Research on Uncertainty of Generation Calculation in Wind Farm Design

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Abstract

This paper mainly studies the built wind farms, and makes the most accurate calculation of the power generation capacity of wind farms by following the uncertainty assessment of the theoretical power generation calculated by the software. The uncertainty of wind power generation is uncertain and unavoidable. The uncertainty of wind power generation is evaluated, and the uncertainty of wind power generation can be understood and quantified to provide a scientific basis for investment in wind power generation.

Keywords

Wind Farm Design, Power Generation, Uncertainty.

1. Introduction

According to the results of the "National Thirteen Five-Year Plan", it is estimated that the installed capacity of wind power in China will exceed 210 million kW in 2020, showing that wind power will maintain rapid development in the future as emerging energy. With the rapid development of wind power, wind speed is better, construction conditions and transportation conditions are relatively good flat terrain wind power development of the basic site is completed, more and more low wind speed wind farm development vision, these wind farms not only wind Low construction conditions are often poor, therefore, the price reduction for low-speed wind farms, the greater impact on the calculation of the accuracy of the calculated results of the feasibility of the project is particularly important. Existing projects are the theoretical reduction of the amount of power, the choice of the reduction factor is often subject to engineering and technical personnel subjective.

The more important purpose of this project is to provide a feasible method to study the calculation result of wind power generation, hoping to make the work of microscopic siting of our institute more scientific, meet the investment needs, and also the follow-up wind power Field general contracting, as a technical reserve, to provide a scientific basis for the guarantee of power generation.

2. Fundamentals of Uncertainty

A confidence interval is the range of predictions that can occur when a certain confidence level (eg, 95%) is reached. It is also understood that 95% of the predicted amount will appear within this confidence interval. We can define this confidence interval as a statistical uncertainty. Obviously, if we extend the confidence interval, then the accuracy of the prediction of more confidence. For example, if the estimated annual energy production (AEP) interval is increased from (10 ±0.1) GWh / year to (10 ±10) GWh / year, then it is more confident that the actual generation falls within this interval , That is, a higher degree of confidence. Thus, for the same calculation, we always choose the one with the smallest uncertainty, that is, the one with the smallest confidence interval. So that the error range of the result is the smallest under the same confidence level.

Wind resource calculation is largely a statistical process, so understanding the statistical uncertainty is crucial. Uncertainty is a more effective way to quantify the credibility of estimation results. In the field of wind resources and micro-site selection, the estimated wind speed is the average annual wind speed or average annual power generation. If the uncertainty is not quantified, the results are almost meaningless. Because it is not possible to determine the extent to which the results are plausible and can not determine the magnitude of the resulting errors, such a result is clearly insufficient to guide the investment decisions of the wind farm.

Uncertainty in the study of wind resource assessment is in fact seeking the standard deviation of the normal distribution. The uncertainty of a well-measured wind tower is usually 2%, which means that the standard deviation of the mean wind speed measured is 2%. The standard deviation of 2% of the wind farm with an average wind speed of 9 m / s corresponds to a wind speed of 0.18 m / s (9 m / s x 0.02). It is important to note that this does not mean that the accuracy of the anemometer is 2% soil.

There are many independent sources of uncertainty in the assessment of wind resources or the assessment of wind farm generation, which need to be separated and quantified. Quantitative uncertainty can be termed uncertainty. The total uncertainty can be calculated simply by summing these independent uncertainties.

For the two components of uncertainty that can be separated, but clearly not independent of each other, the total uncertainty should be the product of two uncertainties, namely,

$$\sigma = \sqrt{\sigma_1 \sigma_2} \tag{2-1}$$

If the uncertainty values are not independent of each other, the total uncertainty is 3.26%, which is much smaller than the results calculated by the formula (2-1).

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3. Uncertainty analysis main content

There are three main types of power generation:

1) Uncertainty of the wind flow model

CFD model is still under development, although its accuracy is increasing, but there are still errors, CFD model in some local terrain there is over-estimated or underestimated, this calculation makes the difference between the difference between generating capacity and the actual generating capacity deviation , If not a certain assessment, especially in the overestimation of the economic investment to bring a great loss.

2) Uncertainty in wind resource assessment

At the same time, the initial assessment of wind energy resources in the micro-site selection process will also produce errors, which will make the CFD model is very precise case, the calculation of the theoretical power will be biased.

3) Uncertainty of loss reduction

We calculate wind power and CFD model as the theoretical power generation. We also consider the power loss due to wake effects, fan utilization, electrical losses, power curve differences, leaf contamination, and climatic factors. When these losses are assessed, the reductions are often between 20 and 35%, and a difference of more than 10% in this reduction can also result in deviations from the actual value of the assessment, affecting the investment analysis.

As mentioned above, there are three main types of power generation, which are independent of each other. There are some influential factors among them, but they are relatively small and are independent of each other. In this paper, the above three types are studied.

4. Uncertainty Analysis Case

4.1 Average wind speed sensitivity analysis

The uncertainties of the wind farm capacity assessment can be divided into two groups: the uncertainty of the wood determinants that affect the annual mean wind speed and the uncertainty of the direct influence on the generation (energy), which can be transformed into the latter by the sensitivity analysis.

If the average wind speed of the wind farm is reduced by 1%, how much energy will be reduced? The answer to this question is the process of average wind speed sensitivity analysis. The average wind speed sensitivity is mainly related to the Weibull distribution and the fan power curve.

W wind farm is 8.6m / s, the Weibull distribution parameter k = 2.96, a = 9.63, according to Weibull distribution function formula.

$$P(v_1 < v < v_2) = \exp\left[-\left(\frac{v_1}{a}\right)^k\right] - \exp\left[-\left(\frac{v_2}{a}\right)^k\right] \quad (4.1\text{-}1)$$

The average wind speed is reduced by 1% and the average wind speed is 8.51m / s. The two wind speeds and the values of a and k are respectively taken into the formula (4.1-1). AEP1 = 367186.3Wh / year and AEP2 = 360955.4 kWh / Equation (4.1-1) finds S = 1.7%.

W wind farm was put into operation in 2012, and the actual wind speed and power generation of W wind farm in 2013 and 2014 were calculated and sorted out.

Comparison of wind speed calculation difference and power generation difference

As shown in Fig. 4.5, for the W wind farm, the difference in wind generation is 1.8 times the wind speed difference, that is, the sensitivity is 1.8%, and the wind speed difference of 1% corresponds to the difference of 1.8%. And the sensitivity of S = 1.7% is calculated using Equation 4.1-1. When the wind towers are representative, the average wind speed sensitivities calculated by Eq. 4.1-1 are more reliable.

In wind farms, it is often acceptable to compute 5% of the variance in power generation, taking into account extreme cases where the software is overvalued at 50%, 50% normal or 50% underestimated, and 50% normal. Separate aircraft, the average wind speed difference of 8%, power generation difference of 14.4% or less are acceptable.

4.2 Uncertainty assessment of wind farm generation

Taking the W wind farm as an example, the main factors influencing the type of power generation are calculated item by item. Table 4.2-1 shows the evaluation table for the uncertainty of W wind farm power generation.

Table 4.2-1. Uncertainty assessment tables for W wind farms

Uncertainty Type		Correction and Reduction	Type Variables	Standard Deviation (%)	AEP Standard Deviation (%)
1	Wind resource data			3.54	6.36
1.1	Wind speed measurement	/	wind speed	1.5	2.7
1.2	Long term correction	/	wind speed	1.5	2.7
1.3	Interannual Differences	/	wind speed	2	3.6

1.4	Future Uncertainty Fix	/	wind speed	2	3.6
2	CFD Modeling			3.24	5.44
2.1	Representative of the wind tower	-5	Power generation	1	1
2.2	Vertical extrapolation	/	wind speed	1.5	2.7
2.3	Horizontal extrapolation	/	wind speed	2.5	4.5
2.4	Forest / Power Generation	/	Power generation	1	1
3	Loss reduction			6.24	6.86
3.1	Effect of wake currents	-2.9	Power generation	2	2
3.2	Fan availability	-5	Power generation	5	5
3.3	Electrical equipment and losses	-3	Power generation	1	1
3.4	Power Curve	-5	Power generation	3	3
3.5	Leaf pollution	-2	Power generation	2	2
3.6	Climatic factors	-3	Power generation	2	2
SUM		-23.24		7.87	10.82

From Table 4.2-1, it is known that the uncertainty of WEP wind farm AEP is 10.82%, that is, the difference of power generation caused by about one σ, that is, the value of P84 is taken into account.

Using the normal distribution to evaluate the power generation calculation results, then:

P50 = [mu] = 3812h

σ = 3812 × 10.82% = 412.5h

P75 == μ-0.6745σ = 3812-0.6745 ×398 = 3534h

P84 = [mu] - [sigma] = 3812-398 = 3400h

P90 = μ-1.28σ = 3812-1.28 ×398 = 3284h

P99 = μ-2.33σ = 3812-2.33 ×398 = 2851h

According to different power generation assessment results, the financial internal rate of return of its own funds is calculated. In the financial evaluation of W wind farms, P50 or 3812h is used to calculate, and the uncertainty is evaluated by 3400h corresponding to P84.

W wind farm as a result of better power generation, anti-risk ability. For different wind farm needs to assess different Px value, from a financial evaluation point of view, P90 for most projects is more appropriate for the P90 project capital financial internal rate of return equal to 8% of the time when the inverse, the annual equivalent hours The number of 2120h , we can see that for a lower than 2120h on-grid power of the wind farm P50 and P90 are quite different, that is relatively poor power on the wind farm, P90 assessment is necessary .

5. Conclusion

1) There are three types of power generation, which are uncertainty of wind flow model, uncertainty of wind resource assessment and uncertainty of loss reduction. These three factors are independent of each other and exist within each influencing factor Some impact, but relatively small, the default is independent of each other.

2) Due to China's national conditions, usually using P50 (that is, 50% of the probability of overrun) for financial decision-making, due to China's national politics, policy stability, internal and external conditions can be controlled, using P50 to assess the risk in China there is no problem, but In many places, the risk is often unpredictable, especially the policy, duration and so easy to deviate from the expected future bad debts is very large, for similar foreign engineering decision-making approach, the application of wind farm power generation, investment decisions , The power generation quantities P75 and P90 are evaluated. P50 is a standard deviation of the difference, for different wind farms need to assess different Px value, from the financial evaluation point of view, P90 is the standard deviation of the power generation, For most projects is more appropriate, the P90 project capital financial internal rate of return equal to 8% of the time when the inverse, the annual equivalent hours is 2120h. For a wind farm with less than 2120h of grid capacity, P50 and P90 are quite different, ie it is necessary to evaluate the P90 for wind farms with relatively low power consumption.

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