Study on Calculation of Power Generation in Micro Terrain of Complex Terrain

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Abstract

Complex terrain areas due to the acceleration effect is better, these complex terrain wind farm development efforts are increasing, and complex terrain will make the atmospheric boundary layer flow around the flow, eddy current and separation or even return, resulting in large differences in wind speed, turbulence The intensity increases, the inflow angle exceeds the design value, thus affecting the efficiency of wind power generation, destroying the safe operation of the fan and reducing the life of the fan. The complex terrain area is mainly micro terrain, the software calculation results are quite different, need to sum up the actual power generation results to modify the analysis. According to the CFD model under the complex terrain, the over - estimated area is modified to improve the wind speed and turbulence, and the power generation is improved. The underestimation of the region and the calculation of the normal part of the local area has been adjusted to improve revenue and reduce risk.

1. Introduction

With the rapid development of wind power, the wind speed is relatively stable, the construction conditions and transportation conditions are relatively good flat terrain wind power site basic development is completed, some complex terrain (such as ridge, valley, Pass, cliff, forest cover, etc.) As the acceleration effect is better, the development of these complex terrain wind power is growing, the relevant research is gradually deepening. And the complexity of the terrain will make the atmosphere boundary layer flow around the flow, eddy current and separation or even return, resulting in a large difference in wind speed, turbulence intensity increases, the inlet angle over the design value, thus affecting the efficiency of wind power, damage the safe operation of the fan, Reduce the life of the fan. Therefore, micro-site selection in wind farm development has become very important. The process of arranging and selecting the wind power generators in the wind farm is called micro-site selection. The micro-site selection mainly solves the problem of power generation and fan safety. The power generation and wind speed, wind direction, air density, Turbulence intensity and so on. The safety of the unit is related to the average wind speed, turbulence intensity, extreme wind condition, wind shear and so on. That is, the micro-site selection needs to study the distribution of wind energy resources at each point of the site.

2. Calculation method

A numerical simulation method based on computational fluid dynamics is used to estimate the wind resource from the measuring point to the position of the fan at the hub height. This chapter introduces the establishment of three - dimensional numerical fluid model, and gives the wind resource map and the theoretical power generation in the field according to the local wind condition in the three - dimensional flow numerical model of the wind field.

In order to obtain the distribution of the measured wind data in the wind farm to obtain any other position distribution, in order to obtain a high-resolution three-dimensional wind resource map, the need for numerical modeling. By entering the digital terrain model, which includes terrain height and roughness data information. Using RANS (Reynolds average Navier-stokes) equation to solve RANS simulation of three-dimensional wind field, that is, in the field of measured wind resources conditions, the simulation of wind resources to obtain the three-dimensional model. In complex terrain wind farms, it is generally necessary to set up two or more wind towers at least within the wind farm to conduct cross-tests to verify the rationality of the calculation results. CFD technology allows the calculation of a specific location of the wind flow variables, even in the absence of the actual measurement of the fluid in order to further understand the relevant properties of the fluid.

The numerical solution of any fluid problem needs to solve the fluid motion equation: Navier-Stokes equations and continuous equations. Fluid equations can be described mathematically by these equations. These equations are a set of coupled nonlinear partial differential equations and have their specific boundary conditions, which are derived from the Newton's second law and follow the momentum conservation.

The basic form of the three-dimensional incompressible instantaneous N-S equation is shown in (1):

$$\frac{\partial(\rho\mu_i)}{\partial t} = -\frac{\partial(\rho\mu_i\mu_j)}{\partial x_j} - \frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\mu\left(\frac{\partial\mu_i}{\partial x_j} + \frac{\partial\mu_j}{\partial x_i}\right)\right] + F \quad (1)$$

The continuity equation is shown in equation (2):

$$\frac{\partial\rho}{\partial t} + \frac{\partial\rho\mu_i}{\partial x_i} = 0 \quad (2)$$

3. Special terrain law

When the number of wind towers is large, it can often represent the wind speed of most ridge, but some local areas, there are some micro-terrain, such as windward slope, leeward slope, branch ridge, solitary peak, Pass, etc., often not necessarily set up Wind tower, or in some micro-terrain on the establishment of wind tower, but the representative is limited, according to the previous calculation results and actual operating data comparison, the need for some special terrain to calculate the rationality of the test.

In some local terrain, such as windward slope, leeward slope, branch ridge, solitary peak, Pass, etc., and the location of the wind tower is not enough ridge, the software calculation results are often greater with the actual deviation. Although most of these micro-terrain seats only a few seats, these seats are prone to wind speed deviation of 10%, such as the average annual wind speed 7.5m / s is 6.7m / s, often affect the power generation More than 20%.

Local area correction law is based on experience to determine a certain terrain calculation is unreasonable, often the Bureau of the region without measuring wind tower or wind tower representative is poor, generally in the synthesis of 5 to 10 on the basis of the basis of the summary Experience library to amend.

The results of the software are compared with the actual results, and the clustering analysis is carried out.

Table.1 Calculation of the results of the classification table

Serial number	affects wind speed	(%)
1	underestimated	
1.1	Gully acceleration (height difference 3D above)	10 ~ 20
1.2	Gully acceleration (height difference below 3D)	5 ~ 10
1.3	Pass terrain (mouth width 4D or more, the machine is located in the middle)	15
1.4	gentle slope (windward slope is less than 25 degrees, leeward reduced to 10 degrees or less)	10
2	overestimate	
2.1	windward slope (10 ~ 35 degrees) slope (from the top is greater than 4D)	10 ~ 30
2.2	Windward slope (45 degrees above) slope (from the top is greater than 4D)	50 ~ 60
2.3	Windward slope (45 degrees above) slope (less than 4D from the top) is not recommended development	
2.4	windward slope (more than 45 degrees) after the slope (from the top is greater than 1D)	60~ 80
2.5	Passed terrain (mouth width 4D below, wind direction assessment)	10 ~ 25
2.6	independent hills	8
2.7	branch ridge (middle)	20
2.8	branch ridge end	12
2.9	sector barrier terrain (height difference is less than D, distance is greater than 5D)	6 ~20
2.1	sector obstacle terrain (height difference greater than D, distance less than 10D)	60
2.11	micro terrain, resolution	10
2.12	along the ridge (no height difference)	25 ~ 50
2.13	along the ridge (gradually increased)	15 to 25
2.14	along the ridge (gradually reduced)	40 ~ 60
2.15	gentle slope (windward slope is less than 25 degrees, downwind, 10 degrees above)	10~ 30
2.16	Cliff edge 0.5D outside (downwind)	40 ~ 60

The results of the statistics are impressive, and there is no over-estimation and underestimation of the same terrain, and both overestimation and underestimation occur in different local terrain. In most wind farms, about 70% of the airfields are located within 2 km of the wind tower, indicating that the wind towers are critical in microscopic site selection. But the representative of the tower is different (to W wind farm as a 6 tower near the 15 seats located within the error range, No. 7 tower 5 seats, 8 tower 10 seats), which also shows that the wind The representation of the tower is limited, not only with the distance, but also the terrain is similar (into the wind conditions) related. According to the CFD model under the complex terrain, the over - estimated area is modified to improve the wind speed and turbulence, and the power generation is improved. On the underestimation of the region and the calculation of the normal area of the aircraft were adjusted to increase the position. Through the local conditions of the design of the actual control of the terrain, combined with software results can be avoided most of the overestimated areas, while the wind energy resources in the region or underestimated the location of the optimal adjustment of the layout, increase the position. By selecting the appropriate confidence factor, adjust the local terrain area to avoid risk. There is still a need for additional wind towers or temporary winds for areas where the wind towers are underrepresented.

4. Conclusion

1) CFD calculation software and the actual results show that in the vicinity of the wind tower or wind conditions similar to the region, the results of a better consistency.

2) In the complex terrain conditions, by collecting the actual power generation data, summed up some laws can be used to guide the calculation. In the micro-terrain conditions, the software calculation results will be overestimated or underestimated, such as gullies, Pass terrain, the software is often underestimated, in the branch ridge, windward slope, obstacle wind and shadow area will be overestimated.

3) In the case of engineering conditions permit, improve the resolution of the grid (numerical reduction), which will help improve the accuracy of the calculation.

4) Under the current technical conditions, the feasible scheme is based on the results of software calculation by summing up the experience, careful arrangement under the micro terrain conditions, reduce the risk, in addition, you can study the representative of the project wind tower, the appropriate increase wind tower The

5) It is necessary to carry out the uncertainty assessment of the relatively poor wind power (such as the annual equivalent of 2120h below).

Fan layout is a complex knowledge, from the perspective of physics to solve the cause of this change is slow, taking into account the current development of wind energy resource computing technology, the current feasible program is to sum up the existing micro-terrain conditions Under the law of the wind, combined with software calculation results, follow-up projects encountered similar cases, to avoid some risks.

References

[1] Meroney R N. Ten questions concerning hybrid computational/physical model simulation of wind flow in the built environment [J]. Building and Environment, 2016, 96: 12-21

[2] Ishugah T F, Li Y, Wang R Z, et al. Advances in wind energy resource exploitation in urban environment: A review [J]. Renewable and Sustainable Energy Reviews, 2014, 37: 613-626

[3] Fitch A C, Lundquist J K, Olson J B. Mesoscale influences of wind farms throughout a diurnal cycle [J]. Monthly Weather Review, 2013, 141(7): 2173-2198

[4] Rai M M. Utilizing Direct Numerical Simulations of Transition and Turbulence in Design Optimization [J]. 2015

[5] Takanori Uchida, Yuji Ohya. Latest Developments in Numerical Wind Synopsis Prediction Using the RIAM-COMPACT® CFD Model—Design Wind Speed Evaluation and Wind Risk (Terrain-Induced Turbulence) Diagnostics in Japan [J]. Energies,2011,43

[6] Renard N, Deck S. Improvements in Zonal Detached Eddy Simulation for Wall Modeled Large Eddy Simulation [J]. AIAA Journal, 2015, 53(11): 3499-3504

[7] Sagaut P, Deck S, Terracol M. Multiscale and multiresolution approaches in turbulence: LES, DES and hybrid RANS/LES methods: applications and guidelines [M]. World Scientific, 2013

[8] Abou-Taouk A, Farcy B, Domingo P, et al. Optimized Reduced Chemistry and Molecular Transport for Large Eddy Simulation of Partially Premixed Combustion in a Gas Turbine [J]. Combustion Science and Technology, 2016, 188(1): 21-39

[9] T.S. Yeow, A. Cuerva‐Tejero,J. Perez‐Alvarez. Reproducing the Bolund experiment in wind tunnel [J]. Wind Energ.,2015,181

[10] Alexandru Cezar Vladut,Costin Ioan Cosoiu, Andrei Mugur Georgescu,Mircea Degeratu,Radu Mircea Damian. Wind Tunnel and Numerical Modeling of Atmospheric Boundary Layer Flow Over Bolund Island [J]. Energy Procedia,2016,85

[11] Cavaglieri D, Bewley T, Mashayek A. Diablo 2.0: A modern DNS/LES code for the incompressible NSE leveraging new time-stepping and multigrid algorithms [J]. Bulletin of the American Physical Society, 2015, 60