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Wind Energy Resource Assessment Based on WRF Model and Key Model for Micro-site Selection of Wind Farms

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Abstract: Wind energy is an important renewable energy the development and utilization of wind energy is of great significance for reducing greenhouse gas emissions, alleviating energy crisis and promoting sustainable development. The purpose of this paper is to study a basic wind energy resource assessment model based on the WRF model. First, the relevant theories of WRF model and wind farm micro-sitting are analyzed. With the technical support of spatial analysis, processing and modeling, combined with the above functional modules, a wind power resource assessment and wind farm micro-selection system based on the WRF model has been developed. Finally, the simulation verifies the comparison with the ground observation data of the meteorological station in City A in December 2020. The comparison meteorological field is the wind speed at a height of 15 meters above the ground. The results show that the simulated value and the observed value are basically consistent, and the extreme points of each wind speed are basically the same. It is simulated, and the simulated value is slightly higher than the observed value by 0.5-1.5m/s.

1. Introduction

Wind energy is essentially a variable form of solar energy, but the development and utilization cost of wind energy is lower than that of solar energy. As an important renewable resource, wind energy has the characteristics of large reserves, renewable energy, wide distribution, and no pollution. Although wind energy resources are abundant and widely distributed, due to the influence of climate, terrain and human production activities, the distribution of wind energy resources across the country is extremely uneven. The cost of wind power systems in some areas is greater than the output, so not every area is suitable for building wind farms. In order to effectively develop and utilize wind energy, it is urgent to discuss and study the issues of wind energy resource assessment

[1-2].

For the early wind farm micro-site selection work, researchers are generally used to adopting a regular wind turbine layout scheme. Markina M, Analyzed the effect of spectral information formulations (longitudinal angle and depth of cut, using full weights and data review) on a 1-year simulation (2010) of 10-meter wind speed and wind field performance. The wave model uses the third generation wave model WAVEWATCH III. The sensitivities of the atmospheric and wave models to the optimal correction formula are investigated by comparison with simulated and observed data. The results show that the reconstructed data have strong stability and consistency in each period, and the annual cycle and regional pattern have nothing to do with the actual parameters of the experiment [3]. Rather N's research was used to obtain India's biomass potential and its resource assessment. Energy produced by hybridization of biomass could prove to be a boon for India. Uttar Pradesh produced the highest cumulative biomass based gasifiers and cogeneration units. Biomass gasification of agricultural residues based on dried husks and sugar cane estimates the biomass power generation potential in Uttar Pradesh alone to exceed 3000 MW. Countries such as Tamil Nadu, Maharashtra, Andhra Pradesh and Chhattisgarh have also developed over 1,500 MW of biomass power generation alone. Jammu and Kashmir has the greatest biomass potential in forest residues and horticultural crops [4]. Bentos TV examined the effects of fire and topography on the growth and survival of four native tree species (Pouteria caimito, Garcinia macrophylla, Dipteryx odorata and Cynometra bauhiniaefolia) planted in the grasslands of the 26-year-old second forest basin. Artificial light gaps in the closed canopy and background of the control samples were evenly distributed in soil and near-water pond soil. Seeds were randomly planted in plots and monitored for 28 months. Seed survival was high (93%) and did not differ between species. Overall, the light gap increased seedling height by 38% compared to the control. Although these four species occur naturally in mature forests, two of the four species grow significantly more in light gaps than in the closed canopy of secondary forests [5]. These studies provide another basis for the site selection operation of practical projects.

Based on the WRF model, this paper studies the basic model of wind farm micro-location, and designs and develops the wind energy resource assessment and wind farm micro-location system. From a macro perspective, wind energy resource assessment can predict the theoretical wind energy resources of a certain area as a whole, and provide a basis for the development of wind energy resources. Effective assessment of wind energy resources is the premise and foundation of wind energy resource development. From a microscopic point of view, the wind farm micro-device studies the optimal site selection and layout of wind turbines under specific ground and wind conditions, achieves the maximum annual power generation at the minimum cost.

2. Wind Energy Resource Assessment Based on WRF Model and Research on the Key Model of Wind Farm Micro-Site Selection

2.1. WRF Mode

The WRF model was developed by the National Center for Atmospheric Research (NCAR). The Federal Aviation Administration (FAA) joint next-generation mesoscale forecast model and real-time forecast experiment of the coordination system show that the WRF model system has good performance in predicting different climates [6-7]. The ground coordinate σ of the system is along the vertical direction, and the model includes physical processes such as surface processes, boundary layer physical processes, subgrid turbulent diffusion processes, atmospheric and surface radiation, microphysical processes and cumulative transport [8-9].

2.2. Wind Energy Resource Assessment for Wind Farm Development

The main purpose of wind energy resource assessment in wind farms is to serve the site selection of wind farms and the setting of wind turbines in wind farm construction. Such small-scale wind energy resource assessments can also provide key technical support for the current focus on decentralized development. In the evaluation of wind energy resources of wind farms, the resolution requirements are relatively high. Generally, the resolution is below, and we need to use a small-scale model for simulation calculation [10-11].

2.3. Parameter Description of Wind

(1) Wind direction

Refers to the direction the wind is blowing, generally determined by the wind vane. The wind direction is usually expressed in 16 azimuths, which are generally caused by atmospheric circulation and vary with the seasonal average. Long-term observation in a region can obtain the number of wind direction observations in each azimuth, which can be divided by the total number of observations in the statistical period to obtain the wind direction frequency in each azimuth [12-13].

(2) Wind speed

Wind speed refers to the distance of airflow per unit time, generally expressed in m/s. Wind speed can be measured with an anemometer. Radiator anemometers, rotational anemometers, and acoustic anemometers are common anemometers. Because the wind speed changes rapidly, in order to describe the wind speed more comprehensively, several parameters are often used to describe the wind speed in the application. The instantaneous wind speed refers to the wind speed measured by an anemometer in a period of time; the average wind speed refers to the average value of the observed wind speed in a period of time [14-15]. The maximum wind speed refers to the maximum instantaneous wind speed in a period of time, the composite wind speed refers to the vector sum of the wind speed and the wind direction [16-17].

(3) Wind energy and wind energy density

Wind energy refers to the kinetic energy generated by wind movement, representing the amount of wind energy resources stored in nature. The weight of the wind is measured by the weight of the wind and the cube of the wind speed. Therefore, wind speed has a decisive influence on the accuracy and scientificity of wind energy assessment [18].

3. Design and Implementation of Micro-sitting System Based on WRF Model

3.1. Analysis of Micro-site Selection in Continuous Space

The wind map shows the wind direction distribution, where the length of each sector represents the wind direction distribution, the annual wind speed distribution takes the Weibull distribution, and the probability density function is:

$$f(v)=\frac{k}{c}\left(\frac{v}{c}\right)^{k-1}\exp\left[-\left(\frac{v}{c}\right)^{k}\right] \tag{1}$$

The main purpose of microsites is to reduce interference between wind turbines and increase the power generation efficiency of wind farms. Furthermore, to ensure safe operation of the fans, the minimum clearances between the fans must be observed. Knowing the wind power movement p(v) and the wind power distribution of the wind, the function of the total annual power of the wind farm is:

$$F(z)=\sum_{j=1}^{N}\rho_p\left[\sum_{i=1}^{M}\int_{v_{im}}^{v_{out}} f(v)p_i(v_p)dv\right]-\gamma\sum_{r=1}^{C}\left|\min\{0,g_r(z)\}\right| \tag{2}$$

Among them, N is the number of wind directions, Pp is the proportion of P wind directions, f(v) is the Weibull distribution function of wind speed, and M is the number of fans.

3.2. Basic Framework of the System

The program is based on the world's first open-source ERSI open-source GIS software AcrGIS regional information system platform, and uses the VB.NET development language to call the software components provided by ArcGIS that conform to the COM framework for integration and school-level engine development of high-level component libraries.

The site selection system developed in this paper mainly realizes the following functions: ①Simple and quick aerial data entry function; Map, wind-based grid map design; weather station, etc. Speed improvement and efficient use of working machines, ⑦ Rich design functions, intuitive and intuitive and clear display of calculation results.

3.3. System Design

The main goal of the system is to achieve wind energy resource assessment and micro-site selection of wind farms. The main functional modules are shown in Figure 1.

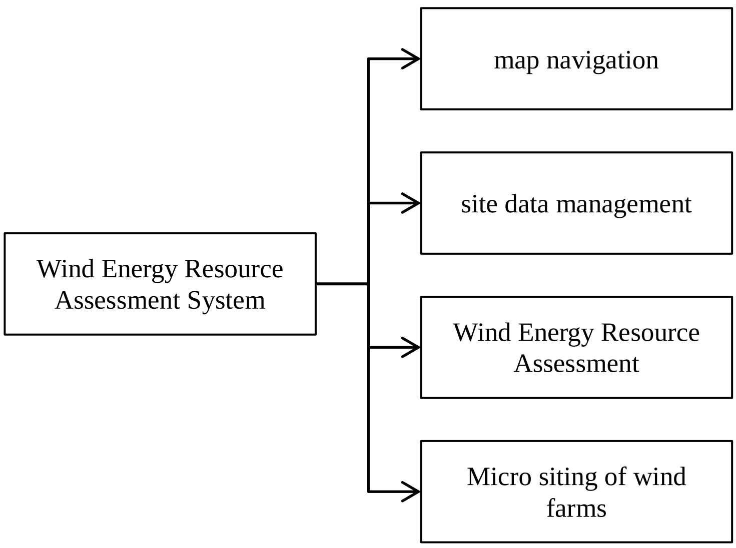

Figure 1. System function block diagram

The main functions of the system include map navigation, meteorological site data management, wind energy resource assessment and wind farm micro-site selection modules. Among them, map navigation includes common functions such as zooming in, zooming out, panning, and querying; meteorological station data management implements functions such as warehousing, sorting, and statistical calculation of QCLCDASCII data, including the elimination and naturalization of some duplicate records. Elimination of serious sites, calculation of Weibull distribution parameters, calculation of site wind energy density, etc; The location selection module realizes the extraction of factors affecting the wind speed by terrain, and the core function is the micro-location function of wind farm based on genetic algorithm.

4. Analysis and Research on the Key Model of Wind Energy Resource Assessment and Micro-site Selection Based on WRF Model

4.1. Simulation Scheme

The simulation verification is compared with the ground observation data of the weather station in City A in December 2020. The meteorological field for comparison is the wind speed at a height of 15 meters above the ground. The comparison time is 05, 10, 15, and 20 every day, a total of 4 times. The comparison results are shown in Table 1.

Table 1. Comparison of simulated and observed wind speed at 15 meters height

Time	05	10	15	20
Analog value	4.5	2	3	3.5
Observations	4.2	1.5	2.7	3

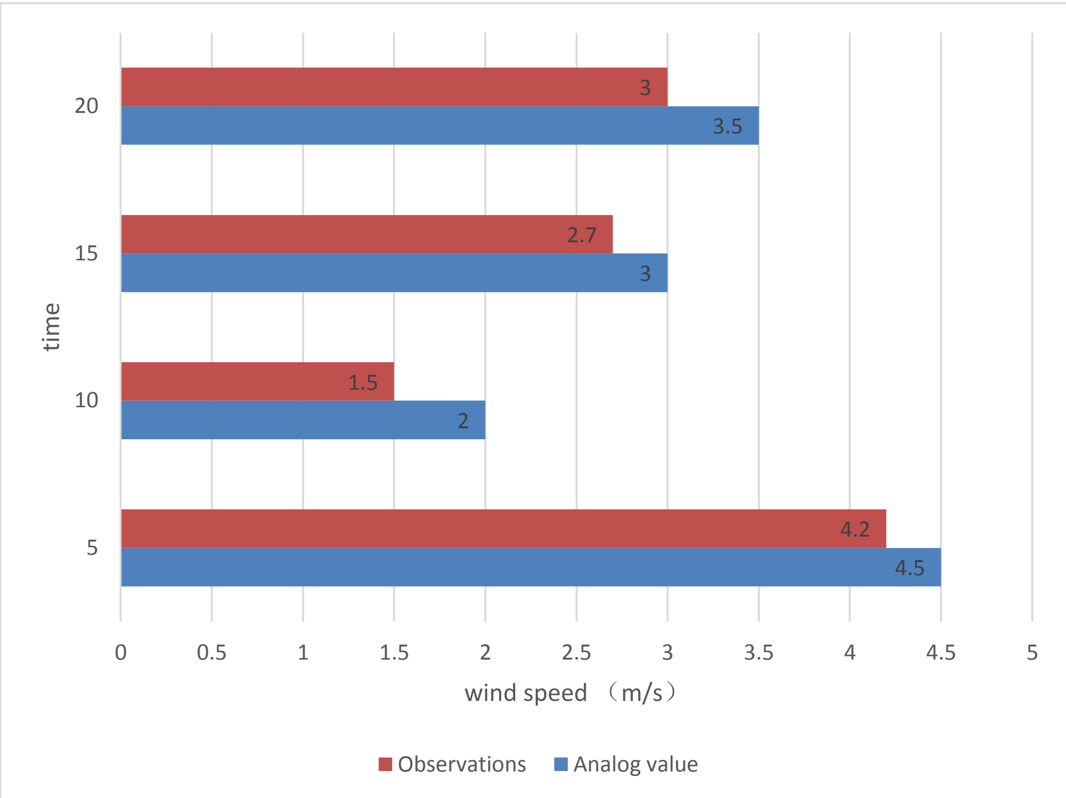

Figure 2. Comparison of simulated wind speed and observed wind speed

It can be seen from Figure 2 that the distribution trend of the simulated value and the observed value is basically the same, the extreme points of each wind speed are basically simulated, and the simulated value is slightly higher than the observed value by 0.5-1.5m/s. The reason may be that the model fails to take into account the accurate local topography of the weather station and the influence of surrounding buildings on wind speed disturbances and the model results are values on a grid rather than a point. This also shows that the WRF model cannot give accurate results at small scales, but the simulated area in this paper is a mesoscale area, and the results are more reliable.

4.2. Micro-sitting Analysis of Wind Farms

In this paper, the dynamic particle swarm algorithm and genetic algorithm will be used. Suppose the wind farm area is: 2200x2200m. Wind farm wind energy is mainly distributed in wind directions 230, 260 and 350. , the sum of the annual probabilities of the three wind directions is 0.479, and the wind farm prevails westerly. The location coordinates of the fan are shown in Table 2:

Table 2. Fan location coordinates for optimal site selection scheme

Serial number	Coordinate	Serial number	Coordinate
1	(48,51)	4	(900,350)
2	(50,1142)	5	(1354,2014)
3	(389,354)	6	(914,350)

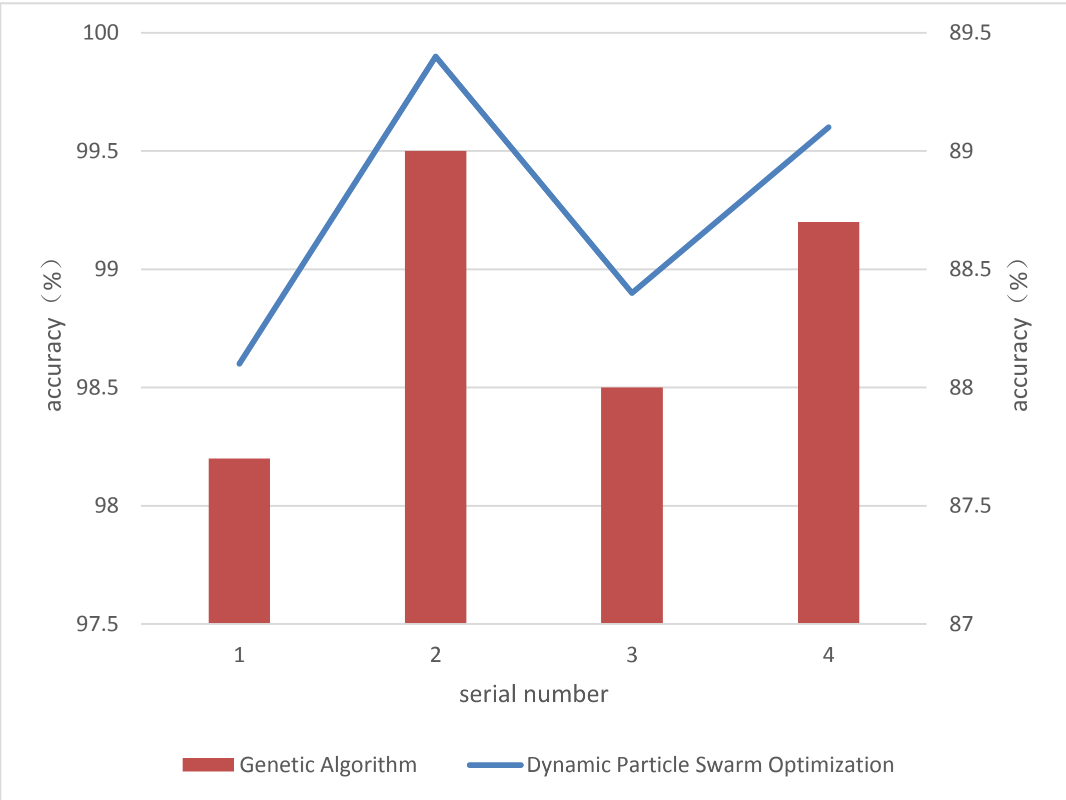

Figure 3. Algorithm accuracy comparison

It can be seen from Figure 3 that the dynamic particle swarm optimization and genetic algorithm site selection schemes in this paper improve the overall results of the wind farm by 10.1% compared with the genetic algorithm optimization scheme. This shows that wind energy losses can be significantly reduced and wind energy resources used more efficiently by increasing the location of the fans in the continuous space.

5.Conclusion

In this paper, based on QCLCD meteorological data, AsterGDEM data and Landsat image data, a wind energy resource assessment model based on meteorological station observation data is established, and a spatial interpolation model of wind energy density considering terrain relief is studied. The problem of wind energy resource assessment in the case of insufficient basic data. A wind farm micro-site selection model based on genetic algorithm is established, and the optimal wind turbine layout in the study area is accurately calculated. Based on the elements of ArcGIS Engine 10.1, spatial analysis, production and modeling related to wind energy resource assessment and wind turbine siting were carried out, and a wind energy resource assessment and micro-sitting system based on the WRF model was developed. The test shows that the distribution map of wind resources evaluated by the system is consistent with the spatial distribution of existing wind farms, and the basic laws of wind turbines and wind farms are basically the same.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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