

ISTANBUL AYDIN UNIVERSITY
FACULTY OF ENGINEERING

WIND TURBINE

B.Sc. THESIS

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FOREWORD

We fell gratitude to our dearest lecturer Prof.Dr. Hasan Huseyin BALIK about his contribution and trust to our project and effort every time. Finally we thank our families because of their support whenever we need.

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ABBREVIATIONS

BC	: Before Christ
MW	: Megawatt
KW	: Kilowatt
WINDPRO	: Wind Energy Software
WASP	: Wind Resource Assessment Software
PWM	: Pulse With Modulation

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WIND TURBINE

SUMMARY

Wind energy is a renewable energy and became very popular in these years because of the progress it made. Wind turbines makes wind energy to electrical energy and the most important components are wing number and wing type.

In this work, our aim was make our turbine produce constant amplitude and constant frequency. We had always tried to stick with this rule while we were making our project. To make them we have searched components to do it and finally we have found 'Voltage regulator' to make 'constant amplitude' and 'PWM(Pulse Width Modulation)' to make 'constant frequency', we set up and made the circuits and get the results using oscilloscope in our university's lab. After that we choosed our materials according to our calculations of the DC Motor we used. Finally when we have finished our project we get same results in all twirl powers and all amounts of the turning.

RÜZGAR TÜRBİNİ

ÖZET

Ruzgar gucu yenilenebilir bir enerjidir son zamanlarda kat ettığı yoldan dolayı cok popöler hale gelmiştir. Ruzgar turbinleri ruzgar enerjisini elektrik enerjisine donusturur ve en onemli bileşenleri kanat sayısı ve kanat tipidir.

Bizim çalışmamızda, amacımız ruzgar turbinimizin sabit genlik ve sabit frekans uretmesiydi. Projemızı yaparken her zaman bu kurala baglı kaldık. Bunları gerceklestirebilmek için gerekli olan arastırmamızı yaptıktan sonra gerekli malzemelerin voltaj regulatoru ve pwm olduğunu anladık. Sabit genlik için voltaj regulatorunu ve sabit frekans için pwm i kullandık. Sonucları elde etmek ve denemeleride yapabilmek için oscilloscope kullanıp sabit frekansı yakalamaya çalıştık. Sonuc olarakta ne kadar dondurursek dondurelim ve guc ne olursa olsun aynı sonucları almayı basardık.

1. INTRODUCTION

From the end of 2004, worldwide renewable energy capacity made progress at rates of 10-60% annually and passed many technologies include renewable energies. For wind power and many other renewable technologies, growth increased in 2009 relative to the previous four years. More wind power capacity was created and added during 2009 than any other renewable technology, that mentioned above. However, PV increased the fastest of all renewable technologies, with a 60% annual average growth rate and it showed the importance of the renewable energies. In 2010, renewable power constituted about a third of the newly built power generation capacities. The Intergovernmental Panel on Climate Change says there are few main technological limits to integrate renewable energy technologies to involve most of total global energy demand. Renewable energy usage is growing much faster than even advocates anticipated. At the national level, at least 30 nations around the world already have renewable energy as a energy supply.

About the wind turbines ; airflows can be used to run wind turbines and it makes the wind turbine works. Modern utility-scale wind turbines are ranged from 600 kW to 5 MW of rated power. Turbines with rated output of 1.5–3 MW is the most common for commercial use. The power available from the wind is a function of the wind speed, so as wind speed increases, power output increases up to the maximum output for the turbine. Areas where winds are stronger and more constant, such as offshore and high altitude sites, are used for the wind turbines to get the best results. Typical capacity factors are 20-40%, with values at the upper end of the range in particularly favourable sites.

Globally, the long-term technical potential of wind energy is believed to be five times total current global energy production, or 40 times current electricity demand, assuming all practical barriers needed were overcome. This would require wind turbines to be installed over large areas, particularly in areas of higher wind resources, such as offshore. As offshore wind speeds average ~90% greater than that of land, so offshore resources can contribute substantially more energy than land stationed turbines.

1.1 Purpose of Thesis

The purpose of this thesis is to explain the processes of creating an Wind Turbine. The thesis will include the following: Description of the Wind Energy and Wind Turbine, usage of the Wind Turbine, components and structure and finally electricity producing through using wind energy. As result, this thesis will give information about the things mentioned above and the set of informations about wind turbines that people in order to understand structure and process of it.

1.2 Outline

1st Chapter contains information gives broaden information about the purpose of the project.

2nd Chapter is about wind energy. Characteristics and informations about usage of it.

3rd Chapter is Wind Turbines. Explained how to make it better, studies of it and classification of all wind turbines used in the world. Detailed informations about components.

4thChapter is about how we can chose our blades material and explained all structure.

5thChapter is about electricity that how can we produce it using wind energy.

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2.WIND ENERGY

Nowadays, one of the most important renewable energy source is wind energy because in technology and its use shows the most rapid growth and also it can compete with conventional energy in economy.

The wind is caused by the movements of the air as the force resulting from the effect unequal heating and cooling of the earth. The motion of the wind which is created by the air flow is called wind energy. Providing the air over the earth's surface to move enables the wind to come and affects the speed of the wind which are in the atmosphere with certain forces; gradient force, the coriolis force, centrifugal force, the force of friction. The air flowing from high pressure to towards low pressure with the force acting is called the pressure gradient force. The coriolis force is the turning back to its place is known as the force of the deflector.

Winds, generally go around the center. As a result of this movement, they find themselves away from the center of circulation under the influence of a force and this force is called centrifugal force. The wind which is not effective in wind forming and tries to lower the speed of wind is called the force of friction. This force is the biggest on the earth, and it is carried high up by the turbines. This force which is arised from the friction of the wind slows the wind 450-600 m height above the ground. The wind energy is formed by the air which is influenced by the force. A useful portion of the wind energy can be converted into mechanical or electrical energy. The starting of the benefit from the power of the wind is based on the very early and old period and nowadays this technology is still continuing to improve and develop its activities.

2.1 Chronology of Wind Power

2800 BC: It is used in commercial sailing by the Egyptians.

IX. Century: it is used as a windmill by the Persians.

XI. Century: Used as a windmill in Europe particularly in Netherlands

XVI. Century: Denmark, Netherlands, Germany used in windmills.

1846-1908: Paul Le Cour has designed the first modern wind turbines.

1918: Denmark had a total installed capacity of 3 MW.

1920-1930: There were a total of 3,000 turbines in Denmark.

1932: The USA designed a turbine which had 20MW power with a 15 m / s wind speed but design had remained only on paper.

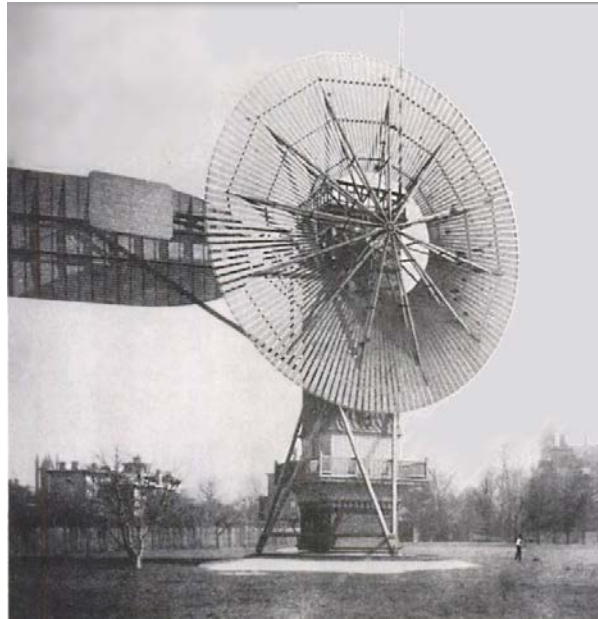


Figure 2.1 :America's First Wind Turbine Generated Electricity In 1888 [24]

1942: The start date of the modern wind technology.

1941-1945: Smith / Putnam installed a turbine with a power of 1250kW in the USA. In 1942 it was damaged in a storm. It was closed down in 1945.

1956-1957: J. Juul in Denmark designed a wind turbine with 200 kW power

1958: According to Ulzich Hütter, Honnef thesis 10kW offshore turbine was installed in an oil platform in the Gulf of Mexico.

1974: Sweden had a total installed capacity of 1 MW.

1980-1981: With the leap in industry and technology the development of modern turbines began.

1985: A wind farm in California which consisted of more than 1000 turbines was established .

1983-1987: Voith - Hütter turbine with a 300 kW capacity was established in the North Sea coast.

1990: In Germany 4 units of Grow II type wind turbine designed by MAN was installed.

1991: Baltic Sea in Denmark, on top of the sea (11x450 kW) wind farm was established.

1995: Neg Micon turbines with 1500kW power were designed.

1996: Turbines with 1500 kW and 3650 kW were designed.

1997: Black coloured rotor blades are made for icy and cold environments.

1998: Enercon E66 wind turbines with 1.5MW power were used in Germany in a wind farm which was Europe's largest wind farm with 52.5 MW power capacity.

1999-2003: 2 MW and 3 MW research.

2006: 4 MW research.

2.2 Measurement of Wind Speed

The energy that can be produced from wind turbine which will be located in an area is directly linked to the wind characteristics there. The wind characteristics of an area depends on parameters such as wind speed, dominant wind direction, temperature and pressure and is determined by the measurements done in that area.

In our country, wind measurements can be done by general directorate of Meteorology connected to ministry of forestry and water affairs, firms which would like to found production facility depending on wind energy, universities and juristic persons. Juristic persons who would like to found electricity production facility through wind energy and to get license have to establish measurement station in the area where the facility will be set up and make measurements along a year at least. They have to stock devices that can measure the wind speed, wind rotation, temperature, pressure and relative humidity of the area.

The height of wind measurement mast has to be 60 m and 30 m at least in the established measurement station and the data obtained from these measurements must be transmitted to the general directorate of Meteorology. Wind measurement station is shown Figure 2.2.

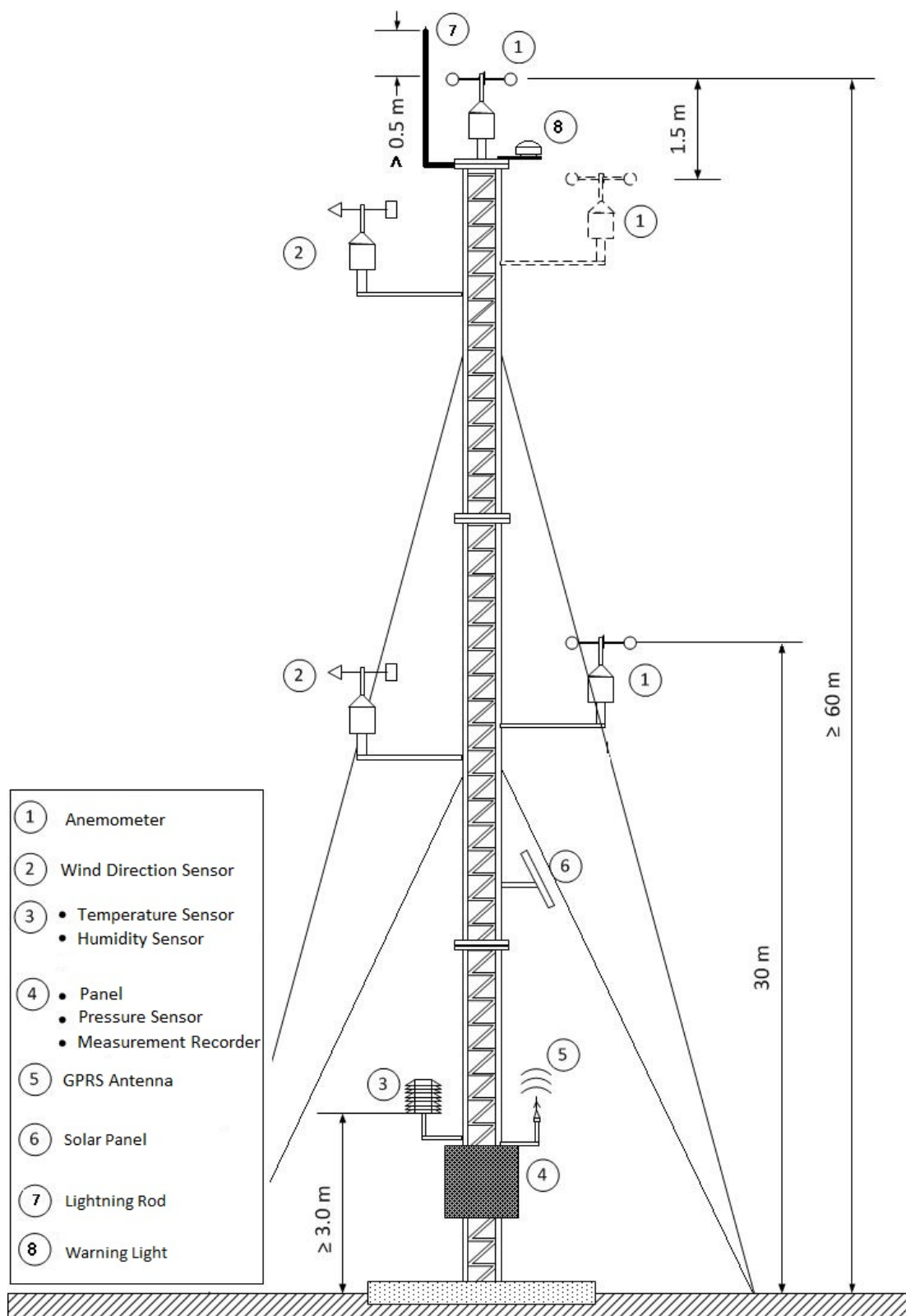


Figure 2.2 : Wind Measurement Station [25]

The most important parameter needed is the wind speed to determine the wind potential in an area. Wind speed is measured with a device called anemometer. Wind speed measurements are generally done by anemometers with ladles. As is shown in figure 2.3 , anemometers with ladles usually consist of three metal ladles. The wind that hits these ladles rotates the shaft on which the ladles are connected. With the change of wind speed, the wind speed is determined depending on the amount of rotation formed in the shaft per unit time. Wind direction does not change the measured wind speed since the ladles in the ladles with anemometers look in different directions [2].



Figure 2.3 : Anemometer[3]

Wind speed can also be measured with deflecting vane anemometers and ultrasonic anemometers other than anemometers with ladles. The wind rotates the shaft by hitting the propellers in deflecting vane anemometers unlike anemometers with ladles. In these anemometers, the wind speed that blows horizontally and vertically can be measured.

As is shown in figure 2.4, ultrasonic anemometers are designed to transmit the sound waves in a vertical and stable direction. Sound waves are detected by the different ends of anemometer and processed in a microprocessor and the wind speed is measured. The advantages of these anemometers compared to other anemometers are they do not have moving parts and they have quicker reaction to sudden wind changes.



Figure 2.4 : Ultrasonic Anemometer[4]

It is necessary to detect the wind direction as well as wind speed to determine the wind potential in an area. Dominant wind direction and the amount of blowing must be determined by means of windsocks that are available in wind measurement stations. Windsocks should be located 1.5 to 2.0 meter below the anemometer for the anemometer not to be effected [2]. An example of windsock is shown in figure 2.5.



Figure 2.5 : Dominant Wind Direction[5]

2.3 Determination of Wind Potential

For electricity generation from wind energy, it is needed to determine the wind potential of the area on which the installation will be made before wind energy facilities are set up. After wind potential is determined, suitable wind turbines that will be installed in that area can be chosen. Determination of velocity distribution of the area is required to determine the wind potential. The most commonly used methods are Weibull and Rayleigh distribution methods to determine wind speed distributions in an area.

Weibull distribution method is the most common method that is used to determine wind speed distribution of an area and is a two-parameter method which gives similar results with the measured values. Weibull distribution function is shown by the equation below:

$$f_w(v) = \frac{k}{c} \cdot \left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^k\right]$$

Here it is described as v : the wind speed

k : Non-dimensional Weibull shape parameter

c : Weibull scale parameter .

Another method that is used to determine the velocity distribution of wind is Rayleigh velocity distribution method. This method is the special condition of Weibull distribution function and the value of non-dimensional Weibull shape parameter is accepted as Rayleigh distribution function is expressed with the equation below :

$$f_r(v) = \frac{\pi}{2} \cdot \frac{v}{v^2} \exp\left[-\left(\frac{\pi}{4}\right) \cdot \left(\frac{v}{\bar{v}}\right)^2\right]$$

Here it is described as \bar{v} : the average wind speed

3. WIND TURBINES

Wind turbines are the systems that convert kinetic energy to electric energy. In the very old ages, wind turbines emerged as windmills used to generate mechanical power. It is supposed that first known windmill has been used in the north of France. A system has been founded by Prof. James Blyth in Scotland in 1887 to produce electricity from windmills. The first wind turbine producing electricity has been founded by Charles F. Brush in 1888 in United States of America. Wind turbine systems whose foundations have been laid during these dates have continued their development rapidly under the leadership of countries such as Germany, Denmark and the United States of America up to the present .

Modern wind turbines generally consist of main parts like basis, tower, nacelle, hub, blades, gearbox and generator. General structure of a wind turbine is shown in figure 3.1.

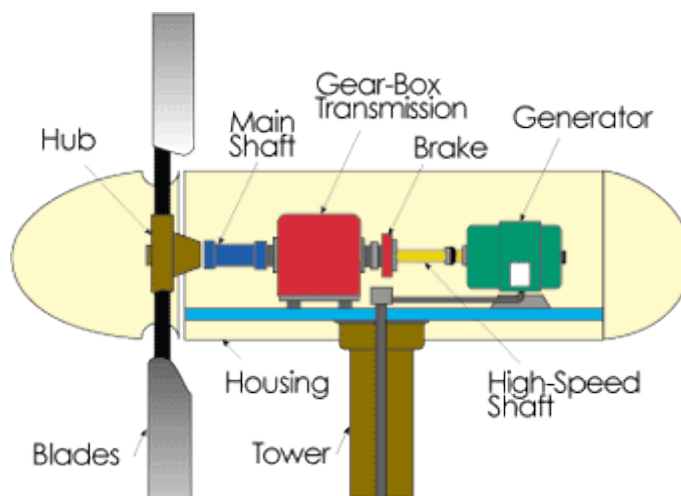


Figure 3.1 : Main Components of Wind Turbine [26]

Wind turbines are classified as single-bladed, double bladed and three-bladed according to the number of blades, front wind field and rear wind field according to wind making conditions and vertical axis, horizontal axis and inclined axis according to the axis.

3.1 Classification of Wind Turbines

Nowadays format of the wind turbines classification is the position of the rotor axis related to earth is most commonly used as classification of wind turbines.

These are divided into three groups :

- Vertical Axis Wind Turbines
- Horizontal Axis Wind Turbines
- Inclined Axis Wind Turbines

3.1.1 Vertical Axis Wind Turbines

The blades of vertical axis wind turbines are connected to a vertical shaft as it is shown figure 3.2. These kind of turbines are also named as Darrieus turbines since they have been developed and patented by G.J.M. Darrieus for the first time. As vertical wind turbine blades turn around a vertical shaft, they can get the wind from any direction and so they do not need to return to wind direction. Also, the installation and maintenance of these kinds of turbines is easier and cheaper when compared to that of horizontal axis turbines because most mechanic and electronic compounds of them are in the ground. Vertical axis turbine blades are exposed to low wind speed because its blades are close to the ground. Therefore, its efficiency is less than horizontal wind turbines. Increasing the blade height is very costly so they are not preferred in electricity generation [6] .



Figure 3.2 : Vertical Axis Wind Turbines [27]

3.1.2 Horizontal Axis Wind Turbines

The blades of horizontal axis wind turbines are connected to a horizontal shaft and are designed as vertically to wind direction. Electromechanical parts are above the tower in these kinds of turbines. Since the blades of horizontal axis wind turbines need to return to wind direction, there is a rotating mechanism in these turbines. A horizontal axis wind turbine is shown in figure 3.3.



Figure 3.3 : Horizontal Axis Wind Turbines [28]

3.1.3 Inclined Axis Wind Turbines

There is a specific angle between the rotation axis and blades of inclined axis wind turbines. Usage areas of these turbines are limited.

3.2 The Studies Relating to Wind Energy In Turkey and In The World

Genç and Gökçek examined the wind characteristics and wind energy potential of Kayseri and some districts of Kayseri. They used the wind speed measured at 10 m height in their studies between 2000 and 2006 and compiled wind speed data with Fortran computer program. As a result of the analysis, it was determined that

Pınarbaşı had the most suitable wind potential among the areas chosen. The average annual speed was calculated as 3.66 m/s, the average annual wind density for the measured values is 111.93 and 83.44 W/ m² for Weibull values [7].

Gökçek and Genç determined the wind characteristics of Pınarbaşı, Nevşehir, Tomarza, Kırıkkale, Kırşehir and Develi in Central Anatolia and determined the annual amount and cost of energy produced for wind turbines that were in different powers using the values they specified. In this work, the annual energy production of wind turbine with capacity of 150 kW/h at 30 m height for Pınarbaşı was calculated as 120.978 MWh and its cost as 30 \$/kWh [8].

Özerdem and Türkeli compiled the wind values measured 16 months for İzmir Institute of Technology campus area using the WAsP and WindPRO packaged softwares. As a result of the study, they calculated the average wind speed of the area as 8.14 m/s and the amount of annual energy production of wind turbine with capacity of 1500 kWh as 5,297 MWh. Additionally, the analysis of wind potential of İzmir Institute of Technology campus area and the economic analysis of wind potential were made by Özerdem et al [9].

The wind speed values measured between the years 2000 and 2003 were compiled with WindPro package software and the economic analysis was made with RETScreen package software. As a result of the study, it was observed that the cost per person decreased as the installed power capacity increased.

Şahin et al. determined the wind potential by compiling the measured wind speed values of Antakya, İskenderun, Karataş, Yumurtalık, Dörtyol and Samandağ regions between 1992 and 2001 in WASP package software. In most of the regions chosen, they calculated the wind potential as 500 W/m² for 25 m height and determined the wind energy potential of Antakya, İskenderun and Samandağ as the most appropriate ones [10].

Uçar and Balo analyzed the wind characteristics and wind energy potentials of Uludağ region using Weibull and Rayleigh distribution functions. For this region, the average wind speed was calculated as 7.08 m/s in the years discussed, the annual

energy production, capacity factors and the cost of produced energy for wind turbines with capacity of 1000, 1500 and 2000 kW were calculated. As a result of the study, it was observed that the cost of energy produced from the wind turbines discussed was changing between 0.255 and 0.306 \$/kWh.

Çelik between 1996-2000 examined the cost of produced energy and the wind energy potential of İskenderun region for the wind turbines whose capacity was changing between 0.6 and 500 kW and whose height was 50 m by using the measured wind speed data. As a result of the study, the lowest energy cost was calculated as 0.15 \$/kWh in the wind turbine with capacity of 500 kW [11].

İlkiliç and Türkbay examined the condition of electricity production facilities through the wind energy and the wind potential of Turkey. In their studies, they used the wind data measured in different regions in 2004. They calculated the average annual wind speed of geographic regions as 2.58 m/s and the annual wind density as 25.82 W/m². They have indicated that the most suitable wind potential is available on the coast of Aegean and Marmara Sea and in the Eastern Anatolia region situated on the north and northwest of Turkey. Also, they have suggested that Turkey can meet the need of energy using the wind energy potential it possesses [12].

İlkiliç determined the wind potential of Turkey using the data measured in various regions of Turkey in 2010 and examined the condition of production facilities based on wind energy. As a result of the study, it was seen that the wind potential of Turkey was 433.35 MW in 2008, this value would be 1503.35 MW at the end of 2008 and the wind potential of Turkey had a great importance in meeting the need of energy [13].

Karsli and Geçit determined the wind potential of Nurdağı region in Gaziantep and situated on the south of Turkey. In their studies, they used the wind speed data measured at 10 m height in the mountain foot of Nurdağı between the months January and December in 1995 and determined the wind speed distribution of the region using Weibull function [14].

They indicated that the average annual speed of the region at 10 m height was 7.27 m/s, the highest monthly average speed was 13.75 m/s in August, the lowest monthly

average wind speed was 2.99 m/s in January. Also, it was calculated that the average wind power density of the region was 222 W/m².

Akpınar et al. examined the wind energy potential of Maden region in Elazığ by compiling the wind speed data measured between 1998 and 2002 in STATISTICA and FORTRAN software and using Weibull function. As a conclusion of the calculations, they found out the average annual wind speed of the region was generally changing between 5 and 6 m/s and the highest wind speed value as 21.3 m/s and they determined the average wind power density of the region as 244.656 W/m² [15].

Shata and Hanitsch analyzed the wind energy potential of the coastal region of the Mediterranean Sea in Egypt by WASP package software using the wind data obtained from the measurements made in 10 different areas. As a result of the study, it was found that the average annual wind speed measured at 3 measurement stations was more than 5 m/s, the annual energy production of wind turbine with capacity of 1 MW in El Dabaa region which had the most reasonable wind speed average as 2718 MWh and the cost of produced energy was calculated as 2 cent/kWh [16].

Bekele and Palm analyzed the wind potential of Addis Ababa, Mekele, Nazret and Debreziti regions in Ethiopia using HOMER package software and calculated the average speed in Debreziti region as less than 3 m/s and around 4 m/s in other 3 areas [17].

Bagiorgas et al. determined the wind energy potential of Western region of Greece. According to their study, it was seen that the unit cost of produced energy decreased as the capacity of wind turbine increased [18].

Rehman et al. analyzed the wind speed data measured at long intervals for Rafha region and calculated the amount of energy that could be produced from wind turbines with capacity of 600, 1000 and 1500 kW using HOMER and RetScreen package software. As a result of their work, the average speed at 60 m height was found as 4.7 m/s and the amount of energy produced annually from the wind turbines with capacity of 600, 1000 and 1500 kW was calculated as 805, 1332 and 1905 MWh respectively [19].

Fawzi and Jowder analyzed the wind data measured between 2003 and 2005 for the Kingdom of Bahrain at 10, 30 and 60 m heights and calculated the maximum power density as 164 W/m^2 , 624 W/m^2 and 1171 W/m^2 respectively, minimum power density as 65 W/m^2 , 244 W/m^2 and 244 W/m^2 . Also, they calculated the average annual power density as 114 W/m^2 for 10 m, 433 W/m^2 for 30 m and 816 W/m^2 for 60 m[20].

3.3 Wind Turbine Components

The below terms are generally used to all wind turbines;

- Midpoint height : Refers to the height from the ground
- Sweeping area : It refers to the scanning area of the disk rotor when it is rotating.
- Edge speed ratio : It is the edge speed of the ratio to wind speed ratio.
- Power rating : It is an electrical output power which is obtained continuously when it is used.

Parts of the wind turbines which is used in the production of electricity are rotor blades, brake system, yaw (rotation system) transmission system , generator and tower. They are seen in figure 3.5 and figure 3.6 . Big parts are placed in outer storing or which we can say in to the fairing. In the subject of fairing, there is a rotation system (yaw) in combination with the tower.

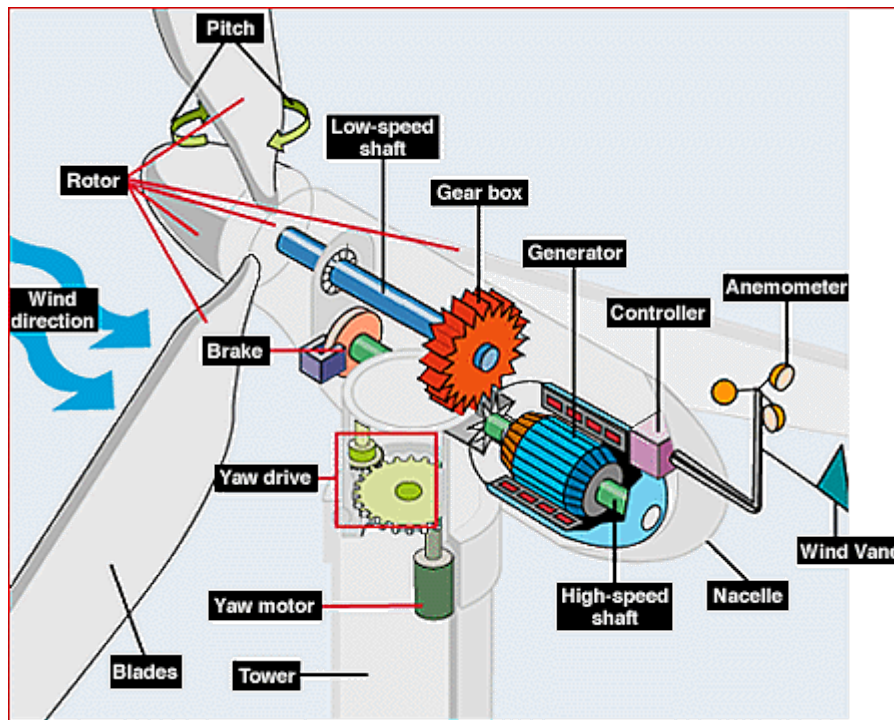


Figure 3.4 : The internal structure of motor [29]

3.3.1 Tower

The tower material is usually steel or concrete. Modern wind turbine has ring width cross sectional towers.

The benefit of wind speed in the height with the depending on the increasing height which is showed in the tower costing is identified with the optimum solution. In tower sizing the other parameters, natural bending frequency, materials of tower and thus this affects the cost significantly. In wind turbines all of the manufacturing expenses which is % 11-20 belongs to the manufacturing of the tower.

3.3.2 Turbine Rotor

The wind turbine rotors are strengthen with aluminum, titan, steel and fiber. It is manufactured by plastic (glass fiber, carbon fiber and aramid fiber) and trees. Most of the modern wind turbines blades are produced by glass fiber with strengthen polyester or like epoxy. Produced by steel blades are very good in bending strength, but they create fatigue resistance and corrosion problems. Aluminum blades are lighter than steel ones, fatigue strength is better and it is more resistant to corrosion. The spraining of the shell-shaped material, the difficulty of the manufacturing technique and being expensive are the weak points of the aluminum materials.

3.3.3 Gear Box

The rotor angular velocity ω is usually not enough for the generator to produce the electrical frequency required. Gearing systems can provide an increase or decrease in mechanical rotational speed. In wind turbines, the angular velocity of gears with low rotational shaft speed are used for the conversion to high rotational shaft speed connected to the generator. For many applications gear sets show severe reactions to the spacing between the two gears the drive gear rotates through an angle before making contact with the opposing gear. The results; until the angular rotation of the input gear occurs, the angular rotational for the output gear cannot occur. In this study, there will be a challenge in the gear box model which does not change the gears to operate in a more ideal manner neither produce severe reactions. The input parameters for the gear box is the low-speed shaft and torque that connects the rotor to the gear box. The output parameters are the angular velocity of the high speed shaft and torque that connects the gear box to the generator.



Figure 3.5 : Gear Box [30]

3.3.4 Generator

Generators used in wind energy facilities may be alternating current or direct current generators. Even if the electric current obtained here is poor quality alternating current or direct current, through the utilization of various power electronics assembly's it can be changed to make it suitable for the network.

Direct current generators are not preferred in producing energy at large powerful wind turbine facilities. This is because direct current generators require frequent maintenance and cost more than alternative current generators. Direct current

generators in today's world are currently only used in small wind energy facilities to store energy in batteries. In order to prevent losses and noise in gears, gears without a box are also used in multi-pole generators. For this reason there is no need for a gear box in a generator with a high number of poles.

In Germiyan, The German firm Enercon using the auto producer system manufactured the Enercon E-40 gear box less wind turbine, which has 84 poles and has the ability to reach 500 kW nominal power with a propeller shaft rotating speed of 38 times a minute.

In alternative current generators connected to a network, electric energy production is limited to the number of cycles of network frequency. For example a wind turbine with the speed of 8 m/s is benefiting at optimum speed. For this reason, in some wind turbines there are two separate generators used for high and low wind speeds.

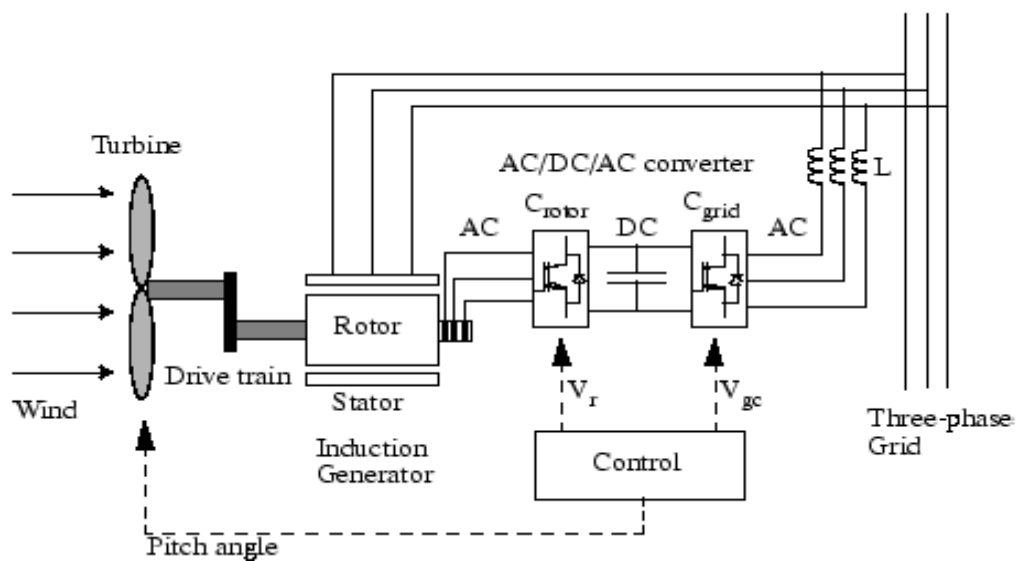


Figure 3.6 : Generator Scheme [31]

3.3.5 Voltage Regulator

Voltage regulator is a smart transformer. That device arranges the output voltage level due to changes on the voltage network. If the value of the input voltage increases or decreases suddenly to the values that may be dangerous, it may give permanent damage to the sensitive electronic devices that we use. The voltage regulator can fix it, by stabilizing the voltage values. In the past, the people think that voltage regulators are the devices which are only decrease and increase the value of the voltage. Therefore, voltage regulators wasn't efficient for these times. After that, one another type of voltage regulators have just came up. Then, servo regulators are used to fix that kind of problems. Nowadays, the new generation that we call as "static regulator" removes that problems permanently by without loss. The voltage regulator shown in figure 3.7.

The voltage of electric network should be standardised 380/220 Volt in Turkey ,but for several reasons that the voltage doesn't transmitted to the everywhere equally.(lower or upper). The voltage regulator is the device that fixes the transmitted wrong voltage values.

Voltage regulator is a smart transformer. That device arranges the output voltage level due to changes on the voltage network. Next, we can't store any energy in voltage regulators. While working it pretends like transformer, that gives us to work on it as much as possible. Also, voltage regulators have a voltage field to fix. We may determine its voltage field while its creation. If we exceed the limits, we can't take any output values from the voltage regulator.

We can't use the voltage regulators in any fields because of cost. When the value of the input voltage field becomes larger, it may cost more than we thought. It also needs a good knowledge about calculation of strength of coils.

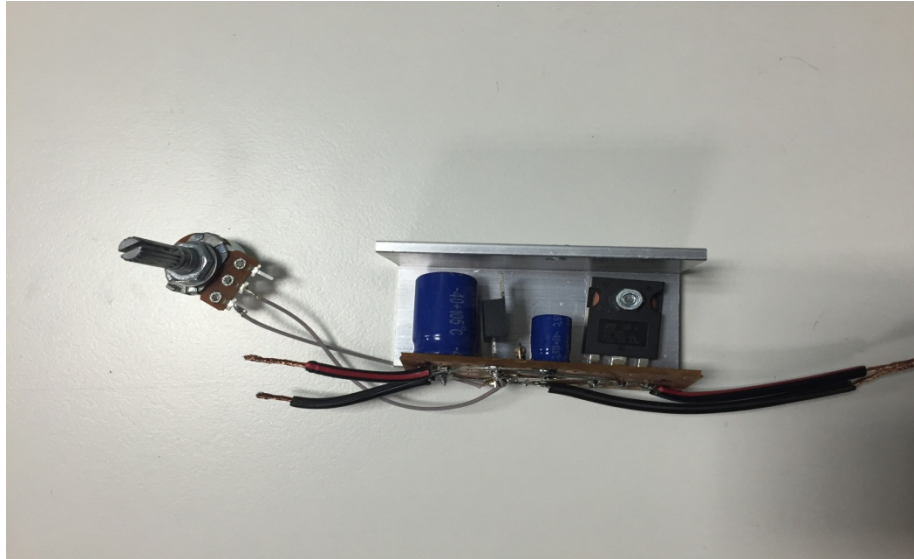


Figure 3.7 : Voltage Regulator

3.3.6 Pulse width Modulation (PWM)

Pwm performs the modulation process and the main aim of this technique is to control the electric power which supplied to the device. This technique can be used in signal processing and signal transmission, besides electronic circuits, as well as more specific applications such as Arduino or electric machines. Its simplest form can be defined as a signal modulation technique. It provide power control and have purpose to shores electric machines and solar battery chargers' circuits. This control is achieved by switching completely. If switching can quickly done, the power of the signal transmitted by the PWM increases. PWM is show in Figure 3.8.



Figure 3.8 : Pulse with Modulation (PWM)

3.3.6.1 Advantages of The PWM Technique

First, it has low-level switching loss. No current flow when the switch is off and as little as negligible voltage drop on the key when the switch is turned on. In this way, besides the lack of power loss, there is a complete accord between PWM and the digital control units. The system can provide so much more comfortable accord about changes the on-off switching. In additions, Pwm is frequently used communication and regulations relating to the duty cycle of the signal used in the communication technology. Thus, the desired signals can be obtained on channels with various applications.

3.3.6.2 PWM Application Areas

1) Communication Systems

2) Power Transmission and Electrical Machines

4. COMPOSITE BLADE STRUCTURE AND MATERIALS

With the rapid development of technology, companies in the industry have increased manufacturing standards and an important feature such as the blades design, materials and production methods have gained importance. Nowadays there is much development and changes in engineering and technology regarding wind turbine blades as there is acceptance with the significant impact it has on turbine efficiency.

The greatest expectations of wind turbine blades are the features such as protecting the durability in a long-term, making additional contributions to the energy efficiency of the turbine aerodynamically and not losing the integrity and surface quality against all external factors. As a result of all studies and trials in order to provide these features, it has been seen that composite technology is the most convenient method of producing the wind turbine blades and that the occurrence of day-to-day development experience of the composite materials used has also supported it.

A wide variety of materials are used in the construction of wind turbines. To obtain a high efficiency from the wind turbine is possible only by choosing the appropriate materials for each unit. Therefore, material development and behavior in all circumstances are examined. Usually five methods are preferred for the material selection in all cases. These methods are called as economic and performance characteristics, the feature measurement values, values analysis, damage analysis and economic benefit analysis.



Figure 4.1 : Composite Blade We Used

4.1 Composite Materials

Composite materials are not new-found materials; but considering the structures existing in nature, they are obtained by merging materials with different properties in different ways (granular, fibrous, stratified, etc.).By definition, it can be said as a combination of two or more materials at the macroscopic level. The objective is providing the properties of materials that don't have prior to construction by combining these materials. For these features, resistance, aging resistance, wear resistance, fracture toughness, thermal properties, conductivity, weight and corrosion resistance etc. can be sorted.

Technologically speaking, after the 1940s, these materials are started to be used in the aviation industry. The goal here is to develop materials with low weight, but more strength, high hardness, wear resistance and fracture toughness instead of traditional materials such as steel and aluminum alloys.

On the other hand, just as in the aviation sector, in the selection of materials for wind turbine rotor blade structure; an important criterion which expresses the ratio of the intensity to the mechanical properties can be said to be a significant advantage in terms of specific values of mechanical properties of the composite material compared to conventional materials. Here in this case, in turbine construction the use of the composite has led to the foreground particularly in the rotor blade design. Glass-reinforced plastics are kind of most preferred composite materials for the wind turbine rotor blades. These composite materials have been preferred because they are easy and economical compared to fibre - reinforced plastics in providing lightness in turbine blades, high resistance and corrosion resistance and production. Carbon fiber-reinforced plastics also have limited use in the rotor blades. Although these composite materials provide strength and lightness higher compared to glass reinforced plastics, their high cost is a disadvantage.

4.2 The Advantages of Composite Materials

Strength and durability; the most important advantage of fiber composites is their high strength and durability compared to conventional engineering materials. These features provide energy savings and performance improvements which are very

important in the design of engineering structures.

Optimal Design; composite materials produced can be designed to meet the specific demands of each application. Possible design options comprise the selecting of the material (fiber and matrix), the processing method and the sheet type (unidirectional or woven) and changing the thickness and number of layers of layer positions in the given direction. This wide range of design changes for composites is an opposite situation compared to traditional engineering materials. This wide diversity in the design of these materials provides obtaining the efficient structures produced by discarding less material. In addition, this great opportunity in diversity enables the use of computers, optimization, expert systems and artificial intelligence in the production of composite structures and the development of design.

Fatigue Time; fatigue time of composite materials is one of the main reasons for use in the aerospace industry. Fatigue time is also important for many other structures (transport vehicles, bridges, industrial components and various structures exposed to wind and water loads).

Dimensional Stability; almost all structures are exposed to temperature changes during the period of use. Tensile (Stress) related to temperature change can result in increasing the friction and thermal stress and the change in size or shape. In some applications, these thermal effects can be critical. The increase of the friction between moving parts (e.g. in the engine) can cause errors due to overheating. Small shape changes in the satellites can lead not to function. Thermal expansion also in highways and roof systems can cause errors. Therefore, there are many applications that require the use of materials with zero or near-zero thermal expansion coefficients. Through appropriate design; in order to obtain composite materials with zero thermal expansion coefficients or minimize the thermal voltage and inconvenience, it is possible to design the coefficient of thermal expansion of the composite to match the thermal expansion coefficients of the other components.

Corrosion Resistance; the polymer and ceramic matrix materials can be selected to improve the corrosion resistance of composite materials against moisture and other

chemicals. Composites produced using this matrix materials do not require maintenance compared to traditional engineering materials.

Efficient Production; composite structures through the use of automated methods such as filament winding , spraying and film layers can be produced efficiently. Efficiency in the production of composite materials results in very little waste generation. Waste produced in the form of a large amount of sawdust is an advantage when it is compared to the metal materials produced in the process of composite material. Production costs are also directly related to the number of parts in composite materials structure and due to ability of composite materials to produce the final shape at a time and to provide more effective fusion of the rivet connection can reduce the number of parts significantly. For example; two sections of the fuselage is made by clinching the aluminum component and the adhesive bonding of composite components. Aluminum construction is made up of approximately 11,000 parts, unlike composite structure consists of approximately 1000 parts. This reduction in the number of parts offers significant savings in composition and assembly costs.

Insulation; many engineering structures are desired to have electrical insulation. For example; the reduce the electrical conductivity , glass / polyester ladders and light poles are preferred to aluminum and stainless steel. Insulating components are important for applications in the electronics industry. In contrast to this, copper matrix composites are underway for use in high temperature applications due to the high thermal conductivity of copper.

Overall of cost of production; cost assessment of structures made of composite material should include the total life cycle cost of the product. Composites are generally more expensive than conventional materials. However, all other factors should be taken into account when comparing costs. First, the composite material has higher strength and durability. Second, automation in the production of composite materials reduces the cost of production. Third, for composite structures, transportation and installation costs are usually lower. Finally, the composite

structures lifespan are longer than the lifespan of traditional materials and require less maintenance during their lifespan.

4.3 Composite Blade Structure

When we look at the cross sections of the blade of wind turbine we can see that they consist of many different parts. The main reason for this is to keep the total blade weight to minimum, each part is designed with just enough strength to withstand the force (direction, angle and vector magnitude) it will be exposed to.

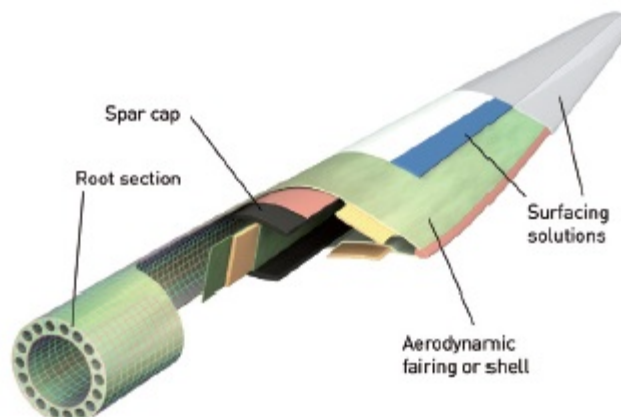


Figure 4.2 : Composite Blade Structure [32]

Monolithic Laminate:

1-Root Infusion

2-Shell Resin : epoxy, polyester or vinyl ester

3-Cutting Network Reinforcement : glass, carbon or aramid fiber

Sandwich Laminate:

4- Main Beam Reinforced: Uniaxial Glass or Carbon Fiber

5- Combinations Structural adhesives

navigation especially in the production of vessels and yachts, in automotive ,in defense systems, in aviation especially in warplanes and in the production of composite products of some other sectors, in the applications in which performance factor is more important than cost factor. Before combining with reinforcing materials to form a composite element, epoxy resins must be mixed with an appropriate structured hardener in rates specified by producers. These are also obtained by dosing machines in mass production plants in general.

4.4.2 Glass and Carbon Fabrics

As a supplement, generally, sophisticatedly, fabrics that are produced by the weaving of threads formed by Glass or Carbon fiber are benefited from.

Among the eye-catching distinctions between glass fabrics and carbon fabrics, the lightness of carbon fibers and high strength, glass fabrics' being found cheaper and common, carbon's electrical conductivity being high, glass fabrics' having an easier traceability in infusion and hand lay-up applications could be considered.

In usage, using weaved fabrics made from glass or carbon threads has brought advantages in sense of handling. In addition, along with the technological progress a transition has been made from threads' being weaved in one line to being weaved in multi axis. This especially has expanded the movement area of sail designers and according to the account of load distributions, the usage of different fabrics has emerged. In general the glass fabrics used in the production of sails are produced by E class glass. During the weaving of sophisticated fabrics, generally maximum four directions are used.

In the diagram below, some weaved fabrics' schematic samples are given:

According to the distribution of the loads in the sail design, what kind of weaved fabrics and in which parts to use them are stated. Up to four directions, the weaving of threads can be possible.

For each direction weaving can be made in a way that the weights of threads for unit area will be different.

4.4.3 Core Materials

Core materials are the backfilling materials used in composite products that are in sandwich structure. Especially their increasing the bending strength has led the usage areas of composite products to increase. Due to the usage of core material, with an approximately %3 weight increase, it is possible to increase the flexural strength 3,5 times whereas the rigidity can be increased 7 times.

In the production of composite materials, the following products are used as an internal material.

Foams: It has content materials such as Polyvinyl chloride [PVC], polyethylene terephthalate [PET], Polyurethane [PU], Polystyrene [PS], Polyetherimide [PEI], Styreneacrylonitrile [SAN]. Etc.

Tree Materials: It is usually Balsa tree, rarely chipboard and tree materials such as plywood.

Looking like Honeycomb Materials: The materials produced from raw materials are craft paper, aluminum, steel, aramid, carbon, polyurethane, polyester, polyethylene, polypropylene and ceramic.

In the Wind Turbine Blades, the internal materials PVC, PET foams and Balsa trees are widely used as plates in varieties thicknesses.

5. ELECTRICITY PRODUCTION THROUGH WIND ENERGY

5.1 The State of Electricity Production Facilities Based on Wind Energy in The World

It is estimated that the global demand for energy will increase one third compared to today's demand. In the near future, it is expected that although the amount of energy obtained from conventional energy sources and nuclear energy increases, its share in total energy produced will decrease. Environmental problems, increasing incentives and the increase in fossil fuel prices show that the interest to renewable energy sources will go up rapidly in the future as well and it is expected that the rate of meeting the total electricity produced in the world from renewable sources will rise to %31 [21].

Electricity production facilities based on wind energy has showed a greater improvement in the recent years compared to other electricity production facilities based on other renewable energy sources. The installed power capacity of electricity production facilities through wind energy between the years 1996 and 2014 is shown in Table 5.1. Today, the rate of meeting the energy produced in the world from the electricity facilities based on wind energy is %2.5 and it is supposed that this rate will be around at %8-12 in 2020 [22].

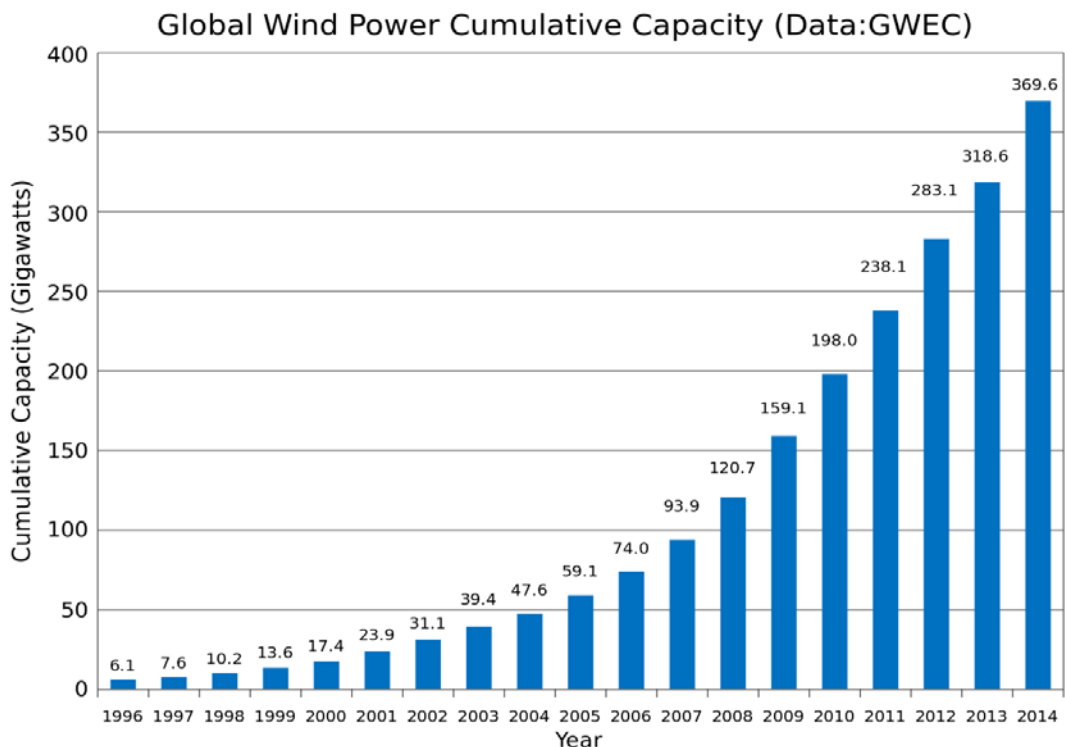


Table 5.1 : Wind Power Capacity of Global [34]

5.2 The State of Electricity Production Facilities Based on Wind Energy in Turkey

Turkish economy has grown at a rate of %5.2 in the last ten years and its population at a rate of %2.1. Concordantly, the demand for energy has increased continuously. Turkey which is not a self-sufficient country in terms of energy needs met nearly %72 of its energy need by importing fossil energy and paid 54 billion dollars to the country imported. Owing to increasing oil and natural gas prices, the payments made for importing energy reached %25 in the total payments made for importation and this caused current deficit to go up considerably. Under these circumstances, Turkey had to reconsider its energy policies [23].

On 18th May,2009-According to Electric Energy Market and Security of Supply Strategy Paper published by Under secretariat of State Planning Organization, increasing the proportion of utilizing domestic resources in meeting Turkey's energy need was presented as the first priority. Accordingly, it was targeted to use all brown coal, mineral coal and hydraulic energy sources in our country until 2023, to meet %30 percent of the produced electricity from the renewable sources and the installed power based on wind energy to reach 20,000 MW. To meet the increasing energy demands, it is being planned that 2 nuclear power stations will come into operation until 2023 and the construction of the third will be launched. Also, the laws that encourage electricity production from renewable sources have been made. %43.1 of the produced electricity in 2013 in Turkey was obtained from natural gas, %15.4 from local coal, %24.2 from hydraulic energy, %12.1 from imported coal, %2 from liquid fuel, %2.4 from wind energy and %0.6 from geothermal and biogas . The usage of wind energy for producing electricity in our country is developing more rapidly compared to other energy sources. As it is show in Table 5.2, the wind energy facility whose capacity was 18.9 MW in 2002 reached 2760 MW after the 2013 incentives and policies were put into practice.

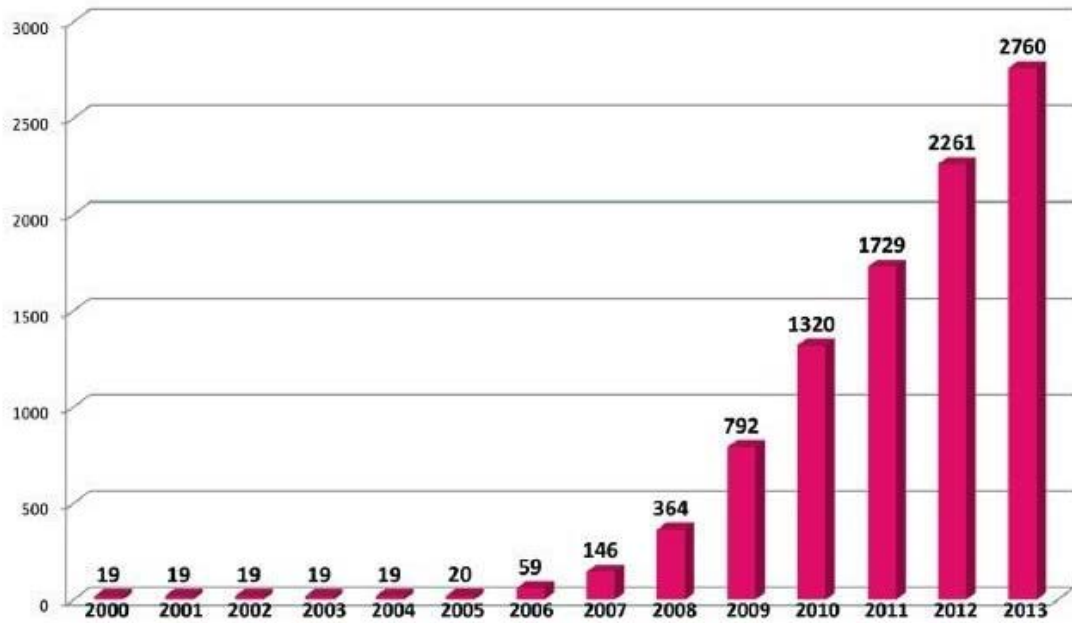


Table 5.2 : Wind Power Capacity of Turkey [36]

5.3 Calculation of Wind Power

The power that can be provided from wind energy depends on wind speed and is expressed with the equation below :

$$P_{total} = \dot{m} \cdot \frac{V_r^2}{2}$$

Here it is described as \dot{m} : Mass flow of air is described as (kg/s).

V_r : Wind speed as (m/s).

The mass flow of air in this equation can be expressed in that way:

$$\dot{m} = \rho \cdot A \cdot V_r$$

The density of air in this equation (kg/m^3) is described as wind area that makes an impact on the blades of A turbine. We get an equation in which the power that can be obtained from wind is directly proportionate to third power of wind speed.

$$P_{total} = \rho \cdot A \cdot \frac{V_r^3}{2}$$

The power calculated by means of this equation is the power which has no losses.

$$P_{total} = \rho \cdot A \cdot \frac{V_r^3}{2} \cdot C_p$$

The maximum power that can be obtained from wind turbine is the condition in which it gets the value of 0.593. This value is called Lanchester - Betz limit and it shows that the theoretical efficiency of wind turbine will not exceed %59.3.

5.4 Capacity Factor

Capacity factor (C_f) is a parameter that shows how efficient a wind turbine works. It is expressed as the proportion of real power that the wind turbine can produce during a specific period in the area wind turbine is established to the power when the wind turbine operates in full capacity. Capacity factor is described as the formula below:

$$C_f = \frac{E_p}{P_n \cdot 8760}$$

Here it is described as ;

E_p : Electric energy that the turbine can produce in a year is expressed as (kWh/year).

P_n : Nominal power of the turbine is expressed as (kW).The value of 8760 in the equation expresses the condition of turbine that works in full capacity (365x24).

5.5 Calculation of Wind Speed Changing with Height

Because the effect of friction will decrease as the height increases, the wind speed goes up as well. As the power that can be obtained from wind energy is directly proportional to the third power of wind speed, the determination of wind speed at the height where wind turbine will be established is very significant in the designing phases of wind turbines. The measurements are generally not made at the height wind turbines will be established in the wind speed measurement stations. For this reason, it is necessary to calculate the wind speed at the height wind turbine will be installed. The wind speed at a specific height can be calculated using logarithmic boundary layer method and using the formula below :

$$v = v_0 \cdot \left(\frac{\ln(z/z_s)}{\ln(z/z_0)} \right)$$

Here it is described as;

V : Wind speed at the required height is expressed as (m/s)

V_0 : Wind speed at the measurement height as (m/s)

Z : Height which the wind speed will be calculated as (m)

Z_0 : Height at which the wind speed is measured as (m)

Z_s : Surface roughness coefficient.

Surface roughness coefficient is chosen according to the landforms of area where wind turbine will be installed. In table 5.3, surface roughness coefficient for different landforms is given.

Landforms	Z_s
Savannah	0.15
Forest	0.5
Maquis shrubland	0.3
Inner city	1.0

Table 5.3 :Surface Roughness Coefficient for Different Landforms

5.6 Energy That Can Be Produced From Wind Turbine for Different Wind Speed

It depends on the designing features of power turbine that can be produced from a wind turbine in a specific area and the wind potential of region. While the wind potential of an area where the wind turbine will be installed can be determined by measurements, the turbine designing features are given by producing companies. Companies producing wind turbine determines the turbine power curves experimentally according to turbine blade design and power losses and presents them to the investors in tables and graphs. In figure 5.1, the power curve of an Enercon E82 model wind turbine with capacity of 3000 kW is shown as an example.

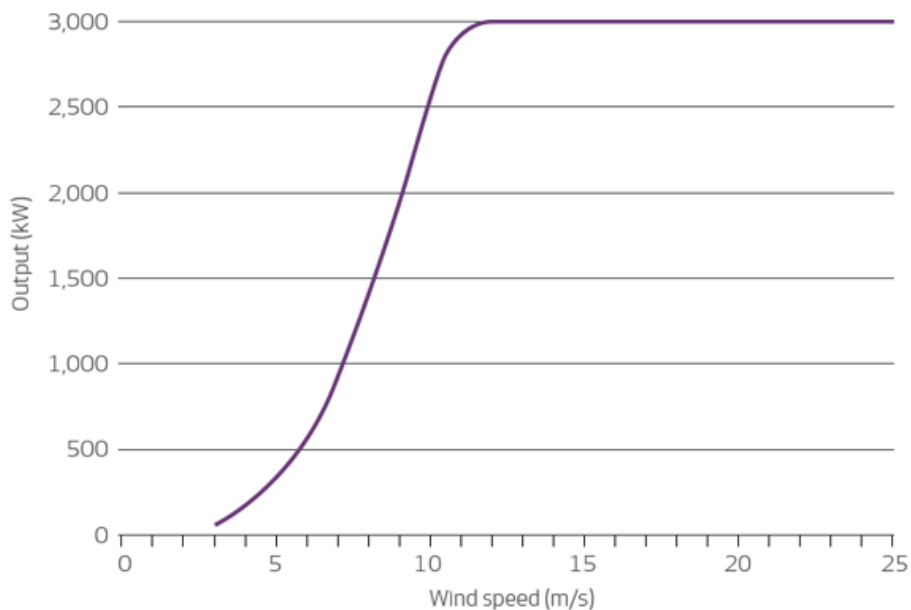


Figure 5.1 :Power Curve of Enercon Wind Turbine [35]

The power curve shown in figure 5.1 as an example indicates that the turbine starts producing energy after 3 m/s, keeps producing energy valued at 3000 kW between 13 m/s and 25 m/s and not producing energy at the speed more than 25 m/s. To calculate the energy that can be produced from wind turbine in different wind speeds, the equation based on wind turbine power curves can be used.

$$P_i(v) = \begin{cases} 0, & v < v_{ci} \\ \left(a_n v^n + a_{n-1} v^{n-1} + \dots + a_1 v + a_0 \right), & v_{ci} \leq v < v_R \\ P_R, & v_R \leq v < v_{co} \\ \left(a_n v^n + a_{n-1} v^{n-1} + \dots + a_1 v + a_0 \right), & v_{ci} \leq v < v_{co} \\ 0, & v \geq v_{co} \end{cases}$$

In this equation;

$P_i(v)$: The power which can be acquired at a specific wind speed is expressed as (kW)

P_R : Nominal power of turbine as (kW).

a_n, a_{n-1}, a_1 ve a_0 : The constant of regression

v_R : The speed which the turbine can produce maximum power as (m/s)

v : The required speed used in calculating the power which the turbine can produce as (m/s)

v_{ci} : The speed which the turbine starts producing power as (m/s)

v_{co} : The speed which the turbine stops producing energy.

The total power which will be produced from the wind turbine can be calculated by gathering the amount of power that can be generated at different wind speeds in a

certain period of time. The total power which will be produced for one-hour period of time is calculated with the formula below:

$$E_{wt} = \sum_{i=1}^n t$$

Here;

E_{wt} : Total power which will be produced from wind turbine is described as (kWh)

n : The number of hours within the discussed time period

t : One-hour period of time.

is described.

CONCLUSION

As a result of this project, we are now well-informed about what is a wind turbine, how to make a wind turbine, what is the structure of wind turbine etc.

We sincerely believe that our work on this project will help us in our future jobs that we are going to have after we graduate.

We will put our work in this project proudly to our resumes because we believe that this project improved our engineering skills. And we hope that whoever read this thesis or try our process to make one, will benefit from our experiences as we aimed when we started to this project.

Finally we want to show some pictures about our turbine and blades as we mentioned and wrote about them.



Figure 5.2 : Our Wind Turbine

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High School: Hava Orgeneral H.İbrahim Fırtına Lisesi , 2005–2009

WORK EXPERIENCES AND INTERNSHIPS:

Intern, Turkish Aerospace Industries,Inc. (TAI),Flight&Flight Tests August 2014 - September 2014

Intern, Ziya Elektrik San. Tic. Ltd. Şti.,Electrical Engineering , March 2014 - June 2014

Intern, Ortaç Mühendislik Elektrik İnşaat Taahüt San. Tic. Ltd. Şti.,Electrical Engineering, September 2013 - October 2013

LANGUAGE SKILLS

English: Proficient in Reading, Writing, Speaking

English Preparatory School - İstanbul Aydin University (2011-2012)

CURRICULUM VITAEII

PERSONAL INFORMATION

Name Surname: Edipcan EYÜBOĞLU

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Istanbul Aydin University, Engineering Faculty, Electrical and Electronic Engineering, 2010 - ..., GPA:2.92 (Current GPA)

Politecnica de Valencia, Engineering Faculty, Electrical and Electronic Engineering ,2012-2013

High School: Fetih Koleji, 2006–2010

WORK EXPERIENCES AND INTERNSHIPS:

Intern, Devisso Mühendislik June 2014 - July 2014

Intern, Kabmak Mühendislik, August 2014 –September 2014

Intern,. Ziya Elektrik San. Tic. Ltd. Şti.,Electrical Engineering , March 2014 - June 2014

Intern, Karınca Logistic,Information Technology(IT) , June 2012 – August 2012

LANGUAGE SKILLS

English: Proficient in Reading, Writing, Speaking

English Preparatory School - Istanbul Aydin University (2011-2012)

CURRICULUM VITAEIII

PERSONAL INFORMATION

Name Surname: Ahmet Utku GÖKÇE

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Place of Birth: Yüreğir /Adana

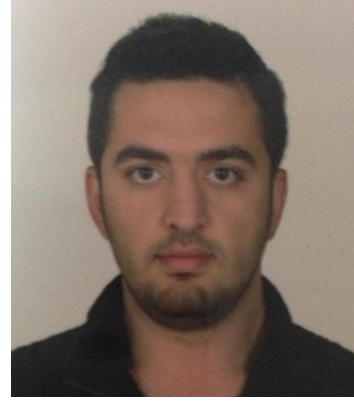
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Politecnica de Valencia, Engineering Faculty, Electrical and Electronic Engineering ,2012-2013

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WORK EXPERIENCES AND INTERNSHIPS:

Intern, Vodafone Türkiye June 2014 - October 2014

Intern, Metaş Elektrik San.ve Tic. Ltd. Şti., August 2014 –September 2014

Intern, Ziya Elektrik San. Tic. Ltd. Şti.,Electrical Engineering , March 2014 - June 2014

LANGUAGE SKILLS

English: Proficient in Reading, Writing, Speaking

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CURRICULUM VITAEIV

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WORK EXPERIENCES AND INTERNSHIPS:

Intern, Silverline Information Technologies, June 2011 - August 2011

Intern, Doğa Bulut Information Technologies, August 2013 –September 2013

Intern, Ziya Elektrik San. Tic. Ltd. Şti., Electrical Engineering, March 2014 - June 2014

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