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Wind Power Potential Assessment of Complex Terrain at RGPV Hill Top

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Abstract

The investigation of site selection for wind turbine on the basis of wind flow characteristic at RGPV Hill Top (Bhopal- M.P, India) is attempted in this paper. The main purpose of this paper is to perform an investigation on wind flow characteristics and wind energy assessment at RGPV Hill Top and to determine the Annual Energy Production for previously installed wind turbines located at the same site. In this work, the recorded time series wind data fetched by the NRG Symphonie Data logger wind mast installed at Energy Park, RGPV at the co-ordinates of E 077° 21.668' longitude and N 023° 18.720' latitude stand a mast. This data analyzed for a period of 1 year i.e. from 4-July-2013 to 4-July-2014 at the height of 20 meter and 40 meter, with a fixed averaging interval of 10 minutes, for studying the observed wind climate. The analyzed data which was worked upon comprises of wind speed data in meter per second and its direction of flow in degrees. The wind turbine site selection tool i.e. WAsP, presented in this paper provides insights into the most feasible sites for a given geographic area based on user inputs. The data were analyzed using WAsP software and regional wind climate of the area was determined, providing vital details which helped in selecting the proposed turbine sites.
Keywords: Wind Speed, WAsP, OWC, GWC, Wind Energy, Wind Mast, Wind Rose

I. INTRODUCTION

Wind energy is one of the most economically viable options among various clean energy alternatives. It presents attractive opportunities to a wide range of promoters including investors and entrepreneurs [1]. The ability of wind power to reliably contribute energy to electricity networks is directly related to the characteristics of the wind resource. In the past ten years, the total amount of wind power installed worldwide has increased more than sevenfold, from 24 GW in 2001 to almost 197 GW in 2010 [2] and this clean power source is just beginning to be tapped on a large scale [3].

An understanding of the characteristics of the wind (velocity, direction, variation) is critical to all aspects of wind energy generation, from the identification of suitable sites to predictions of the economic viability of wind farm projects to the design of wind turbines themselves, all is dependent on characteristic of wind [4] in which the measured maximum speed and direction of the wind represent important data for the design, construction and exploitation of any structure with a dominant wind load, in order to optimize wind energy conversion system and maximize the energy. According to the recommendations of the Indian norms the main wind parameter used in computation of wind action upon structures is the referent wind speed Vref defined as a maximum 10-minute average speed at 20m and 40m above ground level [5].

II. THE ACTION OF APPLYING WAsP

WAsP Wind software is a tool for evaluating the wind conditions of a specific site, taking into consideration the local influences, by applying the wind data of a suitable reference point to this site [6]. Provided with the time series wind data which was recorded by the wind mast installed inside the campus at Energy Park, the data was analyzed and processed accordingly to the standard file as required by the WAsP. And by utilizing the SRTM data the vector map of the specified area was developed to study the orography of the terrain. The software uses the Reynolds-Average Navier-Stokes equation to create a linear model, Wind Atlas, to solve wind flow equations. This Model requires wind data, height contour lines, and Roughness map of the area to calculate energy production of a wind turbine [7].

WAsP can be used for various purposes such as:

- Estimating and optimizing wind farm production and efficiency,
- Mapping of wind resources and

- Digitalizing information on maps, such as height contours.

III. OBJECTIVES OF THE STUDY

- Attainment and analysis of time series data.
- Topographical features of the RGPV hill top.
- Classification of terrain features and roughness description along with a roughness map.
- Determining the observed wind climate at the mast site.
- Preparation of Generalized wind climate for the site.
- Estimation of AEP of installed turbines.

IV. DESCRIPTION OF THE MEASURING MAST

The anemometer mast for wind data recording is installed at 40 meter height from the ground at the geographical co-ordinates East 077° 21.668 longitude and North 023° 18.720 latitude and the elevation of mast base is 591 meters, on which equipment is fixed at different altitude for measurement of wind speed, direction, temperature, pressure and voltage. The campus is spread over an area of approximately 0.964 square kilometers in undulating topography, cultivated and barren land and semi urban dwellings.

The data are logged by NRG Symphonie*PLUS3* data logger that was kept about 2 meter above the ground level in locked waterproof housing and also a data logger for storing the information about directions, thermometer, barometer, cables and terminals to provide the connection. The data sampling frequency of the data logger for used is 0.768 meter per second per hertz with data averaging interval of 10 minutes. The time series data including wind direction and speed were recorded for one year for accurate analysis of wind flow pattern from 4 July 2013 to 4 July 2014. The wind measuring mast is shown in Fig. 1.

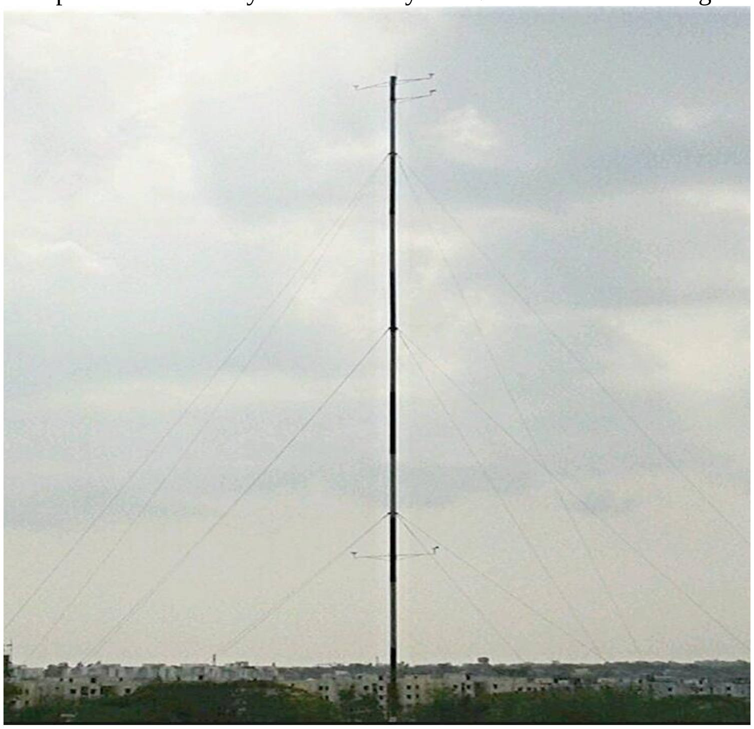

Fig. 1: Wind Measuring Mast

V. TOPOGRAPHICAL FEATURES OF THE RGPV HILL TOP

Topography defines the contours on a map convey the shape of that part of the surface of the earth. It is made up of an assemblage of landforms – the shapes of the individual and groups of natural features of the earth's surface. It is very crucial point in estimating the wind flow over any area, since the characteristics of any terrain directly affects the wind flow. For this purpose WasP uses vector maps to get information about the elevation (orography) and land cover (roughness) characteristics of the landscape in which the modelling is being done.

This study includes the vector map of the site which covers an area about 28 km^2. The map used in this study has 143 elevation contour lines and the area falls in Zone 43 with the central meridian of +75° E, with elevation ranging from a low of 450 m to a high of 546 m as shown in Fig. 2.

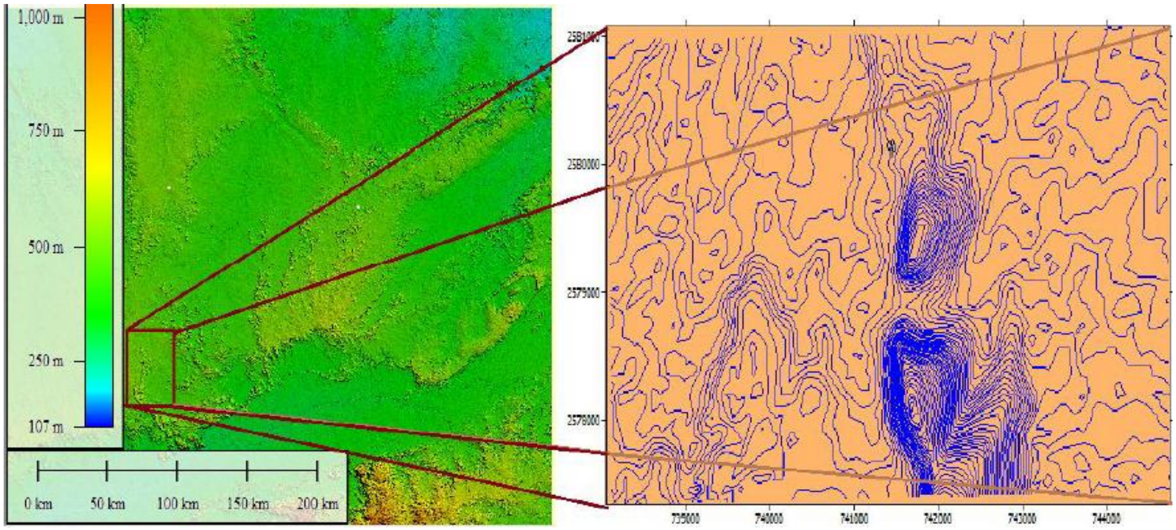

Fig. 2: Vector map of RGPV hill showing elevation contours

VI. OBSERVED WIND CLIMATE

To obtain the observed wind climate the time series meteorological data is to be analyzed with the help of Climate Analyst, and the result of these analyses is the summary which describes some aspect of the climate. The observed wind climate should represent as closely as possible the long-term wind climate at anemometer height at the position of the meteorological mast. WAsP uses Weibull distributions to represent the sector-wise wind speed distributions and the emergent distribution for the total omni-directional distribution, as shown in Table I [8].

Table - 1
Measured Mean Wind Speed and Power Density

	Mean Wind Speed	*Mean Power Density*
Measured at 20 m	*2.45 m/s*	*19 W/m^2*
Weibull-fit at 20 m	*2.62 m/s*	*23 W/m^2*
Discrepancy at 20 m	*1.2 %*	*2.0 %*

VII. WIND ROSE AND WEIBULL HISTOGRAM

A wind rose is a diagram that depicts the distribution of wind direction and speed at a location over a period of time on the basis of meteorological observations of wind speeds and wind directions. The length of each spoke on a wind rose indicates how often the wind comes from this direction. The meaning of longer spokes is the wind comes from this direction more often [9]. A Wind rose is made from dividing the compass into 12 sectors equally, each for 30 degrees of the horizon. (A wind rose can also be drawn for 8 or 16 sectors, but 12 sectors is standard set by the European Wind Atlas) as shown in Fig. 3.

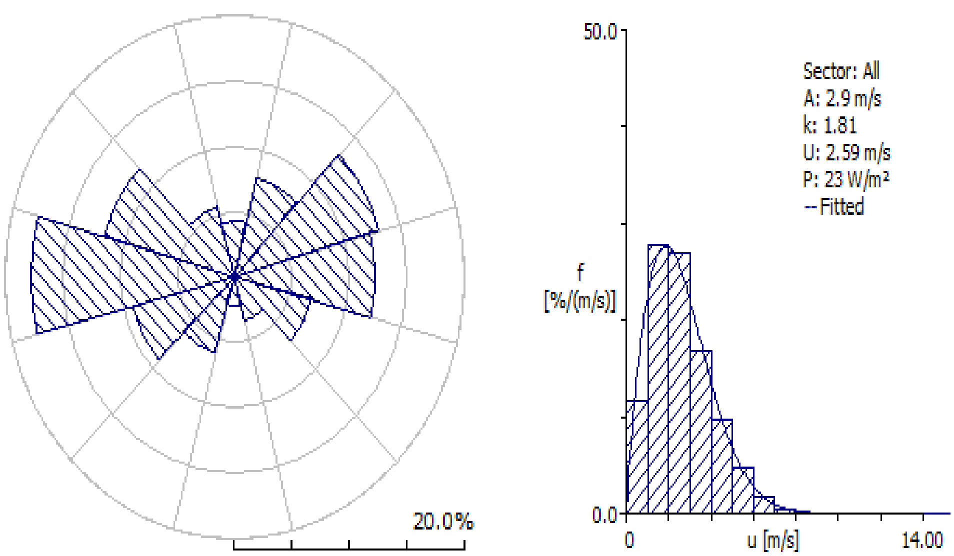

Fig. 3: Wind Rose and Spectrum of Energy Park Mast, RGPV

VIII. Generalized Wind Climate

The observed wind data is converted into a generalized wind climate (GWC). The wind observations have been cleaned in terms of site specific conditions such as: surface roughness, shelter (buildings etc.) and orography. This information was then converted into a map format. When the data has been converted into standard conditions, for four standard roughnesses, five standard heights above ground and 12 azimuth sectors, it can then create a general wind atlas [10]. When the wind atlas data has been generated, WAsP can estimate the wind climate at any particular point by performing the inverse calculation as is used to generate the wind atlas. The wind atlas containing 5 standard heights and 5 standard roughness classes are shown in the Table – II for 20m height respectively.

Table – 2
Wind Atlas at 20 Meter

Height	*Parameter*	*0.00 m*	*0.03 m*	*0.10 m*	*0.40 m*	*1.50 m*
10.0 m	*Weibull A [m/s]*	*3.3*	*2.4*	*2.1*	*1.7*	*1.1*
	Weibull k	*2.13*	*1.88*	*1.90*	*1.91*	*1.77*
	Mean speed [m/s]	*2.93*	*2.14*	*1.87*	*1.48*	*0.98*
	Power density [W/m²]	*28*	*12*	*8*	*4*	*1*
25.0 m	*Weibull A [m/s]*	*3.6*	*2.9*	*2.6*	*2.2*	*1.7*
	Weibull k	*2.19*	*2.01*	*2.02*	*2.02*	*1.85*
	Mean speed [m/s]	*3.21*	*2.56*	*2.31*	*1.95*	*1.49*
	Power density [W/m²]	*36*	*19*	*14*	*9*	*4*
50.0 m	*Weibull A [m/s]*	*3.9*	*3.3*	*3.1*	*2.7*	*2.2*
	Weibull k	*2.24*	*2.22*	*2.21*	*2.18*	*1.97*
	Mean speed [m/s]	*3.45*	*2.96*	*2.71*	*2.35*	*1.91*
	Power density [W/m²]	*43*	*27*	*21*	*14*	*8*
100 m	*Weibull A [m/s]*	*4.2*	*3.9*	*3.6*	*3.2*	*2.7*
	Weibull k	*2.19*	*2.35*	*2.40*	*2.42*	*2.20*
	Mean speed [m/s]	*3.74*	*3.50*	*3.23*	*2.85*	*2.40*
	Power density [W/m²]	*56*	*43*	*34*	*23*	*15*
200 m	*Weibull A [m/s]*	*4.6*	*4.8*	*4.4*	*3.9*	*3.4*
	Weibull k	*2.11*	*2.27*	*2.31*	*2.34*	*2.17*
	Mean speed [m/s]	*4.12*	*4.27*	*3.93*	*3.49*	*2.99*
	Power density [W/m²]	*78*	*81*	*62*	*43*	*29*

IX. Resource Grid

Resource grids manage a rectangular set of points for which summary predicted wind climate data are calculated. The points are regularly spaced and are arranged into rows and columns. WAsP is a linear flow model for neutrally stratified flow. It does not account for Coriolis accelerations. Hence, it can only simulate flow over weak to moderately steep terrain on scale of less than a few kilometer(s). WAsP is used all over world for wind resource assessment. Typical errors in the annual energy prediction of wind turbines are about 10 %. In complex terrain as e.g. mountains larger errors may be expected. The so-called self-prediction of a station is usually very accurate with errors of less than 2 %. It is the prediction for exactly the same location where the original data was measured using the wind atlas generated from it [9].

The structure of resource grid has 10 columns and 6 rows at 400 meter resolutions give 60 calculation sites. Resource Grid Maps for RGPV Hill Top are shown in Figs. 4(a), 4(b) and 4(c) displaying mean wind speed, power density and elevation profile of Resource Grid.

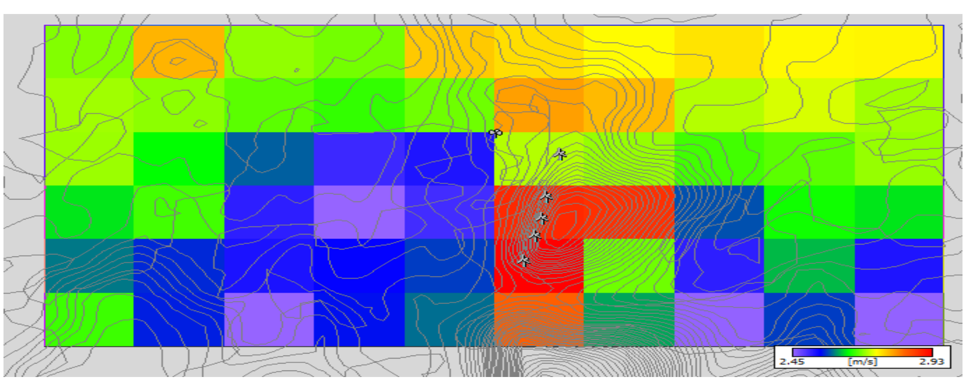

Fig. 4(a): Mean wind speed of resource grid at 20m

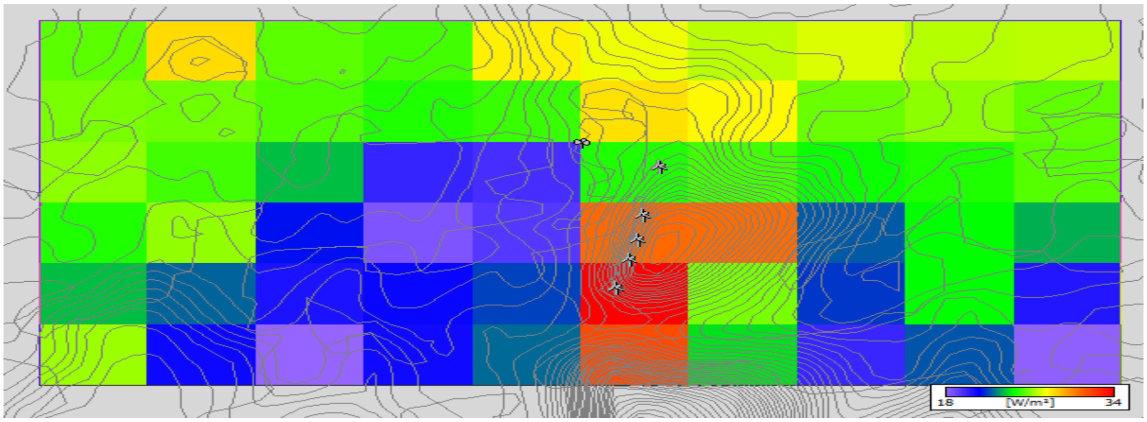

Fig. 4(b): Power density of resource grid at 20

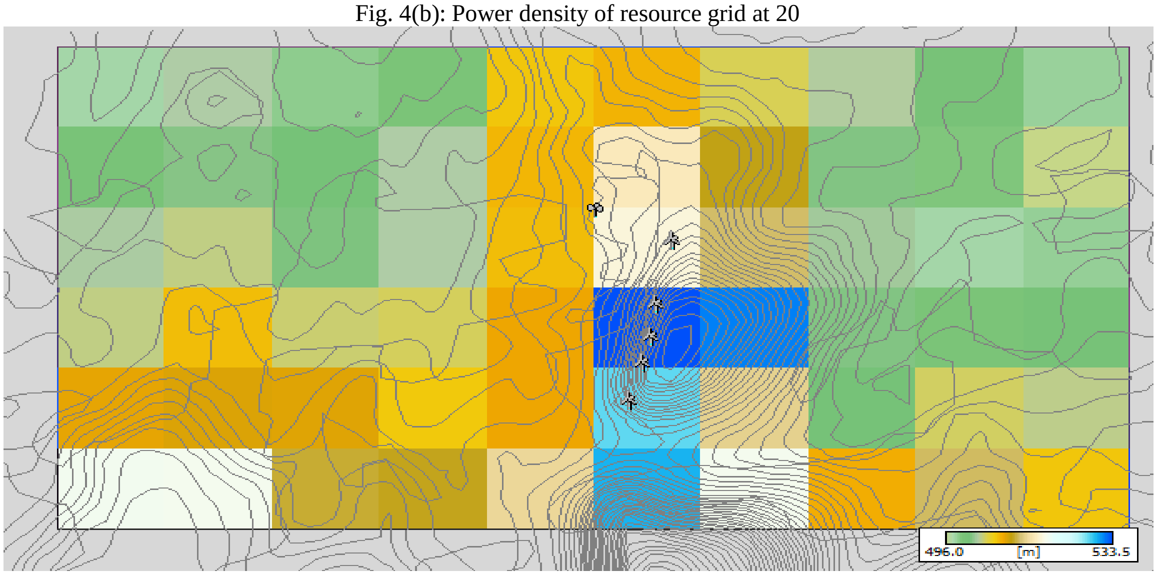

Fig. 4(c): Elevation Profile of Resource Gird
Fig. 4: Resource Grid Maps for RGPV Hill Top

X. CONCLUSION

The following points are extracted from this study:-

- The study has been used to assess the viability of wind energy resource for the duration of 1 year as from 4 July-2013 to 4 July 2014.
- The mean wind speed and mean power density at 20 meter height was found out be 2.59 m/s and 23 W/m^2 respectively.
- The site independent generalized wind climate for 20 meter height was calculated on the basis of observed wind climate at the mast location.
- A wind rose diagram was prepared in order to determine the relative frequencies of wind direction for each sector at the wind recording site. And it was observed that the wind flows predominantly in 10 and 11 sectors from the West-North, West (270°-300°) taking North as reference at 0° indicating a strong influence of the rainy season in the Indian subcontinent.
- To study the effects of roughness on the wind flow the roughness of the whole area surrounding the site was put into consideration and the area was divided into various roughness classes, and as a result it was observed that roughness is a crucial factor in predicting the wind flow and climate.
- In this study only 14 roughness change lines are used. More accurate roughness inputs can help in more accurate results of the modelling.

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