16. Wind Resource Assessment

16.1 The European Wind Atlas

16.1.1 Overview and Basic Concepts

assessment of wind energy resources:
- establish the meteorological basis for the assessment of wind energy resources
- provide suitable data for evaluating wind power output
- high precision requirements because of $P(v^3)$-dependence
- method need high-quality long time series ($>$ 10 a) of wind data due to long term variations in wind climate

problem:
wind speed at a given site depends on two factors:
- overall weather systems (typical scale: 1000 km)
- nearby topography (typical scale: 10 km)

$\rightarrow$ wind data are representative only valid for the actual position of the station
$\rightarrow$ method for transformation of wind speed satistics is required (horizontal and vertical extrapolation)

$\rightarrow$ solution: European Wind Atlas: set of models based on physical principles of boundary layer flow taking into account:
- effect of different surface conditions (roughness)
- sheltering effects (buildings, trees, ..)
- variations of the terrain height (orography)

$\rightarrow$ three main influences:
- terrain class (surface roughness, four classes)
- sheltering obstacles
- terrain height variations (orography)

regional wind climatologies have been calculated from more than 200 sites (at least 10 a of data and accurate site descriptions each)

calculation of generalized wind climate:
- flat and homogeneous terrain
- no nearby obstacles
- heights of 10, 25, 50, 100, 200 m - four roughness classes $\rightarrow$ 20 data sets free from local influences $\rightarrow$ reginally representative

spatial scale of representativeness depends on orographic structure of landsape:
- flat, open terrain: up to 200 km
- mountainous area: close to station

regional data sets mainly give statistical information in terms of the probability distribution function (this is suffcient information foe wind power estimates) $\rightarrow$ use of Weibull distribution division into 12 wind direction classes $\rightarrow$ 240 sets of Weibull parameters

essential: systematic description of topographic characteristics: - effects of obstacles $\rightarrow$ sheltering effects
- surface fo terrain
- topographic elements contributing to roughness: vegetation, houses
- orographic influence: decrease/increase of wind speed due to hills, ridges, cliffs, ..

$\rightarrow$ three main effects of topography:
- shelter
- roughness
- orography

16.1.2 Physical Models

logarithmic profile: $u(z) = \frac{u_*}{\kappa} \ln(\frac{z}{z_0}) - \Psi(\frac{z}{L})$

geostrophic drag law: $u_g = \frac{u_*}{\kappa} \sqrt{((\ln(\frac{u_*}{f z_0}) - A)^2 + B^2)}$

assumptions: stationarity, homogeneity, barotrophy, neutral stability

$\rightarrow$ balance geostrophy and surface roughness

stability corrections:
- small wind speeds not important $\rightarrow$ neutral assumption generally good
- modifications as small perturbations to neutral state
- input: climatitological average, variance of surface heat flux

$\rightarrow$ effect on vertical profiles of climatological means and standard deviations of wind speeds
taking average values for overland and sea stations, respectively

Surface Roughness. roughness is determined by size and distribution of roughness elements
Wind Atlas includes four types: $\rightarrow$ roughness classes
roughness parameterized by length scale z_o
empirical relationship with size of elements: $z_0 = 0.5hS/A_H$ with height h, cross sectional area S and density A_H (average horizontal area occupied by each element)
porosity for nonsolid elements!

seasonal changes of roughness!

Shelter Effects by Obstacles. shelter effect: relative decrease in wind speed behind an obstacle

depending on:
- distance from obstacle to site
- height of obstacle

- height at site (rotor hub height)
- length of obstacle (lateral $\rightarrow$ infinite: max. shelter, zero: no shelter)
- porosity of obstacle ($\simeq 0$ for buildings, ~ 0.5 for trees (changing seasonally), ~ 0.33 for row of buildings with spacings of 1/3 the building length between them

Orographic Effects. Example: flow over Askervein hill (Hebride islands); length scale: 1 km

results: speed increases by a factor of 1.8 on top of the hill; negative speed-up in front and lee of the hill (20-40 percent)

for moderate orography simple corrections for these effects can be applied

for complicated terrain numerical hydrodynamical models have to be used

16.1.3 Application of the Model

Step 1: Select a base station

$\rightarrow$ regional wind climatology (one of the available Wind Atlas sites, i.e. statistical description)

requirement: similar topographic situation; distance usually < 100 km;

mountains, coastlines!

Step 2: Roughness description

classifying surface types around the site

$\rightarrow$ division into 12 30 $\deg$-sectors and sector-by-sector classification (roughness classes)

$\rightarrow$ Weibull distribution for each sector

roughness description with changes in a given sector (roughness change):

$\rightarrow$ non-homogeneous surface $\rightarrow$ problem: defining a unique roughness length

$\rightarrow$ development of internal boundary layer with height h and distance from roughness change x:

$\frac{h}{z_0}(ln(\frac{h}{z_0}-1)) = const\frac{x}{z_0}$

$z_0 = max(z_{01}, z_{02})$

$\rightarrow$ modeling new profile with several logarithmic parts

$\rightarrow$ correction factor for Weibull A parameter: $A = corr A_{upwind}$

$corr = \frac{\ln(z/z_{o2})\ln(h/z_{o1}}{\ln(z/z_{o1})\ln(h/z_{o2}}$

with height h of internal boundary layer

$\rightarrow$ dividing segment into parts with equal roughness

Step 3: Calculation of total Weibull distribution

- A,k for each sector available; also the relative frequencies of occurence
- calculation of mean M_i and mean squares u_i^2 for each sector
- calculate total mean and mean square
- from M^2/u^2 calculate k
- use table to calculate u

$M = A\Gamma(1+\frac{1}{k})$

$u^2 = A^2\Gamma(1+\frac{2}{k})$