

# Wind Resource Assessment: A Review

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**Abstract**— Wind energy is the one of the fastest growing energy source in world; it is clean and renewable source of energy. Many researches are carried out aiming towards designing the bigger size wind turbine for gaining more and more energy at minimum cost. The assessment of wind resources becomes major consent for researchers, due to advent of more complex numerical tools and experimental techniques. The wind turbine is growing in size, installed in sites with complex flow topologies (forest, complex terrain, high elevation). In the development of new wind farm, the wind resources assessment is an essential task for determining the technical and economical feasibility. An overview of techniques used for wind energy resources assessment is presented in this paper.

**Keywords**— Assessment, measurement, Site, wind farm,

## I. INTRODUCTION

A Wind Energy Conversion System can operate at a maximum efficiency only if it is designed for the site where it is to be set up, as rated power, cut-in, rated and cut-off wind speeds would be defined according to the site. In fact, these parameters can be chosen so as to maximize the delivered energy for a given amount of available wind energy. However, as it would be expensive to design a WECS for one site, usually a different procedure is followed, that is to choose for a given site the best among existing machines. Although there is not a definite criterion for making this choice, it is possible to investigate the potentiality of a site in relation to a wind machine by means of a model of the energy exchange between WECS and wind distribution. When a measurement campaign on a site has been carried out and 10 min or hourly data have been recorded for at least 2-3 yr, the frequency distribution of the available energy can be easily calculated. On this basis, the energy output of a wind machine can be evaluated immediately if its operative behavior (the power/wind-speed characteristic) is known. If local wind data are not available and/or the wind machine is not known, the same procedure can be followed with some approximation by resorting to models of the wind frequency distribution and of the WECS output characteristics; the problem in this case is to evaluate the degree of the approximation that was introduced. Commonly, the Weibull and Rayleigh models are used as considered the most and reliable ones to describe the available

wind distribution; on the basis of this merit, they are also adopted for analyzing the wind-WECS energy exchange. This was firstly proposed by Stevens and Smulders (1979), who matched the Weibull distribution with some power-law models of the WECS, and developed by Powell (1981), who considered more general cases, and Lysen (1981), who gave a definite contribution to this method. From then the question of degree of approximation was not examined and the method is currently applied, like by Galanis and Christophides (1990), Mihelic-BogdaniC and Budin (1992) and many other authors.

Although this is the only procedure one can follow when a preliminary analysis of wind potentiality is to be carried out for an area where only mean wind data are available, it is questionable that the results are reliable. On the other hand, when it comes to defining the suitable WECS for a site of known wind data, the analysis can be carried out by matching the actual wind frequency distribution with a suitable model of the energy conversion system. In this case some design parameters are relatively free, and it is possible to optimize the energy output of the wind machine; that is to find values of the free parameters that maximize the energy output.

Due to the nature of wind, loads are highly variable. Varying loads are more difficult to handle than static loads because the material becomes fatigued easily. Moreover, as a working medium the air is of low density so that the surface required for capturing energy must be large. The wind resources estimation is the first step before any wind farm establishment. Wind measurement over the site topography and simulating the wind field with numerical data according to the IEC 61400-1 standard is the main step for wind resources assessment. [1]

Author Landberg et al. provided the methodology for wind resources assessment; he describes eight methods depending on the FOLKLORE model and the amount of data available. Although important advances has been made in the field of wind resources assessments methods keeping the basic principal except folklore model, like for regional wind mapping mesoscale models can be used, CFD( computational fluid dynamics ) can be used for nonlinear micro scale models LIDAR systems are used for remote sensing instrument as a supplement of mast based system.

The wind resources estimation provides very important data's to wind energy designers about how much wind power can be obtained from selected site and in size selection of plant. It also provides basic inputs for feasibility analysis which tells about how profitable the wind turbine plant will be and determines if the turbines are within the IEC design limits.[2]

The objective of this paper is to review various methods available for wind turbine resources estimation and

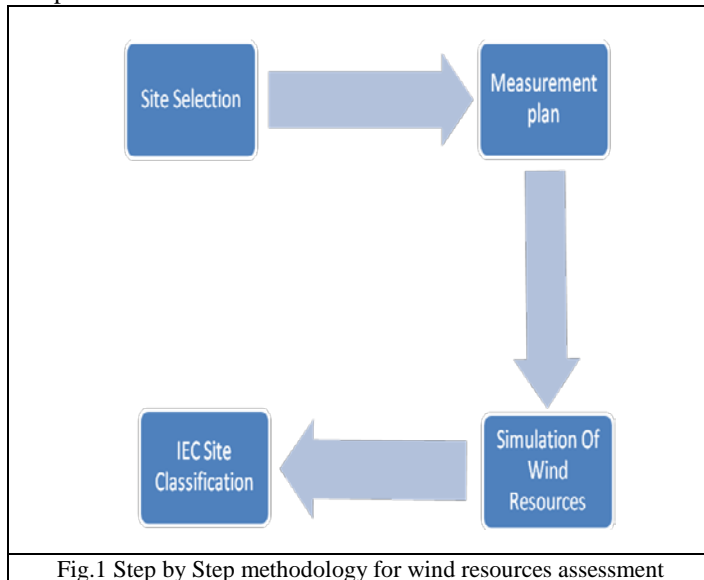
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incorporation of an efficient design methodology.

## II. METHODOLOGY

There are different methodologies used by researchers to obtain good results for wind resources estimation. Different steps used for assessment discussed below.



## III. SITE SELECTION

In the process of wind resources assessment, the first step is site selection. In this phase the researchers select suitable wind resources area. Site selection is done in three phases; in first phase preliminary area identification is done by the help of data available from area topography, airport wind data and flagged trees. Evaluation of wind resources is done in second phase in which verification of obtained data is done to justify weather sufficient wind resources are available in the site. Micro siting is third step in site selection phase; it is used to set location of wind turbines for maximizing the production of energy. [3]

The onsite evaluation and cartographic survey is traditional approach for site selection, which is done by the use of political map, physical map and wind atlas, whereas regional wind atlas produced with Mesoscale model and GIS platform are used in advance approach of site selection.

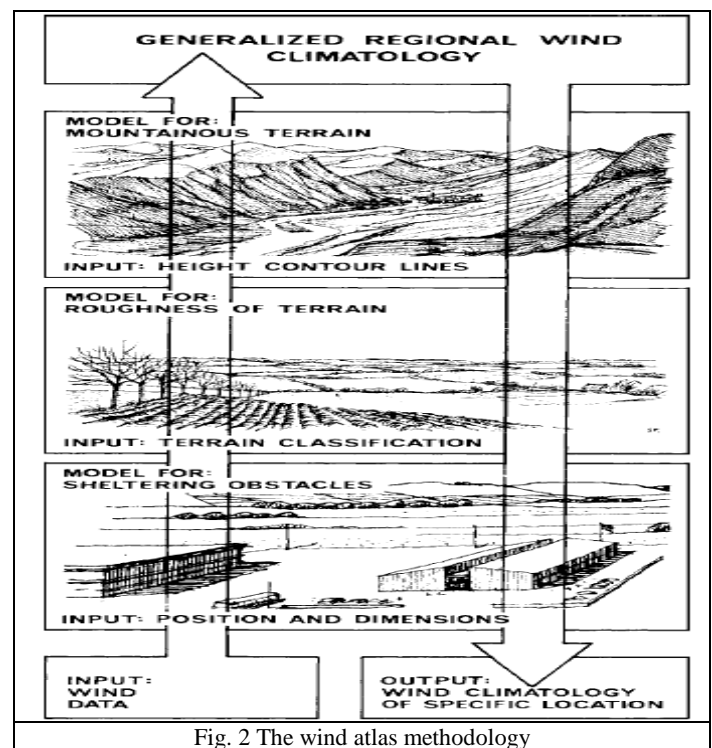
## IV. MEASUREMENT CAMPAIGN

After completion of site selection phase, the next step in wind resources assessment is micrositing phase. In this phase onsite measurement are conducted in order to determine whether selected site is economically feasible and technically viable for installation of wind turbine farm or not. Traditionally onsite reference masts are used for measuring campaign, in which 40-80m tall masts are assembled with turbine cups and vanes. The complete measurement has been done in 5-10 years so that long term scales are obtained. Measure correlate predict (MCP) is another technique which is used for estimating the wind resources in the site. In this method, a short measuring campaign is done in the potential

site and related with nearby reference site where long term measurement data are available.[4]

These measurement is based on historical data available at nearby reference site, and if the historical data are not available then global circulation model or reanalysis produced by metrological centers (NCAR/ ECMWF) may be used. Due to evolution of multi megawatt turbine plants, the sizes of wind turbines increases considerably that causes increase in size of rotor diameter and height of hub. Hence, there is great increment in cost associated with mast-based measurement. Thus, Remote sensing equipment (LIDAR and SONAR) used as a substitute as introduces possibility of using ground based equipment to measure wind speed. [5]

Remote sensing equipment also used in offshore wind resources assessment by using the satellite images. The satellite SAR (synthetic aperture radar) images are used to obtain spatial distribution of wind. [6].



## V. SIMULATIONS OF WIND RESOURCES USING NUMERICAL MODEL

Wind assessment measurement gives good result when the measurements taken are as close as hub height, which is difficult and very costly. A simulation is done either by conventional power law profile method or by numerical method. In wind resources assessment, numerical model are used to extrapolate the wind measurement horizontally to find the wind maps and numerical weather model are used to maintaining the virtual history time sources data via statistical downscaling. CFD (computational fluid dynamics) is used progressively in numerical model for wake modeling complex terrain. The application of CFD in wind resources assessment is based on RANS (Reynolds average navier stroke) turbulence model and used as

complement of traditional linear model. CFD model has high flexibility to adapt the atmospheric condition and specific topographic of site and it is good indicator of onsite terrain condition. [4,7]

## VI. IEC SITE CLASSIFICATION

After completion of simulation of wind resources, the next step is the analysis of extreme winds and effective turbulence for determining the technical viability of wind turbine class, accordance to IEC norms.

The wind resources assessment process includes the validation of design by IEC 61400-1 norms for safety of turbine plant over 20 year span. In this process wind condition factors such as effective turbulence exist at site and wind speed are evaluated accordance to IEC 61400-1 norms.[1]

IEC 61400-1 norms are used to check the safety of wind turbine blade at extreme wind condition which has been installed in proposed site. The IEC norms for extreme wind speed is defined as the value of extreme wind speed at potential site, which is averaged over 10 minutes, with annual exceeding probability of 2%. [4]

## VII. SCOPE OF WIND RESOURCE ASSESSMENT SURVEY

A wind analyst is defined in the context of this survey as someone with capabilities to process wind measurements and simulate the wind field with a numerical model in order to design a wind farm layout. This activity is typically called micrositing and it is composed of two steps: the wind resource assessment, which produces the wind field over the site topography, and the site assessment which involves design of the wind farm layout and the selection of the appropriate wind turbine class according to the IEC 61400-1 standard.

## VIII. APPROACHES OF WIND ASSESSMENT

There are various approaches for wind assessment, some of them are:

### A. Preliminary Area Identification

This process screens a relatively large region (e.g., state or utility service territory) for suitable wind resource areas based on information such as airport wind data, topography, flagged trees, and other indicators. At this stage new wind measurement sites can be selected.

### B. Area Wind Resource Evaluation

This stage applies to wind measurement programs to characterize the wind resource in a defined area or set of areas where wind power development is being considered. The most common objectives of this scale of wind measurement are to:

1. Determine or verify whether sufficient wind resources exist within the area to justify further site-specific investigations.
2. Compare areas to distinguish relative development potential.
3. Obtain representative data for estimating the performance and/or the economic viability of selected wind turbines.

4. Screen for potential wind turbine installation sites.

### C. Micrositing

The smallest scale, or third stage, of wind resource assessment is micrositing. Its main objective is to quantify the small-scale variability of the wind resource over the terrain of interest. Ultimately, micrositing is used to position one or more wind turbines on a piece of land to maximize the overall energy output of the wind plan.

## IX. OBJECTIVES OF WIND ASSESSMENT

The main objective of a siting program is to identify potentially windy areas that also possess other desirable qualities of a wind energy development site. There are three steps in the siting effort:

- 1) Identification of potential wind development areas;
- 2) Inspection and ranking of sites; and
- 3) Selection of actual tower location(s) within the sites

## X. MEASUREMENT PARAMETERS

The core of the monitoring program is the collection of wind speed, wind direction, and air temperature data.

### A. Wind Speed

Wind speed data are the most important indicator of a site's wind energy resource. Multiple measurement heights are encouraged for determining a site's wind shear characteristics, conducting turbine performance simulations at several turbine hub heights, and for backup.

### B. Wind Direction

To define the prevailing wind direction, wind vanes should be installed at all significant monitoring levels. Wind direction frequency information is important for identifying preferred terrain shapes and orientations and for optimizing the layout of wind turbines within a wind farm.

### C. Temperature

Air temperature is an important parameter in wind farm's operating environment and is normally measured at either near ground level (2 to 3 m), or near hub height. In most locations, the average near ground level air temperature will be within 1°C of the average at hub height. It is also used to calculate air density, a variable required to estimate the wind power density and a wind turbine power output.

## XI. INSTRUMENTS USED FOR WIND MONITORING

There are various instruments that are required in the monitoring of wind and especially various parameters of the wind. Some of them are illustrated below:

### A. Wind Speed

Cup or propeller anemometers are the sensor types most commonly used for the measurement of horizontal wind speed.

**1. Cup anemometer:** This instrument consists of a cup assembly (three or four cups) centrally connected to a vertical shaft for rotation. At least one cup always faces the oncoming wind. The aerodynamic shape of the cups converts wind

pressure force to rotational torque. The cup rotation is nearly linearly proportional to the wind speed over a specified range. A transducer in the anemometer converts this rotational movement into an electrical signal, which is sent through a wire to a data logger.

**2. Propeller anemometer:** This instrument consists of a propeller (or prop) mounted on a horizontal shaft that is oriented into the wind through the use of a tail vane. The propeller anemometer also generates an electrical signal proportional to wind speed.

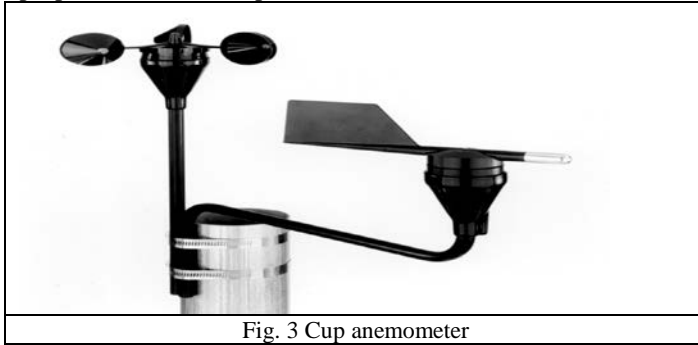


Fig. 3 Cup anemometer

### B. Wind Direction

A wind vane is used to measure wind direction. The most familiar type uses a fin connected to a vertical shaft. The vane always remains in a position of force equilibrium by aligning itself in the direction of wind. Most wind vanes use a potentiometer type transducer that outputs an electrical signal relative to the position of the vane. This electrical signal is transmitted via wire to a data logger and relates the vane's position to a known reference point (usually true north).

### C. Air Temperature

An ambient air temperature sensor is made up of three parts: the transducer, an interface device, and a radiation shield. The transducer contains a material element (usually nickel or platinum) with a relationship between its resistance and temperature. Thermistors, resistance thermal detectors (RTDs), and semiconductors are common types of transducer that can be used. The resistance value is measured by the data logger (or an interface device), which uses a known equation to calculate the actual air temperature. The transducer is kept inside a radiation shield to prevent it from direct solar radiation.

## XII. CONCLUSION

This paper provides a review of methodology for wind resources assessment process. The wind resources assessment process produces the platform for energy developer to know how much wind power has been extracted from selected site and energy harvested in the site. Wind resources assessment gives information about feasibility analysis of wind farm and tells how profitable the wind plant will be over 20 years span. This paper aims at providing an overview of the degree of integration of state-of-the-art wind assessment techniques in the wind energy sector.

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