Bibliografía general eólica

Libros

Wind energy explained - Theory, design and application

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1 Introduction: Modern Wind Energy and its Origins

The purpose of this chapter is to provide an overview of wind energy technology today, so as to set a context for the rest of the book. It addresses such questions as: What does modern wind technology look like? What is it used for? How did it get this way? Where is it going?

1.1 Modern Wind Turbines

In terms of total generating capacity, the turbines that make up the majority of the capacity are, in general, rather large – in the range of 1.5 to 5 MW

fundamental facts underlying their operation. In modern wind turbines, the actual conversion process uses the basic aerodynamic force of lift to produce a net positive torque on a rotating shaft, resulting first in the production of mechanical power and then in its transformation to electricity in a generator. Wind turbines, unlike most other generators, can produce energy only in response to the resource that is immediately available. It is not possible to store the wind

the horizontal axis wind turbine (HAWT). That is, the axis of rotation is parallel to the ground. HAWT rotors are usually classified according to the rotor orientation (upwind or downwind of the tower), hub design (rigid or teetering), rotor control (pitch vs. stall), number of blades (usually two or three blades), and how they are aligned with the wind (free yaw or active yaw)

The rotor consists of the hub and blades of the wind turbine. These are often considered to be the turbine's most important components from both a performance and overall cost standpoint.

Most turbines today have upwind rotors with three blades

Most manufacturers use pitch control, and the general trend is the increased use of pitch control, especially in larger machines

The blades on the majority of turbines are made from composites, primarily fiberglass or carbon fiber reinforced plastics

The power curve gives the electrical power output as a function of the hub height wind speed

1.2 History of Wind Energy

2 Wind Characteristics and Resources

2.1 Introduction

2.2 General Characteristics of the Wind Resource

worldwide wind circulation involves large-scale wind patterns which cover the entire planet. These affect prevailing near surface winds. It should be noted that this model is an oversimplification because it does not reflect the effect that land masses have on the wind distribution.

In one of the simplest models for the mechanics of the atmosphere's wind motion, four **atmospheric forces** can be considered. These include pressure forces, the Coriolis force caused by the rotation of the earth, inertial forces due to large-scale circular motion, and frictional forces at the earth's surface.

The direction of the **Coriolis force** is perpendicular to the direction of motion of the air. The resultant of these two forces, called the geostrophic wind, tends to be parallel to isobars.

The general circulation flow pattern described previously best represents a model for a smooth spherical surface. In reality, the earth's surface varies considerably, with large **ocean and land masses**. These different surfaces can affect the flow of air due to variations in pressure fields, the absorption of solar radiation, and the amount of moisture available.

Examples of tertiary circulation, **valley and mountain winds**, are shown in Figure 2.4. During the day, the warmer air of the mountain slope rises and replaces the heavier cool air above it. The direction reverses at night, as cold air drains down the slopes and stagnates in the valley floor. An understanding of these wind patterns, and other local effects, is important for the evaluation of potential wind energy sites.

variations in **wind speed in time** can be divided into the following categories: . **inter-annual; . annual; . diurnal; . short-term (gusts and turbulence).**

Wind speed is also very dependent on local topographical and ground cover variations.

Wind direction also varies over the same time scales over which wind speeds vary

The maximum power-producing potential that can be theoretically realized from the kinetic energy contained in the wind is about 60% of the available power.

2.3 Characteristics of the Atmospheric Boundary Layer

One would expect the horizontal wind speed to be zero at the earth's surface and to increase with height in the atmospheric boundary layer. This variation of **wind speed with elevation** is called the vertical profile of the wind speed or vertical wind shear.

two methods were described (log profile and power law profile laws) for modeling the vertical wind speed profile.These were developed for flat and homogenous terrain

the mean wind speed increases with height, which defines the phenomenon called wind shear.
Turbulence in the wind is caused by dissipation of the wind's kinetic energy into thermal energy via the creation and destruction of progressively smaller eddies (or gusts). Turbulent wind may have a relatively constant mean over time periods of an hour or more, but over shorter times (minutes or less) it may be quite variable.

The most basic measure of turbulence is the **turbulence intensity**. It is defined by the ratio of the standard deviation of the wind speed to the mean wind speed

The influence of **terrain** features on the energy output from a turbine may be so great that the economics of the whole project may depend on the proper selection of the site.

Non-flat terrain has large-scale elevations or depressions such as hills, ridges, valleys, and canyons.

An important point to be made here is that information on wind direction should be considered when defining the terrain classification.

Depressions are characterized by a terrain feature lower than the surroundings. The change in speed of the wind is greatly increased if depressions can effectively channel the wind

2.4 Wind Data Analysis and Resource Estimation

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2.5 Wind Turbine Energy Production Estimates Using Statistical Techniques

2.6 Regional Wind Resource Assessment

2.7 Wind Prediction and Forecasting

2.8 Wind Measurement and Instrumentation

2.9 Advanced Topics

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13. **WIND FLOW MODELING**.. 13-1 13.1.

Conceptual Models: are theories describing how the wind resource is likely to vary across the terrain

Experimental Models: creating a sculpted scale model of a wind project area and testing it in a wind tunnel.

Statistical Models: are based on relationships derived entirely or primarily from on-site wind measurements.

Types of Wind Flow Models ....
13-2 13.2.
Numerical Wind Flow Models: The models fall into four general categories: massconsistent, Jackson-Hunt, computational fluid dynamics (CFD), and mesoscale numerical weather prediction (NWP) models.
Mass-Consistent Models. T they solve just one of the physical equations of motion, that governing mass conservation. massconsistent models are able to take advantage of data from additional meteorological towers in a natural way, by modifying the initial guess
J**ackson-Hunt Models:** include momentum conservation by solving a linearized form of the Navier-Stokes equations governing fluid flow. The most important simplification in the Jackson-Hunt theory is that the terrain causes a small perturbation to an otherwise constant background wind. **WAsP**, a Jackson-Hunt model developed by the Risoe National Laboratory of Denmark, which has been and probably remains the most widely used numerical wind flow model in the wind industry. Including the ability to incorporate the effects of surface roughness changes and obstacles
CFD Models: solve a more complete form of the equations of motion known as the Reynolds-averaged Navier-Stokes, or RANS, equations. This means they are capable of simulating non-linear responses of the wind to steep terrain, such as flow separation and recirculation. allows CFD models to simulate the influences of roughness changes and obstacles directly.
Mesoscale Numerical Weather Prediction Models: they incorporate the dimensions of both energy and time, and are capable of simulating such phenomena as thermally driven mesoscale circulations (such as sea breezes) and atmospheric stability, or buoyancy.
One way around this problem is to couple mesoscale models with a microscale model of some kind. This could be a statistical model, if there is sufficient on-site wind data to create reliable statistical relationships. More often, it is a simplified wind flow model - usually either a mass-consistent model or a Jackson-Hunt model

Application of Wind Flow Models ....
13-13 13.3.
Topographic Data: Accurate, high-resolution topographic data is essential for all wind flow modeling. A typical spatial resolution for modeling is 50 m.
Land Cover Data

Mast Number and Placement: all wind flow modeling must be anchored in high-quality observations from the project area. Wind resource data should be collected at locations representing the full range of wind conditions likely to be encountered by the wind turbines in the project.This criterion is sometimes translated into distance - as in the rule that no turbine should be placed farther than one kilometer from a met mast in complex terrain

Adjustments to Multiple Masts:

Determining the Modeling Uncertainty 13-16

It is possible to directly estimate the modeling uncertainty if the following criteria are met: 13-17 • There are at least five masts in the project area. • The masts are well distributed within the proposed turbine array and among the site conditions likely to be experienced by the wind turbines. • There is sufficient data from each mast to accurately compare mean annual wind speeds.

Aerodynamics of wind turbine wakes

Literature review

B. Sanderse

In this report the existing literature on the calculation of wind turbine wakes is reviewe

1 Introduction

2 Aerodynamics of wind turbines

chapter 2 gives an overview of the aerodynamics of a wind turbine, including a description of the atmospheric effects that influence its working. Simplified models are used to explain the basic aerodynamic concepts

2.1 Characteristics of the atmosphere

2.2 Actuator disk concept (impreso)

2.3 Vorticity-based description of the flow field

2.4 Near and far wake; turbulence, velocity deficit and vorticity

2.5 Wind farm aerodynamics

2.6 Wake meandering

2.7 Effect of yaw

3 Engineering models

In chapter 3 we will look at more complicated models, what we call ‘engineering models’, that exist for designing wind turbines and wind farms.

In chapter 3 different engineering models for fast prediction of both rotor performance and wake aerodynamics were discussed. The blade element momentum method is the most widely used method for rotor computations, while for wake calculations many codes use superposition of velocity deficits and turbulent kinetic energies

3.1 Blade element momentum method

3.2 Lifting line method and vortex wake method

3.3 Boundary integral equation method

3.4 Wind farm and wake models

4 Computational Fluid Dynamics

Chapter 4 considers even more advanced models for simulating flows around wind turbines which are based on CFD

The mathematical model for wind farm aerodynamics simulations should be the unsteady, viscous, incompressible Navier-Stokes equations

4.1 Governing equations and their properties

4.2 Modeling techniques (impreso)

A widely used technique is the actuator approach, in which the rotor is represented by forces. These forces depend on the flow field and are obtained from tabulated airfoil data. The first steady actuator disk computations have now evolved to unsteady actuator line and actuator surface techniques. The actuator technique has been successfully used for the **simulation of entire wind farms**

4.3 Verification and validation

5 Optimization

Optimization of wind farm layouts with current CFD (Computational Fluid Dynamics) codes is not yet possible due to the large computational effort already required for a single wind farm computation

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3 Aerodynamics of Horizontal-axis Wind Turbines 41

3.1 Introduction 41

Assuming that the affected mass of air remains separate from the air which does not pass through the rotor disc and does not slow down a boundary surface can be drawn containing the affected air mass and this boundary can be extended upstream as well as downstream forming a long stream-tube of circular cross section.

3.2 The Actuator Disc Concept 42 (impreso)

we can begin an analysis of the aerodynamic behaviour of wind turbines without any specific turbine design just by considering the energy extraction process. The general device that carries out this task is called an actuator disc

3.2.1 Momentum theory 43

3.2.2 Power coefficient 44

3.2.3 The Betz limit 45

3.2.4 The thrust coefficient 46

3.3 Rotor Disc Theory 46

3.3.1 Wake rotation 47

3.3.2 Angular momentum theory 47

3.3.3 Maximum power 49

3.3.4 Wake structure 50