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Mechanical and electrical study of wind turbines

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I dedicate this work

To my dear mother

To my father

To my wife

To my children

To my brothers and sisters

To all those dear to me

To all those I love.

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General Introduction

Electric energy is a crucial element for all socio-economic development. In the daily lives of people. Particularly in developed countries, it has become a form of energy that we can do without. Given the extent of industrialization in recent decades, the proliferation of domestic appliances that consume more and more electrical energy, the demand for electrical energy has become very significant. Faced with this and with the reduction in global hydrocarbon stocks and especially the fear of increasingly invasive and environmentally destructive pollution, industrialized countries have massively resorted to nuclear power plants

This energy source has the undeniable advantage of not generating atmospheric pollution unlike traditional thermal power plants, but the risk of nuclear accident (like the Tchimbay disaster of April 26, 1986 which remains in common memory), the treatment and the burial of waste are the very real problems which make this energy unattractive for future generations. Faced with this dilemma, it is necessary to use new energy sources which will have no consequences for man. and the environment.

This is how industrialized countries have embarked on the development and use of renewable energy sources such as solar, biomass, geothermal, tidal, hydraulic, etc…..

Wind energy, harnessing the power of the wind to generate electricity, stands at the forefront of renewable energy sources globally. It represents a pivotal solution in the quest for sustainable, clean energy alternatives. The concept is elegantly simple yet profoundly impactful: converting the kinetic energy of wind into mechanical energy through turbines, which subsequently converts it into electricity.

The utilization of wind energy dates back centuries, with early applications in milling and pumping water. However, modern wind power technologies have evolved dramatically. Today, wind turbines dot landscapes across continents, from vast wind farms in rural areas to offshore installations harnessing powerful coastal winds.

Key advantages of wind energy include its environmental benefits—reducing greenhouse gas emissions and dependence on fossil fuels—and its potential to enhance energy security and independence. Moreover, technological advancements continue to improve efficiency, reliability, and affordability, making wind energy increasingly competitive in the global energy market.

Challenges remain, such as intermittency and the need for grid integration solutions. Nevertheless, ongoing research and development aim to address these issues, further bolstering wind energy's role in the transition towards a sustainable energy future.

The mechanical aspects of wind energy focus on the design, operation, and efficiency of wind turbines. These turbines are the core technology used to capture wind energy and convert it into rotational mechanical energy. Modern wind turbines typically consist of rotor blades that capture the wind's kinetic energy, a hub that connects the blades to a shaft, and a gearbox that increases the rotational speed to drive a generator.

Key considerations in the mechanical design include optimizing blade shape and size to maximize energy capture, ensuring durability and reliability under varying wind conditions, and minimizing maintenance requirements. Advances in materials science and aerodynamics have significantly improved the efficiency and reliability of wind turbines, leading to larger and more powerful designs capable of harnessing wind resources more effectively.

The electrical aspects of wind energy involve the conversion of mechanical energy into electrical power. This process occurs within the nacelle of the wind turbine, where a generator converts the rotational energy of the turbine's shaft into electrical energy. The generator produces electricity typically at a low voltage, which is then stepped up to a higher voltage suitable for transmission through power lines to consumers.

Integration into the electrical grid is a critical consideration in the electrical design of wind farms. Grid connection requires synchronization with existing electrical systems, ensuring stable and reliable electricity supply. Additionally, advanced control systems and grid management technologies are employed to regulate the output of wind farms and maintain grid stability despite the intermittent nature of wind resources….

Wind energy represents a synergistic blend of mechanical and electrical engineering principles aimed at harnessing renewable energy sources sustainably. The ongoing advancements in both mechanical turbine design and electrical generation and grid integration technologies continue to drive the growth and competitiveness of wind energy on a global scale. As a clean and abundant energy source, wind power plays a pivotal role in reducing carbon emissions, enhancing energy security, and fostering a more sustainable energy future for generations to come.

Chapter 1

Renewable Energies

I.1 – Introduction

Since the use of windmills, wind sensor technology has continually evolved. It was in the early 1940 that true prototypes of airfoil blade wind turbines were successfully used to generate electricity. Various technologies are employed to harness wind energy (vertical-axis or horizontal-axis sensors), and the structures of the sensors are becoming increasingly efficient. Besides the mechanical characteristics of the wind turbine, the efficiency of converting mechanical energy into electrical energy is crucial. Here again, numerous devices exist, most of which use synchronous and asynchronous machines. The control strategies for these machines and their potential grid connection interfaces must allow for capturing the maximum amount of energy over the widest possible range of wind speed variations, all with the aim of improving the profitability of wind installations.

In this Chapter, we will address the generation of energy from renewable sources with a description of onshore and offshore wind turbines and their classification, mentioning the advantages and disadvantages of wind turbines, their main components, and how they operate. We will conclude with wind energy in Algeria. **[1]**

I.2 – History

Sailboats can be considered the first use of wind energy. In 3500 BCE, the Sumerians were already navigating with the help of sails. In the 7th century, the Persians harnessed the power of the wind by channeling it into paddle wheels, which could operate pumps. The Egyptians used the same strategy, but for irrigating land by raising water through a pumping system that moved it into small reservoirs. Later, the Persians improved their machines by attaching sails to a vertical axis. This technique allowed for better use of wind energy and aimed to maximize the efficiency of this new machine, now called a "windmill." The numerous Arab invasions and especially the Crusades enabled the Western world to benefit from this magnificent Persian invention and technological advancement. By the early 16th century, European artisans had improved and significantly complicated the windmill blades. The Dutch were probably the European people who used the windmill most effectively, which allowed them to drain land and create the famous polders. (***Fig*** I.1)

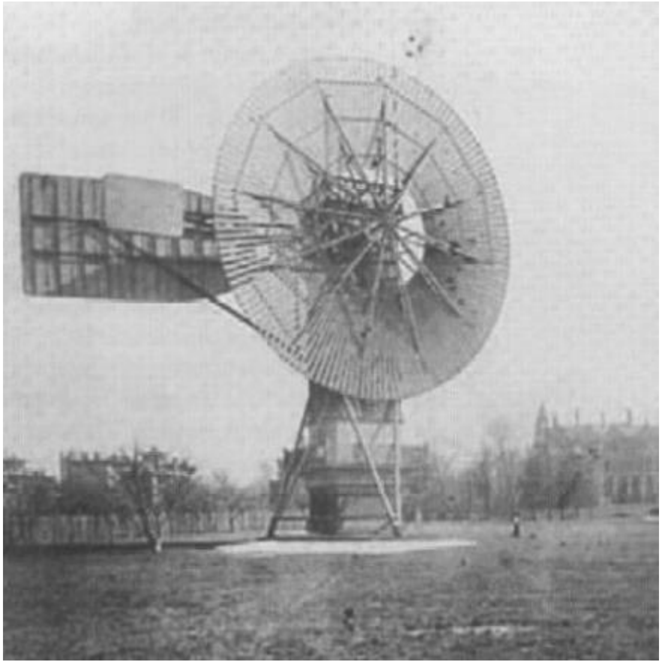

Figure* I.1*: Berton Mill

In 1839, a Frenchman named P. Berton invented a new windmill sail system to spare millers the constant task of climbing into the sails to install and remove canvases according to the wind. This sail system served as the precursor to modern wind turbines, consisting of a deformable parallelogram without canvass but featuring numerous thin, movable, and retractable planks arranged like tiles. In 1841, Belgian Nollet speculated that wind could generate electricity. By 1880, C. Brush, J. Blyth, and V ***(Fig I.2)***. de Feltre conducted multiple experiments and created the first wind generators (depicted here is a wind turbine by C. Brush). Seven years later, C. de Goyon invented a wind turbine equipped with two dynamos. In 1956, J. Juul built a 200 kW wind turbine, which became the benchmark for future turbines that could generate several thousand kW. Wind turbines experienced significant development in Denmark, becoming increasingly efficient and quieter, establishing themselves as a prominent, environmentally friendly energy source that should not be overlooked today. **[2]**

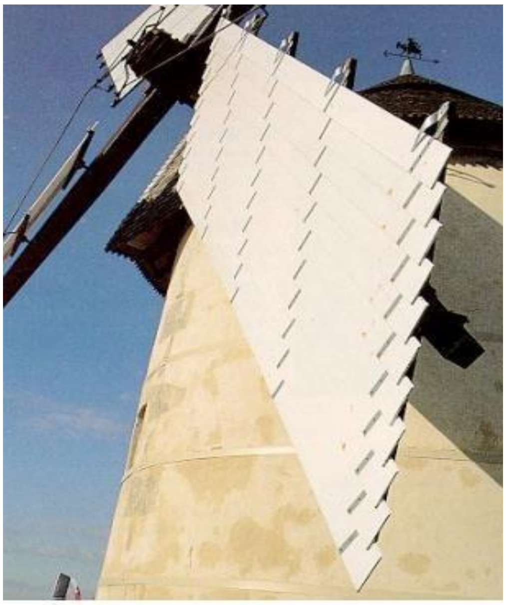

Figure I.2: C. Brush's Wind Turbine [3]

I.3 - Generation from Renewable Energies

One of the limiting factors in the use of renewable energy is that the raw material (energy source) is not transportable in most cases, unlike traditional sources such as oil or uranium, which are extracted from respective deposits and transported "without major issues" to distributors or factories that can be thousands of kilometers away. However, the location where renewable energy is harvested determines its transformation site. Only biomass seems to have fewer restrictions. For example, a wind site must be precisely located in consistently windy geographical areas, solar panels obviously need to be placed in sunny zones, and wave properties are not favorable everywhere in the seas **[4]**, **[5]**. In areas where the grid exists, it is practical and often necessary to convert renewable energy into electrical form, which is transportable via power lines. Energy production becomes centralized and interconnected between multiple production and consumption sites. However, the unpredictable nature of renewable sources poses challenges for energy availability and mass storage, currently primarily managed through hydropower.

Among renewable energies, three main categories emerge: mechanical energy (wave, wind), electrical energy (photovoltaic panels), and thermal energy (geothermal, solar thermal, etc.), all originating from solar energy transformed by the Earth's environment. Since mechanical energy is difficult to transport, it can only be used directly for specific applications (direct water pumping, mills, etc.). Therefore, it is mostly converted into electrical energy. Apart from biomass and hydropower, another major drawback of renewable energies is the irregularity of resources.

Conversely, fluctuations in power demand during annual or daily periods may not align with resource availability. For instance, there is a higher energy demand in winter for heating and lighting, but shorter daylight hours. The solution lies in diversification or coupling of multiple sources, such as combining solar with wind energy. Large-scale electrical energy storage is currently not feasible, although hydrogen synthesized by water electrolysis appears promising as an outlet for renewable energies. Hence, fuel cells operating on renewable-origin hydrogen would constitute a completely clean and available pathway. Moreover, storing hydrogen while generating electricity from a wind farm or solar plant can absorb surpluses from these "capricious energies" and significantly improve electricity production smoothing, a critical aspect for grid operators dealing with renewable energies. Conversely, coupling renewable energies (solar, wind) with fuel cells largely resolves the energy availability issue. Research and development efforts are underway, for example, on wind-origin hydrogen storage in Spain (Navarre region), where EHN, the world's leading wind developer, has partnered with Canadian company 'Stuart Energy Systems' **[6]**, specialized in hydrogen technologies.

I.4 - Description of Wind Turbines

A wind turbine is a device that harnesses the force of the wind to pump water or generate electricity. An aerogenerator is a device that converts the kinetic energy of the wind into mechanical energy available on a transmission shaft, and then into electrical energy through a generator.

Wind turbines can be installed on land (onshore wind farms) and at sea (offshore wind farms), taking into account the presence of favorable wind conditions.

There are two modes of exploiting wind energy:

- Onshore wind turbines are installed on land.
- Offshore wind turbines are installed at sea.

I.4.1 - Onshore Wind Turbine

A land-based wind turbine, or onshore turbine, is installed on land by definition. This renewable energy is harnessed through the force of the wind using an aerogenerator. The production of wind energy depends on the geographic, topographic, and meteorological data of the site **[7]**. Wind energy can be used in two main ways:

- **Mechanical energy conservation:** Wind is used to propel a vehicle, pump water, or turn the millstone of a mill.

- **Transformation into electrical energy:** The wind turbine is coupled with an electrical inverter to produce direct current (DC) or alternating current (AC). It is connected to an electrical grid or operates autonomously with a backup generator (e.g., a diesel generator) or battery **[8]**.

I.4.2 - Offshore Wind Turbine

The term "offshore" in English literally means "away from the shore," in contrast to onshore wind turbines. Offshore wind turbines operate on the same principle as traditional onshore turbines, utilizing the kinetic energy of the wind to generate electricity. The main difference between a marine model and a land-based model of wind turbine lies in the foundation type, which allows it to be either fixed on the seabed or anchored deep in the sea **[9]**.

I.5 - Classification of Wind Turbines

Wind turbines are divided into two main families based on the orientation of their axes of rotation. These two types are:

- **Vertical Axis Wind Turbine (VAWT)**
- **Horizontal Axis Wind Turbine (HAWT)**

I.5.1 - Vertical Axis Wind Turbines

The rotor axis is perpendicular to the ground, and its blades rotate around a vertically positioned shaft. In this case, there are two types of vertical axis wind turbines

I.5.1.1 - Darrieus Vertical Axis Wind Turbine

Darrieus-type wind turbines harness the wind's lift force, significantly reducing noise while operating efficiently in winds exceeding 220 km/h from any direction. However, these turbines have a startup drawback: the rotor's weight presses on its base, causing friction.**(** ***Fig I.3)***

Figure I.3: Darrieus Vertical Axis Wind Turbine. [10]

I.5.1.2 - Savonius Vertical Axis Wind Turbine

This type of wind turbine consists of half-cylinders connected to a vertical axis. It utilizes the wind's drag force. This type of machine is capable of harnessing lower wind speeds because its efficiency is lower compared to turbines that use lift force. ***(Fig I.4)***

Figure I.4: Savonius Wind Turbines

I.5.1.3 - Cycloturbine Wind Turbines

Equipped with a rotor featuring movable parts, allowing the blades to be oriented based on the azimuth of the blade. This differs from the previous two technologies.

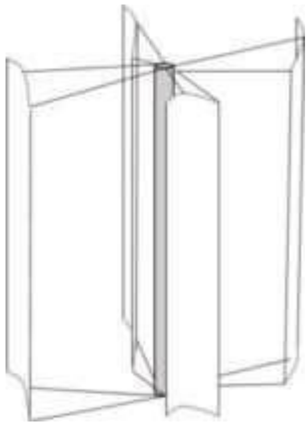

Figure I.5: Cycloturbine Wind Turbines [11]

I.5.1.4 - Advantages and Disadvantages of Vertical Axis Wind Turbine

Advantages:

- Adapts well to various wind directions.
- Captures low-speed winds (starting speed from 2m/s).
- Requires less space than horizontal axis wind turbines.

Disadvantages:

- Lower efficiency compared to horizontal axis wind turbines.
- Generates less electricity.
- Susceptible to aerodynamic and turbulence-related issues.

I.5.2 - Horizontal Axis Wind Turbine

The horizontal axis wind turbine has blades perpendicular to the wind, mounted on a mast. It is based on the ancient technology of windmills and consists of several aerodynamically profiled blades, similar to airplane wings. The number of blades used for electricity generation typically ranges from 1 to 3, with the three-blade rotor being the most common due to its balance between power coefficient, cost, and wind turbine rotation speed.

There are two categories of horizontal axis wind turbines:

I.5.2.1 - Upwind

The wind blows onto the front of the blades towards the nacelle. The blades are rigid, and the rotor is oriented into the wind direction by a mechanism.

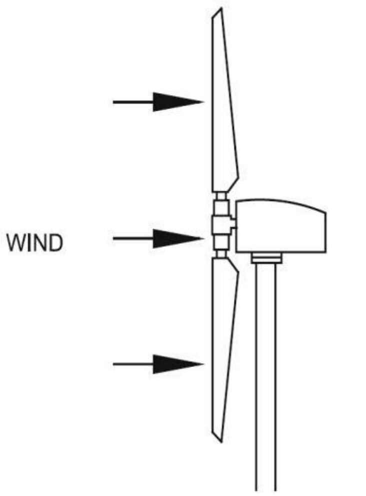

Figure I.6 : Horizontal axis wind turbine in upstream position

I.5.2.2- Downstream

the wind blows on the back of the blades starting from the nacelle. The rotor is flexible and self-orienting. ***(Fig I.7)***

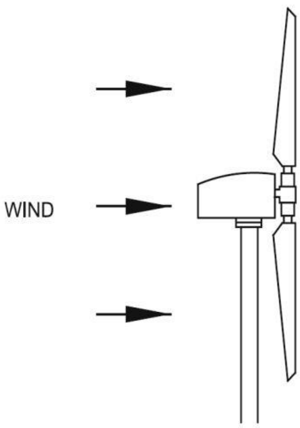

Figure I.7: Horizontal axis wind turbine in downstream position

I.5.2.3 - Main advantages and disadvantages of horizontal axis wind turbines

Advantages:

- Its efficiency is excellent.
- It captures wind energy optimally and self-orients towards the wind direction.

Disadvantages:

- It is less resistant to strong winds compared to vertical axis wind turbines.
- It takes longer to start up.

I.6 - The main components of a wind turbine

The essential components of a horizontal axis wind turbine are :**(** ***Fig I.8)***

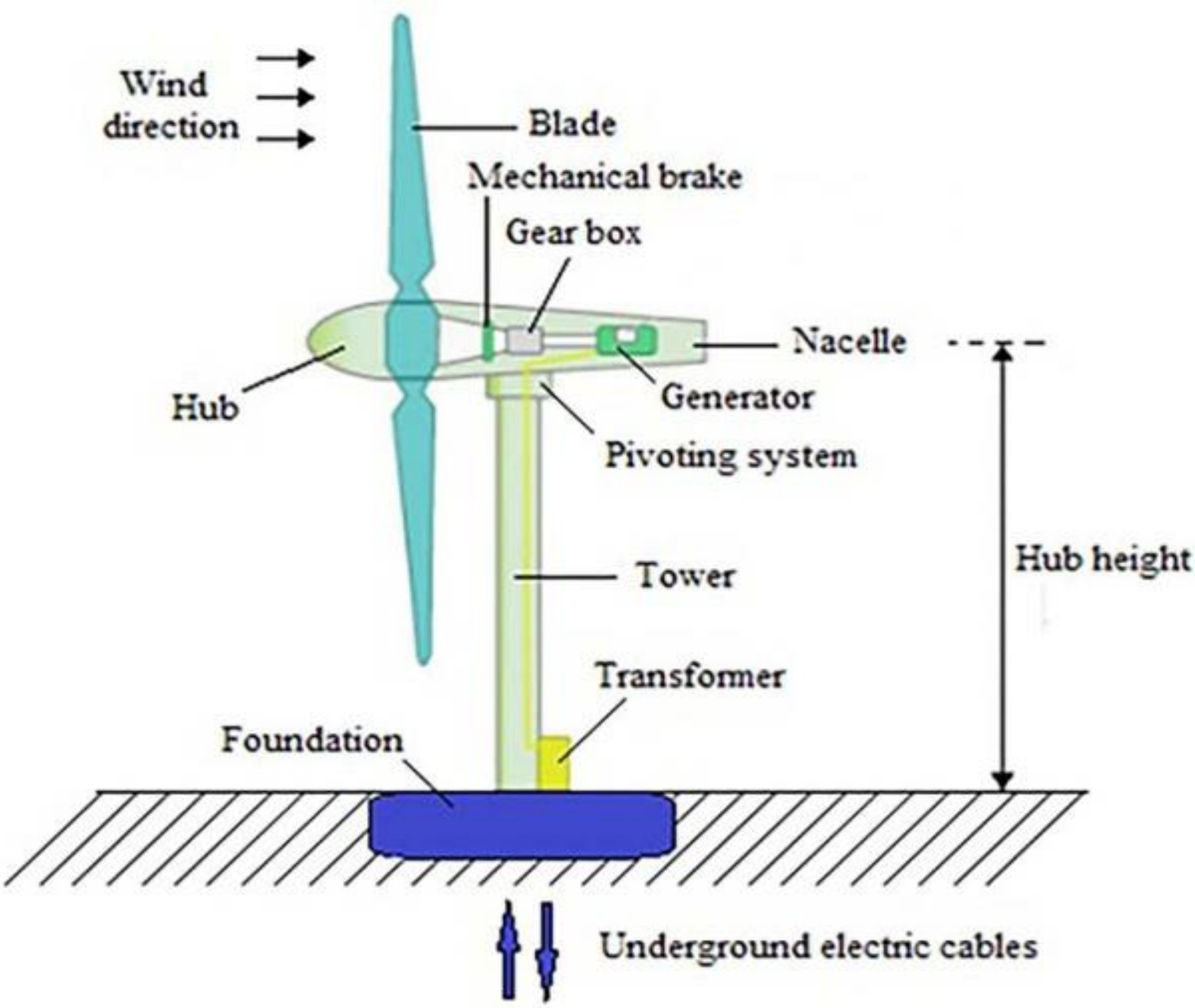

Figure I.8: Main components of a wind turbine

A wind turbine consists of several parts:

- Foundation: The foundation is typically made of concrete. It needs to be strong enough to support the entire structure of the wind turbine.
- Tower: The tower varies in size depending on the wind turbine's power and is made of metal to provide strength. It supports the main elements of the wind turbine: the nacelle and the rotor. Some towers can reach heights up to 100 meters. A taller tower improves the turbine's efficiency as the blades are less obstructed.
- Nacelle: The nacelle is the heart of the wind turbine. Inside it houses the electricity generator that converts the energy from the blade movement into electricity, along with other machinery that controls the blade orientation based on wind strength (braking, yaw mechanism, shutdown).
- The nacelle monitors the turbine's operation and can stop it when the wind is insufficient, too strong, or in other problematic conditions. The supervisory and control systems are highly efficient.
- Rotor (nose + blades): The rotor consists of the nose cone and the blades. The blades, usually three in number, are positioned in front of the nacelle and are connected to it. The blades harness wind energy, converting it into mechanical energy that the nacelle then converts into electricity. The electricity produced is transported through cables inside the tower to a power distribution cabinet.
- Power distribution cabinet: Located at the base of the wind turbine, the power distribution cabinet connects to the electrical grid. It distributes the electricity generated, either storing surplus electricity for later use or feeding it directly into the grid.

I.7 - Technical Aspect

I.7.1-Operation of a Wind Turbine

The operation of a wind turbine involves converting the kinetic energy of the wind into mechanical energy, which is then transformed into electrical energy. This process is carried out through the main components of a wind turbine: altered due to the Coriolis force, which causes winds to deflect because of the Earth's rotation. Other more localized winds are created due to temperature differences between land and water:

a) - The Rotor: Blades and Hub

- **Blades:** Capture the wind's kinetic energy and convert it into rotational mechanical energy.
- **Hub:** Connects the blades to the main shaft and transfers the rotational energy.

b) - Gearbox, Low-Speed Shaft, High-Speed Shaft

- **Gearbox:** Increases the rotational speed from the low-speed shaft to the high-speed shaft, making the energy transfer more efficient to the generator.
- **Low-Speed Shaft:** Connects to the rotor and transfers the mechanical energy to the gearbox.
- **High-Speed Shaft:** Connects to the generator and transfers the increased rotational energy.

c) - Generator

- Converts mechanical energy from the high-speed shaft into electrical energy.

d) - Tower, Foundations, Nacelle

The tower elevates the wind turbine to a height where the average wind speed is higher and more consistent than at ground level. It supports the nacelle and the rotor. Towers are typically tubular or lattice (see **Fig *I.3*** and ***I.4***), **(*Fig I .9)***. Tubular structures offer several advantages: they are highly visible to birds, which perceive them as obstacles to avoid and cannot nest on them. Additionally, wind passing over a tubular tower generates less noise compared to a lattice tower. ***[12]***

Figure I.9: Tubular Tower

Finally, an internal ladder provides better safety for personnel. The nacelle, located at the top of the tower ***(*Fig I.10)**, houses all the electronic and mechanical devices involved in converting the rotational motion into electrical energy, as well as all the hydraulic, orientation, cooling, and control systems. Only the weather vane and blades (rotor) held by the nacelle are outside. In modern, high-power wind turbines, a person can stand upright inside the nacelle without any problem. The foundations, hidden underground or partially in water for offshore wind turbines, are made of concrete and support the entire visible structure. **[13]**

Figure I.10: Lattice Tower [14]

e)Control System

- Monitors and optimizes the turbine's performance by adjusting the blade pitch and rotational speed according to wind conditions to maximize efficiency.

f)Distribution Cabinet

- Distributes the generated electricity to the electrical grid or stores it in batteries

I.7.2- Operation Process

1. Wind Capture: The blades of the rotor capture the kinetic energy from the wind.
2. Energy Conversion: The rotor turns the low-speed shaft, which is connected to the gearbox.
3. Speed Increase: The gearbox increases the rotational speed, transferring it to the high-speed shaft.
4. Electricity Generation: The high-speed shaft drives the generator, converting mechanical energy into electrical energy.
5. Control and Distribution: The control system ensures optimal performance, and the distribution cabinet manages the electrical output, either feeding it into the grid or storing it.

This process ensures that wind turbines can efficiently convert wind energy into a reliable source of electricity, contributing to renewable energy solutions.

I.8 - Wind turbine in Algeria

According to the Renewable Energy Development Center, Wind Energy Laboratory & ALGEOL National Research Project, domiciled at CDER:

- One of the current concerns in Algeria is the revaluation of agricultural land in arid and semi-arid zones.
    - To achieve food self-sufficiency.
    - To fix the populations.
- The developed atlases show that the renewable energy potential
    - geothermal. - solar. - wind turbines.
- Estimated in the south is favorable to the establishment of energy systems based on these energy sources

I.8.1- Seasonal wind speed map

Creating a seasonal wind speed map for Algeria typically requires analyzing data from meteorological stations across the country. Generally, wind patterns in Algeria can vary significantly by season and altitude.

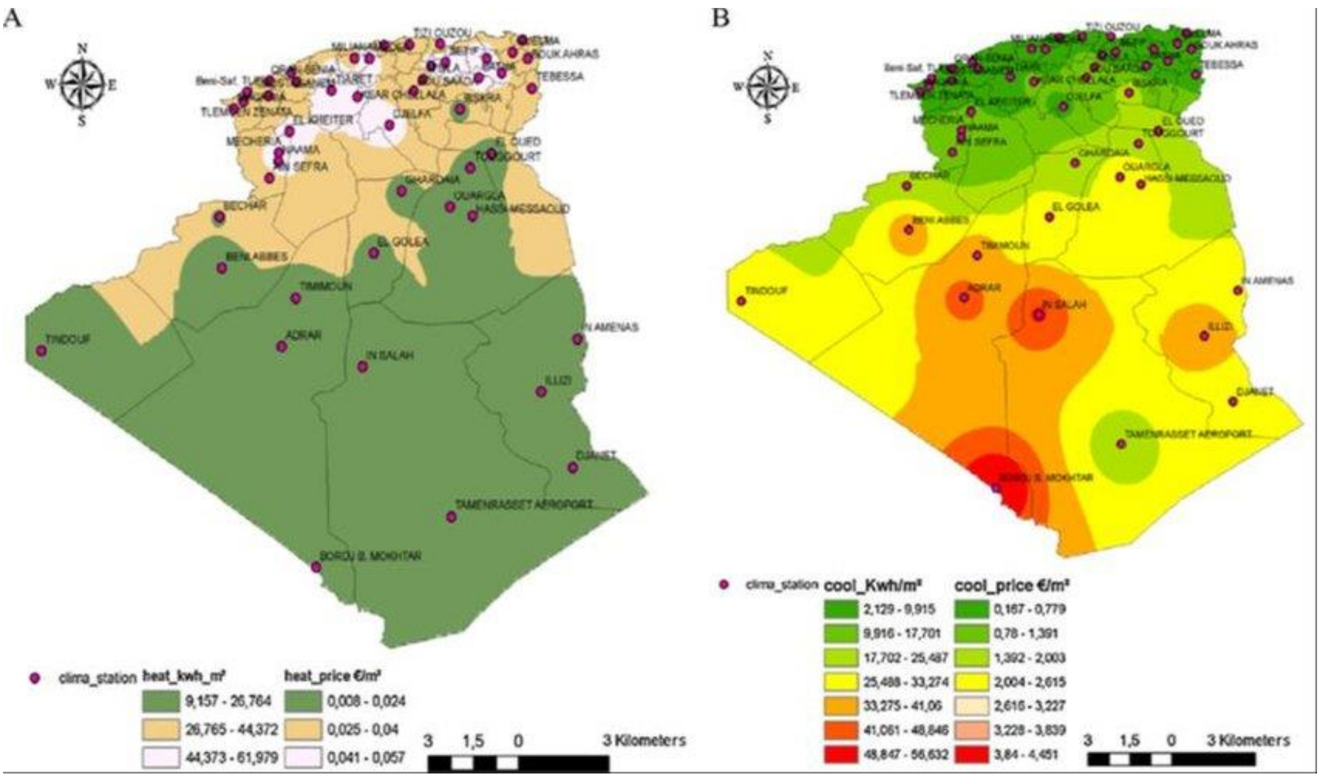

Figure I.11: seasonal wind speed maps: (A) heating; (B) cooling [15]

This dataset was collected from meteorological instruments at the University Center of Naama city, including cup anemometers and wind vanes at heights of 10 m, 30 m, and 50 m. The instruments recorded wind velocities and directions at a frequency of one hertz, which were then averaged over ten-minute intervals to create a more manageable dataset. ***Fig I.12and Fig I.13***

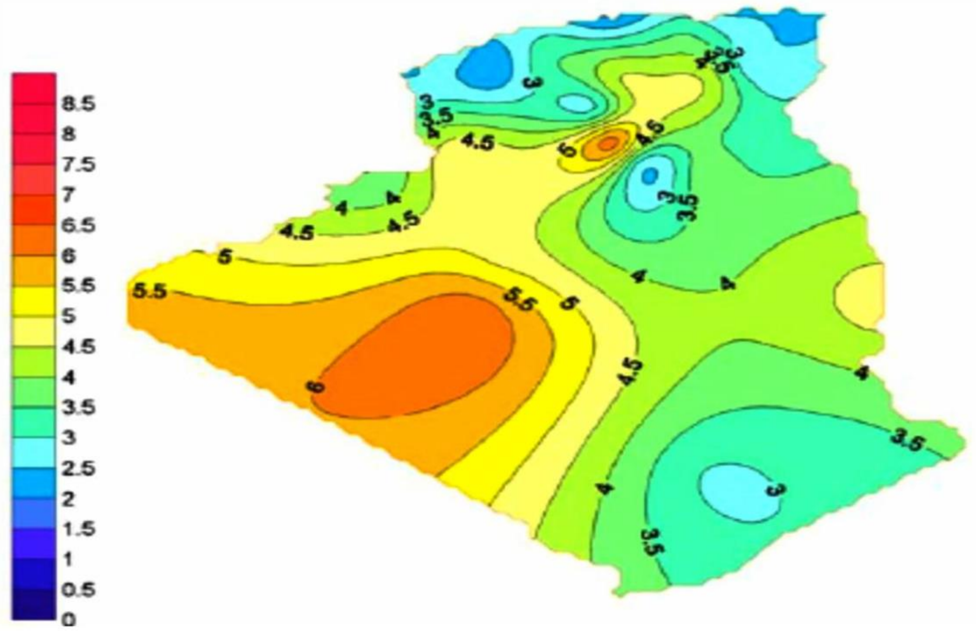

Figure I.12: atlas of wind speed at 10m [16]

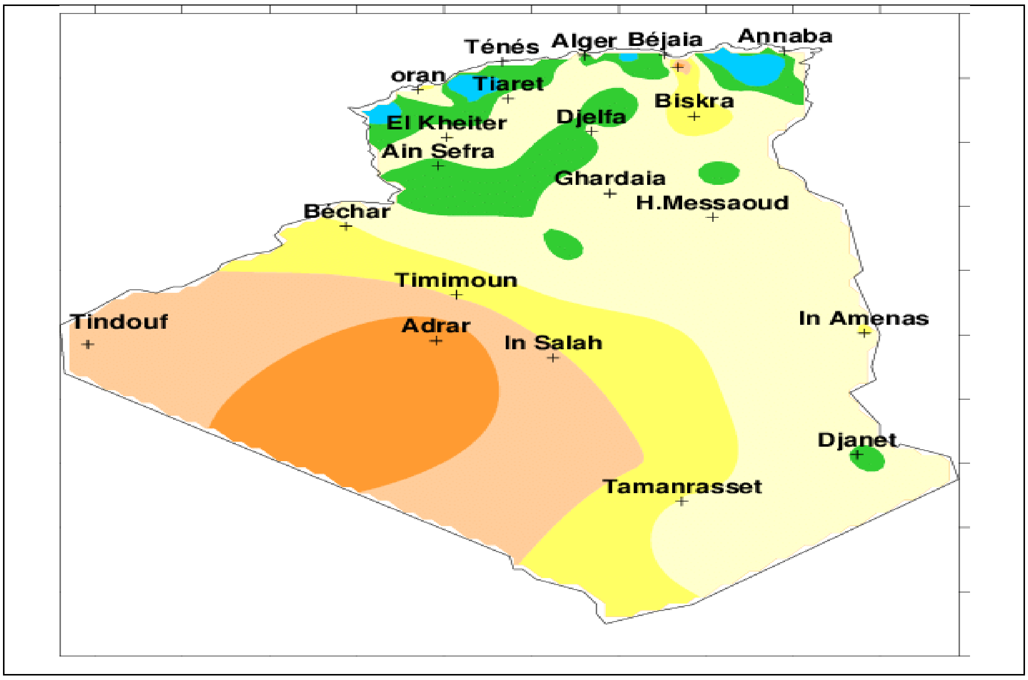

Figure I.13: atlas of recoverable energy power at 50m

I.8.2- Security, risks under surveillance

Like any technology, wind turbines can be subject to incidents, accidents, the main causes of which are strong winds then lightning, or breakdowns.

Around twenty accidents have been recorded in France since 2000, with little material consequences. No injuries to passers-by or residents have ever been reported. Most accidents in the past have occurred on small machines with high rotational speeds.

The introduction of machine safety devices (braking, feathering, lightning arresters, etc.) makes it possible to better and better control the risk of wind accidents. Regular maintenance must be implemented throughout the duration of operation (estimated at 20 years).

As part of the ICPE regulations (see p. 16), a hazard study must now be produced before the installation of wind turbines to assess the risks likely to generate health impacts (falling objects, etc.) or environmental (oil leak, etc.). This study must specify the extent of the dangers and risks and present the measures to manage them. In addition, based on its results, the prefects decide on the distance to be observed between wind farms and roads

A typical hazard study is being carried out by the National Institute of Industrial Environment and Risks (INERIS). ***(Fig I.14)***

Figure I.14: machine safety

I.8.3- Health, a very present concern

Recent wind turbines are not very noisy, and studies have not shown any particular impact of noise on residents living near wind farms. The machines are subject to constant technical improvements to further reduce noise: reduction in the rotation speed of the blades, silent precision
gears, mounting of the transmission shafts on shock absorbers, padding of the nacelle.
Wind projects are subject to regulations relating to the fight against neighborhood noise (decree 2006-1099 of 08/31/2006). (***Fig I.15)***

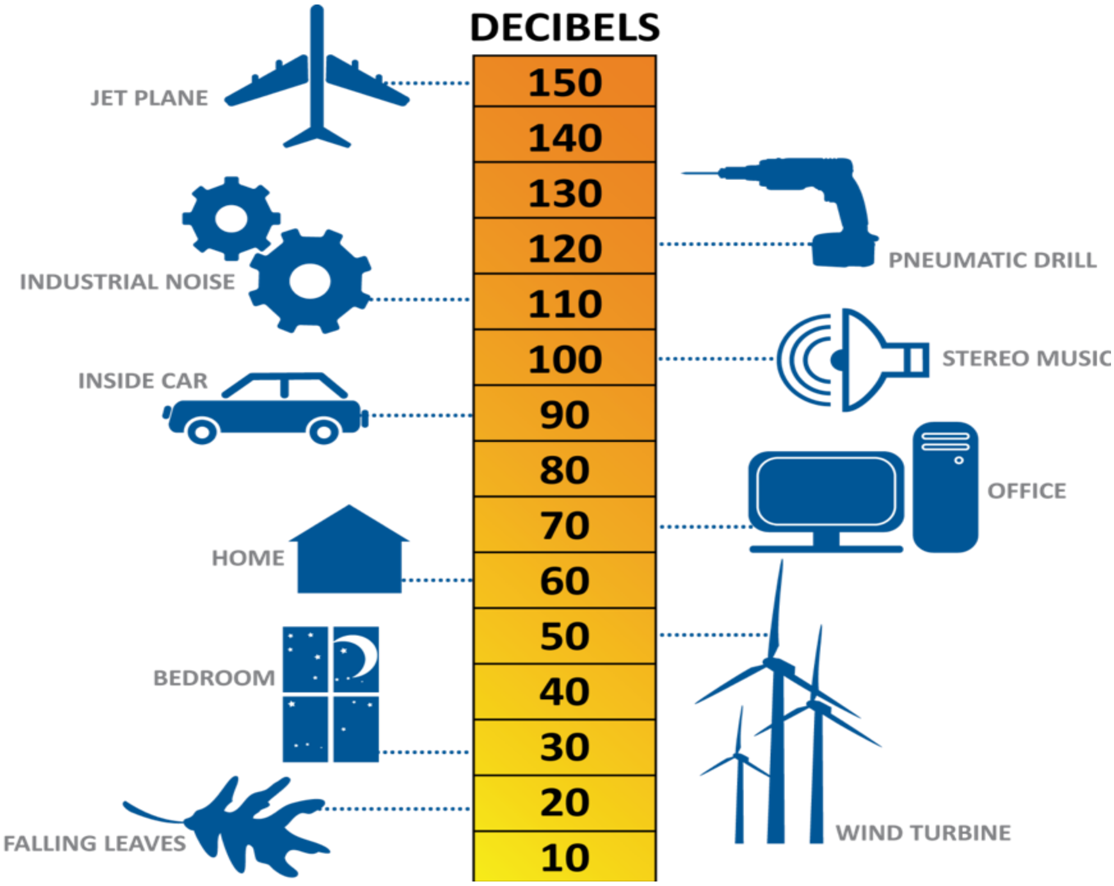

Figure I.15: noise scale

I.8.4- A generally favorable perception

The French are clearly in favor of installing wind turbines in France (74%) and in their region (69%). The majority of them still have them (54%) if the project is located less than 1 km away. from their house.

When they are not in favor of installing a wind turbine less than 1 km from their home, they motivate their response by fear of nuisance to the landscape and noise. Concern about noise often fades after visiting a wind farm.

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Chapter II

Theoretical Study of Wind Energy

II.1 Introduction

The process of transforming kinetic energy into mechanical, electrical energy

The electrical or mechanical energy produced by a wind turbine depends on three parameters: the shape and length of the blades, the wind speed and finally the temperature which influences the density of the air.

The energy recoverable by a wind turbine is proportional to the surface swept by its rotor and to the cube of the wind speed.

Recoverable energy corresponds to the kinetic energy that can be extracted. It is proportional to the surface swept by the rotor and to the cube of the wind speed.

The maximum recoverable power (P) is given by Betz's law: P=0.37.S.V3; where 0.37 is the air constant at standard atmospheric pressure (1013 hPa), S the swept area and V the wind speed.

In practice, a wind turbine produces four times more energy if the blade is twice as large and eight times more energy if the wind speed doubles. Air density also comes into play: a wind turbine produces 3% more electricity if, for the same wind speed, the air is 10°C colder. Wind power mainly depends on wind intensity and its variations. Wind energy is therefore intermittent energy and random.

The wind is stronger and more constant at sea. The wind turbines installed there are also more powerful.

The blade/rotor assembly is oriented into the wind by a rudder system. Most wind turbines start when the wind speed reaches around 3 m/s and stop when this speed reaches 25m/s. Generally, wind turbines are configured to make the best use of winds from intermediate powe

II.2 Historical Theoretical Study of Wind Energy

The theoretical study of wind energy dates back to ancient civilizations such as the Egyptians and Babylonians, who harnessed wind for various practical purposes, including water transportation and sailing. In the 17th century, scientists like Galileo and Newton made significant contributions to understanding the basic principles of air movement and aerodynamics.

The early 20th century marked a pivotal period for wind energy theory, with researchers beginning to analyze the conversion of kinetic wind energy into mechanical or electrical energy. One of the key figures was Albert Betz, who formulated Betz's Law in 1919, establishing the maximum efficiency limit for energy extraction from wind using wind turbines.

Over the subsequent decades, various turbine designs were developed and optimized, enhancing performance and efficiency. With advancements in technology and a growing demand for renewable energy sources, wind energy became a focal point of research and development globally.

Today, wind energy is recognized as one of the most effective renewable energy sources, significantly contributing to electricity generation and reducing dependence on fossil fuels. This progress is a testament to the extensive theoretical and technical advancements achieved over the years.

II.3 Wind Energy Extraction

Wind energy is the kinetic energy of large masses of air moving over the earth. A wind energy conversion system (WECS) converts this kinetic energy into mechanical energy and electrical energy using airfoils, a drive train, and a generator. The conversion process begins as air flows over a blade, called an airfoil that is similar to an airplane wing or propeller. Airflow over a stationary airfoil produces two forces, a lift force perpendicular to the airflow and a drag force in the direction of airflow, as shown in **(Fig *II.1)***. The drag force is used to drive the parachute that tugs on a rope that in turn lifts the bucket of water from the well, so the drag force is used the mechanical applications, where lift force is suitable for electricity generation. A wind turbine is characterized by its power-speed characteristics. **[1]**.

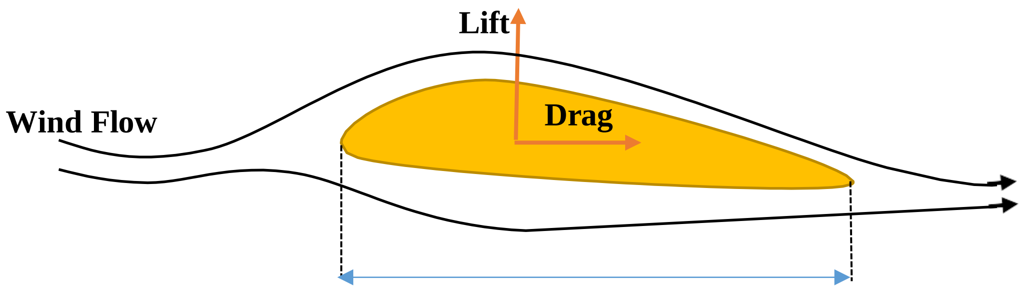

Figure II.1: Air Foil

II.4 Kinetic Energy to Wind Energy

The kinetic energy of wind, which is the function of the mass and velocity of the air volume can be considered. If the air density (mass per unit volume) is constant, the energy suppliedby wind can be written as a function of speed.

Wind kinetic energy

$$E_c = \frac{1}{2} \cdot m \cdot \upsilon^2 \qquad (1)$$

Where

m: mass of air volume (in kg)

υ : instantaneous wind speed (in m/s)

E_c : kinetic energy (in joules)

At normal atmospheric pressure and 15°C (60°F), temperature air weighs about 1.225

kilograms per cubic meter (0.0763 lb/ft^3), However, the density decreases slightly when the humidity increases. Similarly, the cold air is denser than warm air, as the air density is lower at high altitudes (in the mountains) due to the lower air pressure that prevails. Therefore, the mass of the air becomes

$$m = \rho V \qquad (2)$$

Where

m : mass of air volume (in kg)

V : volume of occupied air (in m^3)

ρ : density (in kg/m^3)

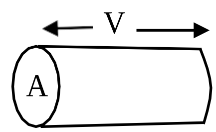

Figure II.2: Mass of column ρAV

In the unperturbed state shown in (Figure II.2) , a column of wind upstream of the turbine with cross-sectional A of the turbine disk. Then Equation 1 becomes:

$$E_c = \frac{1}{2} . (\rho A V). \mathrm{V}^2 \qquad (3)$$

II.5 Wind Power

The density ρ is the function of height and meteorological condition, so wind speed increase with height and from one place to another place, but here we considered general, which means speed and air density are constant with time and over the area of the air column. The air slows down when turbine blades are approached, the power from wind is proportional to wind speed cubic (V^3). The power that can be extracted from wind is given by given Equation (4).

$$p = \frac{1}{2} . \mathrm{e}. \mathrm{K}. A. \rho. V^3 \qquad (4)$$

Where

e = efficiency of the blades

k = conversion factor for unit (e.g. ft. lb to kw)

A: outer swept area of the blades ($\pi.r^2$)

V : velocity of wind for enough upstream

ρ : density of air approximately 1.22 kg/m^3 (0.0763 lb/ft^3) at sea level.

The theoretical maximum energy that can be extracted from wind is formulated by German Albert Betz in 1919, Equation 5 shows the Betz Limit.

$$P_{max} = C_p \times P \qquad (5)$$

C_p, the power coefficient is the ratio of power extracted by a wind turbine to power available in wind at that location, as Betz derived the value of C_p is 16/27 or 0.593. [2] So in Equation 5, the theoretical maximum of 59.3% of available power can be extracted. Practically a typical maximum of 30% including gearbox, generator, or pump losses is achieved. Wind turbines can produce energy at minimum wind speed near 3.6 ms^{-1}, but requires a speed above 5ms^{-1} to economically viable **[1]**

II.6 Electric Power Generation of WECS

WECS used to produce electricity tend toward low solidity designs that have tip speed ratios for high rpm operation. There are two methods to drive generators. **(Fig II.3*)***

1) Direct Drive Generator – In this method, the wind wheel directly turns the generator which was a low-speed unit
2) Transmission Mounted – This method uses a gearbox that increases the rotorrpm by a factor called gear ratio typically 4, 5, or more.

The block diagrams of the two methods are shown in the Figure below:

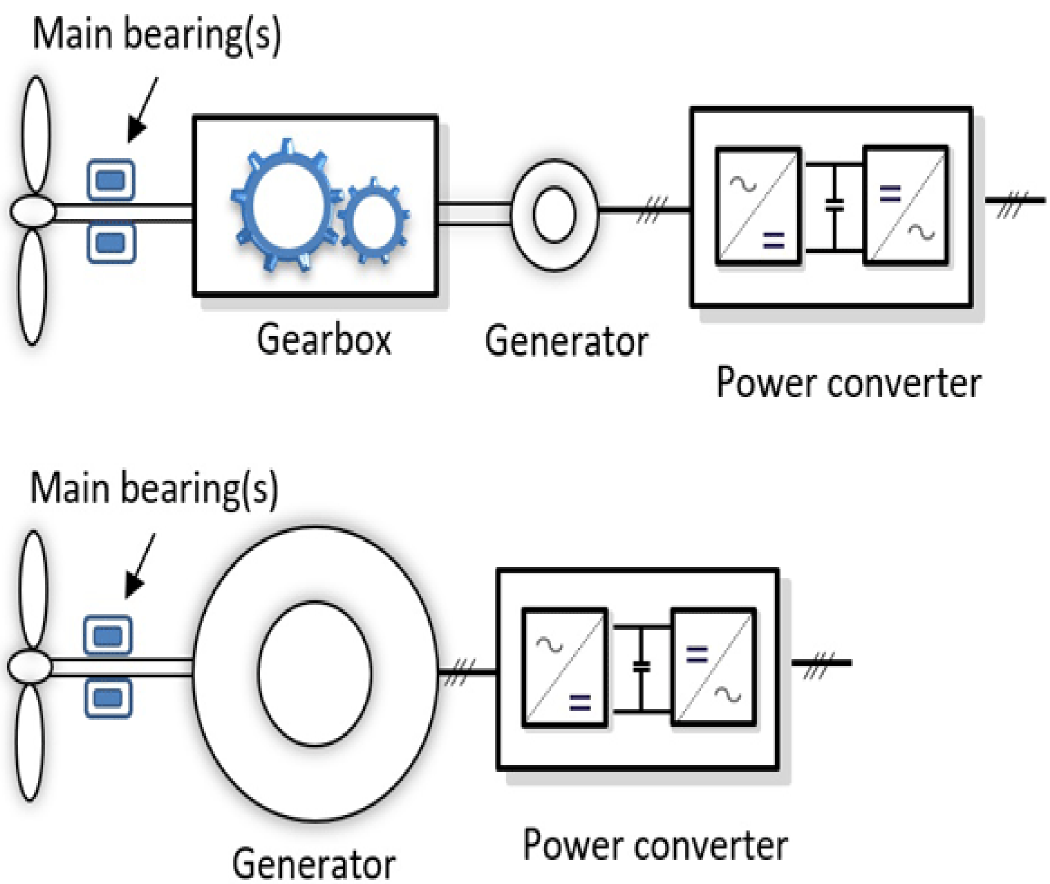

Figure II.3: Wind Turbine Driving A Generator: a) Transmission Mounted; b) Direct Method

Wind Energy Conversion System involves many technical complexities apart from the above two methods**. (Fig II.4*)*** shows the detailed block diagram of method two including control systems: Wind Energy Conversion System (WECS) can be AC type WECS or DC type WECS. An AC type uses Synchronous generators that can produce alternating current that can be fed directly to the load or grid. The DC type involves DC generators or other electronic mechanism that produce Direct Current that can be stored in the batteries or given to DC load, Wind turbine can be installed into offshore wind turbine site and offshore wind turbine site as shown in **(Fig II.4)**:

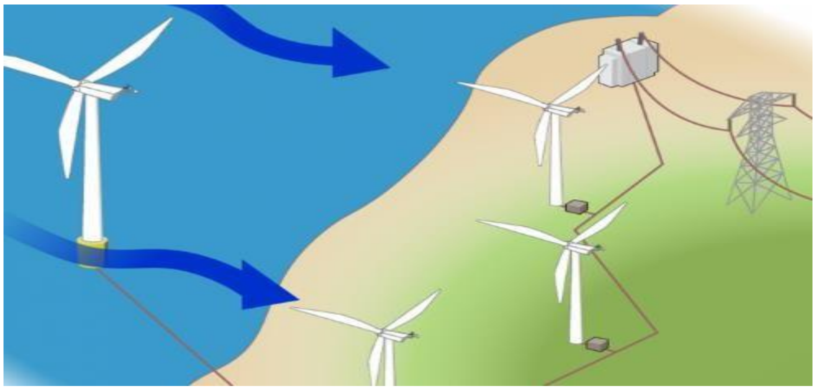

Figure II.4: Wind turbine site Operation

II.7 Classifications of Wind Turbine

Wind turbines can be classified into horizontal axis wind turbines and vertical axis wind turbines depending up on the orientation of axis of rotation of their rotor as shown in the figure below:

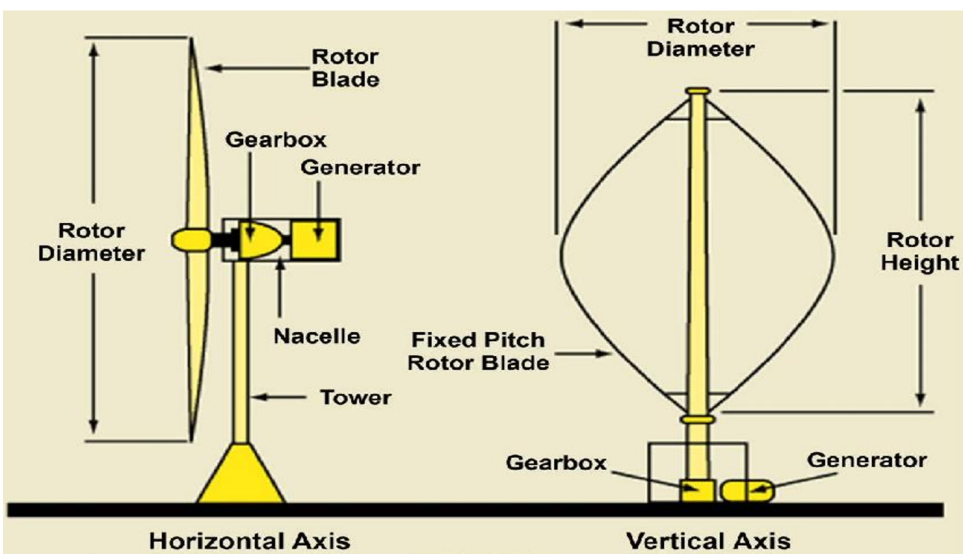

Figure II.5: Types of Wind Turbines [3]

Horizontal axis turbines, the rotor axis is kept horizontal and it is aligned parallel in the direction of the wind stream. In vertical axis turbines, the rotor is vertical and fixed. It remains perpendicular to the wind steam. According to the wind turbine rotors there are four different types of wind turbine rotors as shown in **(Fig II.6)**. Multi-bladed rotor is a horizontal axis wind turbine fabricated from curved sheet metal blades. Number of blades used ranges from 12 to 18. Propeller rotor is the horizontal wind turbine comprises two or three aerodynamic blades made form strong but light in weight materials such fiber glass reinforced plastic. It has a diameter ranges from 2 m to 25 m. Savonious rotor is a verticalaxis wind turbine comprises two identical hallow semi-cylinders fixed to vertical axis, two cylinders face each other to have S shaped cross-section. Darrieus Rotor is a vertical axiswind turbine that has two or three thin curved axis turbine blades of flexible metal strips. It looks like an egg-beater, and it operates wind coming from any direction. It can be installed close to ground to reduce the cost of a tower.

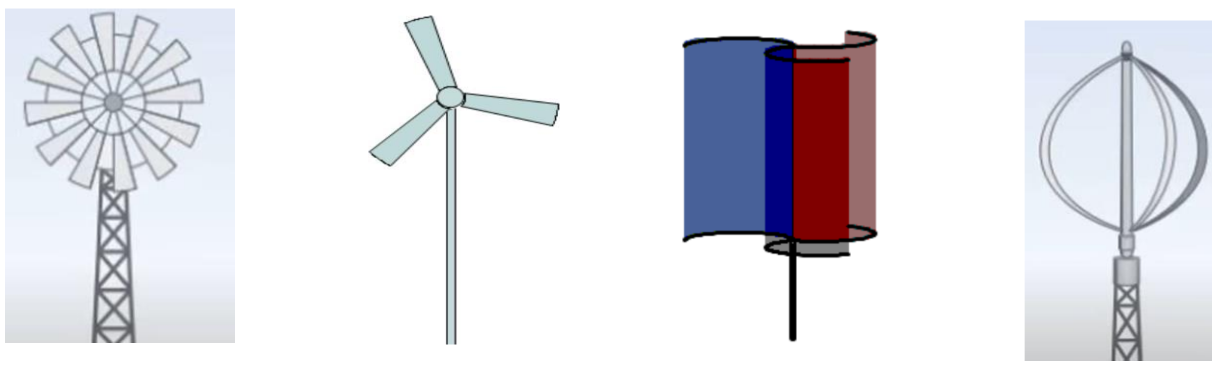

Figure II.6: Types of Wind Turbine Rotors: a) Multiblade rotor; b) Propeller rotor; c) Savonious rotor; d) Darrieus rotor

II.8 Modes of Wind Power Generation

By nature, wind is not a steady source of energy, therefore, it cannot on its own meet the needs of consumers at all times. Necessarily, it has to be integrated with some other sources to provide a constant backup. Wind Electric Generators (WECs) operate in one of thefollowing three modes:

1) **Standalone Mode:** This system is a decentralized energy source. It is used where an individual energy consumers or a group of consumers install their own wind turbine. It can have two applications) power supply for domestic use and battery charging) windmill water pump for irrigation anddrinking purposes.
2) **Backup Mode:** Wind energy, being intermittent, requires a backup of diesel generator to maintain a 24-hour power supply.

3) **Grid Connected Mode:** A common arrangement for connecting WECs to the grid is shown in Figure 7. This WECs also feeds local loads.

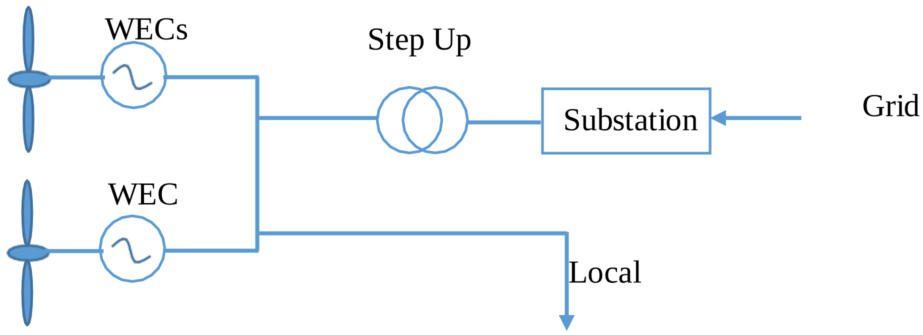

Figure II.7: Grid Connected Wind Turbine Generators

II.9 Theoretically recoverable energy

Considering a device for recovering this surface energy S and assuming that the wind speed is identical at each point of this surface, the volume of air which crosses this surface in 1 second is equal to vs. Wind speed created by the movement of the blade

$$\mathbf{U} = \omega \;\; \mathbf{. \, r = 2\pi \, .} \boldsymbol{f}\mathbf{.r = 2\pi} \; \frac{\boldsymbol{n}}{\mathbf{60}} \mathbf{.} \boldsymbol{r}$$

U: wind speed due to the movement of the blade or tangential speed (in m/s)

ω: angular speed of the rotor (in rad/s)

r: $distance\ from\ the\ point\ considered\ to\ the\ axis\ of\ rotation\ (in\ m)$

f: rotor rotation frequency (in hertz == s^{-1} == revolution/second)

f: rotor rotation frequency (in (revolution.K^{+1})/(second.K^{-0})

f: rotor rotation frequency (in (revolution.K^{+0})/(second.K^{-1})

with K^{+1} element of R^{-+}, therefore $K^{+1} > 0$

$\boldsymbol{n}$: rotor rotation frequency (in revolution/min)

II.9.1 Recoverable power

Wind power contained in a cylinder of section S

$P_{cinétique} = \frac{1}{2}.\rho.\alpha.S.V^3_{turbine}$

$V_{turbine} = \alpha.V_f$

V_f : fluid velocity at the turbine level (in m/s)

P : density of air (dry atmospheric air, approximately 1.23 kg/m³ at 15°C and at atmospheric pressure 1.0132 bar).

S :projected surface of the wind collector (in m²)

This power (in Watt) is a theoretical power; it is of course impossible for it to be recovered as is by a wind turbine (this would amount to stopping the wind).

II.9.2 Betz limit/Betz formula

The recoverable power is lower, since the air must retain residual kinetic energy for there to be a flow. The German Albert Betz demonstrated in 1919 that the maximum recoverable power is

Maximum recoverable power

$\mathbf{P}_{max} = \frac{16}{27}.\mathbf{P}_{kinetics} = \frac{8}{27}.\rho\,S.\,\upsilon^3$

With $\mathbf{P}_{kinetics} = \frac{1}{2}.\rho.S.\upsilon^3$, when $\upsilon_{aval} = \frac{1}{3}.\upsilon_{amont}$

ρ : density of the fluid (dry atmospheric air, approximately 1.23 kg/m³ at 15°C and at atmospheric pressure 1.0132 bar)

S: surface of the wind collector (in m²)

υ : incident speed (upstream) of the fluid (in m/s)

The maximum theoretical yield of a wind turbine is set as 16/27, approximately 59.3%. This figure does not take into account energy losses incurred during the conversion of mechanical wind energy into electrical energy.

In the case of a helix of diameter D, the Betz limit is equal to:

$$p = 0.37\frac{\pi}{4}.D^2.V^3$$
$$p = 0.29.D^2.V^3$$

The power supplied by a wind generator is proportional:

- Squared rotor dimensions
- Cubed by wind speed

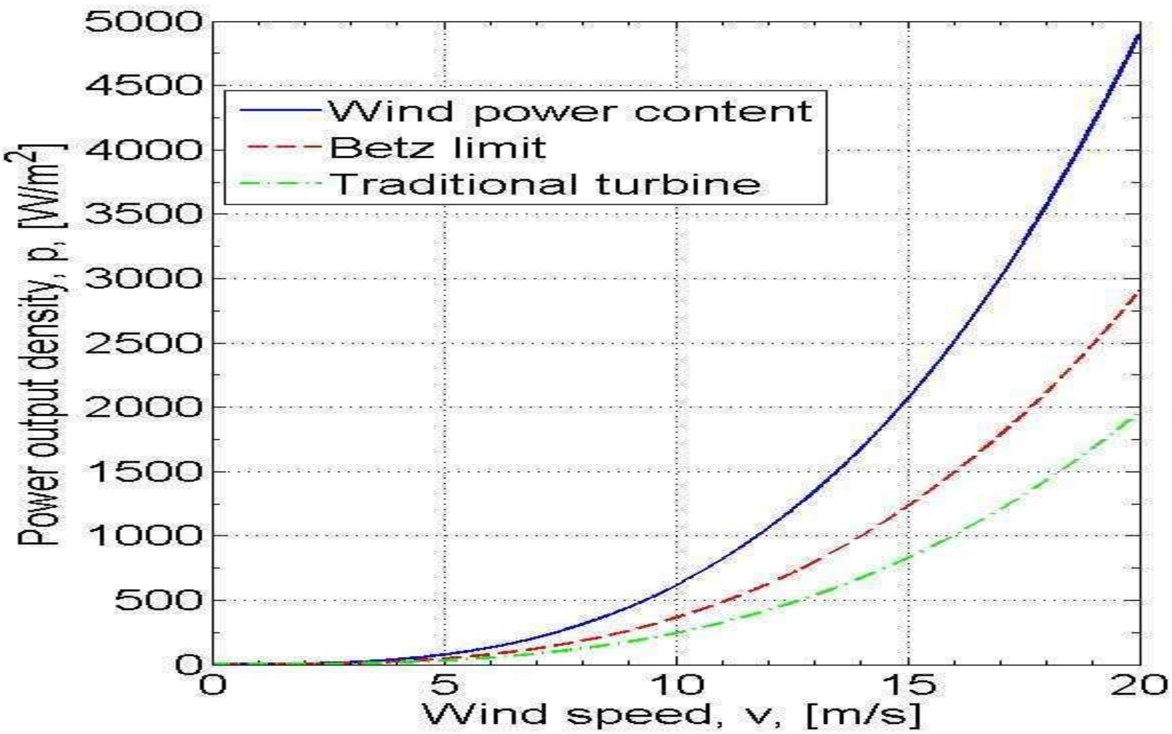

Figure II.8 The power generated varies with the wind speed

The energy provided by the wind generator being converted from one form to another, this limit is therefore affected by all the yields specific to the different transformations.

- Propeller: $0.2<\boldsymbol{\eta}<\mathbf{0.8}$
- THE multiplier or the reducer: $0.7<\boldsymbol{\eta}<\mathbf{0.98}$
- The alternator or generator continues: $0.80<\boldsymbol{\eta}<\mathbf{0.98}$
- The transformer: $0.85<\boldsymbol{\eta}<\mathbf{0.98}$
- The rectifier: $0.9<\boldsymbol{\eta}<\mathbf{0.98}$
- Batteries: $0.7<\boldsymbol{\eta}<\mathbf{0.8}$

The efficiencies of each element vary with the operating speed linked to the rotation speed of the propeller, which apart from the nominal speed further reduces the overall efficiency of the device; it seems difficult to exceed 70% of the Betz limit

II.9.3 Rotor angular speed

Angular velocity ω, also called angular frequency or angular frequency, is a measure of rotational speed. That is to say one angle per second:

Angular velocity

$$\omega = 2\pi \,.\, f \qquad (6)$$

ω: angular speed (in rad/s)

f : rotor rotation frequency (in s¹ or Hz)

II.9.4 Tangential speed

Consider a stationary propeller whose axis of rotation is parallel to it wind, for each pale we can trace the resultant perpendicular to the profile applied to the center of the aerodynamic thrust. We obtain :

- T1 and T2 parallel and in the same direction which tend to move the propeller in a translational movement in the direction of the wind
- P1 and P2 parallel and in opposite direction, perpendicular to the direction of the wind

These two forces create a driving torque which tends to turn the propeller in a plane perpendicular to the wind direction.

II.9.5 Speed reduction downstream of the rotor

The most common model for calculating the reduction in speed in the wake is that developed by WASP/Park2,softwareused as standard by the wind industry This model is based on the linear development of a Wake rectangular.

Wind speed downstream of the wind turbine

$$\upsilon = U\left[1 - \sqrt{(1 - CT)}\left(\frac{D}{D + 2KX}\right)^2\right] \qquad (7)$$

υ = wind speed in the wake, downstream of the rotating rotor (in m/s)

U: undisturbed wind speed upstream (in m/s)

CT : wind turbine drag coefficient (dimensionless)

X : rotor diameter (in m)

D: rotor diameter (in m)

K : is a wake decay constant

Wake decay constant

$$K = \frac{A}{\ln\left(\frac{h}{z_0}\right)}$$

A : constant (A = 0.5)

h: hub height (rotor center)

z_0 : Roughness length

II.9.6 Mechanical torque produced by the wind turbine

$$\Gamma = \frac{p}{\omega}$$

Γ : mechanical torque produced by the wind turbine (in N.m)+

P : mechanical power (in W)

ω : rotor rotation frequency (in rad/s)

Engine torque is the rotational force that turns the rotor. This couple is obtained by a summation of the components of lift and of streak and is a function of the number of rotor blades:

engine couple

$$\Gamma : \int_D^L d\Gamma = \eta \, . \int_D^L [\xi . \sin \alpha - D \, . \cos \alpha \,]$$

Γ : engine torque (in N.m)

η: number of blades (without unit)

A : blade attack angle (in degrees)

ξ : Lift (in N)

D : drag (in N)

L : blade length (in m)

Assuming the angle α constant over the entire length of the blade it is possible to simplify this equation by considering a constant relative speed over the entire length of the blade. We find that the engine torque can be expressed in the following form:

Couple moteur

$$\Gamma = \eta \,.\, L. \,[\xi.\, \sin\alpha - D.\, \sin\alpha]$$

$$\Gamma = \eta \,.L^2.\frac{\rho\,.\,c}{2}\left(\upsilon^2 + \frac{1}{\sqrt{3}}\,.\upsilon^2\,.\,[C_z\,.\sin\alpha\;.\,C_x\,.\,cas\;\alpha]\right)$$

Γ: engine couple (N·m)

η: number of blades (unitless)

α: blade attack angle (in degrees)

ξ : Lift (in N)

D: drag (in N)

L: blade length (in m)

II.9.7 Assessment of wind energy around the world

Cumulative worldwide installed wind power capacity from 1990 to 2015, and annual installed capacity, in gigawatts (GW). Data Source: GWEC's Annual market update adjusted for offshore installed but non-connected capacity in Europe, and other minor adjustments.

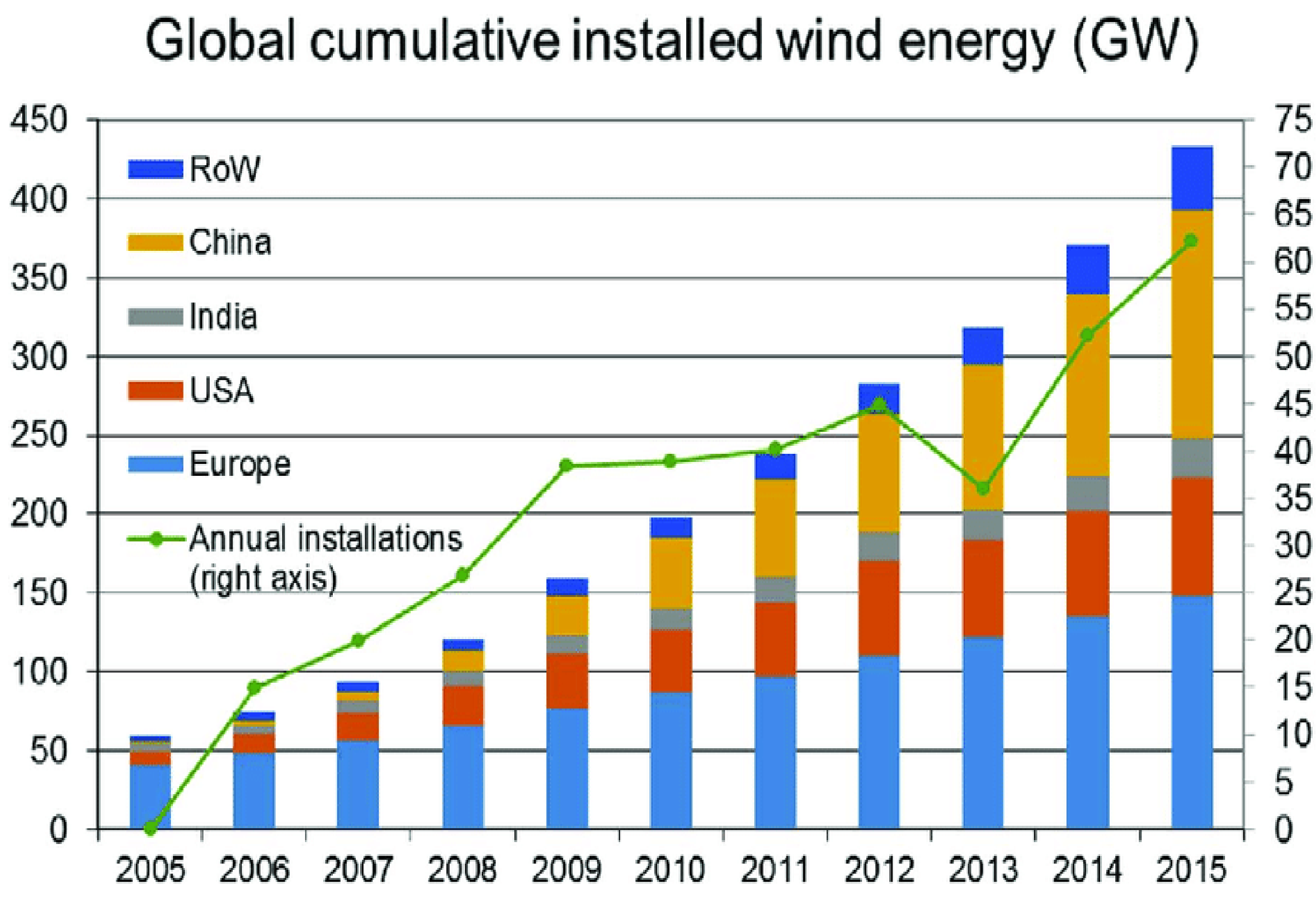

Figure II .9: wind energy au1er January of each year [4]

References

[1] V. D. Hunt, "4 Fundamental Operation of Wind Energy Conversion System," in *Windpower: A Handbook on Wind Energy Conversion*, London, Van Nostrand Reinhold Co, 1981, pp. 68-88.

[2] S. I. Khan, U. M. Mahfuz, T. Aziz and N. M. Zobair, "Prospect of Hybrid Wind System in Bangladesh," in *Second International Conference on Electrical and Computer Engineering*, Dhaka, 2002.

[3] A. Ahmad, A. Loya, M. Ali, A. Iqbal, F. Baig and A. Afzal, "Roadside Vertical Axis Wind Turbine (VAWT): An Effective Evolutionary Design for Australian Highway Commuters with Minimum Dynamic Stall," *Scientific Research Publishing*, vol. 12, no. 10.4236/eng.2020.129042, 2020.

[4] GWEC's Annual market update adjusted for offshore installed but non-connected capacity in Europe, and other minor adjustments.

Chapter III

Calculus of Weibull parameters and fonction density simulation of region of saida

III.1 Introduction

Saida Province (34° 50′ 00″ north, 0° 09′ 00″ east) is located in the western high plateau region of Algeria, approximately 470 km from the capital, Algiers. It covers an area of 6613 km². The village itself is situated at an altitude of 800 meters within the mountainous Atlas range on the Southern Oran High Plateau, which provides natural protection from northern winds.

he Weibull distribution is commonly used to model various types of data, such as wind speeds, lifetimes of systems, and environmental data. For the Saida region (in Algeria), Weibull analysis is particularly useful in fields like wind energy assessment, rainfall distribution, or reliability analysis of infrastructure.

Monte Carlo simulation is a computational technique that uses randomness to solve problems that might be deterministic in principle. It is widely used in various fields such as finance, engineering, physics, and risk analysis. The core idea is to use random sampling and statistical modeling to estimate mathematical functions and mimic the behavior of complex systems.

III.2. Methods

III.2.1 Weibull parameters

We import from **[1]** 207 speed wind values for the year 2023 **(Fig III.1)**. We regroup them in to the **table III.1**

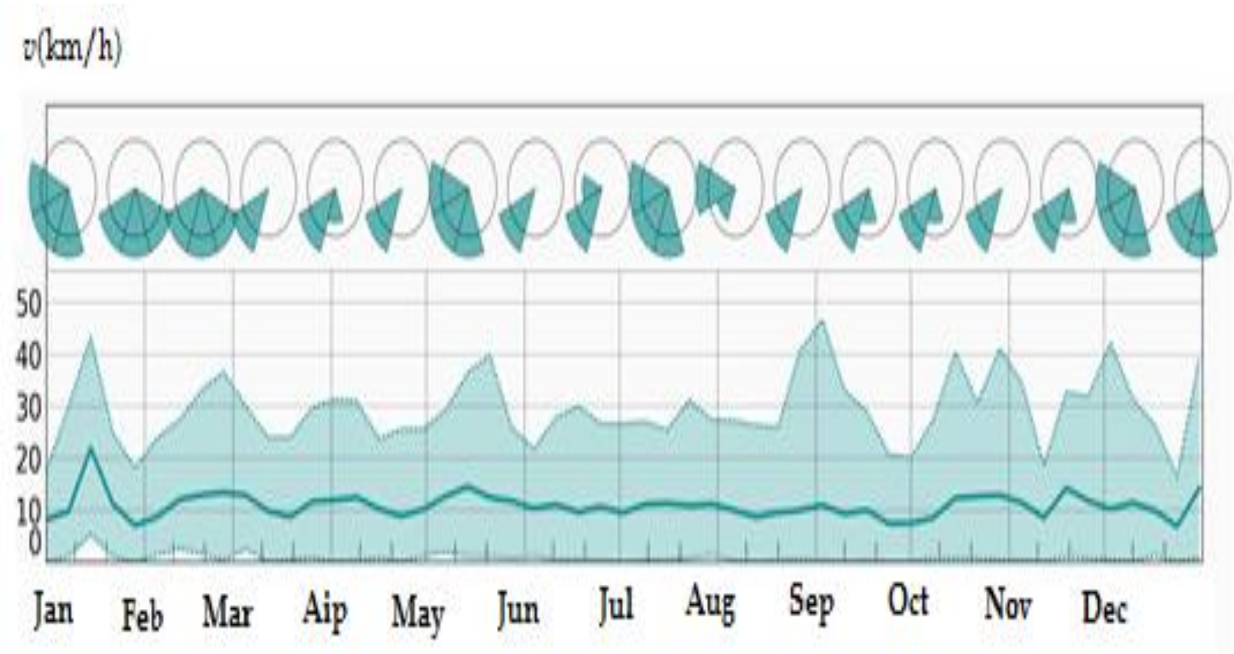

Figure III.1 Wind direction and speed for the year 2023 in the region of Saida

Colonne	Colonne:	Colonn	Colonr	Colonn	Colonn	Colonn	Colonr	:olon	Colonne	Colonne1	Colonne1	Colonne	olonı
2.4	2.3	3.9	3.5	2.4	2.8	3.5	2.9	3.6	3.0	3.2	2.8	3.6	3.7
2.6	2.4	3.8	3.6	2.1	2.6	3.5	3.0	3.6	3.1	3.2	2.8	3.7	4.1
2.6	2.6	3.7	3.6	2.2	2.4	2.2	2.2	3.5	3.1	3.2	2.9	3.8	4.1
2.8	2.8	3.4	3.6	3.2	3.2	2.8	3.2	3.4	2.9	3.3	2.9	3.8	3.8
3.4	3.1	3.3	3.7	3.3	3.1	2.9	3.1	3.4	2.9	3.3	3.0	3.8	3.7
4.3	3.3	3.0	3.5	3.6	3.1	3.0	3.0	3.3	2.2	3.2	3.1	3.8	3.5
5.1	3.6	2.8	3.3	3.7	3.1	3.1	2.9	3.2	2.2	3.6	2.2	2.2	3.8
6.0	3.6	2.7	3.2	3.9	3.2	3.3	2.8	3.2	2.3	3.4	2.3	2.2	3.6
6.6	3.7	2.7	3.0	4.0	3.3	3.3	2.7	3.1	2.4	3.3	2.4	3.6	3.4
3.0	3.8	2.6	2.9	4.1	3.2	3.3	2.6	2.9	2.4	3.1	2.4	3.6	3.3
4.9	3.8	2.6	2.8	4.3	3.1	3.3	2.5	2.8	2.6	2.8	2.6	3.7	3.1
4.1	3.9	3.0	2.7	4.2	2.9	3.3	2.6	2.7	2.9	2.6	2.9	3.8	3.8
3.3	3.9	3.2	2.6	4.0	2.8	3.3	2.6	2.7	3.2	2.6	3.2	3.8	
3.0	3.9	3.4	2.7	3.9	2.9	3.3	2.7	2.9	3.4	3.0	3.4	3.8	
2.7	3.9	3.5	2.8	3.7	2.9	3.2	2.8	2.9	3.6	3.3	3.6	3.8	

Table III.1 207 speed values (in m/s) from Figure III.1

We arrange the relative and cumulative frequencies of speed according to the proposed intervalsand show the results in **Table III.2** and in (**Fig III. 2)** the corresponding graphs.

Interval	Frequence	Re. Fr.	Cum. Fr.
2.1-2.5	20	9.66%	9.66%
2.5-2.9	47	22.71%	32.37%
2.9-3.3	58	28.02%	60.39%
3.3-3.7	47	22.71%	83.09%
3.7-4.1	25	12.08%	95.17%
4.1-4.5	6	2.90%	98.07%
4.5-4.9	0	0.00%	98.07%
4.9-5.3	2	0.97%	99.03%
5.3-5.7	0	0.00%	99.03%
5.7-6.1	1	0.48%	99.52%
6.1-6.5	0	0.00%	99.52%
6.5-6.9	1	0.48%	100.00%
	207	**100.00%**	***

Table III. 2 Relative and cumulative frequencies

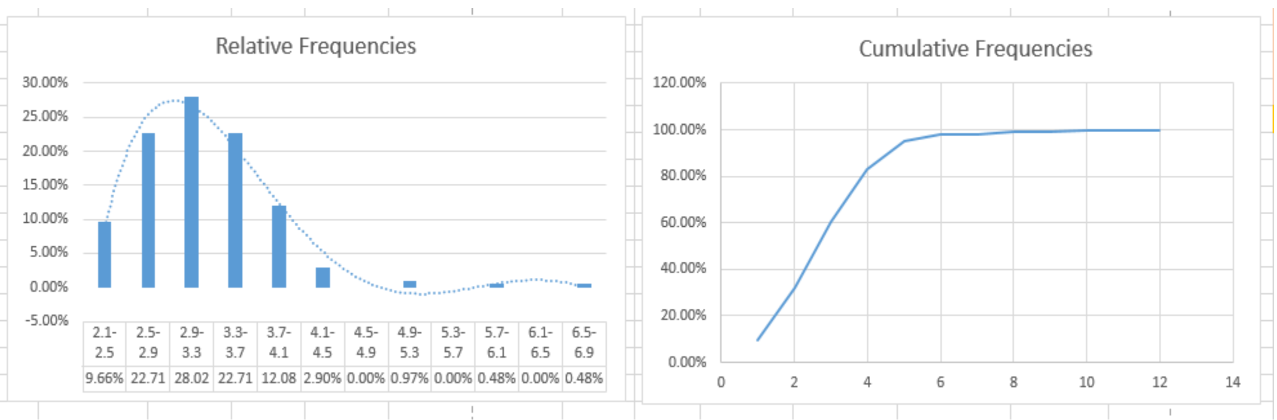

Figure III. 2 Relative and cumulative frequencies

Wind speeds v is represented by the well-known Weibull distribution **[2]**, which has the density over $[0, \infty[$

$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left(-\left(\frac{v}{k}\right)^{k}\right) \quad (1)$$

k, and c are respectively the shape and scale parameters with the formulas

$$k = \left(\frac{\sigma}{\langle v \rangle}\right)^{-1.086}$$

$$c = \frac{\langle v \rangle}{\Gamma(1+\frac{1}{k})} \quad (2)$$

The partition function is defined by

$$F(u) = \int_0^u f(v)dv = 1 - \exp\left(-\left(\frac{u}{k}\right)^{k}\right) \quad (3)$$

By simple calculus, we get

$$\ln\left(\ln\left(\frac{1}{1-F(u)}\right)\right) = k\ln(u) - k\ln(c) \quad (4)$$

which has a linear form $y = a\,x + b$ With the identifications

$$y = \ln\left(\ln\left(\frac{1}{1-F(u)}\right)\right),$$

$$x = \ln(u) \quad (5)$$

Consequently,

$$k = a, \text{ and } c = \exp\left(-\frac{b}{k}\right) \quad (6)$$

III.2.2 Monte Carlo Simulation

In this section, we will simulate the wind speeds in the region using Monte Carlo simulation over 8760 hours of the year using the experimental values (6) of k and c. The density and partition functions (1), (3) are represented in **(Fig III.3)**. To generate random numbers u_i according to the law $f(v)$, we need first to reverse the partition function. Thus, we have

$$u = c\exp\left\{\frac{1}{k}\ln\left(\ln\frac{1}{1-F(u)}\right)\right\} \quad (7)$$

In discrete notation

$$u_i = c\exp\left\{\frac{1}{k}\ln\left(\ln\frac{1}{1-Y_i}\right)\right\} \quad (8)$$

Since Y_i represents$F(u)_i$, it is a random uniform number (from the law v (0, 1)), and u_i are the simulated wind speed according to weibul distribution $f(v)$.

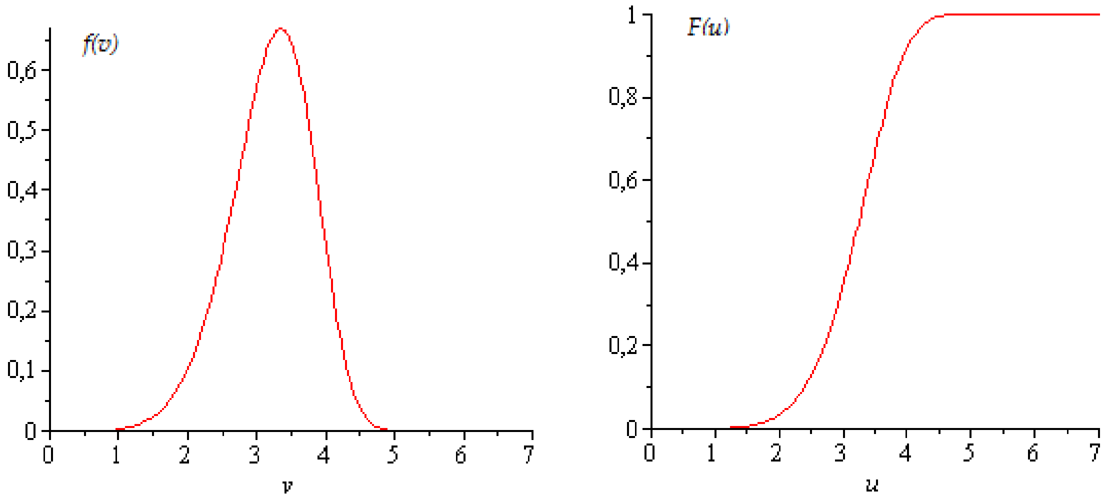

Figure III.3 Density and partition functions

III.3. Results

III.3.1 Weibull parameters

The **table III.3** presents the associated (x, y) values from the **table III.2**

X	Y
0.91629	-2.287
1.06471	-0.939
1.19392	-0.077
1.30833	0.5751
1.41099	1.1086
1.50408	1.3728
1.58924	1.3728
1.66771	1.5346
1.74047	1.5346
1.80829	1.6739
1.8718	1.6739

Table III. 3 the associated (x, y) values (5)

We represent in the following 98% of the speeds values (from table 1), andusing least squares method, we obtain a linear representation **(Fig III.4)** of the partition function $F(u)$with a percentage accuracy of 98%. We get the experimental values

$$k = 6.2160, \text{ and } c = 3.4544\,\frac{\text{m}}{\text{s}} \tag{9}$$

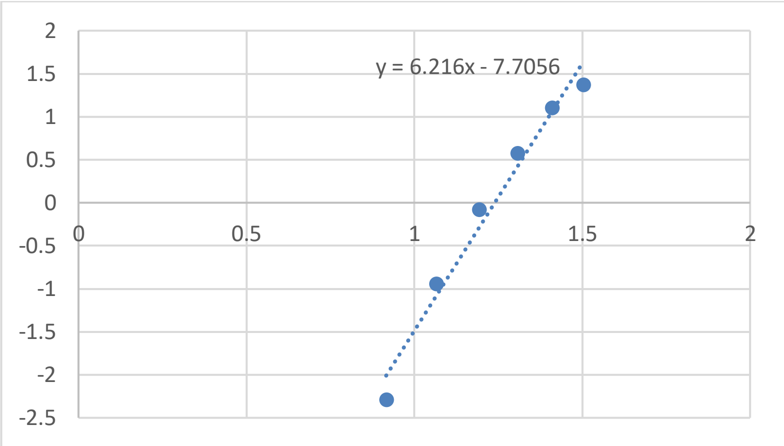

Figure III. 4Linear representation of F (u)

The standard deviation is

$$\sigma = 0.6\, m/s$$

Then, we get the theoretical values (2)

$$k = 6.0423, \text{ and } c = 3.4534\,\frac{\mathrm{m}}{\mathrm{s}} \quad (10)$$

The errors in the two values are

$$\frac{\Delta k}{k} = 2.87\%, \text{ and } \frac{\Delta c}{c} = 0.03\% \quad (11)$$

III.3.2 Monte Carlo Simulation

The results of our simulation are collected in **table *III. 4*** with a comparison with the experimental data

	Experimental data (207 values)	Simulation (8760 values)
Minimum (m/s)	2.1	0
Maximum (m/s)	6.6	4.6
Mean speed (m/s)	3.2	3.0
Standard deviation:σ(m/s)	0.6	1
Speeds which are less than 4.3 m/s	98%	98%
Speeds which are greater than 2.9 m/s (speed threshold)	67.63%	73%
Mean cubic speed:$\langle v^3\rangle$(m^3/s^3)	36.8	34
Wind power density:P(W/m^2)	23.76	22

Table III. 4 Experimental and simulation results

The wind power density is given by **[3]**

$$P = \frac{1}{2}\rho\langle v^3\rangle \quad (12)$$

With the air density $\rho = 1.29\ kg.m^3$

The maximum theoretical power that can be recovered to operate wind turbines is expressed by the following Beth relationship

$$Pmax = \frac{16}{27}P \quad (13)$$

In the site, ideal turbines benefit from 35% to 45% of wind energy P. **[4]**

III.4. Discussion

Through relations (11), we can say that the Weibull distribution is suitable for representing 98% of wind speeds in the studied region with negligible errors. For the simulation, we generalized the wind speed measurements over the course of the year, estimated at 8760 hours.The minimum value of the speed that operates wind turbines is estimated at 2.9m/s **[5].** We calculated the percentage of speeds greater than this value (which we called speed threshold) and found values close to the experimental results in the data. As for power, we can say that the simulation gave us good results within the limits of measurement errors (Table III.4).

Based on Monte Carlo simulation, we can say that the energy obtained during the year is considered significant energy, and we can study planting fields for wind turbines. On the other hand, we can benefit from the high areas to obtain a greater wind speed **[6]**.

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Conclusion

Résumé

Dans cette recherche, nous avons exploré deux méthodes pour évaluer le potentiel de l'énergie éolienne dans la région de Saïda en Algérie pour l'installation éventuelle de turbines éoliennes. La première méthode a impliqué une approche computationnelle, en utilisant des mesures de vitesse du vent de l'année 2023. Nous avons calculé les coefficients de forme et d'échelle de Weibull : K et C, en utilisant la méthode de représentation graphique de la fonction de répartition (fréquences cumulées). De plus, nous avons simulé la vitesse du vent sur 8760 heures durant l'année 2023. Nos résultats simulés correspondaient étroitement aux données expérimentales.

ملخص

في هذا البحث، استكشفنا طريقتين لتقييم إمكانات طاقة الرياح في منطقة سعيدة بالجزائر لتركيب محتمل لتوربينات الرياح. الطريقة الأولى تضمنت نهجًا حسابيًا باستخدام قياسات سرعة الرياح لعام 2023. قمنا بحساب معاملات الشكل والمقياس لتوزيع ويبول K :وC، باستخدام طريقة التمثيل البياني لدالة التقسيم (الترددات التراكمية). بالإضافة إلى ذلك، قمنا بمحاكاة سرعة الرياح على مدار 8760 ساعة خلال عام 2023. وكانت نتائج المحاكاة متطابقة بشكل كبير مع البيانات التجريبية..

Abstract

In this research, we explored two methods to assess wind energy potential in the Saida region of Algeria for the possible installation of wind turbines. The first method involved a computational approach, utilizing wind speed measurements from the year 2023. We calculated the Weibull shape and scale coefficients: K and C, using the graphical representation method of partition function (cumulated frequencies). Additionally, we simulated wind speed over 8760 hours during the year 2023. Our simulated results closely matched the experimental data.