Research on calculation methods for wind shear index in wind farm

Xiangdong Zhu [a], Dezheng Ning, Shouyuan Fan, Wentao Zhang

China Energy Engineering Group Yunnan Electric Power Design Institute Co., Ltd., Kunming 650051, China.

[a]mcloud2028@foxmail.com

Abstract

This paper mainly compares the nine calculation methods of wind shear index in wind farm, analyzes each error, and uses case analysis to verify and summarize the reasons. The precautions when estimating the wind speed at wind turbine are proposed.

Keywords

Wind farm design, wind shear index, calculation methods.

1. Introduction

In order to meet the wind power development needs in low wind speed regions, long blade models are constantly being introduced, and large-capacity models have also become the trend of wind power technology development. These will inevitably require the height of the tower to be higher and higher. The height of the tower required by some models exceeds 140m, which is more than 40% higher than the 90m or 100m towers developed earlier, and most wind farms are often lower than 120m. it is necessary to estimate the wind speed of the hub height using the wind shear index. This article will compare various calculation methods.

2. Wind shear index

Wind shear is an atmospheric phenomenon in which wind vectors (wind direction, wind speed) change in air horizontal and/or vertical distance. There are two main reasons for wind shear, one is caused by changes in atmospheric movement itself; the other is caused by geographical and environmental factors. Sometimes it is a combination of the above two.

Wind shear is also often referred to as wind shear, which can be considered as another expression of wind profile, which is an engineering application of wind profile. The wind profile allows us to derive the average wind speed from one height to another, telling us what the average wind speed difference between the two heights is. Wind shear is used to characterize the relationship between two altitude average wind speeds.

The wind shear index is calculated by:

$$\alpha = \frac{\lg(v_2 / v_1)}{\lg(z_2 / z_1)} \tag{2-1}$$

v_2, v_1 -- measured wind speed values (m/s) for two heights

z_2, z_1 : Height corresponding to v_2, v_1 (m)

3. The calculation method introduction

Several different calculation methods are used to calculate the wind shear index, and then the wind speed is calculated according to the calculated wind shear index and power law formula, The calculated wind speed and the measured wind speed are also be compared and analyzed. The magnitude of the error, in turn, determines the accuracy of each method for calculating process.

In order to calculate the wind shear index, the following nine different methods were selected.

For data sets containing wind speeds at two or more heights above ground, calculate the power law exponent that best fits the vertical wind speed profile. To see how, we need to do a little algebra. That equation is in the general slope-intercept form: $y = mx + b$, so if we were to plot $\ln(U(z))$ versus $\ln(z)$, we would expect a straight line with slope equal to the power law exponent a, and the intercept equal to $\ln(b)$.

Use linear least squares regression to find this line of best fit, and therefore the best-fit value of the power law exponent.

Wind Shear Analysis calculates the best-fit power law exponent versus month, time of day, direction, speed, and other factors, and reports the frequency histogram and extreme values as well.

Specify as a constant

The wind shear index is calculated using the annual average wind speed.

Specify by month

Calculate the average wind shear index for each month and use it to calculate the annual data.

Specify by hour of day

Calculate the hourly average wind shear index for the year and use it to calculate the full year data.

Specify by direction sector

It is divided into 16 sectors for wind shear index calculation.

Specify by month and hour of day

The hourly average wind shear index is calculated monthly.

Specify by direction sector and month

The average wind shear index is calculated by sector and month.

Specify by direction sector and hour of day

The hourly wind shear index is calculated by sector.

Caculate in each time step

It calculates the wind shear profile from the existing, valid wind speed data in that time step. Or, similarly the wind veer rate or the temperature gradient. It checks whether that calculated parameter from this profile fits within the restricted range (if specified), and if not it limits it to the minimum or maximum allowable value. It uses the best-fit to calculate the wind speed at the desired height(s).

Specify as a constant in windspeed 3m/s~25m/s

4. Calculation Case

4.1 Data source

A wind tower with a height of 150m was selected, and the wind tower have 8 wind channels at 10m, 50m, 70m, 80m, 100m, 120m, 140m and 150m. Through the data inspection and processing, a complete year of wind energy resource data is obtained.

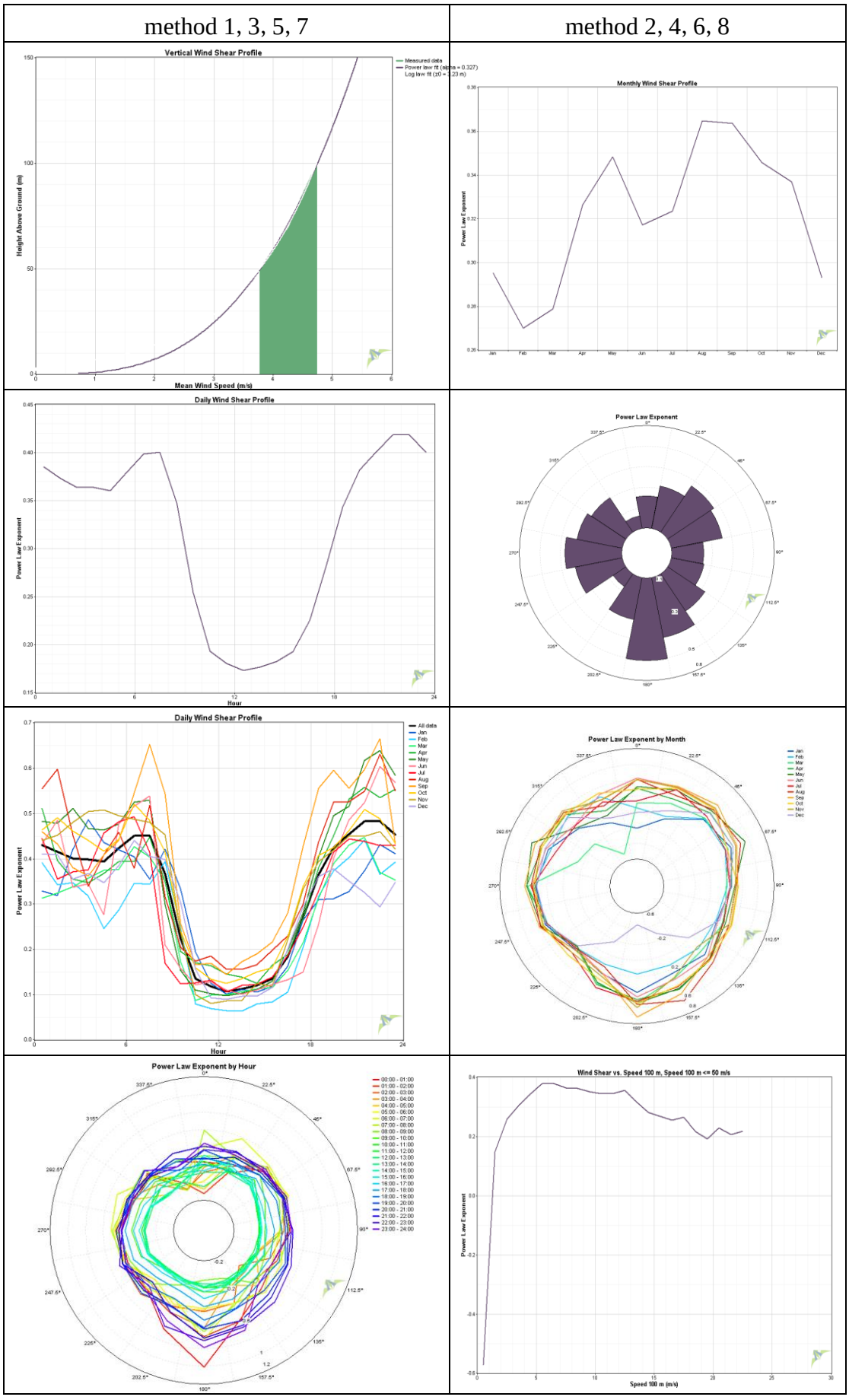

Figure 2-1 Wind shear index represented by Method 1-

4.2 Wind shear index to calculate wind speed

1) Using the nine methods in Section 2, using 50m, 70m, 80m, 100m to calculate 120m and 150m data, and comparing with the measured data, the advantages and disadvantages of the wind shear estimation method are obtained, and the height difference error is estimated.

2) Using the eight methods in Section 2, compare the difference between the estimated 150m and 50m, 70m, 80m, and 100m 150m data for 10m, 50m, 70m, 80m, and 100m, and compare the height effects.

4.3 Wind shear index calculation results

Table 4-1 Error Statistics

Calculation methods		Estimated 120m	Measured 120m	error（%）	Estimated 150m	Measured 150m	error（%）
method 1	constant（0.327）	5.028	5.01	0.36	5.408	5.292	2.19
method 2	month	5.029	5.01	0.38	5.411	5.292	2.25
method 3	hour	5.036	5.01	0.52	5.431	5.292	2.63
method 4	direction	5.03	5.01	0.40	5.414	5.292	2.31
method 5	month and hour	5.037	5.01	0.54	5.437	5.292	2.74
method 6	direction and month	5.032	5.01	0.44	5.421	5.292	2.44
method 7	direction and hour	5.038	5.01	0.56	5.439	5.292	2.78
method 8	step	5.073	5.01	1.26	5.647	5.292	6.71
method 9	Constant（0.353）	5.082	5.01	1.44	5.466	5.292	3.29

1) From the calculation results, the annual average wind shear index estimation error is moderate, these methods give results without big difference, and the annual average wind speed error calculated in various calculation methods is the smallest. The method 2~7 is used as the deformation of the method 1, and different wind shear indexes are used for the specific wind conditions, and the estimated error is slightly larger than the method 1.

Method 8 use the wind shear index at each moment to fit and estimate the wind speed at each moment. The error is large. Only the existing wind speeds of each height layer are used in the calculation of wind speed, indicating that the wind shear index is not only It is related to wind speed, and it is effective to amplify it to a statistical value of a long time period or a certain number of wind speeds.

Method 9 is to take the value between the cut-in wind speed and the cut-out wind speed. When the wind speed is below 6m/s, the shear index is small. When the wind speed is 6~8m/s, the shear index is the largest, and the 8m/s is gradually reduced, as shown in Figure 3-1. When calculating the wind shear index, it is necessary to consider the influence of the wind speed frequency below 3 m/s on the average wind shear index. In the selected data instance, the calculation error is greater than the first method, but considering the actual physical meaning, it is closer to the true wind speed at the cut-in wind speed and the cut-out wind speed segment. However, the fact is that the calculated error still reaches 4.27%. The main reason is that the wind shear index of the small wind speed section is removed in this example. The wind shear index of the small wind speed section is smaller than the comprehensive shear index, and the wind shear index is closer to the fan running time. The comprehensive shear index, but still getting larger, the larger wind shear index with larger wind shear index will bring more error.

Wind shear is not a concept with precise physical meaning. It is a numerical value fitted by mathematical statistics and is affected by topography, landform, and atmospheric stability.

Considering that wind shear is related to terrain conditions, surface roughness, atmospheric stability, etc., only certain conditions related to wind shear are considered in the month and sub-sector, and all conditions are not considered at the same time. In the actual calculation, it is often considered that the atmospheric stability is basically unchanged, which is inconsistent with the difference in the shear index corresponding to different wind speeds, as shown in Figure 3-1.

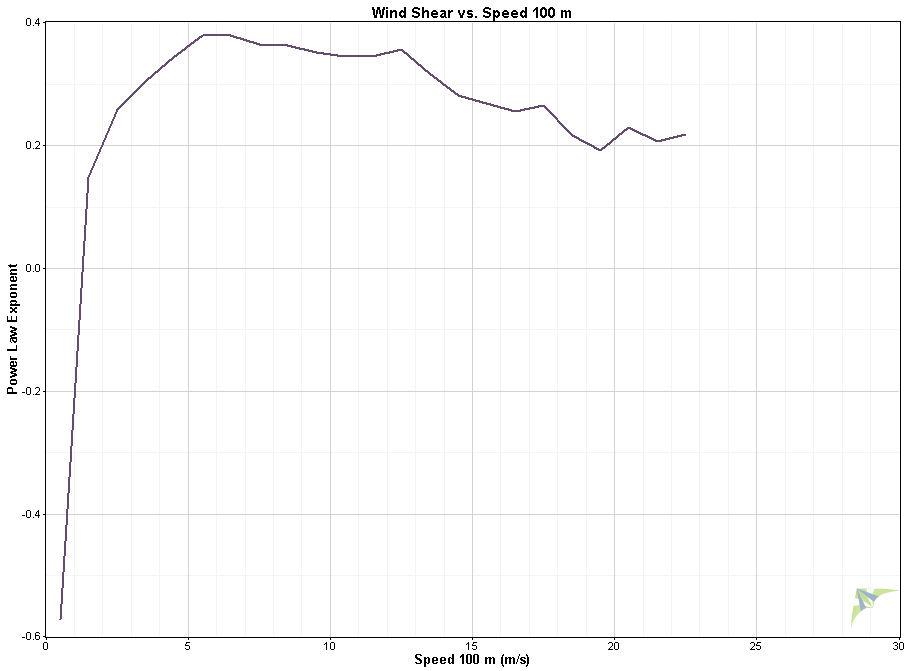

Figure 4-1 Wind shear index corresponding to different wind speeds

Based on the external conditions affecting wind shear, the calculation error considering the wind-segment segmentation method is still 2.27%, which is slightly larger than the comprehensive wind shear index calculation result.

2) The error of the calculated wind speed at 120m is obviously less than 150m. It indicates that when the height of the wind measurement data differs from the estimated height by more than 20%, the estimation error gradually increases, and the error is acceptable value within 20%.

5. Conclusion

1) By comparing various methods to calculate the error between the actual wind speed and the wind speed calculated by the wind shear index, it is found that the annual comprehensive wind shear index is the optimal method closer to the measured data.

2) Wind shear is not a concept with strict physical meaning. It is a numerical value fitted by mathematical statistics. It is actually affected by topography, landform and atmospheric stability. The instantaneous wind shear calculation is less meaningful.

3) When using the existing wind height data to estimate the wind speed of the higher layer, it is recommended that the height difference should not be greater than 20% When exceeds 20%, it is recommended to set up a wind tower with a calculated height for wind speed observation or laser radar for wind shear verification, and pay attention to the wind shear variation law of each month.

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