Validation of the WAsP Model for a Terrain Surrounded by Mountainous Region

Mohammadamin Zanganeh, Vahid Khalajzadeh

Abstract—The problems associated with wind predictions of WAsP model in complex terrain are already the target of several studies in the last decade. In this paper, the influence of surrounding orography on accuracy of wind data analysis of a train is investigated. For the case study, a site with complex surrounding orography is considered. This site is located in Manjil, one of the windiest cities of Iran. For having precise evaluation of wind regime in the site, one-year wind data measurements from two metrological masts are used. To validate the obtained results from WAsP, the cross prediction between each mast is performed. The analysis reveals that WAsP model can estimate the wind speed behavior accurately. In addition, results show that this software can be used for predicting the wind regime in flat sites with complex surrounding orography.

Keywords—Complex terrain, Meteorological mast, WAsP model, Wind prediction

I. INTRODUCTION

In 2010, the world celebrated the 194 GW mark in installed wind energy total capacity. Fig. 1 shows the top 10 countries in wind energy installed capacity in 2010 [1]. Iran is one of the countries that have recently paid a great attention to install, and build wind turbines. Wind power generators can be a proper replacement for fossil fuel and are considered as one of the cleanest methods of producing electricity. So far, Iran has made some initial progress towards promoting wind energy [2].

Fig. 1 Top 10 total installed capacity [1]

II. MODELS & METHODS

A. The Wind Resource Estimation Program WAsP

WAsP (Wind Atlas Analysis and Application Program) is one of the most popular models in simulation of wind farms. It contains models for the vertical extrapolation of wind data taking into account sheltering of obstacles, surface roughness...
changes and terrain height variations.

“In WASP, meteorological models are used to calculate the regional wind climatology from the raw data series. In the reverse process - the application of wind atlas data - the wind climate at any specific site may be calculated from the regional climatology” [6].

B. Statistical Distribution for Wind Data and Wind Power Generation

The Weibull distribution is a two-parameter probability density function that models the observed or predicted frequency distribution of wind speeds at a particular site very well. It represents wind speed data given initially as a histogram, to a smooth curve described by a specific formula [7][8]. Equation (1) gives the probability density function (PDF) of the wind speed.

\[
f(V) = \frac{k}{c} \left( \frac{V}{c} \right)^{k-1} e^{-\left( \frac{V}{c} \right)^k}
\]

- \( f(V) \) is the probability density function of the wind speed;
- \( c \) is the Weibull scale parameter (m/s);
- \( V \) is wind speed (m/s);
- \( k \) is the dimensionless Weibull shape parameter

In general, \( k \) specifies how steep the peak of the curve is, while \( c \) is a value close to the mean wind speed. The Weibull parameters \( k \) and \( c \) are empirically derived by statistical calculations based on the wind data. Equation (2) defines the cumulative distribution function (f(V)).

\[
f(V) = 1 - e^{-\left( \frac{V}{c} \right)^k}
\]

The available wind power \( P(V) \) (W) that can be obtained by a cross sectional area \( A \) (m\(^2\)) perpendicular to the wind at a given speed with air density \( \rho \) (Kg/m\(^3\)), is done by (3).

\[
P(V) = \frac{1}{3} C_p \rho A V^3
\]

- \( C_p \) is the coefficient of the power, which will always be less than 0.59, as determined by Betz

Equation (4) defines the wind energy (E) that can be extracted by a wind turbine.

\[
\frac{P}{A} = \int P(V) f(V) dV = \frac{1}{2} \rho c e \Gamma
\]

- \( \Gamma \) is Gamma function

III. SITE SPECIFICATION

In this study, the site area is located in Northern part of Iran and site center is located at N: 360 42' 36" and E: 490 18' 42". Two masts (mast 1 and mast 2) are installed in this site for assessing wind resource of the region (Fig. 2). As shown in Fig. 3, the site area is a flat plain between two mountainous areas in north and south. The steepness contour of site is depicted in Fig. 4. Although in the site area and mast locations are classified as low-steep lands (less than 5 deg.), site is surrounded by high-steep areas (25-90 deg.).
The mast 1 and mast 2 are located across approximately 4.3km and their elevations are 390m and 355m above mean sea level, respectively. The elevation profile between mast 1 and mast 2 is shown in Fig. 5. Elevation changes in range of 357 m to 400 m while slope changes from 5% to -0.3%.

For simulation, the erroneous data should be eliminated from time series. Therefore, this task has been done in WAsP software package by comparing three concurrent data sets. Digital 3D maps, with scale of 1-25000, are used for inserting orography of site and extended to cover at least 5km from each mast location. This 3D maps are prepared by Iran Survey Organization. The surface roughness data was supplied for this area from Iran Forest, Range and Water Shed Management (FRW) Organization with scale of 1:50000 raster images.

IV. RESULTS & DISCUSSION

Probability for different wind speed versus the wind speed and fitted Weibull distributions for mast 1 and mast 2 are shown in Fig. 6 and Fig. 7. In addition, comparison of Weibull distributions and Weibull parameters for mast 1 and mast 2 are presented in Fig. 8 and TABLE I, respectively.
TABLE I

COMPARISON OF WEIBULL PARAMETERS

<table>
<thead>
<tr>
<th>Mast</th>
<th>C Parameter (m/s)</th>
<th>k Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mast 1</td>
<td>9.27</td>
<td>1.5771</td>
</tr>
<tr>
<td>Mast 2</td>
<td>8.94</td>
<td>1.5986</td>
</tr>
</tbody>
</table>

The most important results of simulation are shown in TABLE II that includes the predicted wind speed by WASP, the amount of over prediction, and over prediction percentage.

TABLE II

CROSS PREDICTION ERRORS

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Predicted at</th>
<th>Predicted wind speed</th>
<th>Measured wind speed</th>
<th>Over prediction wind speed</th>
<th>Over prediction percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mast 1 @ 40m</td>
<td>Mast 2 @ 40m</td>
<td>9.61</td>
<td>9.5</td>
<td>-0.07</td>
<td>-0.7%</td>
</tr>
<tr>
<td>Mast 1 @ 20m</td>
<td>Mast 2 @ 20m</td>
<td>9.32</td>
<td>8.99</td>
<td>-0.05</td>
<td>-0.6%</td>
</tr>
<tr>
<td>Mast 1 @ 10m</td>
<td>Mast 2 @ 10m</td>
<td>8.62</td>
<td>8.18</td>
<td>-0.48</td>
<td>-5.5%</td>
</tr>
<tr>
<td>Mast 2 @ 40m</td>
<td>Mast 1 @ 40m</td>
<td>9.57</td>
<td>9.55</td>
<td>-0.07</td>
<td>-0.7%</td>
</tr>
<tr>
<td>Mast 2 @ 20m</td>
<td>Mast 1 @ 20m</td>
<td>9.04</td>
<td>9.35</td>
<td>0.04</td>
<td>0.4%</td>
</tr>
<tr>
<td>Mast 2 @ 10m</td>
<td>Mast 1 @ 10m</td>
<td>8.65</td>
<td>9.15</td>
<td>0.52</td>
<td>6%</td>
</tr>
</tbody>
</table>

Obtained results from TABLE II show that the percent of error for 40-m and 20-m data, which are the most important heights to predict the wind speed, is less than 1%. Based on the small error in cross prediction of WASP, it is clear that the model can predict the wind resource accurately. Due to the effects of near ground obstacles at 10m, the amount of error is more than 5% for this height. In Fig. 9 measured wind speed and predicted wind speed curves are depicted.
In present paper, the accuracy of WAsP model for a windy site in Manjil with flat terrain and complex surrounding topography is studied. For this purpose, the gathered data from two masts with cross-distance of approximately 4.3km is used. The results show that the calculations of WAsP model are precise enough to predict the wind regime in the site. Since the topographical condition of most wind sites in Iran is similar to this site (flat terrain surrounded by complex mountainous terrain), it seems that WAsP is a reliable model for wind prediction in most cases.

REFERENCES

[1] GWEC e Global wind 2010 report