People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

EchahidHamma University of El-OuedLakhdar

FACULTY OF TECHNOLOGY

DEPARTMENT OF MECHANICAL ENGINEERING

End of study dissertation

Presented for graduation from

ACADEMIC MASTERS

Field: Science and Technology
Field: Mechanical Engineering

Specialty: Electromechanical

Theme

WIND TURBINES-COMPONENT AND DESIGN BASICS

Realized by:

- MELIK Mohammed
- ZOBIEDI AbdElkerim
- KOCHI Noureddine
- MOUSSAOUI Yacine

Framed by:

- Dr. BENAMOR Afaf

Defended on 13-06-2022 In front of the jury:

GERFI YOUCEF	**M.A.A**	**Rapporteur**
ZINE EL-BACHIR	**M.C.A**	**President**
ZANEENA MOHAMMED	**M.A.A**	**Rapporteur**

College year2021/2022

﴿ رَبَّنَا لاَ تُؤَاخِذْنَا إِن نَّسِينَا أَوْ أَخْطَأْنَا رَبَّنَا وَلاَ تَحْمِلْ عَلَيْنَا إِصْرًا كَمَا حَمَلْتَهُ عَلَى الَّذِينَ مِن قَبْلِنَا رَبَّنَا وَلاَ تُحَمِّلْنَا مَا لاَ طَاقَةَ لَنَا بِهِ وَاعْفُ عَنَّا وَاغْفِرْ لَنَا وَارْحَمْنَا أَنتَ مَوْلاَنَا فَانصُرْنَا عَلَى الْقَوْمِ الْكَافِرِينَ﴾ **سورة البقرة : الآية286 .**

" صدق الله العظيم"

Appreciation

*We give thanks to God for having given us the courage and the conscience to carry out this work. First of all, our deep gratitude to our supervisor **Dr. BENAMOR Afaf**, Professor at Hama Lakhder University of El-Oued, for having supervised our thesis and her availability.*

Our valiant thanks to all those who have contributed from near or far, directly or indirectly, particularly our colleagues and our family for having trust as well as their valuable advice and encouragement throughout theyears, in a continuous or occasional manner, to the successful completion of this work.

Thank you to all of you.

From the number of students:

MELIK Mohammed

ZOBIEDI AbdElkerim

KOCHI Noureddine

MOUSSAOUI Yacine

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SYMBOLS AND ABBREVIATIONS

VAWT : Vertical axis wind turbines**.**

HAWT: Horizontal axis wind turbines.

**EIA : ** Energy Information Administration.

**RO : ** reverse osmosi.

**MVC : ** mechanical vapour compression.

ED : ** electro-dialysis.**

GWh :gigawatt-hour.

GRP : Glass Reinforced Plastic.

DFIG :doubly fed induction generator.

SCIG :squirrel cage induction generator.

EESG :electrically excited synchronous generator.

PMSG:permanent magnet synchronous**.**

MPT : Maximum Power Tracking **.**

CFRP :carbon filament-reinforced-plastic .

GRP : ** carbon reinforced-plastic **.

General Introduction

General Introduction

Wind energy is a clean renewable energy source that has been used by man since ancient times, and it has become necessary to develop and improve the performance of wind turbines through turbine simulation strategies to reduce the cost of power generation, which is highly desirable by professionals in the wind energy exploitation industry.

Wind energy is energy extracted from the kinetic energy of the wind by using wind turbines to produce electrical energy, and it is considered a type of electromechanical energy. Wind energy is one of the types of renewable energy that has been widely used as an alternative to fossil fuels, and it is abundant and renewable energy, but its availability varies from one location to another. It is a clean, renewable energy that does not produce emissions such as greenhouse gases (greenhouse gases) during operation, and it needs varying areas depending on the size of the plant and the type of towers used.

On the environment is usually less problematic than other energy sources. To avoid this, it is possible to benefit from production by connecting it directly to the public electricity network or installing batteries to store that energy and use it throughout the day. Usually in off-grid electrical systems on the scale of homes, wind energy is not used alone without the presence of other sources of renewable energy such as photovoltaic energy, for example, so that both support each other and increase the reliability of electricity production.

The objective also of this work, presented within the framework of this ***MASTERACADEMY*** thesis, is centered on the application of the design and operation principles of the wind turbine.

To do this, the writing of the thesis is organized as follows:

In a first chapter, a detailed bibliographic study on the evolution of wind energy conversion systems is presented, where the available wind energy varies according to the wind speed, and one of its most important resources is the nature of wind, the geographical variation in the wind resource.Then, we expose the geographical variation in the wind resource, and the modern wind turbines and methods

Aerodynamics, where the types of turbines can be studied. The vertical and horizontal axis, the generator, advantages of wind energy and the applications of wind turbine inverters are presented.

A first part of the second chapter will be entirely devoted to the types of turbines, including the horizontal head three-axis (HAWT) turbine with blades up wind of the tower that produces the vast majority of wind energy in the world today. These turbines contain a main shaft and an electric generator at the top of the tower. In the second part, and component the turbine and design basics are consecrated.

In a third chapter, we propose a modeling and experimental design of the small wind turbine. The design and simulation of wind turbine, it includes information on turbine design and technology as well as information on its expected performance. As the electromechanical transmission system is more complex, and explained the reasons for moving wind turbine blades, the materials used and the number of rotor. Finally, simulation results and general form of our turbine are presented.

A **general conclusion** summarizing the essence of our work will be presented at the end of the manuscript followed by some **future perspectives** in natural continuity to our research work and the **bibliography** and **bibliographicalreferences** which are the basis of our work.

Chaptre I:

Theory of Wind Turbine

I.1. Introduction

Wind energy is one of the clean renewable energies. It is the movement of air from one place to another caused by differences in atmospheric pressure over the earth. Wind can be classified into two types, global and local. However, global wind corresponds to large air movements and local wind corresponds to small movements in a specific part of the earth. Wind turbines are among the best known and most accessible devices for converting ambient energy into electricity. However, wind power, like most other renewable energy sources, has high investment costs, but over the past few years, this trend has changed significantly.

This chapter developed to the generalities of wind energy; firstly, we will explain the definition of wind energy and its components. Subsequently, the fixed and variable speed operating modes and the different generators used are presented.

I.2. Brief history of wind turbine

The use of wind as a form of energy dates from 5000 B.C. in Egypt where people navigated the Nile River on sail boats powered by wind. Windmills were first utilised in China then in the Middle East for food processing by the 11th century. Then, Europeans imported this technology to do mechanical work. With the advent of the Industrial Era, windmills continued to be used and towards the end of the 19th century first experiments took place in USA and in Denmark to generate electricity from wind. Afterwards, years of low interest in wind energy began and lasted till the oil crisis in the 1970's, which caused many countries to seek new forms of energy source. Nowadays wind power is a fully active contributor to electricity production and as reported in the reference in the last two decades there have been tremendous advances in the energy efficiency of wind turbines. In fact, a 2006 wind turbine would produce 180 times more electricity than one at the same location installed 20 years before and at half the cost per kilowatt-hour (kWh) [Abdl 16].

I.3. Generality

Renewable energy mainly depends on weather as a resourceSupply, such as solar, wind and rain, which can be unpredictable. In the event of a shortage ofsupply, the energy sources lack the ability to produce energy. In addition, it is more difficult. A large amount of energy is produced from renewable sources compared to power plants that run on fossil fuels.Therefore, more facilities must be built to keep up with the demand for energy and new roads. It must be found to reduce energy consumption. In addition, fossil fuels are usually higher Energy density compared to renewable sources and therefore easier to deal with. A major concern [Mar 16].

By having this knowledge, preventive measures can be taken to reduce stakeholder losses. However, it is unclear how much information about the turbines the owners have access to, and this could limit the possibility of their analysis.

Fossil-based energy sources are the basis of human civilization and progress. These energy sources are used to heat our homes, power our cars, and light our buildings; However, the cost of using these energy sources is significant in monetary terms as well as the environment. In recent decades, global political policies have given some understanding of the current problems related to fossil energy sources, including cost, availability of fossil fuels and impact on the environment [Hir 16]. The figures I.1 and I.2; have shown the renewable energy sources.

Due to these factors there is an increasing demand in the development of renewable energy sources, for example, solar, wind and water power, bioethanol and biodiesel [Hir 16 - Mar 16].

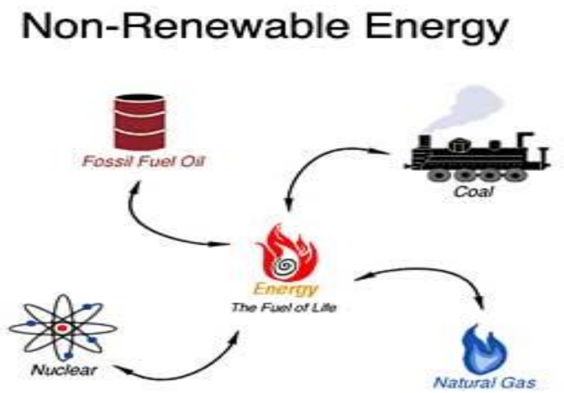

Figure.I.1. Energyresources.

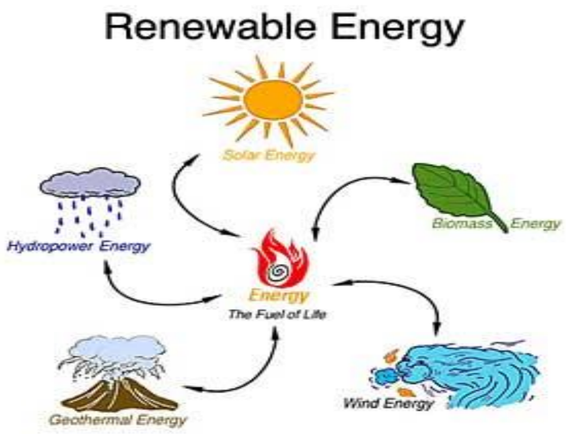

Figure.I.2. Renewable source of renewable energy.

Like other countries, Algeria has recently started to use wind energy to generate electricity, as Algeria's first wind farm has been established in a desert area located in the south, in Cabertin, Adrar province. This wind farm consists of twelve large wind turbines. The rotor diameter of the installed wind turbine is 52 meters and the height of the tower is 55 meters. Each wind turbine has a power of 850 kW (a total of 10.2 MW for the wind farm). It is clear that the potential of the available winds and the availability of large areas are among the most important criteria that led to the selection of this area more than others. However, the characteristics of the sandy winds of these desert regions may affect the performance of the turbines and this leads us to ask an important question: To what extent can sand particles affect the aerodynamic performance of wind turbines installed in desert regions. To our knowledge, the effect of sand on aerodynamics is still not well known so far [Abd 16].

I.4. Wind resources

I.4.1. Nature of the wind

The energy available in the wind varies as the cube of the wind speed, so an understanding of the characteristics of the wind resource is critical to all aspects of wind energy exploitation from the identification of suitable sites and predictions of the economic viability of wind farm projects through to the design of wind turbines themselves, and understanding their effect on electricity distribution networks and consumers.

Wind speed varies from place to place depending on the surface of the earth and altitude at a given location, temporal variability on a large scale means that the amount of wind may vary from one year to the next, with even longer scale variations on a scale of decades or more. These long-term variations are not well understood, and may make it difficult to make accurate predictions of the economic viability of particular wind farm projects, for instance On timescales shorter than a year, seasonal variations are much more predictable, although there are large variations on shorter timescales still, which although reasonably well [Garr 01].

I.4.2. Geographical variation in the wind resource

Underlying tendencies remain which lead to clear climatic differences between regions. These differences are tempered by more local topographical and thermal effects Hills and mountains result in local regions of increased wind speed. It is also partly a result of the acceleration of the wind flow over and around hills and mountains, and funnelling through passes or along valleys aligned with the flow. Equally, topography may produce areas of reduced wind speed, such as sheltered valleys areas in the lee of a mountain ridge or where the flow patterns result in stagnation point's Thermal effects may also result in considerable local variations [Garr 01].

Coastal regions are often windy because of differential heating between land and sea. While the sea is warmer than the land, a local circulation develops in which surface air flows from the land to the sea, with warm air rising over the sea and cool air sinking over the land. When the land is warmer the pattern reverses. The land will heat up and cool down more rapidly than the sea surface, and so this pattern of land and sea breezes tends to reverse over a 24-hour cycle [Garr 01-Abd 16].

I.4.3. Long-term wind speed variations

There is evidence that the wind speed at any particular location may be subject to very slow long-term variations. Although the availability of accurate historical records is a limitation careful analysis by, for example (1991) has demonstrated clear trends. Clearly these may be linked to long-term temperature variations for which there is ample historical evidence. There is also much debate at present about the likely effects of global warming caused by human activity, on climate, and this will undoubtedly affect wind climates in the coming decades Apart from these long-term trends there may be considerable changes in windiness at a given location from one year to the next. These changes have many causes. They may be coupled to global climate phenomena such as El Niño, changes in atmospheric particulates resulting from volcanic eruptions, and sunspot activity, to name a few these changes add significantly to the uncertainty in predicting the energy output of a wind farm at a particular location during its projected life time [Garr 01-Abdl 16].

I.4.4. Gust wind speeds

It is often useful to know the maximum gust speed which can be expected to occur in any given time interval. This is usually represented by a gust factor G, which is the ratio of the gust wind speed to the hourly mean wind speed. G is obviously a function of the turbulence intensity, and it also cl early depends on the duration of the gust – thus, the gust factor for a one-second gust will be larger than for a three-second gust, since every three-second gust has within it a higher one-second gust[Garr 01- R. Doe13].

I.4.5. Wind speed prediction and forecasting

Because of the variable nature of the wind resource, the ability to forecast wind speed some time ahead is often valuable. Such forecasts fall broadly into two categories: predicting short term turbulent variations over a time scale of seconds to minutes ahead, which may be useful for assisting with the operational control of wind turbines or wind farms, and longer-term forecasts over periods of a few hours or days, which may be useful for planning the deployment of other power stations on the network Short-term forecasts necessarily rely on statistical techniques for extrapolating the recent past, whereas the longer-term forecasts can make use of meteorological methods. A combination of meteorological and statistical forecasts can give very useful predictions of wind farm[Garr 01-Abdl 16].

I.5. Types and classifications of wind turbines

Wind turbine, by definition, is the device to convert kinetic energy in wind into useful mechanical power which can be utilized to generate electricity. There are two types of wind turbine system, differentiated by the outward appearance of the blades: vertical axis wind turbines (VAWT) and horizontal-axis wind turbines (HAWT) [Mod 13-Szc 16].

I.5.1. Vertical axis wind turbines

Vertical-axis wind turbines (or VAWTs) have the main rotor shaft arranged vertically Figure 3. One advantage of this arrangement is that the turbine does not need to be pointed into the wind to be effective, which is an advantage on a site where the wind direction is highly variable. It is also an advantage when the turbine is integrated into a building because it is inherently less steerable. Also, the generator and gearbox can beplaced near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, improving accessibility for maintenance. However, these designs produce much less energy averaged over time, which is a major drawback [Don-Abde 16].The key disadvantages include there latively low rotational speed with the consequential higher torque and hence higher cost of the drivetrain, the inherently lower power coefficient, the360-degree rotation of the aero foil within the wind flow during each cycle and hence the highly dynamic loading on the blade, the pulsating torque generated by some rotor designs on the drive train, and the difficulty of modelling the wind flow accurately and hence the challenges of analysing and designing the rotor prior to fabricating a prototype[Poo 13-Abd 16].

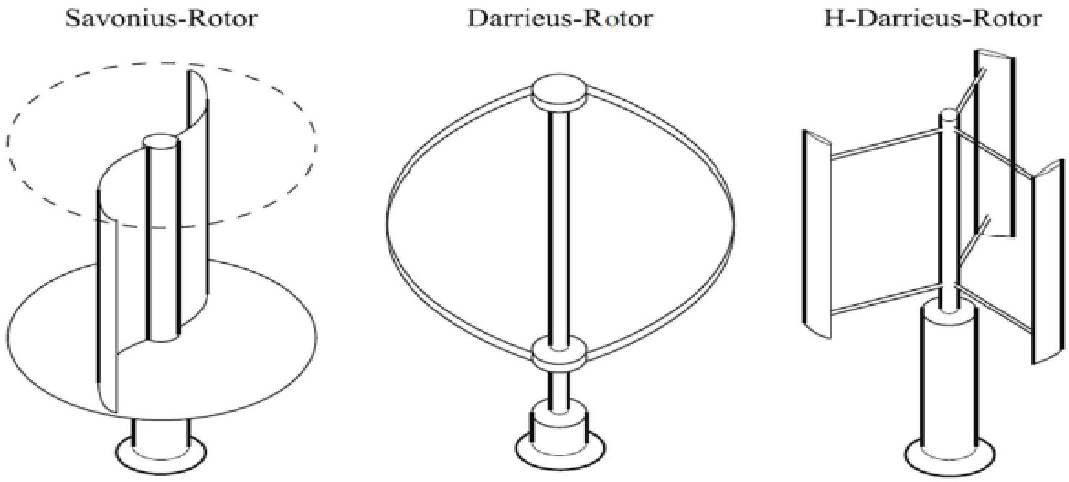

Figure.I.3. Different types of vertical axis wind turbines.

I.5.1.1. Darrieus Wind Turbine

"Eggbeater" turbines, or Darrieus turbines, were named after the French inventor, Georges Darrieus [Ver 13]. They have good efficiency, but produce large torque ripple and cyclical stress on the tower, which contributes to poor reliability. They also generally require some external power source, or an additional Savonius rotor to start turning, because the starting torque is very low. The torque ripple is reduced by using three or more blades, which results in greater solidity of the rotor. Solidity is measured by blade area divided by the rotor area. Newer Darrieus type turbines are not held up by guy-wires but have an external superstructure connected to the top bearing [Exp 12]. Figure I.5 an Example of Vertical Axis Wind Turbines (VAWTs).

I.5.1.2. Savonius Wind Turbine

These are drag-type devices with two (or more) scoops that are used in anemometers, Flettner vents (commonly seen on bus and van roofs), and in some high-reliability low-efficiency power turbines. They are always self-starting if there are at least three scoops. Twisted Savonius is a modified savonius, with long helical scoops to provide smooth torque. This is often used as a rooftop wind turbine and has even been adapted for ships.[Rob 12]. (see Figure I.6).

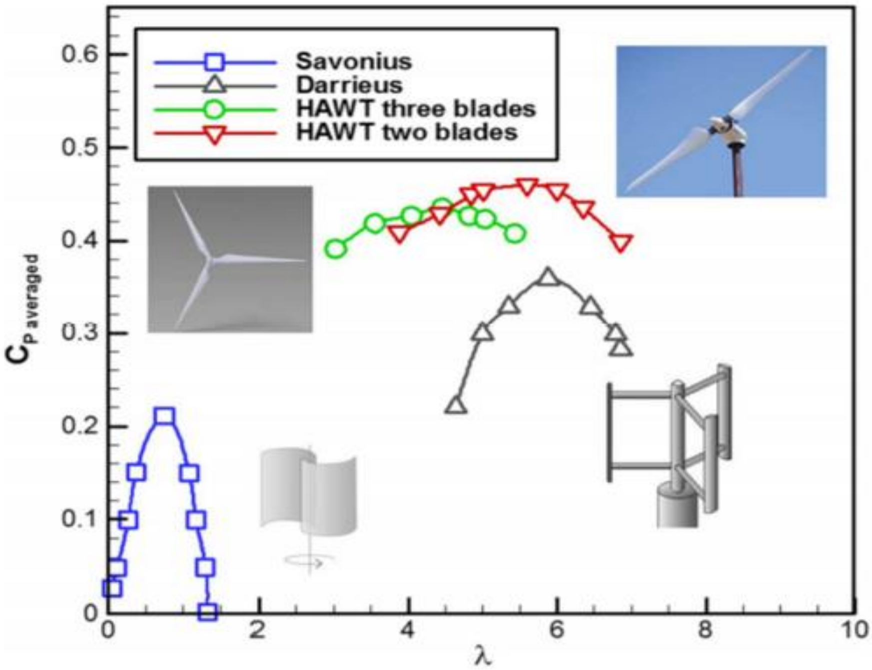

Figure.I.4. Average power factor curves for tip velocity ratio for various wind turbines, reproduced from [Abdl 16].

I.5.2. Horizontal axis wind turbines

Generally, more of the wind energy can be captured from HAWT blades than from VAWT blades due to the fact that the entire area swept by HAWT blades always faces in to the wind during operations.

Figure.I.5. The rotor of a gearless wind turbine being set.

This particular turbine was prefabricated in Germany, before being shipped to the U.S. for assembly. These turbines have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a wind sensor coupled with a yaw system. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator. These don't need a gearbox and are called direct-drive, meaning they couple the rotor directly to the generator with no gearbox in between. While permanent magnet direct-drive generators can be more costly due to the rare earth materials required.

HAWTs are classified according to the diameter of the blade as follows: micro-scale (μSWT, diameter ≤ 0.1 m), small-scale (SSWT, 0.1 m < diameter ≤ 1 m), mid-scale (MSWT, 1 m < diameter ≤ 5 m), and large-scale (LSWT, diameter > 5 m). Large-scale HAWTs are installed either as wind farms or in offshore areas. Small-scale HAWTs are commonly seen in residential areas [Mod 13-Kam 14].

I.6. Types of Wind Energy Conversion Systems

There are basically two wind turbine technologies WECS, fixed speed wind turbines which mostly contain a squirrel cage asynchronous generator and its rotor speed is fixed to a particular speed, and variable speed ones. This also improves the quality of the electrical power produced, by introducing flexibility in the system's reaction to sudden fluctuations in wind speed.

I.6.1. Fixed speed wind turbines

In this case, the wind turbines operate at a rotation speed that is regulated by the orientation of the blades (pitch control). These wind turbines are mainly based on the use of a squirrel-cage asynchronous machine directly connected to a powerful energy network which imposes its frequency (50Hz) on the stator quantities [Abdl 16]. To ensure operation as a generator, it is necessary that the rotation speed of the MAS is beyond synchronism (negative slip) [Hir 12-Adv 17].Since fixed speed systems do not allow significant variations in rotor speed, these systems are incapable of achieving the various rotor speeds that result in the maximum C_p value under varying wind.

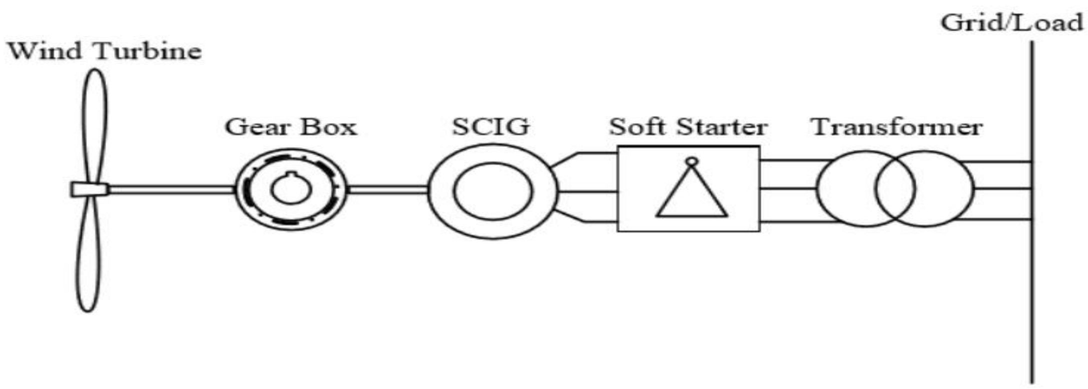

Figure.I.6. Constant Speed Wind Energy Conversion System.

I.6.2. Variable speed wind turbines

Figure I.7 shows the second case. Despite its simplicity, the fixed speed operating system can be noisy, due to the modification of the aerodynamic characteristics due to the orientation of the blades, and limits the range of exploitable wind speeds [Hir 12]. A power interface adapts the frequency of the generator currents to that of the network and thus makes it possible to operate at variable speed [Win 16] this then makes it possible to maximize the power extracted from the wind [Hir 12-Kam 14]. But in this case, a direct connection to the network is no longer possible because of the variable nature of the frequency of the stator voltages. A power electronics interface between the generator and the network is then necessary [Awe 12]. The latter is conventionally made up of two converters (a rectifier and an inverter) connected via a DC voltage stage [Sid 97 – Hir12].

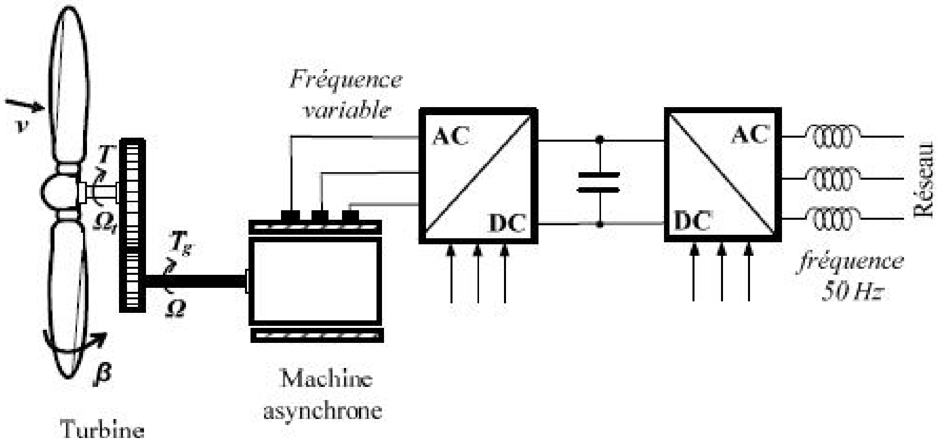

Figure.I.7. Variable speed wind turbine based on the cage asynchronous machine.

I.7. Configurations of Variable speed WECS

Wind turbines are categorized by generator type. The use of electronic transducers is essential to maintain efficient generator operation.

The four types of wind turbine generators are as follows:

Type 1: squirrel cage induction machine (almost constant speed).

Type 2: variable resistance rotary wound induction machine (wider speed/torque range).

Type 3: Rotary wound induction machine with power electronics (double feed, widest range).

Type 4: complete transformer interface machine (usually PMSG or other synchronous combination).

Note the use of the term "machine"; Each of these machines can be run as either an engine or a generator. The difference is whether the force is applied to the shaft, or extracted from it; The gear ratio is such that the desired torque/speed characteristic is reached, or in the case of control interfaces, the transducer is programmed to follow the desired torque/speed curve.

The generator with Wind Turbine Simulator (WTS) shown in this brochure is an outdoor field synchronous machine (mainly a car alternator). It is a type 4 configuration with a transducer interface consisting of a simple rectifier circuit; A boost converter circuit can be added to the output to control the torque of the generator. This is a common machine, and is very popular among wind turbine enthusiasts due to its durability and ease of use. However, it is interesting to note that the performance of the turbine is greatly affected by the way the generator is operated. The WTS generator is configured to operate in an uncontrolled manner, with the stator terminals rectified to provide DC voltage and current; This generator has a voltage range from 6 to twenty-fivevolts,relyingontherateandareaelectricity.Numerousexperiments are included later on this manual to illustrate the dependence of overall performanceat themanipulateapproach[Sid 97-Win 16]

I.7.1. Synchronous Generator

It is this type of machine that is used in most traditional electricity production processes, especially in those of very high power (thermal, hydraulic or nuclear power stations). Synchronous generators used in the wind sector, those from 500 kW to 2 MW are much more expensive than induction generators of the same size.

Furthermore, when this type of machine is directly connected to the network, its rotation speed is fixed and proportional to the frequency of the network.As a result of this great rigidity of the generator-network connection, the fluctuations of the torque captured by the wind turbine are propagated to the electrical power produced. This is why synchronous machines are not used in wind turbines directly connected to the network. On the other hand, they are used when they are connected to the network via power converters (see figure I.8) [Mod 13].

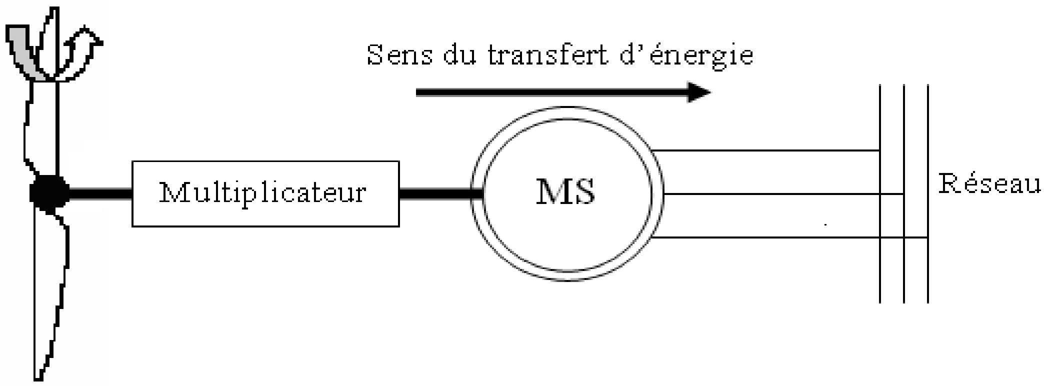

Figure.I.8. Variable speed wind turbine based on the cage asynchronous machine.

In this configuration, the network frequency and the rotational speed of the machine are decoupled. This speed can therefore vary so as to optimize the aerodynamic efficiency of the wind turbine and dampen the fluctuations of the torque in the power train. Some variants of synchronous machines can operate at low rotational speeds and therefore be directly coupled to the aero-turbine.They thus make it possible to dispense with the multiplier, an element present on most wind turbines and require significant maintenance work.

I.7.2. Asynchronous generator

The direct connection to the network of this type of machine is much smoother thanks to the variation of the slip occurring between the flux of the stator and the speed of rotation of the rotor. This explains why almost all fixed speed wind turbines use induction machines. There are two categories of asynchronous machine: squirrel cage asynchronous machines and wound rotor asynchronous machines.

I.7.2.1. Asynchronous squirrel cage machine

Cage asynchronous electric machines are the simplest to manufacture and the least expensive. They have the advantage of being standardized, manufactured in large quantities and in a very large scale of powers. They are also the least demanding in terms of maintenance and have a very low failure rate. The direct connection to the network of this type of machine is much smoother thanks to the variation of the slip occurring between the flux of the stator and the speed of rotation of the rotor. This explains why virtually all fixed speed wind turbines use induction machines.

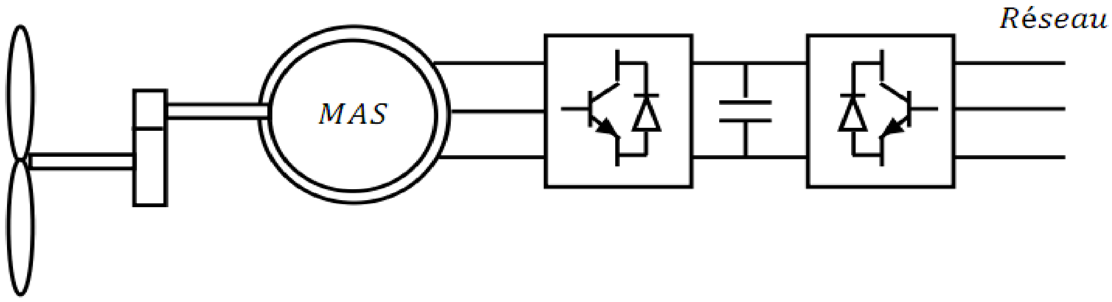

Figure.I.9. Variable speed wind turbine based on the cage asynchronous machine.

A squirrel cage induction machine (SCIG), with a rotor connected to the grid via a power electronic converter, is also an alternative for variable speed. In this case, the capacitor bank is replaced by a full scale converter, which enables variable speed operation whatever the speed of the wind, as shown in figure I.10. Siemens is using this concept in the model of Bonus 107-3.6 MW on the market.

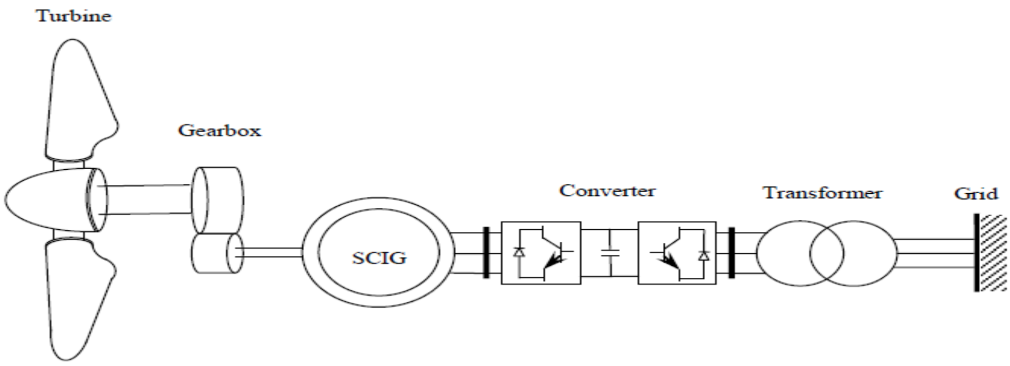

Figure.I.10. Multiple-stage geared SCIG concept with full-scale converter.

I.7.2.2. Double-fed asynchronous machine of the "wound rotor"

Type Along with synchronous generators; it is currently one of two competing solutions in variable-speed wind power. The generator stator is directly coupled to the grid, most often by a transformer. Instead of the squirrel-cage rotor, these machines have a wound rotor whose electric adjustment ensures the variation of the slip. Currently, the majority of wind projects above 1MW are based on the use of the asynchronous machine driven by the rotor. Its stator circuit is directly connected to the electrical network. A second circuit placed at the rotor is also connected to the network but via power converters[Ide].

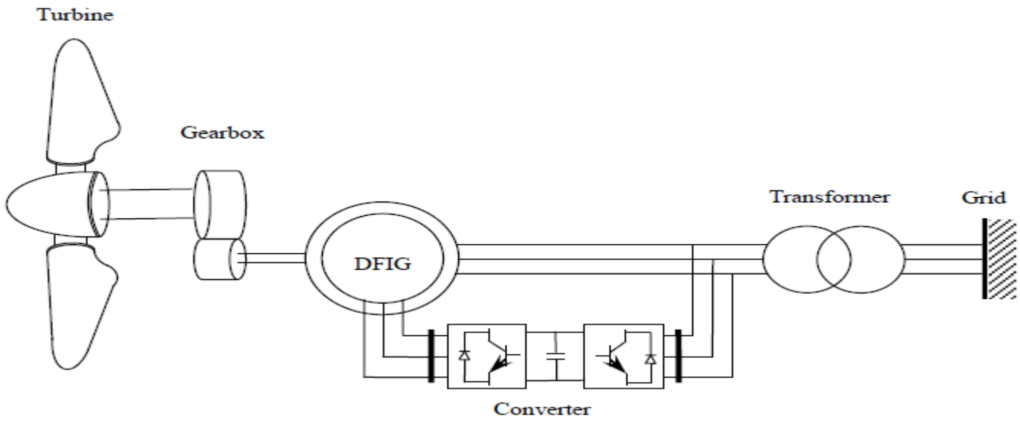

Figure.I.11. Variable speed concept with DFIG.

I.7.2.3. Permanent Magnetic Synchronous Generator System

A permanent magnetic synchronous generator (PMSG) connected to the grid through a full scale converter is a possible configuration for a variable speed system. The converter converts the variable-frequency generator voltage into the grid frequency.

In recent years, the use of PMSG is more attractive than before because the performance of permanent magnetic (PM) is improving and the cost of PM has been decreasing.

The advantages of PMSG can be summarized as follows:

- Higher efficiency and energy yield.
- No additional power supply for the magnet field excitation.
- Absence of fieldlosses.
- Lesser losses due to the absence of mechanical components such as slip rings.
- Lighter and therefore higher power to weight ratio.

However, PMSG have the following disadvantages:

- High cost of PM material.
- Difficulties to handle in manufacture.
- Demagnetisation of PM at high temperature.

PM machines are not standard machines and they allow a great deal of flexibility in their geometry; therefore various topologies may be used. PM machines, based on the direction of flux penetration, can be classified into three types: radial flux, axial flux and transversal flux [Kam 14].

I.8. Advantages of Wind Energy

- Wind energy produces no polluting emissions of any kind, including those thatcause global warming.

- Wind turbines use a fuel that is free, inexhaustible and immune from the drastic price swings to which fossil fuels are subject.
- With careful siting and outreach to the local community, wind farms can be built in a fraction of the time it takes to construct coal or natural-gas power plants. A 50-megawatt wind farm can be completed in less than a year.
- When installed at the right location, it takes only three to eight months for a wind energy farm to recoup the energy consumed by its building and installation, one of the fastest "energy payback times" of any energy technology on the market.
- Wind power consumes no water during operation. This will be an increasingly important attribute as the water-energy nexus grows in importance and as water use becomes an increasingly important facet of defining sustainability [Eri 05].

I.9. Application of wind turbine converters

Spring Field had explained about the use of rotational energy produced by the rotation of blades to operate a mechanical device such as a water pump or to produce electricity by means of generator [Spr 89], described the various applications of wind turbine such as desalination processor suitable for coupling to wind turbines are reverse osmosis(RO), mechanical vapour compression (MVC) and electro-dialysis (ED) [Gar 04].

Siding had compared the two conventional pumping methods and revealed the wind turbine is the feasible pumping prime mover at average wind speed exceeding 3 m/s [Sid 97]. Thomas et al invented wind energy-capturing device for moving vehicles. The electrical energy may be stored in a battery system and used to drive the motor of an electric vehicle (or) hybrid electric vehicle [Tho 05].

I.10. Conclusion

According to study is made on all the wind turbines used in this chapter. We have presented the main theories that govern the interaction between the wind and the wind turbine, and then we have described the different structures that make up the wind turbine conversion chains (horizontal and vertical axis type). Finally, the various machines used for the conversion of electricity were presented. As part of our work, we have therefore chosen to study a variable-speed wind turbine. In the next chapter, we will examine the design basics of the wind turbine which is used in the conversion of the kinetic energy of the wind into electrical energy.

Chaptre II:

Component of the Turbine and Design Basics

II.1. Introduction

Wind power may be considered as one of the most promising renewable energy sources after its progress during the last three decades. However, its integration into power systems has a number of technical challenges concerning security of supply in terms of reliability, availability and power quality. Smaller wind turbines are used for applications such as battery charging for auxiliary power for boats or caravans, and to power traffic warning signs. Larger turbines can contribute to a domestic power supply while selling unused power back to the utility supplier via the electrical grid.wind turbines can be divided into two parts. These are horizontal-axis wind turbines and vertical axis wind turbines. HAWT have the main rotor shaft at the top of a tower and it turns parallel to wind.

The design existence of a wind turbine is often stated to be round twenty years. In exercise it isoften observed that components in a turbine fail in advance and must be replaced before the statedlifetime. Therefore, it's miles very crucial for the stakeholders of wind generators to be able to get anawesome estimation of a aspect’s final lifetime a good way to put up a appropriate renovation agendaanddecide on how to exhaust thefactor within the maximum best way.

In this chapter, among several wind turbine types taking horizontal axis turbine to presents the components and design basics, disadvantages, advantage and electric system room.

II.2. Wind turbine components

The entire system of a grid connected wind turbine includes several components, which contribute with their specific function in the energy conversion process from wind energy into electrical energy. Figure 3.1 illustrates the main components of a modern wind turbine, which are to a greater or lesser extent common for all wind turbine concepts.

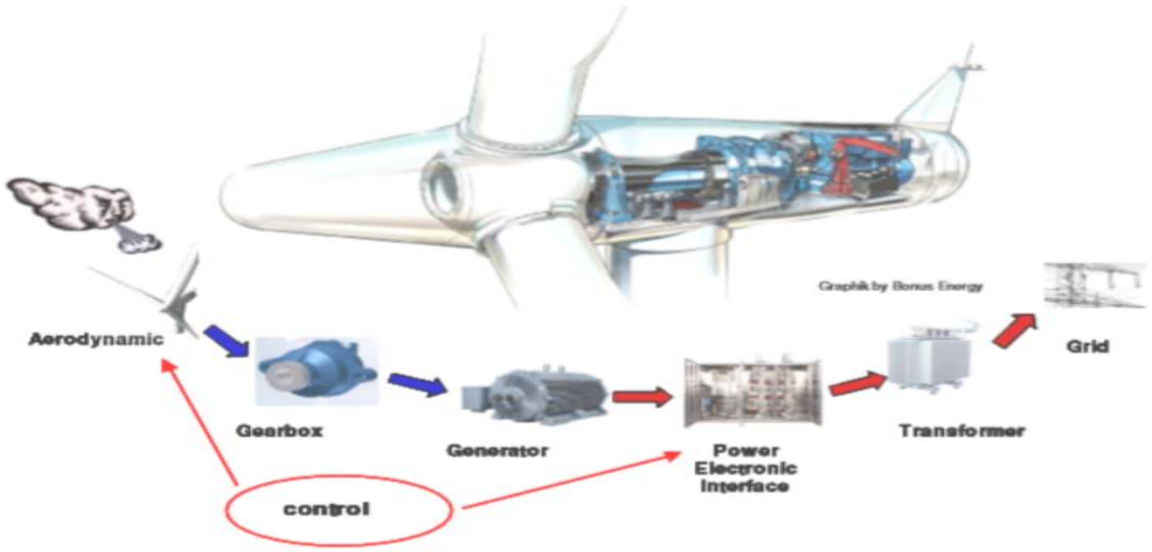

Figure.II.1. Wind turbine components.

II.2.1. Mechanical and aero dynamical components

• Rotor effective wind.

• Turbine rotor.

• Blade pitching mechanism.

• Drive train (flexible shaft, bearings).

• Emergency breaks.

• Gear.

• Tower.

II.2.2. Electrical components

- Generator types Squirrel cage induction generator Wound rotor induction generator Doubly-fed induction generator Permanent magnet synchronous generator Electrical excited synchronous generator.
- Power electronic interface Soft starter Capacitor bank Static VAR compensator Frequency converter.
- Protection system.
- Transformer.
- Cable.

II.2.3. Control system

- Converter controller.
- Blade angle controller.

- Overall controller (TSO demand).

The fourth main group, called “grid components” contains components, which do not directly belong to the wind turbine itself; however, when the impact of windturbines with the power system is investigated the grid components play a major role.

II.2.4. Grid components

Interacting with grid connected wind turbines.

- Conventional power plants (synchronous generators).
- Frequency and voltage controller.
- Transformer;Cable.

II.3. Horizontal axis wind turbine components

Huge three-bladed horizontal-axis wind generators (HAWT) with the blades upwind of the towerproducetheoverpoweringmajorityofwindelectricityinsidetheinternationalnowadays.Those turbines have the principle rotor shaft and electrical generator at the pinnacle of a tower, and need to bepointed into the wind. Small generatorsare pointed with the aid ofa simple wind vane,at thesametime as large generators commonly use a wind sensor coupled with a yaw system. Maximum have agearbox, which turns the gradual rotation of the blades into a quicker rotation that is more suitable topressure an electrical generator [Wid 03]. A few mills use a one of a kind type of generator suitable toslower rotational velocity enter. These do not want a gearbox and are called direct-force, which meanstheycouple therotor directlyto thegeneratorwithout a gearboxin among.

Even as permanent magnet direct-force turbines may be more steeply-priced because of theuncommon earth substances required, these gearless turbines are now and again favored over gearboxgenerators because they "cast off the gear-speed increaser, which is susceptible to big collected fatiguetorqueloading,associated reliabilityissues, andmaintenanceprices[G.B 07].

There is additionally the pseudo direct pressure mechanism that contains a few blessings over theeverlastingmagnetdirectpressuremechanism[Abdl-hostel12].Millsutilizedinwindfarmsfor industrial producing of electrical electricity area unit sometimes 3-bladed. Those have low force ripple,whichcontributes to precise responsibility.

The blades are usually colored white for daytime visibility by aircraft and range in length from 20to 80 meters (66 to 262 ft). The size and height of turbines increase year by year. Offshore windturbinesarebuiltupto8MWtodayandhaveabladelengthupto80meters(260ft).Designswith10to 12 MW were in preparation in 2018 [Cle 18] and a "15 MW+" prototype with three 118 meters (387ft) blades is planned to be constructed in 2022 [Alm 21]. Usual multi megawatt turbines have tubularsteeltowers with aheightof 70mto 120 m and in extremes upto 160 m.

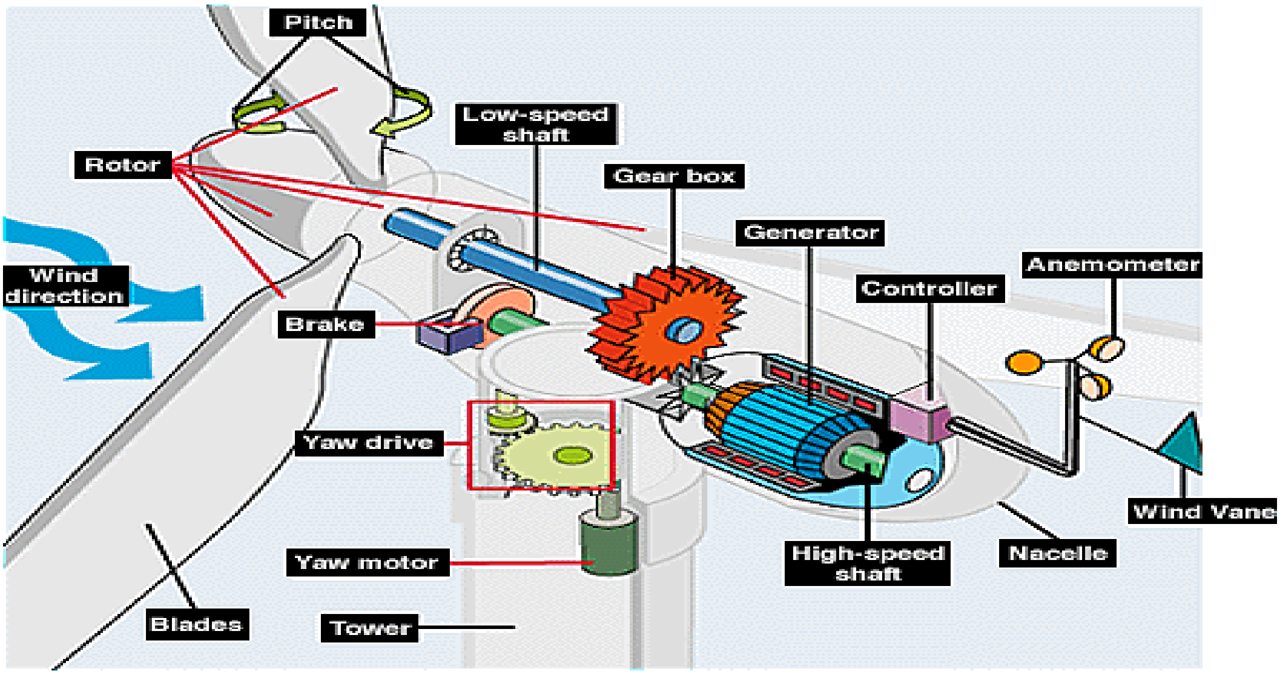

Figure.II.2. Components of horizontal wind turbine.

Basically, horizontal-axis wind turbines consist of 5 main parts. These are,

1. Foundation .

2. Tower .

3. Nacelle .

4. Rotor .

5. Electricity System Room [Szc 16] .

Figure.II.3. Components of horizontal wind turbine.

II.3.1. Foundation

Figure.II.4. Concrete foundation of onshore wind turbine.

Turbines have to sit in a steel reinforced concrete foundation like Figure II.4. Depending on the size of the turbine dimensions, the foundation size should be obtained. The foundation is important for withstanding strong wind conditions. The foundation is generally underground when construction is completed, there is no chance to see this [Szc 16].

II.3.2. Tower

The mission of the tower is to hold the rotor and nacelle's mass. One ideal style of the tower will transfer loads, which come back from wind Associate in rotor to the muse so as to avoid an accident. The price of turbine tower is around 30-33% of the entire investment. So as to avoid the massive value of the tower, diminution of the mass of the tower is incredibly crucial work for the last 20 years. Nowadays, hollow round shape towers area unit utilized in the assembly of contemporary wind turbines, thus o.k. form towers are often made mistreatment this technique. So very well shape components area unit factory-made in 20-30 meters long welded cans and that they area unit fastened with one another on the positioning [Mic 14].

Steel hollow round shape towers is also factory-made because the tapered steel or concrete. in line with production condition, steel tower can be ironed or welded along in every will. This method can be tired a plant or on web site. one in all the necessary topics is transportation. Generally, the allowance diameter of tower is four.4m for transportation. So, some special permission area unit needed so as to hold towers. Sometimes, victimization specific strategies of assembly within the field will solve transportation issues [G.B 07].

II.3.3. Nacelle

According to the nacelleis a cover housing thathouses all of thegenerating components in awind turbine, including the generator, gearbox, and drive train and brake assembly. The nacelle of a wind turbine is the box-like component that sits atop the tower and is connected to the rotor. The nacelle contains the majority of the approximately 8000 components of the wind turbine.The nacelle housingis made of fiberglass and protects the internal components from the environment. The nacelles cover isfastened to the main frame, which also supports all the other components inside the nacelle. The mainframes are large metal structures that must be able to with stand large fatigue loads. One general view of nacelle can beobserved in Figure II.5 [Fra18].

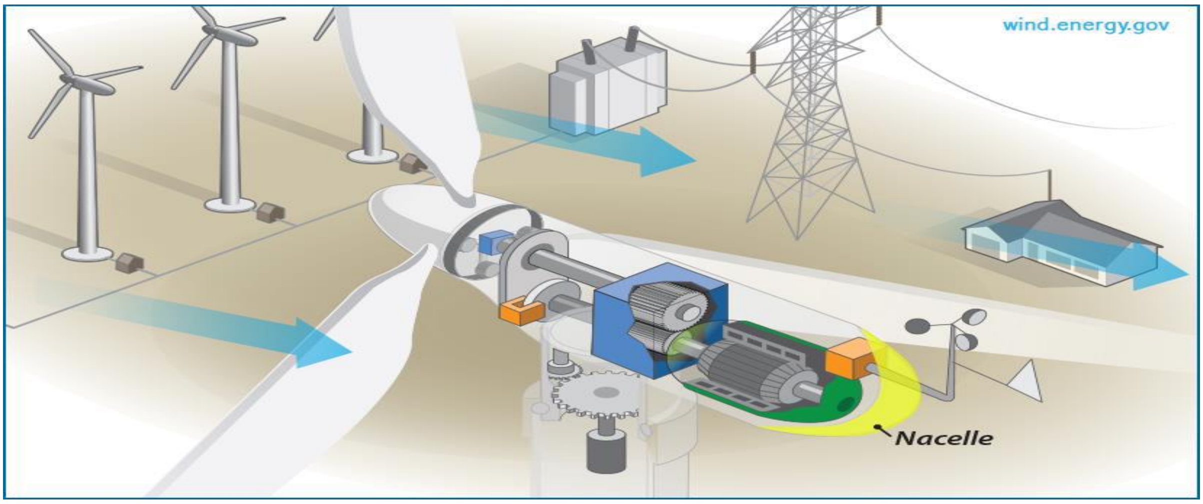

Figure.II.5. The Inside of a Wind Turbine.

II.3.4. Rotor

The rotor consists of blades and a hub. Generally, 3 blade systems are most popular. However, there are a few examples of 2 blades systems. Blades are produced by fiberglass and carbon fiber. On the other hand, there can be many kinds of hub type [Cle 18].

II.3. 5 Electric System Room

Under the wind turbine, there is a room that is called the electric system room. This room is for some kind of electricity activities. Generally, inside the room, one can see many cables, transformers, converters and power factor correction capacitors [Run 16].

II.4. Advantages

Wind turbines produce electricity at between two and six cents per kilowatt hour, which is one of the lowest-priced renewable energy sources [Byw 17- Fra 18]. As technology needed for wind turbines continued to improve, the prices decreased as well. In addition, there is currently no competitive market for wind energy, because wind is a freely available natural resource, most of which is untapped [Kre 16]. The main cost of small wind turbines is the purchase and installation process, which averages between $48,000 and $65,000 per installation. The energy harvested from the turbine will offset the installation cost, as well as provide virtually free energy for years [D.c 17].

Wind turbines provide a clean energy source [Cer 21], use little water [Eva 09], emitting no greenhouse gases and no waste products during operation. Over 1,400 tonnes (1,500 short tons) of carbon dioxide per year can be eliminated by using a one-megawatt turbine instead of one megawatt of energy from a fossil fuel [Par 17].

II.5. Disadvantages

Wind turbines can be very large, reaching over 140 m (460 ft) tall and with blades 55 m (180 ft) long, [Tur] and people have often complained about their visual impact **.**Environmental impact of wind power includes effect on wildlife, but can be mitigated if proper monitoring and mitigation strategies are implemented [T.R 17]. Thousands of birds, including rare species, have been killed by the blades of wind turbines [Hos 11], though wind turbines contribute relatively insignificantly to anthropogenic avian mortality. Wind farms and nuclear power plants are responsible for between 0.3 and 0.4 bird deaths per gigawatt-hour (GWh) of electricity while fossil fueled power stations are responsible for about 5.2 fatalities per GWh. In 2009, for every bird killed by a wind turbine in the US, nearly 500,000 were killed by cats and another 500,000 by buildings [B.K13].

Energy harnessed by wind turbines is intermittent, and is not a "dispatchable" source of power; its availability is based on whether the wind is blowing, not whether electricity is needed. Turbines can be placed on ridges or bluffs to maximize the access of wind they have, but this also limits the locations where they can be placed [Bar]. In this way, wind energy is not a particularly reliable source of energy. However, it can form part of the energy mix, which also includes power from other sources. Notably, the relative available output from wind and solar sources is often inversely proportional. Technology is also being developed to store excess energy, which can then make up for any deficits in supplies.

II.6. Types of Wind Turbine Towers

Nowadays, wind turbine towers can be produced in many types and made of many materials. As a material, towers are made of concrete or constructional steel. In generally, towers can be divided into four categories, lattice towers, cylindrical towers, concrete towers and hybrid towers which are made from both concrete and metal [Mr 09].

II.6.1. Lattice Towers

As it can be seen in Figure II.6, lattice tower consists from many pieces of metal stick. The connection between these metal parts is made by bolts. One of the positive aspects of this structure is it is easily accessible. This kind of small parts can be found in all metal producer. Also, according to the shape of the tower, the wind load effect is lower than other structure types. However, this kind of structure cannot carry very heavy nacelles and the main cost is higher than other tower types [Alm 21]

Figure.II.6. Lattice tower sample.

II.6.2. Steel Cylindrical Towers

Nowadays, in the wind energy sector, the most chosen type of wind turbine tower is the steel cylindrical tower. Considering to other towers, these kinds of towers are quite lighter than the others. These are not only lighter but also economic. Actually, the main reason to choose this type of tower is the strength of the structure. Compared with other tower types, cylindrical towers are much stronger [Run 16].

Generally, these towers' main sections are connected to each other with bolts. But before connection, in order to produce the cylindrical part, bended flap metal must be welded from their vertical welding line. Generally each can is chosen around 2-3 meters. Then these 2-3 meters part are welded horizontally. A sample of a cylindrical tower and flange connections can be seen in Figure II.7 [Mar 12].

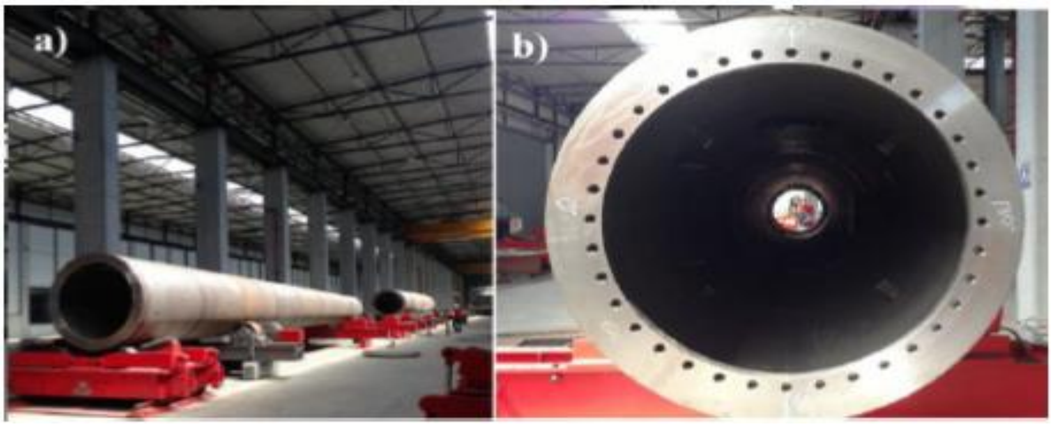

Figure.II.7.a) Steel cylindrical tower **b)** Flange connection.

II.6.3. Concrete Towers

Compared with steel towers, concrete towers are not as popular as steel structures. On the other hand, according to energy requirements, the height of tower and rotor diameter are going to increase a lot. The result of this increment, in order to reach more safety structures, investors turn to concrete structures. Especially, dynamic analyzes results of concrete structures are quite impressive [Alm 21]

Generally, concrete towers are assembled in the field, as it can be seen in following Figure II.8. Additionally, concrete is used in construction sector a lot, so there is no provider problem. For wind towers, a pre-stressing concrete method is used by companies. As a result of this method, a number of crack on the concrete get decrease. Less crack mean is long life in terms of fatigue. One another good aspect of concrete is local torsions or bending. During assembly, steel structures must be checked very carefully for local torsions or bending [Mic 14].

Figure.II.8. Concrete towers for wind turbines.

II.6.4 Hybrid Towers

As it can be understood from its name, hybrid towers use steel and concrete together. These tower consist of two main parts. One good sample can be observed in Figure 10. The first part is the concrete foundation and half of the tower, the second part is the cylindrical tower above the concrete. The aim of the hybrid tower is benefitting from both tower types positive aspects. For instance, the concrete tower doesn't have the problem of transportation, and steel structures are lighter than concrete. Using a hybrid tower can give flexibility for companies.[Szc 16]

Figure.II.9. Assembly process for hybrid tower.

II.7. Developments of wind turbines

In recent years, researches in wind turbine technology have increased rapidly as a result of an increased interest in reconstructing the energy system into a more sustainable one. Figure

II.10, shows how the global installed wind capacity has escalated swiftly in the last years [Alm 21-Art 14].

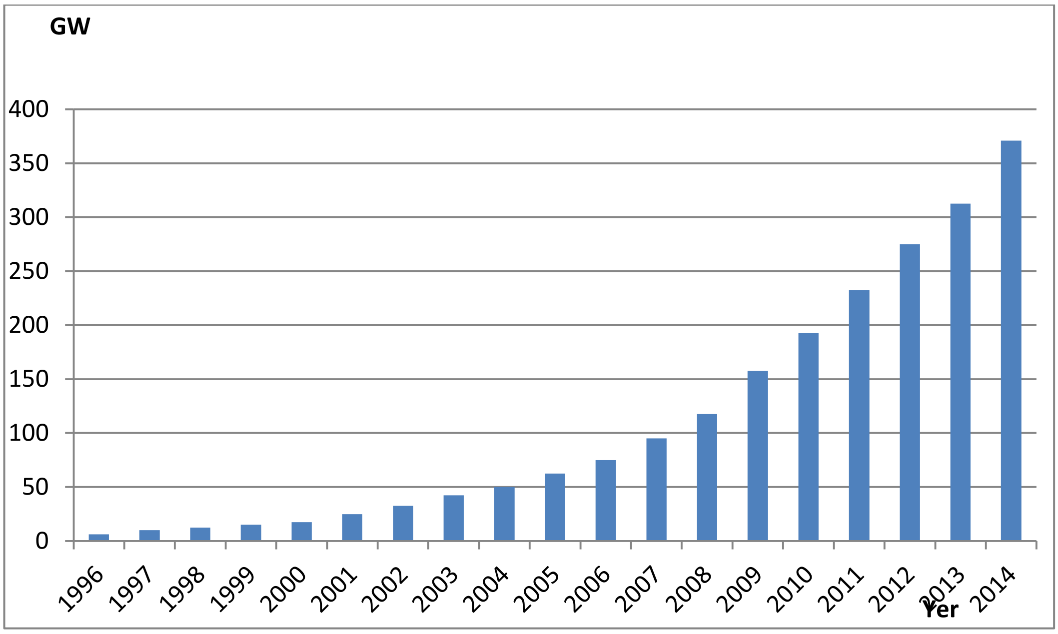

Figure.II.10. Total global installed capacity of wind power between 1996-2014.

The size of wind turbines has increased considerably over the last decades. The main reason for this transformation is that the energy output from the bigger wind turbines are substantially larger than from a smaller model while it does not require as high installation cost to manufacture bigger turbines. In addition, larger turbines can harness wind energy higher from the ground, which is where the wind is stronger. The power ratings of wind turbines are mostly ranging from 250 kW to 7 MW [Mic 14].

II.8. Horizontal Axis Wind Turbine (HAWT) Parts

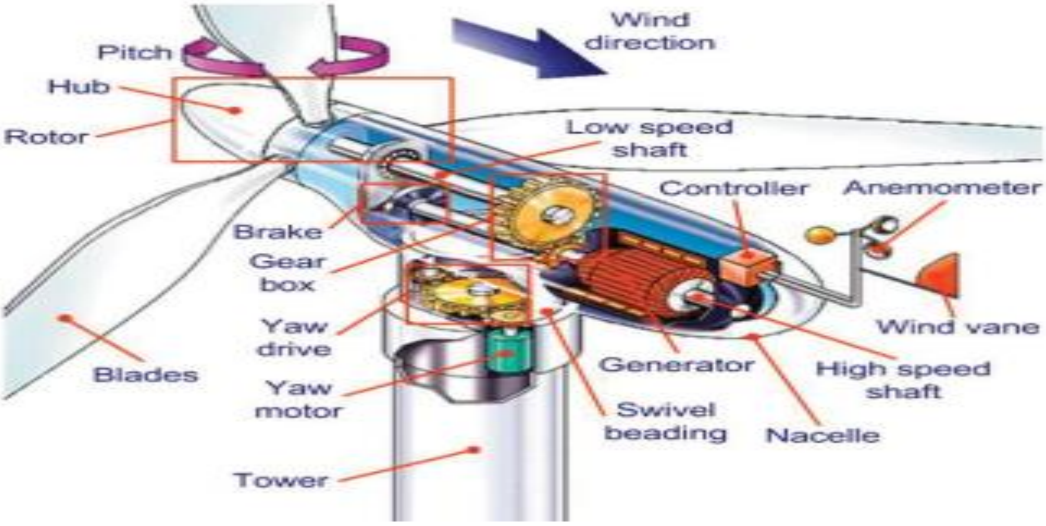

Figure.II.11. HAWT parts.

As shown in the above figure 2, the HAWT consist of several mechanical parts. Some of the parts work to generate the electric power and some parts for protecting the turbine. The parts as follows:

II.8.1. The Rotor

The rotor works as collecting the energy from the wind, the rotor and its blades convert the wind power to a rotational mechanical power. The rotor consists of two or more wooden, fiberglass, or metal blades. The rotor blade design has advantage from airplanes wind technology; it works by using the Bernoulli aerodynamic lift and drag force. The shape of the rotor blade and their angle of attack proportion to the direction of wind and affects on the performance of the rotor blade Assembly of the rotor can be placed in two directions (see figure II.12) [Mr 09- Dr. 14].

II.8.2. The blades

It is designed aerodynamically to work on the precept of lift and drag to convert kinetic energy which is produced from the wind into mechanical energy in order to be transferred through the main shaft then converted to electrical energy by using the generator. the rotor blades have variables such as materials, number of blades, length and blade pitch The following materials have been considered for rotor blades[Dr. 14].

II.8.2.1. Metals

Alloys of aluminium and steel have been used; the mechanical properties of steel has a good fatigue strengthHowever, it is comparatively dense so that steel can be sort of heavyFor the same weight aluminium has better.

II.8.2.2. Wood

Wood has a low density, good strength and good fatigue resistan; an improved use of wood is to shape the blades from bonded stratum of wood sheets using.

II.8.2.3. Synthetic composites

It consisted of a polyester or epoxy matrix which isreinforced with glass fibers. They have an advantage of low density compared to metals and good tensile properties. Glass Reinforced Plastic(GRP) blades are strong,economical with temperate fatigue [Mol.11]

II.9. Effect of number of blades

When the number of blades on a wind turbineincreases, the efficiency of aerodynamic increases. However, as we move from two blades to three blades we get an increases in efficiency of 3% but as we move from three blades to four blades the efficiency gain is marginal Moreover, as we increases the number of blades cost of the system increases When we use more number of blades, the blade should be thinner wind turbines with three blades accommodated a thicker root are used. Generally, the less number of blades on the wind turbine, the cost of material and manufacturing will be lower [Dr. 14].

Figure.II.12. Efficiency gain increases by increases the number of blade.

The modern wind turbine has been built with an odd number of blades and the important reason of that is the stability of the turbine. The rotor with an odd number of blades can be considered to be similar to a disc when calculating the dynamic properties of the machine Moreover, the modern HAWT rotors which are consist of two or three thin blades and have a specification design as low solidity rotors, it is offer a low fraction of the area swept by the rotors being solid The wind turbine blades experience mainly two aerodynamic forces Lift and Drag, the lift force is an important factor which make the blade rotate. The shape of cross section for airfoil is more around on the top and less on the bottom, the advantage of this design basically creates faster airflow over the top of the blade and therefore less pressure [Dr.14]-[Mr09].

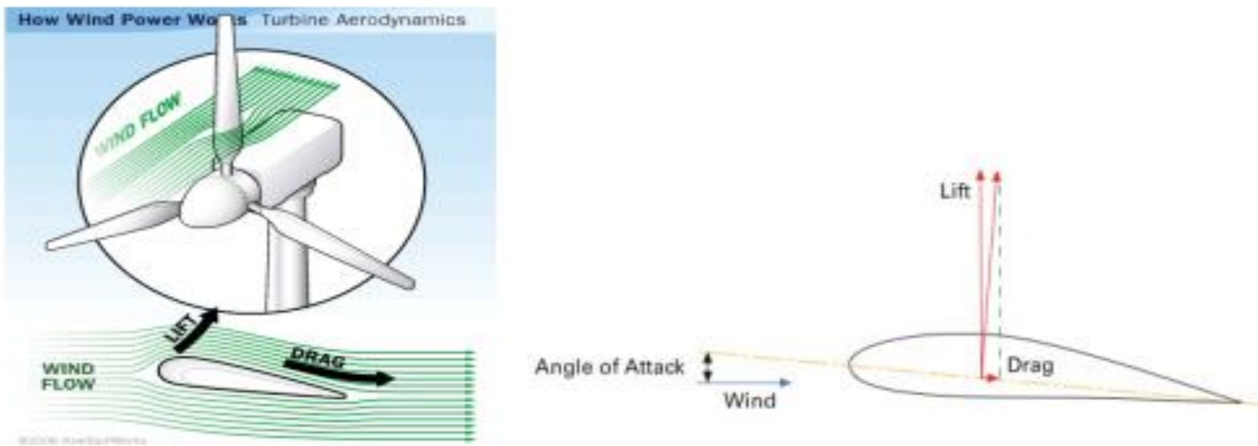

Figure.II.13. Shows the mainly two aerodynamic forces Lift and Drag.

II.10. Conclusion

The general components and design basics about the wind turbine and emphasizes their different characteristics are presented and types of wind turbine concepts predominate the market are presented. The most conventional wind turbine concept is the fixed speed stall controlled wind turbine with induction generator. In contrast to this, the variable speed pitch controlled wind turbine concept with doubly-fed induction generator and partial-scale frequency converter has increased its market penetration enormously, that the main trend in wind turbine technology is recently the variable speed option using pitch control and power electronic interface.

ChapterIII:

Modeling and

Experimental Achievement

III.1. Introduction:

Wind turbines are manufactured in a wide range of sizes, with either horizontal or vertical axes. Wind turbines convert wind energy to electrical energy for distribution. Conventional horizontal axis turbines can be divided into three components. In our work we studied the basics and designing of wind turbines and their types, as well as simulating the turbine a horizontal axis.

Although the wind technology introduces many positive things to the energy sector, it also brings along uncertainties, such as environmental impacts, as well as how the optimal operation and maintenance plan should be structured. Even though the unknown factors concerning the wind technology are many, the impact the technology can have on the future energy system is considerable. It is therefore worth investing more time and resources on improvements in this field of study.

The modelling and experimental achievement the wind turbine horizontal axis the wind turbine will be study in this part, that's after discussing the components of the turbine horizontal axis.

III.2. Wind turbine model

III.2.1. TurbineTechnologies

Wind turbines have evolved rapidly over thepast 20 years and the turbines have grown in sizefrom 100 kW in the early 1980s to over 2.5 MWtoday. The evolution of wind technology isexpected to continue over the next decadesresulting in a continued improvement in reliabilityand energy capture with a modest decrease incost. The improvements in blade design andmaterials, innovative rotors, drive systems, towers,and controls are expected to enable this continuedimprovement in the cost effectiveness of windtechnology.

III.2.2.General Remarks

In the 1990s, wind turbines were generally designed to operate at a constant speed. This means that regardless of the wind speed, the speed of the turbine rotor is constant and limited by the frequency of the main grid. The most reactive energy is pulled. Moreover, due to the intrinsically extreme torque-velocity characteristic, all fluctuations in wind power are transmitted in the grid. [Mat 11].Variable speed wind turbines are designed to achieve maximum aerodynamic efficiency over a wide range of wind speeds, by varying the speed of shaft rotation. The electromechanical switching system is more complex compared to the other. It is usually equipped with an induction generator or a synchronous generator and connected to the network through a power transformer. The transducer controls the speed of the generator; thus there is a possibility to offset wind fluctuations more easily.

The main advantages of variable speed wind turbines are increased energy capture, improved energy quality, and reduced mechanical stress on wind turbines.

Once the wind is blowing stronger than the nominal speed, the power output should be limited. The reduction of output power in the wind speed region between rated and cut-off is achieved by reducing the efficiency of the aerodynamic conversion of wind energy into rotational kinetic energy. This can be done by using a turbine blade coil in two different ways. The blades can be designed in such a way that they lose their efficiency as the wind increases; this method is called stall regulation. Alternatively, the blades can be taken out by the wind; this method is called pitch regulation. Stall regulation was used mainly for earlier wind generators, and is also used today for constant speed wind generators, while pitch control is used for variable speed generators [T.A 05-Mat 11].

III.2.3.Wind turbine family

It is common practice to group the wind turbines produced worldwide in four main typologies depending on the type of generator they are equipped with:

A) Fixed speed induction generators.

B) Small variable speed induction generators.

C) Variable speed doubly fed induction generators.

D) Variable speed full converter with synchronous or asynchronous generators.

III.3. Mainassumptions Wind turbine model description

The wind turbine model realized is described from an electromechanical perspective, thus it provides: an analysis of the aerodynamic behaviour of the rotor including the pitch control system, the shaft dynamic and the maximum power tracking characteristic [M.M 08]. The model is tuned for a 2 MW full converter direct drive equipped generator. This typology of wind turbine is characterized by the absence of the gearbox and the presence of ac/dc/ac converter sized for the whole power. Since the model is not intended to analyse dynamics faster than a fraction of second, there is no need to characterize in a detailed way the generation/conversion system, which thus it is modelled as a negative load [S.A 04]. The rest of the electromechanical conversion system needs an accurate detail due to the interest in studying the possibility to reduce the output in certain conditions. There is, in fact, the need to model the delays introduced by the pitch controller and by the shaft rotational speed [A.H 07].

III.4. Wind Turbine Blades Move in the Wind

There are two important reasons why wind turbine blades are able to spin in the wind: Newton's Third Law and the Bernoulli Effect.

III.4.1. Newton's Third Law

Newton's Third Law states that for every action, there is an equal and opposite reaction. In the case of a wind turbine blade, the action of the wind pushing air against the blade causes the reaction of the blade being deflected, or pushed. If the blade has no pitch (or angle), the blade will simply be pushed back wards (down wind). But since wind turbine blades are set at an angle, the wind is deflected at an opposite angle, pushing the blades away from the deflected wind. This phenomenon can be viewed on a simple, flat blade set at an angle. If you push the blade with your finger from the direction of the oncoming wind, the blade will deflect away from your finger [Hau 06].

III.4.2. The Bernoulli Effect

The Bernoulli Effect tells us that faster moving air has lower pressure. Wind turbine blades are shaped so that the air molecules moving around the blade travel faster on the downwind side of the blade than those moving across the upwind side of the blade. This shape, known as an airfoil, is like an uneven teardrop. The downwind side of the blade has a large curve, while the upwind side is relatively flat. Since the air is moving faster on the curved, downwind side of the blade, there is less pressure on this side of the blade. This difference in pressure on the opposite sides of the blade causes the blade to be "lifted" towards the curve of the airfoil [Hau 06].

Figure.III.1. Bernoulli Effect.

III.4.3. Torque

Torque is a force that turns or rotates something. When use a wrench on a bolt or twist a screw loose with a screwdriver. Torque is a lot like leverage. If you are trying to turn a wrench, sometimes we need a lot of leverage to loosen a tight bolt. Wind turbine blades are like big levers-but instead of your muscle turning them they use the force of the wind.

Torque is equal to the force multiplied by distance. This means that the longer your blades are, the more torque you can generate [Fet 15]-[Hau 06].

III.5. Modelling of the Horizontal Axis Wind Turbine

The modelling of the turbine consists in expressing the extractable power according to the incident speed of the wind and the operating conditions, its speed of rotation in particular. This will make it possible to know the wind torque applied to the shaft of the wind turbine. Finally, we can obtain a global model composed of three subsystems, the turbine, the multiplier, and the shaft as shown in Figure III.2.

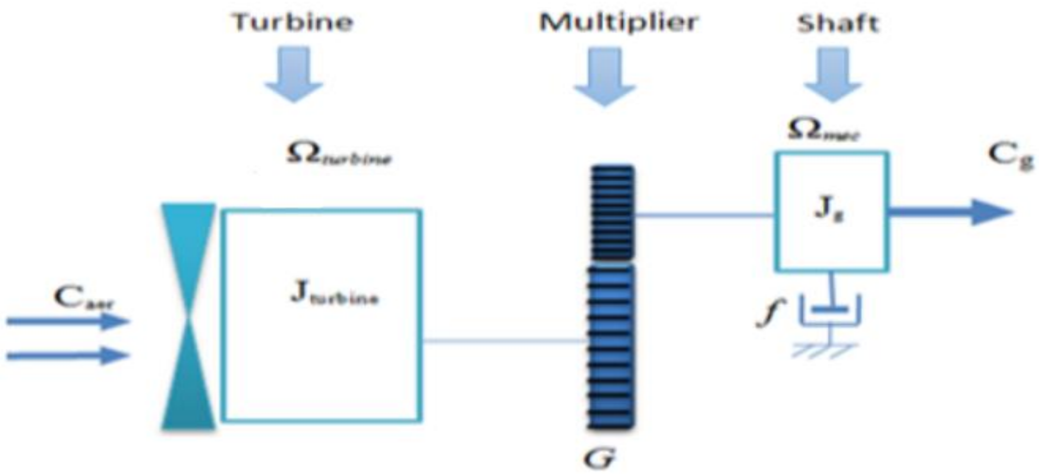

Figure.III.2. Simplified mechanical model of the turbine.

III.5.1. Modelling of the Turbine

The available power of the wind crossing a surface (S) is defined by Equation (III.1):

$$P_{vent} = \frac{1}{2}\rho S V_{vent}^3 = \frac{1}{2}\rho.\pi.R^2.V_{vent}^3 \quad \text{(III.1)}$$

Where ρ is the air density (approx. 1.22 kg.m³ at atmospheric pressure at 15°C), and S is the circular area swept by the turbine. The radius of the circle is determined by the length of the blade. In reality, the conversion device (the wind turbine) extracts an aerodynamic power (P_{aer}) that is lower than the available power (P_v), as shown in Equation (III.2):

$$P_{aer} = \frac{1}{2}C_p(\lambda,\beta)\rho\pi R^2 V^3 \quad \text{(III.2)}$$

The power coefficient C_p represents the aerodynamic efficiency of the wind turbine ($\frac{P_{aer}}{P_v}$). It depends on the characteristic of the turbine. This coefficient varies with the angle of orientation of the blades (β) and the speed ratio (λ). The speed ratio is defined as the ratio between the linear speed of the blades and the wind speed (see Equation (III.3)):

$$\lambda = \frac{\Omega_t R}{V} \tag{III.3}$$

Where Ω turbine is the speed of the turbine. Knowing the speed of the turbine, therefore the aerodynamic torque is directly determined by Equation (III.4):

$$G_{aer} = \frac{P_{aer}}{\Omega_t} = \frac{1}{2} C_p \rho S V_{vent}^3 \frac{1}{\Omega_t} \tag{III.4}$$

We assume the angle of orientation of β is constant so the coefficient Cp is given by the following Equation (III.5):

$$P_{aer} = \frac{1}{2} C_p(\lambda, \beta) \rho \pi R^2 V^3 \tag{III.5}$$

$$C_p(\beta, \lambda) = \left(0.5 - 0.0167.(\beta - 2)\right). \sin\left(\frac{\pi.(\lambda + 0.1)}{18.5 - 0.3(\beta - 2)}\right) - 0.00184(\lambda - 3).(\beta - 2) \tag{III.6}$$

Thus, the maximum value of the coefficient C_p is 0.548 corresponding to λ = 6.4.
The multiplier adapts the (slow) speed of the turbine to the speed of the generator. This multiplier is mathematically modeled by the following Equations (III.7 and III.8):

$$C_g = \frac{G_{aer}}{G} \tag{III.7}$$

$$\Omega_t = \frac{\Omega_{mec}}{G} \tag{III.8}$$

The mechanical equation that manages this set is given by Equations (III.9 and III.10):

$$C_{mec} = J_t \frac{d\Omega}{dt} \tag{III.19}$$

L’équation mécanique qui gère un tel ensemble est donnée par :

$$C_{mec} = C_g - C_{em} - C_{vis} \tag{III.10}$$

$$C_g - C_{em} = J_t \frac{d\Omega_{mec}}{dt} + f\Omega_{mec} \tag{III.11}$$

By using LAPLACE Transfer, we obtain the speed (look at Equation III.12):

$$\Omega_{mec} = \frac{1}{J_t + f}(C_g - C_{em}) \tag{III.12}$$

III.5.2. Shaft Dynamic Equation

The mass of the wind turbine is plotted on the turbine shaft as inertia $J_{turbine}$ and includes the mass of the blades and the mass of the turbine rotor. The proposed mechanical model considers the total inertia J consisting of the inertia of the turbine transferred to the rotor of the generator and the inertia of the generator in equation (III.13):

$$J = \frac{J_t}{G^2} + J_g \tag{III.13}$$

It should be noted that the inertia of the generator rotor is very low compared to the inertia of the turbine reported by this axis. The fundamental equation of the dynamics makes it possible to determine the evolution of the mechanical speed from the total mechanical torque (C_{mec}) applied to the rotor equation (III.14):

$$J_t \frac{d\Omega_{mec}}{dt} = C_{mec} \tag{III.14}$$

Where *J* is the total inertia that appears on the generator rotor. This mechanical torque takes into account the electromagnetic torque C_{em} produced by the generator, the viscous friction torque C_{vis}, and the torque resulting from the multiplier C_g. The resistant torque due to friction is modelled by a viscous friction coefficient f (see Equation III.15):

$$C_{vis}=f.\Omega_{mec} \tag{III.15}$$

By taking into account the inertia and the friction of the bearings the wing can be presented as in Figure III.3. The electrical equivalent of such an inertial system is shown in Figure III.4.

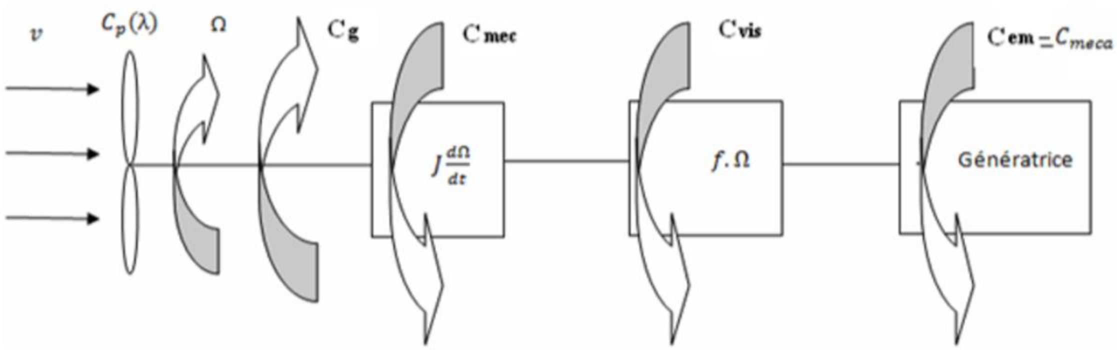

Figure.III.3. Model of a wind turbine.

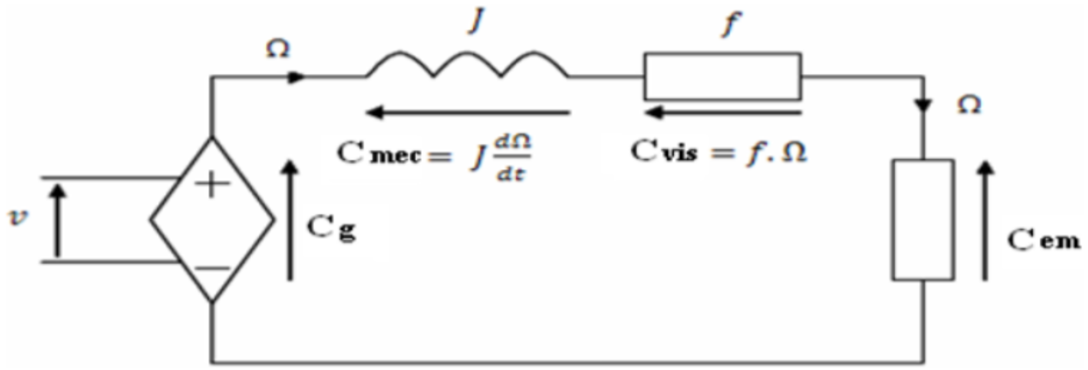

Figure.III.4. Equivalent electrical diagram of the turbine of a wind turbine.

III.5.3. Turbine Control Strategy

Figure III.5, shows the Power-speed characteristic of a wind turbine. There are four main operating areas.

Zone1: From a certain minimum speed necessary to drive the wind turbine, the wind turbine begins to rotate.

Zone2: From a certain threshold speed of the generator (corresponding to a slip of 30%), a control algorithm allowing the extraction of the maximum wind power (MPPT) is applied. The pitch angle is maintained at its minimum value which corresponds to the maximum of the power coefficient.

Zone3: Beyond, the wind turbine operates at a constant speed. In this zone, the power reaches up to 90% of its nominal value.

Zone 4: arrival at nominal power, the speed must be limited, this is the phase where speed limitation occurs by blade orientation (pitch angle), this is “Pitch Control” [A.B 06.].

In the following, we are interested in zone 2 or the maximization of the electrical energy extracted; this operation is carried out by controlling the electromagnetic torque generated.

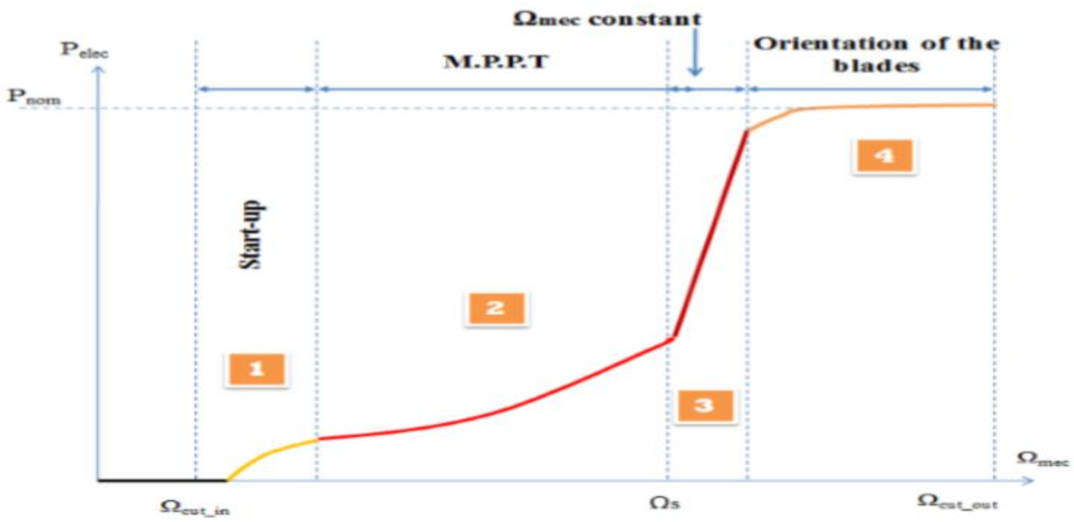

Figure.III.5. Power-speed characteristic of a wind turbine.

III.5.4.Maximization of Power Extracted

In practice, the rotation speed is controlled by the electromagnetic torque, to maximize the electrical power generated; this is the principle of MPPT. There are two command structures: Mechanical speed servo control and Control without mechanical speed control. It is difficult to accurately measure the wind speed which is by nature a very fluctuating quantity. An erroneous measurement of the speed, therefore, leads to a degradation of the power captured according to the MPPT technique. This is why most wind turbines are controlled without speed feedback [E.E01].

III.6. Experimental realization of the wind turbine

On a real wind turbine, the long blades give the turbine a lot of leverage to provide power to the generator. Utility scale wind turbines often have large gearboxes that increase the RPM of the rotor by 80 or 100 times. This big gear reduction demands a lot of leverage from the blades. Think about riding bicycle when you shift into a higher gear it may be harder to pedal. A higher gear ratio demands more torque.

In our work small turbine blades will generally, may require more torque as well. A simple illustration of this is to use model turbine to power a small LED light bulb and a small incandescent light bulb.

Wind turbines come in many sizes and configurations and are built from wide range of materials. In simple terms, a wind turbine consists of a rotor that has wing shaped blades attached to a hub; a nacelle that houses a drivetrain consisting of a gearbox, connecting shafts, support bearings, the generator, plus other machinery; a tower; and ground-mounted electrical equipment.

The turbine blades play very important role in the wind turbines. Blades are required to preserve an optimum cross-section for aerodynamic efficiency to generate the maximum torque to drive the generators. The efficiency of the wind turbine depends on the material of the blade, shape of the blade and angle of the blade. Therefore, the material of the turbine blade plays a vital role in the wind turbines. The material of the blade should possess high stiffness, low density and long fatigue life features.

Most rotor blades in use today are built from glass fiber-reinforced-plastic (GRP). Other materials that have been tried include steel, various composites and carbon filament-reinforced-plastic (CFRP). As the rotor size increases on larger machines, the trend will be toward high strength, fatigue resistant materials. As the turbine designs continually evolve, composites involving steel, GRP, CFRP and possibly other materials will likely come into use. For purposes of example, blades materials is shown in Figure III.6 and III.7.

Blades are primarily made of GRP, which is expected to continue, while use of CFRP may help to reduce weight and cost to some extent.

A wide range of materials are used in wind turbines. There are substantial differences between small and large machines and there are projected changes in designs that will accommodate the introduction of new material technologies and manufacturing methods. Wind turbine blades built up with composite materials have much less weight than traditional constructions.

The blade design process starts with a “best guess” compromise between aerodynamic and structural efficiency. The choice of materials and manufacturing process will also have an influence on how thin (hence aerodynamically ideal) the blade can be built. For instance, prepared carbon fiber is stiffer and stronger than infused glass fiber. The chosen aerodynamic shape gives rise to loads, which are fed into the structural design. Problems identified at this stage can then be used to modify the shape if necessary and recalculate the aerodynamic performance.

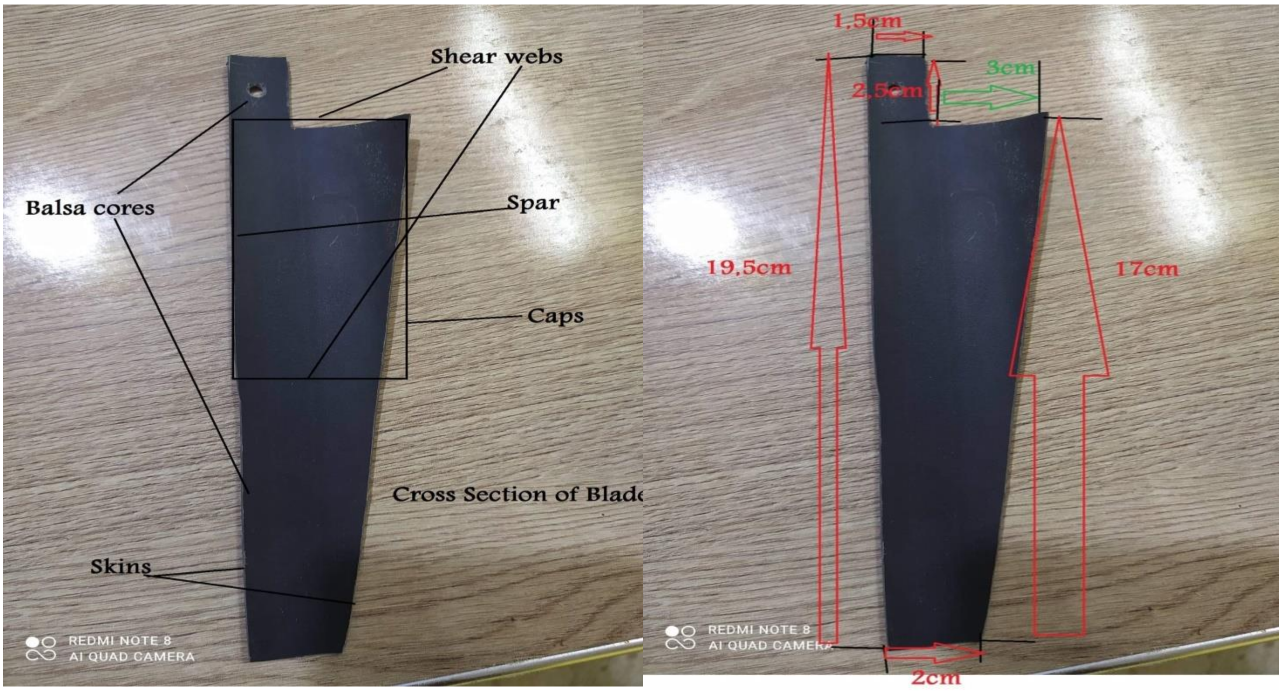

Figure.III.6. Typical Blade design process and its cross-section.

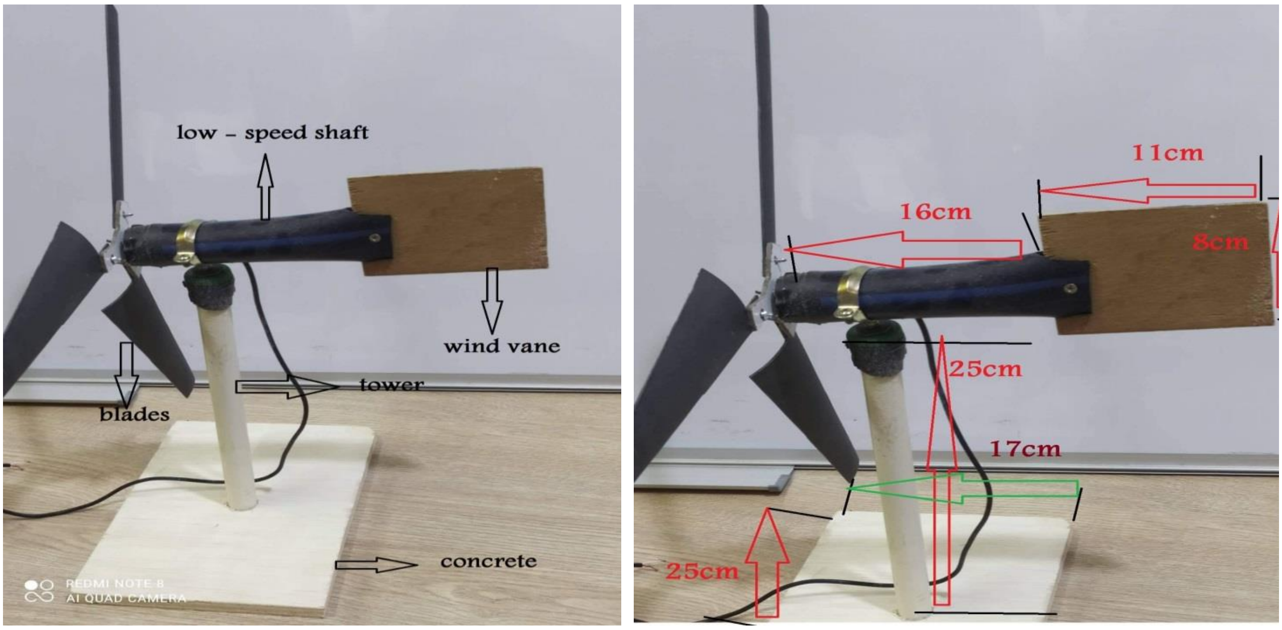

Figure.III.7. The optimum number of Bales.

Figure.III.8. SmallWind turbine at three blades.

III.7. Results and discussion

III.7.1. Characteristic of the Power Coefficient Evolution

Figure (III.9, III.10 and III.11) represents the power coefficient characteristic as a function of the relative speed λ. Note that any increase in speed ratio will be tracked by the power coefficient Cp. Note that the maximum values are 9.14 for speed ratio λ and 0.5 for the Cp.

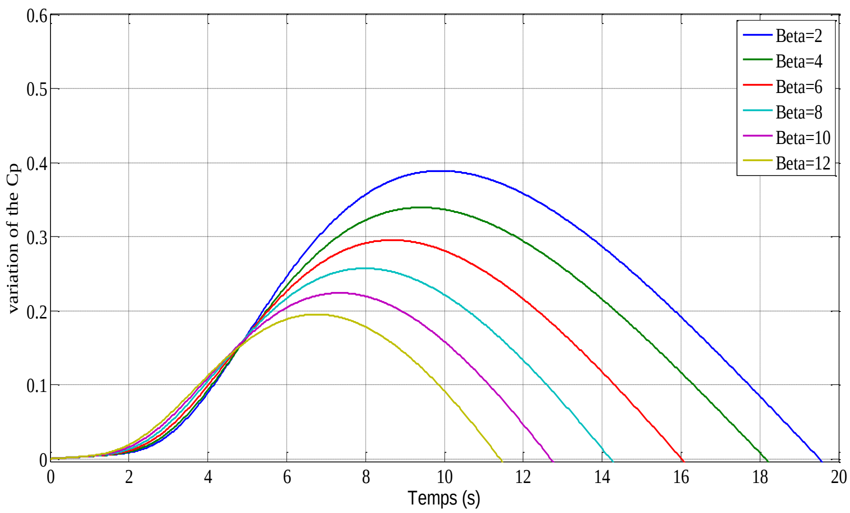

Figure.III.9. Characteristic of the power coefficient evolution.

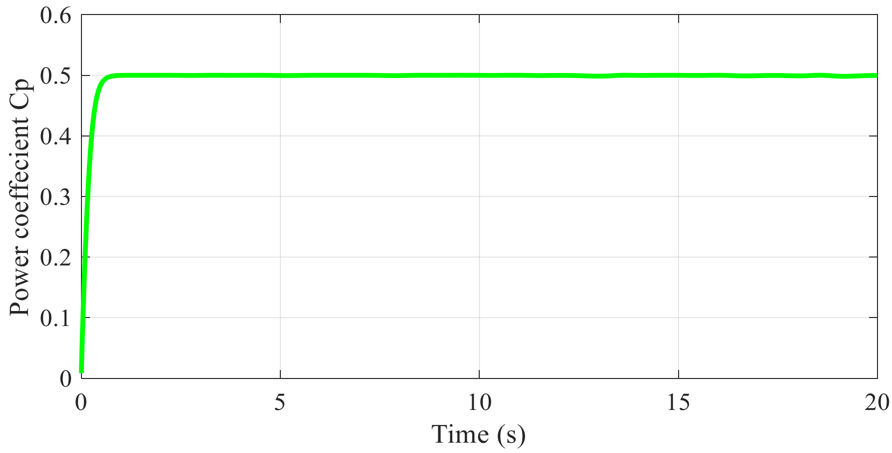

Figure.III.10. Characteristic of the power coefficient in (Beta=2).

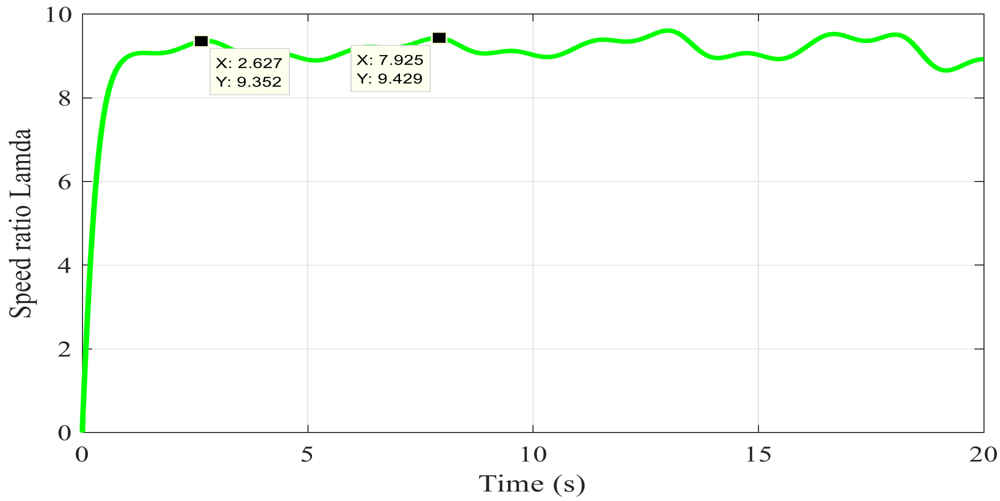

Figure.III.11. Characteristic of the speed ratio evolution

III.7.2. Wind Profile

Our simulations are focused only on the mechanical part of the wind turbine. They are made in the MATLAB/SIMULINK environment and this allows us to develop control block diagrams and associate them with machine models. Note that we are not going to connect the propeller and the multiplier to a generator but simply observe the torque produced at theoutput of the multiplier according to the evolution of the wind. To do this, we need the value of the electromagnetic torque multiplier, torque which would be imposed by the generator according to the power it produces. We are therefore going to set ourselves a reference torque and use the wind profile to validate the model established previously. We will observe the shape of the mechanical speed and the reference power according to the evolution of the wind. Figure III.12, shows this wind profile that will be applied for the wind turbine, which varies between 7-13 (m/s).

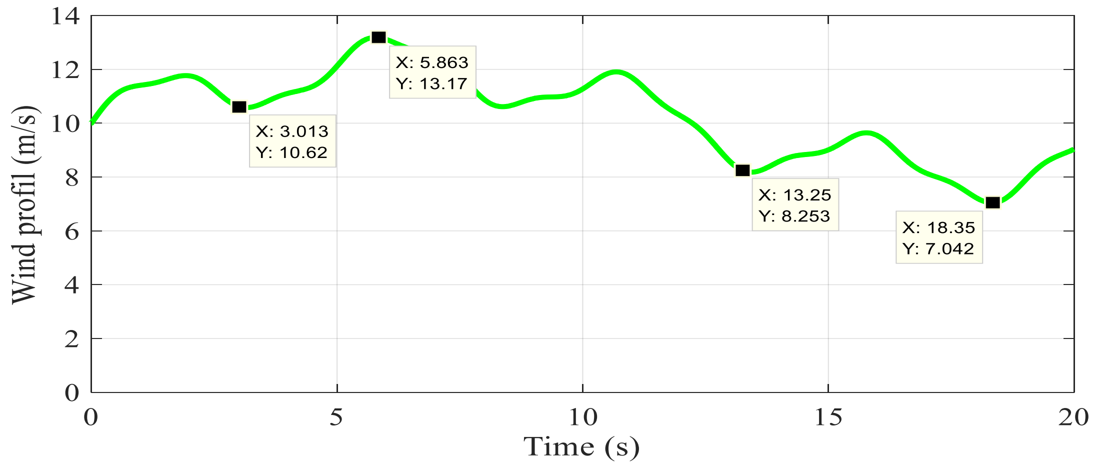

Figure.III.12. Wind profile evolution.

III.7.3. Mechanical Speed

Neglecting the losses of electrical origin, then the electrical power will be equal to the electromagnetic power and respect the receiver convention of the whole. When these two powers are equal, the wind turbine rotates at a fairly stable speed as shown in Figure III.13. The speed in our case is between (50-100rd/s).

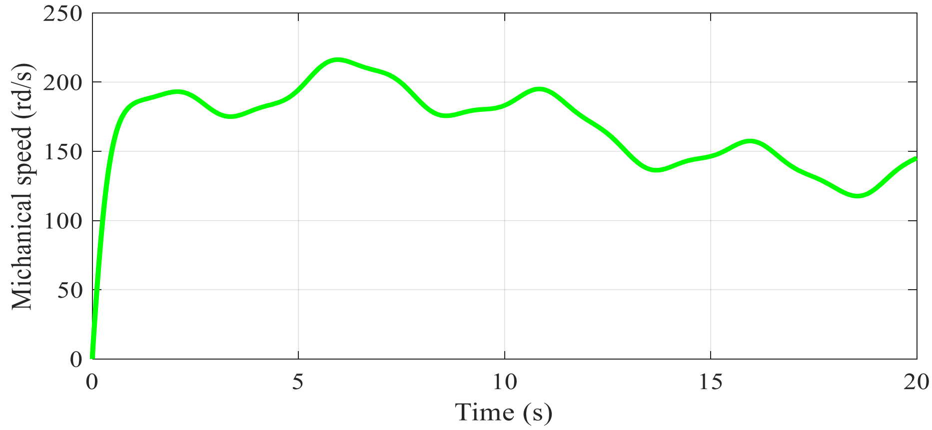

Figure.III.13. Mechanical speed (rd/s) evolution.

III.8. Conclusion

In this work, we have detailed modelling of the different parts of the wind turbine taking into account the characteristics of the blade profile, its offset angle, and the wind profile used.

We modelled the mechanical assembly including the multiplier, allowing the interconnection with a generator that will have the torque as input and the speed as output. This model makes it possible to obtain the shape of the couple.

The mechanical part is a very essential element in wind turbine conversion. It has its control to maximize the power extracted from the wind by MPPT.

General Conclusion

General conclusion

The renewable energy market has evolved considerable development in recent years. The intensive consumption of electrical energy, the instability of hydrocarbon prices and the concern to preserve the environment have led several countries to initiate national and international programs intended to produce electrical energy from renewable resources. The production of renewable energy, especially that of the wind type, is distinguished by its random and intermittent nature, which is often the source of serious problems causing instabilities to the electrical networks, thus are placed the desired objectives of our work and where the improvement of performance and the control of the exploitation of wind energy constitute the main wish.

To do this, we knew and were able to deal with the following objective points:

- Wind turbine and how to exploit it as a renewable energy using the types of wind turbines and their characteristics and their global use.
- Delved into the type of horizontal wind turbine most commonly used, and we mentioned all its components and parts, especially the breeding blade. We also mentioned the types of generators and the most important is the methods of installing and installing it.
- Finally, in the third chapter, we applied the simulations of wind turbines as a model close to large turbines, with the completion of a small practical work to bring the idea closer and to conclude that there are factors that we can control, the most important of which are the diameter of the blades and the inertia torque, and all of this to have a good profitability of the turbine to improve its manufacture and use in an ideal case.

Based on our own findings and remarks from our experience drawn at the end of this research work, we propose, in terms of future prospects and in terms of the natural continuity of this work, the following:

- Validation on industrial sites of the theoretical results connected to the electrical network.
- When it comes to developing and improving the dynamic performance of drives and control systems, it is useful to examine the technique of optimization by RTO to closely see its impact on the gains and also on the matrix of inference from fuzzy regulators or on other regulators.

Abstract

This work presented with in the frame work of this theme, is centered on the application of the design and operation principles of thewind turbine.

In first chapter, developed to the generalities of wind energy; firstly, we will explain the definition of wind energy and its components. Subsequently, the fixed and variable speed operating modes and the different generators used are presented.

In the second chapter, among several wind turbine types taking horizontal axis turbine to presents the components and design basics, disadvantages, advantage and electric system room.

In a third chapter, we propose a modeling and experimental design of the small windturbine. The design and simulation of wind turbine, it includes information on turbine design and technology as well as information on its expected performance. As the electromechanical transmission system is more complex, and explained the reasons for moving wind turbine blades, the materials used and the number of rotor. Finally, simulation results and general form of our turbine are presented.

الملخص

يتم تقديم هذا العمل في إطار هذا الموضوع ، ويتمحور حول تطبيق مبادئ التصميم والتشغيل لتوربينات الرياح.

في الفصل الأول ، تم تطويره لعموميات طاقة الرياح ؛ أولاً سوف نشرح تعريف طاقة الرياح ومكوناتها. بعد ذلك ، يتم عرض أوضاع التشغيل ذات السرعة الثابتة والمتغيرة والمولدات المختلفة المستخدمة.

في الفصل الثاني، من بين العديد من أنواع توربينات الرياح التي تستخدم توربينات ذات محور أفقي لعرض المكونات وأساسيات التصميم، وعيوبها، ومزاياها، وغرفة النظام الكهربائي.

في فصل ثالث ، نقترح تصميم نمذجة وتجريبية لتوربينات الرياح الصغيرة. تصميم ومحاكاة توربينات الرياح ، ويتضمن معلومات عن تصميم التوربينات والتكنولوجيا بالإضافة إلى معلومات عن أدائها المتوقع. نظرًا لأن نظام النقل الكهروميكانيكي أكثر تعقيدًا ، وشرح أسباب تحريك ريش توربينات الرياح والمواد المستخدمة وعدد الدوار. أخيرًا ، يتم عرض نتائج المحاكاة والشكل العام لتوربيننا.

Résumé

Ce travail présenté dans le cadre de ce thème, est centré sur l'application des principes de conception et de fonctionnement de l'éolienne.

Dans un premier chapitre, un développé aux généralités de l'énergie éolienne ; dans un premier temps, nous expliquerons la définition de l'énergie éolienne et de ses composantes. Par la suite, les modes de fonctionnement à vitesse fixe et variable et les différents générateurs utilisés sont présentés.

Dans le deuxième chapitre, parmi plusieurs types d'éoliennes prenant une turbine à axe horizontal, on présente les composants et les bases de conception, les inconvénients, les avantages et le local du système électrique.

Dans un troisième chapitre, nous proposons une modélisation et une conception expérimentale de la petite éolienne. La conception et la simulation d'une éolienne comprennent des informations sur la conception et la technologie de l'éolienne ainsi que des informations sur ses performances attendues. Comme le système de transmission électromécanique est plus complexe, on explique les raisons du déplacement des pales des éoliennes, les matériaux utilisés et le nombre de rotor. Enfin, les résultats de simulation et la forme générale de notre turbine sont présentés.

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