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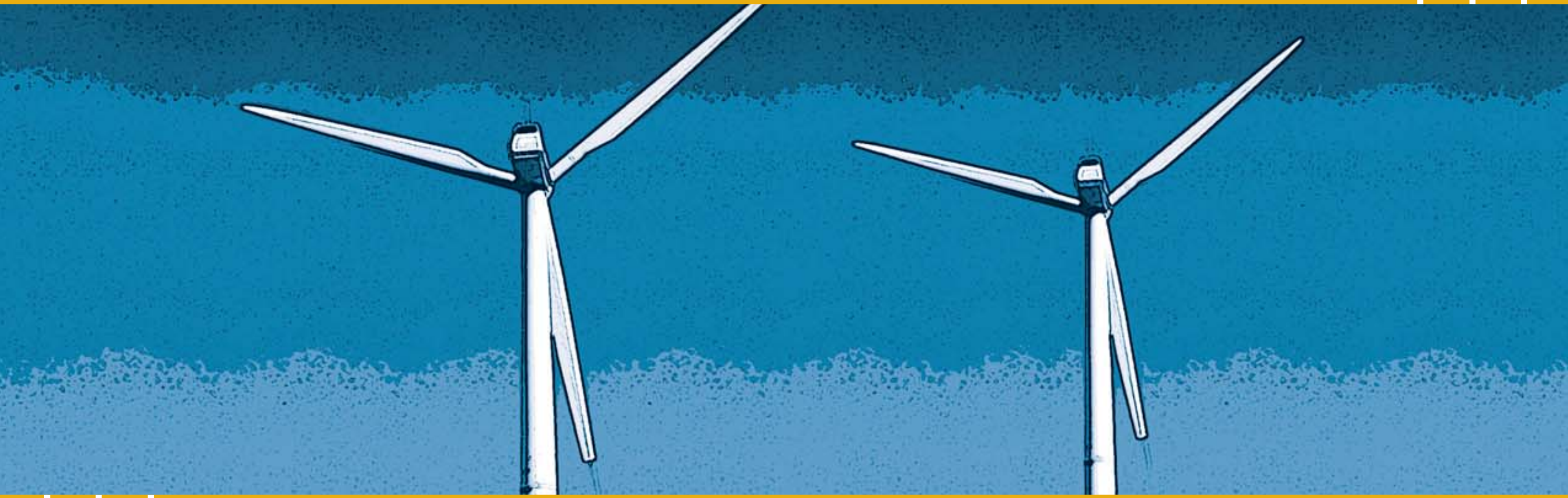
CLEAN ENERGY PROJECT ANALYSIS:
RETSCREEN® ENGINEERING & CASES TEXTBOOK



CANMET Energy Technology Centre - Varennes (CETC)

In collaboration with:

NASA

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GEF

WIND ENERGY PROJECT ANALYSIS

CHAPTER

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WIND ENERGY PROJECT ANALYSIS CHAPTER

Clean Energy Project Analysis: RETScreen® Engineering & Cases is an electronic textbook for professionals and university students. This chapter covers the analysis of potential wind energy projects using the RETScreen® International Clean Energy Project Analysis Software, including a technology background and a detailed description of the algorithms found in the RETScreen® Software. A collection of project case studies, with assignments, worked-out solutions and information about how the projects fared in the real world, is available at the RETScreen® International Clean Energy Decision Support Centre Website www.retscreen.net.

1 WIND ENERGY BACKGROUND[1]

The kinetic energy in the wind is a promising source of renewable energy with significant potential in many parts of the world. The energy that can be captured by wind turbines is highly dependent on the local average wind speed. Regions that normally present the most attractive potential are located near coasts, inland areas with open terrain or on the edge of bodies of water. Some mountainous areas also have good potential. In spite of these geographical limitations for wind energy project siting, there is ample terrain in most areas of the world to provide a significant portion of the local electricity needs with wind energy projects (Rangi et al., 1992).

Figure 1:
39.6 MW Central-Grid Windfarm in Spain.

Photo Credit:
Photo © BONUS Energy A/S

1. Some of the text in this "Background" description comes from the following two CANMET supported reports: ***Wind Energy Basic Information***, Backgrounder published by the Canadian Wind Energy Association (CanWEA), and, Rangi, R., Templin, J., Carpentier, M. and Argue, D., ***Canadian Wind Energy Technical and Market Potential***, EAETB, Energy, Mines and Resources Canada (CANMET), ON, Canada, October 1992.

The world-wide demand for wind turbines has been growing rapidly over the last 15 years. During 2001 alone the wind energy industry installed close to 5,500 MW of new generating capacity. More than 24,000 MW of wind energy capacity is now estimated to be in operation around the world (Wind Power Monthly, 2001). Much of this demand has been driven by the need for electric power plants that use "cleaner fuels." Windfarms that use multiple turbines are being constructed in the multi-megawatt range, as depicted in ***Figure 1***. Over the last decade, typical individual turbine sizes have increased from around 100 kW to 1 MW or more of electricity generation capacity, with some wind energy projects now even being developed offshore, as shown in ***Figure 2***. The result of all this progress is that, in some areas of the world, large-scale wind energy projects now generate electricity at costs competitive with conventional power plants (e.g. nuclear, oil and coal).

Figure 2:

2 MW Wind Turbines at 40 MW Offshore Windfarm in Denmark.

Photo Credit:

Photo © BONUS Energy A/S

In addition to these larger scale applications, there are a number of other applications for wind turbines, such as medium scale applications on isolated-grids and off-grid uses for pumping water and providing smaller amounts of electricity for stand-alone battery charging applications.

Wind energy projects are generally more financially viable in "windy" areas. This is due to the fact that the power potential in the wind is related to the cube of the wind speed. However, the power production performance of a practical wind turbine is typically more proportional to the square of the average wind speed. The difference is accounted for by the aerodynamic, mechanical and electrical conversion characteristics and efficiencies of the wind turbines. This means that the energy that may be produced by a wind turbine will increase by about 20% for each 10% increase in wind speed. Wind energy project siting is critical to a financially viable venture. It is important to note that since the human sensory perception of the wind is usually based on short-term observations of climatic extremes such as wind storms and wind chill impressions, either of these "wind speeds" might be wrongly interpreted as representative of a windy site. Proper wind resource assessment is a standard and important component for most wind energy project developments.

1.1 Description of Wind Turbines

Wind turbine technology has reached a mature status during the past 15 years as a result of international commercial competition, mass production and continuing technical success in research and development (R&D). The earlier concerns that wind turbines were expensive and unreliable have largely been allayed. Wind energy project costs have declined and wind turbine technical availability is now consistently above 97%. Wind energy project plant capacity factors have also improved from 15% to over 30% today, for sites with a good wind regime (Rangi et al., 1992).

Modern wind energy systems operate automatically. The wind turbines depend on the same aerodynamic forces created by the wings of an aeroplane to cause rotation. An anemometer that continuously measures wind speed is part of most wind turbine control systems. When the wind speed is high enough to overcome friction in the wind turbine drivetrain, the controls allow the rotor to rotate, thus producing a very small amount of power. This cut-in wind speed is usually a gentle breeze of about 4 m/s. Power output increases rapidly as the wind speed rises. When output reaches the maximum power the machinery was designed for, the wind turbine controls govern the output to the rated power. The wind speed at which rated power is reached is called the rated wind speed of the turbine, and is usually a strong wind of about 15 m/s. Eventually, if the wind speed increases further, the control system shuts the wind turbine down to prevent damage to the machinery. This cut-out wind speed is usually around 25 m/s.

The major components of modern wind energy systems typically consist of the following:

- Rotor, with 2 or 3 blades, which converts the energy in the wind into mechanical energy onto the rotor shaft;
- Gearbox to match the slowly turning rotor shaft to the electric generator;
- Tall tower which supports the rotor high above the ground to capture the higher wind speeds;
- Solid foundation to prevent the wind turbine from blowing over in high winds and/or icing conditions (CanWEA, 1996); and
- Control system to start and stop the wind turbine and to monitor proper operation of the machinery.

Figure 3 illustrates the configuration of a typical "Horizontal Axis Wind Turbine" or HAWT wind energy system. A "Vertical Axis Wind Turbine" or VAWT is an equally viable alternative design, although it is not as common as the HAWT design in recent projects implemented around the world.

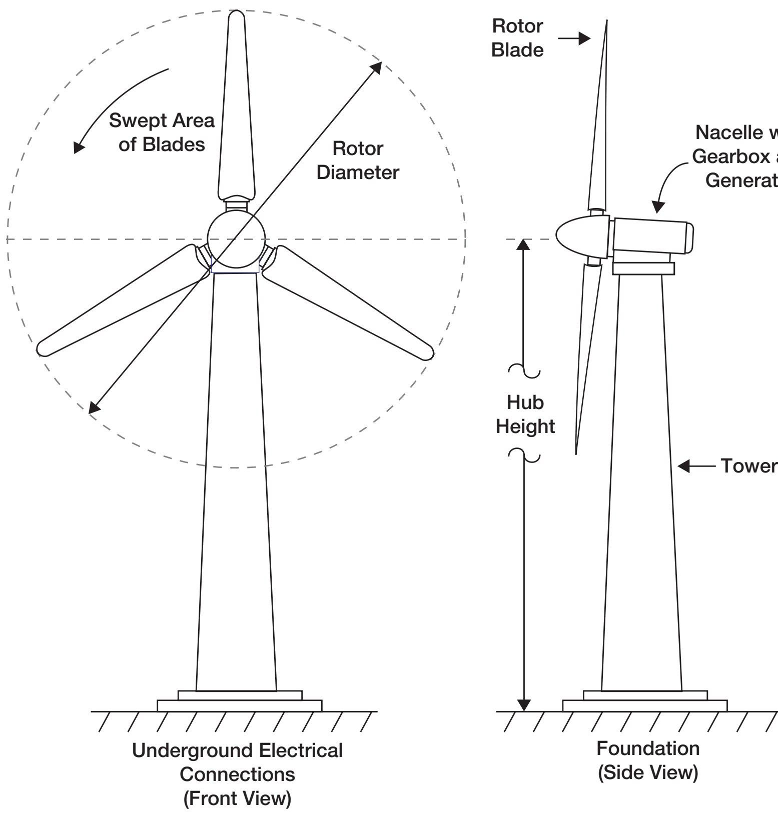

Figure 3:

Wind Energy System Schematic.

1.2 Wind Energy Application Markets

Wind energy markets can be classified based on the end-use application of the technology. Wind energy projects are common for off-grid applications. However, the largest market potential for wind energy projects is with on-grid (or grid-connected) applications.

1.2.1 Off-grid applications

Historically, wind energy was most competitive in remote sites, far from the electric grid and requiring relatively small amounts of power, typically less than 10 kW. In these off-grid applications, wind energy is typically used in the charging of batteries that store the energy captured by the wind turbines and provides the user with electrical energy on demand, as depicted in ***Figure 4***. Water pumping, where water, rather than energy, can be stored for future use, is also a key historical application of wind energy. The key competitive area for wind energy in remote off-grid power applications is against electric grid extension, primary (disposable) batteries, diesel, gas and thermoelectric generators. Wind energy is also competitive in water pumping applications (Leng et al., 1996).

Figure 4:
10 kW Off-Grid Wind Turbine in Mexico.

Photo Credit:
Charles Newcomber/NREL Pix

1.2.2 On-grid applications

In on-grid applications the wind energy system feeds electrical energy directly into the electric utility grid. Two on-grid application types can be distinguished.

1. Isolated-grid electricity generation, with wind turbine generation capacity typically ranging from approximately 10 kW to 200 kW.

2. Central-grid electricity generation, with wind turbine generation capacity typically ranging from approximately 200 kW to 2 MW.

RETScreen® International Wind Energy Project Model

The RETScreen® International Wind Energy Project Model can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for central-grid, isolated-grid and off-grid wind energy projects, ranging in size from large scale multi-turbine wind farms to small scale single-turbine wind-diesel hybrid systems.

Isolated-grids

Isolated-grids are common in remote areas. Electricity generation is often relatively expensive due to the high cost of transporting diesel fuel to these isolated sites. However, if the site has good local winds, a small wind energy project could be installed to help supply a portion of the electricity requirements. These wind energy projects are normally referred to as wind-diesel hybrid systems. The wind energy system's primary role is to help reduce the amount of diesel fuel consumption. A wind-diesel hybrid system is shown in ***Figure 5***.

Figure 5:

50 kW Isolated-Grid Wind Turbine in the Arctic.

Photo Credit:

Phil Owens/Nunavut Power Corp.

Central-grids

Central-grid applications for wind energy projects are becoming more common. In relatively windy areas, larger scale wind turbines are clustered together to create a windfarm with capacities in the multi-megawatt range. The land within the windfarm is usually used for other purposes, such as agriculture or forestry. Another common approach for wind energy project development includes the installation of one or more larger scale wind turbines by individuals, businesses or co-operatives.

A windfarm, as depicted in ***Figure 6***, consists of a number of wind turbines (which are often installed in rows perpendicular to the wind direction), access roads, electrical interconnections and a substation, a monitoring and control system and a maintenance building for the larger farms. The development of a wind energy project includes the determination of the wind resource, the acquisition of all authorisations and permits, the design and specification of the civil, electrical and mechanical infrastructure, the layout of the wind turbines, the purchasing of the equipment, the construction and the commissioning of the installation. Construction involves preparing the site, grading roads, building turbine foundations, installing the electrical collection lines and transformers, erecting the turbines, and construction of the substation and building.

Figure 6:

Components of a Windfarm in the United States.

Photo Credit:
Warren Gretz/NREL Pix

The wind resource assessment and approvals for a windfarm are often the longest activities in the development of the wind energy project. These can take up to 4 years in the case of a large windfarm requiring a comprehensive environmental impact study. The construction itself can normally be completed within one year. The precise determination of the wind resource at a given site is one of the most important aspects in the development of a wind energy project as the available wind resource at the project site can dramatically impact the cost of wind energy production. In the case where a pre-feasibility study indicates that a proposed wind energy project could be financially viable, it is typically recommended that a project developer take at least a full year of wind measurements at the exact location where the wind energy project is going to be installed (Brothers, 1993), (CanWEA, 1996) and (Lynette et al., 1992). ***Figure 7*** shows the installation of a 40 m tall meteorological mast at the CANMET Energy Technology Centre - Varennes in Canada.

Figure 7:
Installation of a 40 m Meteorological Mast.

Photo Credit:
GPCo Inc.

For very small-scale projects (e.g. off-grid battery charging and water pumping), the cost of wind monitoring could actually be higher than the cost to purchase and install a small wind turbine. In this case a detailed wind resource assessment would normally not be completed.