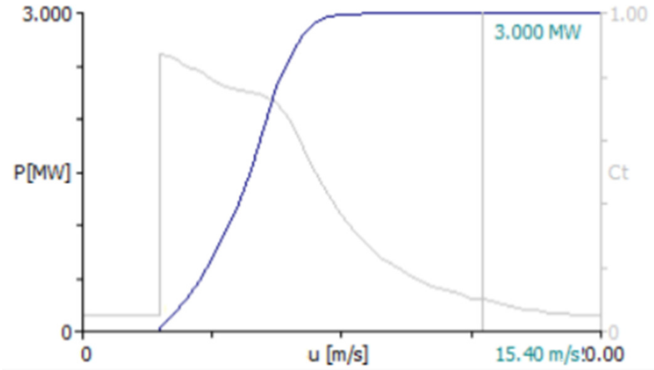

Fig. 3. Characteristics chart of wind turbine Envision EN 156.

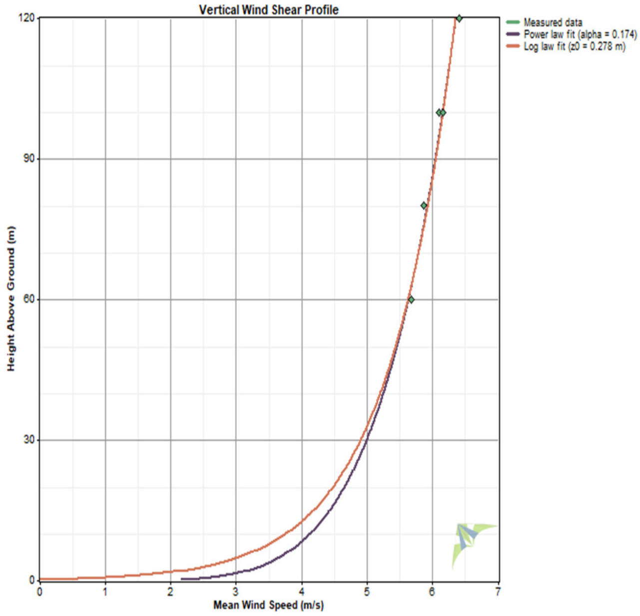

Fig. 4. Wind profile graph according to altitude at the measuring station.

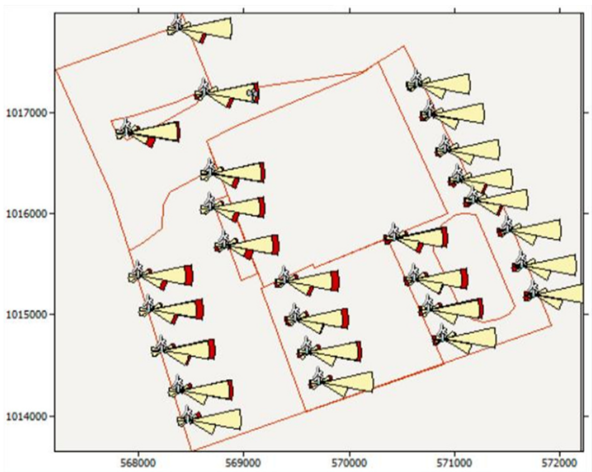

Fig. 5. Plan 1 of turbine layout.

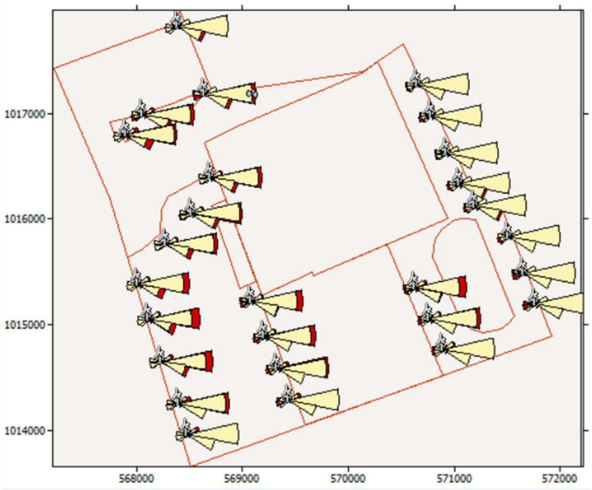

Fig. 6. Plan 2 of turbine layout.

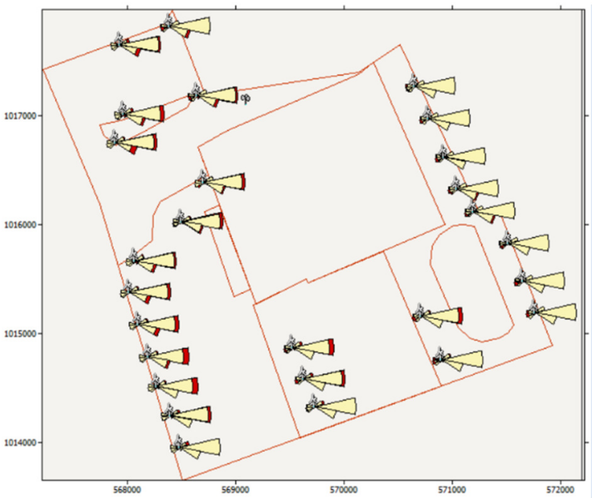

Fig. 7. Plan 3 of turbine layout.

TABLE III. ENERGY CALCULATION RESULTS

Plan	1	2	3
Capacity (MW)	80	80	80
Wind turbine	Envision EN-156-3.0	Envision EN-156-3.0	Envision EN-156-3.0
Height[m]	140	140	140
Electricity (after wake) [MWh]	361,684	362,929	366,445
Wake loss [%]	9.52	9.21	8.33
Maximum wake loss (%)	15.58	13.43	11.62
Number of wind turbines	27	27	27
Capacity utilization factor (%)	42.31	42.45	42.86
Equivalent full load (h)	3706	3719	3755
Commercial electricity (MWh) (after deducting losses) (P50)	300,198	301,231	304,149

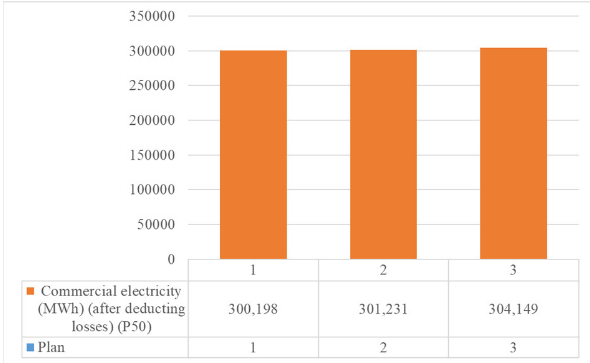

Fig. 8. Commercial electricity (MWh) (after deducting losses).

Variable	Total	Mean	Min	Max
Total gross AEP [GWh]	399.749	14.806	14.806	14.806
Total net AEP [GWh]	366.445	13.572	13.086	14.363
Proportional wake loss [%]	8.33	-	2.99	11.62
Mean speed [m/s]	-	6.94	6.94	6.94
Power density [W/m2]	-	308	308	308
RIX	-	-	0.0	0.0

Fig. 9. Power output of the selected plan.

Site description	Gross [GWh]	Net AEP [GWh]	Loss [%]
T01	14.806	14.047	5.12
T02	14.806	13.742	7.19
T03	14.806	13.836	6.55
T04	14.806	13.562	8.4
T05	14.806	13.434	9.26
T06	14.806	13.863	6.37
T07	14.806	13.977	5.59
T08	14.806	13.989	5.52
T09	14.806	13.935	5.88
T10	14.806	13.194	10.89
T11	14.806	14.026	5.26
T12	14.806	13.304	10.14
T13	14.806	13.086	11.62
T14	14.806	14.363	2.99
T15	14.806	13.800	6.79
T16	14.806	13.455	9.12
T17	14.806	13.353	9.81
T18	14.806	13.360	9.77
T19	14.806	13.476	8.98
T20	14.806	13.461	9.08
T21	14.806	13.257	10.46
T22	14.806	13.340	9.9
T23	14.806	13.233	10.62
T24	14.806	13.290	10.24
T25	14.806	13.223	10.69
T26	14.806	13.399	9.5
T27	14.806	13.442	9.21

Fig. 10. Power output of each wind turbine of the selected plan.

The model's uncertainty (or accuracy) needs to be estimated by taking into account the sum of all uncertainties in the entire calculation process. These uncertainties are generally random and uncorrelated. Additionally, any systematic deviation of the modeling results from the reference value, known as bias (or precision), needs to be addressed and corrected. Accurate estimates are characterized by low uncertainty and precision values. The mean value represents the forecasted output of WasP (P50), while the reference value is the correct value being forecasted. The power output of each wind turbine is influenced by the specific terrain conditions at its location. The research results exhibited in Figure 10 indicate that wind turbine No. 14 has the highest power output after losses, at 14.363 GWh, while wind turbine No. 13 has the lowest value, at 13.086 GWh.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The current study analyzed the power generation capacity of a wind power project in Southeast Vietnam using WAsP software. After deducting losses at 17%, the total power output is 304,149 MWh. Wind turbine No. 14 achieved the highest power output after losses at 14.363 GWh, while wind turbine No. 13 had the lowest value at 13.086 GWh.

B. Recommendations

The type and location of wind turbines in relation to wind energy potential greatly impact the success of wind power plant investments. Investors should consider factors such as wind energy potential surveys and feasibility design. This study recently estimated power output of a wind power project in Southeast Vietnam and plans to compare results with projects in other regions.

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