INVESTMENTS IN RENEWABLE ENERGY SOURCES IN LIBYA

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INVESTMENTS IN RENEWABLE ENERGY SOURCES IN LIBYA

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I certify that in my opinion the thesis submitted by Hamza RAJAB titled "INVESTMENTS IN RENEWABLE ENERGY SOURCES IN LIBYA" is fully adequate in scope and in quality as a thesis for the degree of Master of Science.

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ABSTRACT

M. Sc. Thesis

INVESTMENTS IN RENEWABLE ENERGY SOURCES IN LIBYA

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The Department of Mechanical Engineering

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It was the wind that ushered in the age of research and allowed goods and goods to be transported over long distances. Long after, the first sails followed, to use wind energy to do mechanical work in mills and power water pumps. Wind has been used for production purposes with the emergence and invention of electricity in the modern era. In this thesis, starting from the situation of wind energy in the world, Europe and Libya, a brief explanation is presented about the formation of wind, which is transformed into a kinetic form of energy due to different temperatures or pressures. Important characteristics of winds, namely wind direction and speed, and the effect of surface roughness on wind speed are also listed. Systems for using wind energy, ie wind turbines using kinetic wind energy to drive the generator, and their own operating characteristics and application areas are described.

An SPSS (SPSS: Statistical Package for the Social Sciences) analysis of the wind energy potential for Tripoli airport area, Dernah area, Back and Magron in Libya was performed based on average wind speeds as measured by annual wind gusts at 40 m above ground surface and the wind potential An example is provided to calculate. The environmental characteristics of wind farms and their effects on the environment were also mentioned.

Key Words : Wind Energy, Wind Speed, Wind turbines, wind energy potential.
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ÖZET

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Araştırma çağını başlatan ve malların ve malların uzun mesafelerde taşınmasını sağlayan rüzgardı. Uzun zaman sonra, değirmenlerde mekanik işler yapmak ve su pompalarını çalıştırmak için rüzgar enerjisini kullanmak için ilk yelkenler takip edildi. Rüzgar, modern çağda elektriğin ortaya çıkması ve icadı ile üretim amacı ile kullanılmaya başlanmıştır. Bu tezde, rüzgar enerjisinin dünyadaki, Avrupa'daki ve Libya'daki durumundan başlayarak, farklı sıcaklık veya basınçlar nedeniyle kinetik bir enerji formuna dönüşen rüzgarın oluşumu hakkında kısa bir açıklama sunulmaktadır. Rüzgarların önemli özellikleri, yani rüzgar yönü ve hızı ile yüzey pürüzlülüğünün rüzgar hızına etkisi de listelenmiştir. Rüzgar enerjisini kullanmak için sistemler, yani jeneratörü çalıştırmak için kinetik rüzgar enerjisini kullanan rüzgar türbinleri ve rüzgar türbinlerinin kendi çalışma özellikleri ve uygulama alanları açıklanmaktadır.

Libya'daki Trablus havalimanı bölgesi, Dernah bölgesi, Sırt ve Magron için rüzgar enerjisi potansiyelinin bir SPSS (SPSS: Statistical Package for the Social Sciences) analizi, yer yüzeyinden 40 m yükseklikte yıllık rüzgar esintileri ile ölçülen ortalama rüzgar hızlarına dayalı olarak yapıldı ve rüzgar potansiyelini hesaplamak için bir örnek sunuldu. Rüzgar çiftliklerinin çevresel özellikleri ve çevreye olan etkilerine de değinildi.

Anahtar Kelimeler : **R**üzgar, Rüzgar hızı, Rüzgar türbinleri, Rüzgar enerijısi potansiyeli.

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ABBREVITIONS

CFD : computational fluid dynamics

LES : large eddy simulation

RANS : reynolds-averaged navier-stokes

SGS : sub-grid scale

PART 1

INTRODUCTION

1.1. HISTORY

The history of using wind energy goes back to the time when people first sailed on ships and thus were able to make long voyages, and also decided to entrust their lives to this unexpected source of energy. It can be said that it was the winds that started the era of research and made it possible to transport goods and goods over long distances. Long after the first sails of using wind energy to do mechanical work in mills and start water pumps. In the modern era, with the advent and invention of electricity, it began to be used for the purpose of producing it [1].

The main advantage of electricity is that it can be easily transferred to the end user. The problem that arises is production, that is, the largest share of electricity production in the world. Thermal power plants using fossil fuels have energy. In addition to being a finite resource, fossil fuels are also massively polluting Earth's atmosphere. Therefore, there is a need for a new source of energy, which is wind [2].
In the past ten years, wind energy has been promoted as the fastest growing branch of the industry and one of the sources of energy that every electrical grid in its system should rely on [3].

1.2. WIND ENERGY IN THE WORLD

Wind energy today creates hundreds of thousands of new jobs around the world. In the last few years, wind farms have been responsible for most of the newly installed electricity generation power in the energy sector. Wind turbines have become specialized for almost all types of terrain and climatic conditions and can be found in tropical areas, but also in Arctic conditions. The combined height of the column and blades on the largest wind turbines reaches heights above 200 m, which is almost two thirds of the height of the Eiffel Tower [4].

At the same time, the development of dimensions has developed new technologies and knowledge about the impact of wind farms on the electricity grid, developed wind turbines that support the grid and have a positive impact on system stability, developed advanced wind forecast models with high accuracy up to several days in advance. periods up to 24 hours in advance, the prices of produced kWh fall, and energy is clean and free [5].

The record year for the wind industry was 2015, when the installed capacity of 60 GW / g was surpassed for the first time. Total investments in the clean energy sector last year amounted to about 300 billion euros, an increase of 4% compared to 2014 when investments amounted to about 240 billion euros [6].

The total installed capacity of wind farms at the end of last year was 432.9 GW with an annual growth of more than 17%. This growth is due to China with new installations of 30,753 MW [7].

In early 2015, expectations for growth in the wind energy market were not high due to the slow growth of the economy in Europe and political uncertainty in the US. It was estimated that 53.5 GW of installed capacity would be generated per year, but China's capacity was not taken into account [8].

1.2.1. Wind Energy and its Current State at the Present Time

New global wind energy capacity was installed in 2017, and cumulatively, the annual market in 2017 reached 52.6 GW [9], down slightly from 54 GW in 2016 [10]. China installed 37% of new global capacity in 2017 (2016: 43%), followed by the European Union with 30% (2016: 23%), the United States with 13% (2016: 15%) and India with 8% (2016: 6%) [11] (see Fig.1). The global annual market reached a record high in 2015 with 63 GW installed, which is a milestone in a period (since 2009) when it remained at a very high level around or above 40 GW. In 2017, it decreased to 52.6 GW which is still a very important number [12].

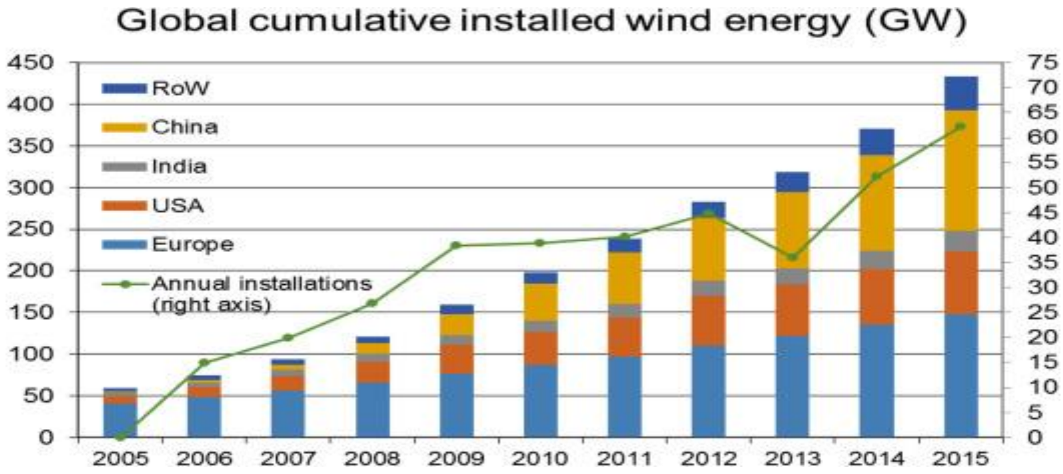

Figure 1.1. Annual installed wind energy generating capacity in the country, and the EU's share of that capacity [13].

1.2.2. The Largest Wind farm in Europe

The European Wind Energy Association (EWEA) has published a list of the ten largest wind farms in Europe with a total capacity of 3176 MW with a total of 1214 wind turbines . The estimated annual electricity production of these wind farms, when fully completed, is 6.7 TWh, which is sufficient to cover the consumption of about two million households [14].

The largest wind farm in Europe is located in Romania, Fantanele & Cogealac, with a capacity of 600 MW. The next four places on the list are UK offshore wind farms, and the first on that list is Whitelee, a 539 MW offshore wind farm that uses 215 Siemens wind turbines and is owned by Scottish Power [15]. The top ten also includes Alto Minho wind farms in Portugal, Andau in Austria, Maranchon in Spain, Jadraas in Sweden and other wind farms in the UK [16].

1.2.3. Wind Energy in World

1.2.3.1. Libya

Libya is a country located in North Africa Libya, is an oil exporting country in North Africa covering an area of approximately 1,750,000 km² with a coastline of 2,000 km [17]. The country has a population of about 6 million, of whom 166,610 are non-citizens. Libya tends to be an important country in the Mediterranean basin and the richest in North Africa in terms of natural resources. Recently, Libya has become one of the primary energy sources in the world because it is the largest exporter of natural gas and an exporter of oil [18].

Like other countries, Libya has suffered from high conventional energy prices, environmental issues, rapid demand growth, and high energy consumption. The main source of income for Libya is oil, and the state relies heavily on the oil it produces as its main source of income [19]. It should be noted that Libya has a high potential for renewable energies, especially wind and solar energy, which can create local jobs, move local economies and reduce carbon pollution [20]. However, Libya wants to reduce dependence on oil as a source of income by improving investment in the industries of natural gas, fisheries, mining, and tourism [21]. Libya is trying to use the substantial resources it derives from oil to invest in the infrastructure that will support the rapid realization of dependence on oil as a major source of income. Libya wants to realize these projects through design, development and applications that would support the realization of this project. In addition, Libya plans to make itself one of the most influential economic countries that mediate between Europe and Africa commercially. Recently, there have been indications that Libya is likely to move towards liberalization and economic reform and a decline in the government's direct role in the country's economy. Libya has plans to reduce dependence on oil as its main source of income and increase investment in it [22].

Agriculture, fisheries, tourism, natural gas and mining. Diversification is a critical issue because current production rates indicate that Libyan oil reserves are unlikely to survive this decade [23]. In this way, the long-term health of the economy depends heavily on maintaining the self-sufficient oil sector. The agricultural sector has become a top government priority in the hope that the Manmade River, a $ 30 billion project, will help tap groundwater to reduce dependence on food imports and reduce water shortages in the country. The demand for oil resources will be greatly reduced if the natural gas, tourism, fisheries and mining industries are designed and implemented effectively. Only through effective investment and effective implementation of these industries will Libya achieve its goal of reducing dependence on oil as a major source of income. Other renewable energy such as wind and solar energy will help Libya reduce dependence on oil. These renewable energies will help Libya reduce dependence on oil as a major source of income if its components are designed, manufactured and implemented correctly and effectively [24]. This article provides an overview of renewable energy in Libya, in particular research into the use of solar and wind energy, presenting the results of historical and modern research and development projects regarding the use of solar and wind energy in Libya and the situation in order to forecast and advise on the development of renewable energy in the future [25].

This helps researchers learn the current research state and aids in decision making. The second part of this article will discuss the availability of solar and wind energy in Libya on the basis of an overview of renewable energy development. Then the authors attempted to promote public awareness and inspire the local government to devote more money and efforts into the use of renewable energy in Libya. The third part of this article identifies short and long-term policies, strategic plans developed by the Libyan government for the future, the implementation of renewable energy technologies in Libya, the obstacles they encounter, and how the Libyan government intends to achieve these goals [26]. As Figure 1.1.

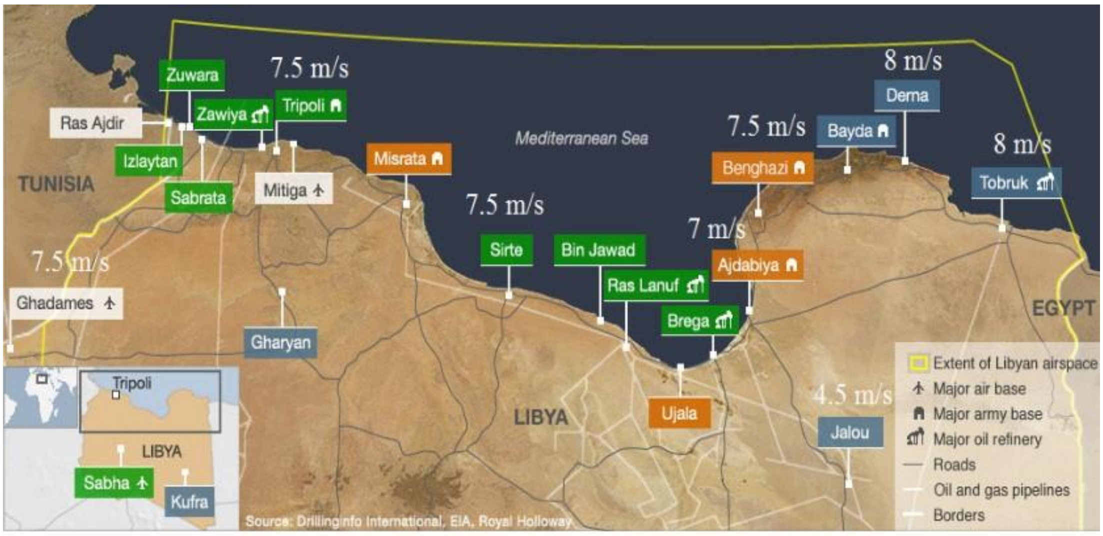

Figure 1.2. Wind energy in Libya [13].

1.2.3.2. Current Energy in Libya

The main sources of energy in Libya are natural gas and oil. Libya, which has oil reserves of 35 billion barrels by 2005, about 47 billion barrels by 2012 and 54 trillion cubic meters of natural gas, is an extremely important oil country for European countries. Basically, oil features the largest total primary energy supply with a share of 66% by the year 2000 although this has decreased in the last few years to 62% consisting of 20% heavy fuel oil and 42% light fuel oil due to the introduction of natural gas with a quota. 38% for electrical power generation as shown in Fig.1 (a). In the next few years, the demand for electric power is likely to increase rapidly with the use of desalination plants as the main power driver [8]. It should be noted that oil export revenues are important to the country's economic development as they account for 90% of total revenues [27]. In 2010, the majority of Libyan oil was sold to European countries. Europe receives more than 85% of Libyan crude oil exports, such as Italy 376,000 barrels per day (22%), France 205,000 barrels per day (16%), UK 95,000 barrels per day (9%), Greece 63, 000 bpd (15%), Germany 144,000 bpd (8%), Spain 136,000 bpd (12%) and others 14.5%. While the rest goes to China, it imports approximately 3% of 150,000 barrels per day of crude oil from Libya [28].

The United States reported importing Libyan oil at an average of 43 barrels per day in 2004, higher than in 2011, at an average of 95,000 barrels per day. Basically, the

Libyan energy sector plays an important role in achieving the country's economic and social development. Total primary energy supply continues to increase with an average annual growth of over 5% with oil having the highest share and the highest consumption in the oil sector. Electricity covers about 99% of the population by using photovoltaic systems to power nearly 2,000 homes in rural areas. In fact, the Libyan economy is unique in the northern part of Africa. While Morocco, Egypt, Tunisia and Algeria have great agricultural potential, well-established industrial bases and large populations, Libya has only some advantages [29].

Libya has a small population and an oil-driven economy and this indicates that Libya has an economy similar to that of the oil-exporting countries of the Persian Gulf state than other North African countries. According to the Oil and Gas Journal (OGJ), Libya has the largest proven oil reserves in Africa and is among the top ten countries in the world. Total proven oil reserves are 47.1 billion barrels, followed by Nigeria's reserves of 37.2 billion barrels in 2012 as shown in Figure 1 (b). After increasing oil export revenues, Libya achieved strong economic growth in 2004 and 2005, with a 6.5% increase in GDP. Despite the economic growth, the rate of unemployment continues to rise. Regardless, Libya has an unclear legal structure with arbitrary government decision-making processes and other structural inertia that tend to impede economic growth and foreign investment [30].

Although economic uncertainty remains high and infrastructure deteriorated during the civil war, the NTC is making efforts to develop a new system of governance and restore the rule of law. The past few years have witnessed a rapid growth in energy demand in Libya, with current plans calling for a doubling of power generation capacity [31]. In the summer of 2004, the country suffered a blackout because the power plants were able to keep up with the increasing demand. It should be noted that in order to meet the increasing consumption of energy and prevent power outages, the Libyan state-owned General Electricity Company (GECOL) has built several power plants. Most of the existing power plants in Libya were converted to natural gas, and thus new gas-fired power plants were built in order to increase the volume of oil for export [32].

1.2.3.3. Wind Energy in Libya

Wind energy in Libya is not properly developed in Libya because more maintenance is needed in a timely manner. Libya is more dependent on fossil fuels to generate electricity. It appears that this country is insecure in the energy sector, which could affect its economy in the future. As a result, the country may also face some problems such as depletion of valuable non-renewable energy resources, negative impacts on climate conditions and global warming [33].

In order to avoid these problems, various regulatory bodies have decided to include renewable energy as an energy source. In 2000, the Libyan Electricity Facility (GECOL), together with the Center for Solar Energy Studies (CSES), began identifying potential renewable energy resources in the form of wind energy and establishing and developing commercial wind farms to generate electricity economically [34].

These authorities conducted a wind speed survey in 2004, which exposed Libya's high wind energy capacity. It increased the prospect of wind energy development in Libya's coastal regions. A contract has been signed in Libya for the construction of 25 MW as a pilot project, from which many windmills will be installed and wind energy will be generated in the future [35].

Professional expertise will be passed to the chosen candidates who will serve in the area of wind energy technologies in future projects as a result of this initiative. As a result, the primary goal of this initiative is to build a wind farm using the latest technical expertise and project preparation for local engineers. Libya has also contracted with another project to collect accurate data on solar and wind energy throughout the world, allowing for effective study of the country's wind and solar energy capabilities [36].

Both programs are aimed at preparing and producing wind energy in Libya. This policy helps Libya to collect the requisite information and expertise to create an atmosphere conducive to wind energy generation, allowing it to use wind as a sustainable resource.

In order to construct the wind tower in Libya, a number of schemes have been launched in various locations. As a result, the responsible authorities started researching the appropriate locations for erecting wind turbines to generate wind energy. The aim of this project was to collect wind data from 16 meteorological stations in Libya at various altitude levels. This study aided in the selection of suitable sites for wind energy projects and the establishment of Libya's first wind farm [36].

The Darnah area has a stronger wind pattern than the rest of Libya. The fact that the wind rose in our house means that the northeast coast is ideal for the prevailing winds. The average wind speed in various months will produce varying amounts of energy in our home. In general, this website is more favorable to wind energy production. A Waybill distribution was used to characterize the wind velocity distribution using both of these data. The probability density function and the cumulative distribution function are used to calculate the variations in wind speed in this case [37].

All of the data was analyzed statistically, which included useful knowledge about a good location for a wind farm. The renewable energy authorities concluded, based on the above analysis, that our house is a suitable location with a high potential for producing wind energy in Libya. The wind conditions in our house were perfect for generating wind energy. The average wind velocity in our Darnah was measured at 9.8 and 10.8 m/s at an altitude of 50 and 100 meters, respectively, according to the data review. Among the various locations in Libya, this wind speed trend was the most favorable [38].

Since the winds flow mostly from the northeastern to the southwest coast at this spot, Libya has begun construction of a 61.75 MW wind farm in the Fatih district, near Darnah on the northeast coast. In addition, it is expected that a power plant will be built in Libya in two stages: The estimated installation costs for a power plant consisting of two wind turbines with a combined capacity of 60 MW would be € 103 million. The cost of a wind tower is determined by the plant's scale, height, and power, among other factors. Due to its favorable conditions, this country has also intended to launch other wind projects in different areas, including the southeast and southwest [39].

In Libya, wind energy has not been adequately built due to a lack of timely maintenance. Libya is more reliant on fossil fuels for power generation. It demonstrates that this country's energy security is in jeopardy, and may have an effect on its economy in the future. As a result, the nation could face issues such as the depletion of important nonrenewable energy supplies, adverse climatic conditions, and global warming [40].

Various regulatory bodies agreed to use solar energies as a power source in order to mitigate these issues. In the year 2000, the Libyan electricity utility GECOL, in collaboration with the Centre for Solar Energy Studies (CSES), began to recognize possible renewable energy options in the form of wind energy and to build and expand commercial wind farms to produce electricity at a reasonable cost. These authorities conducted a wind speed survey in 2004. Libya has a lot of wind energy promise, according to many studies. It increased the likelihood of wind energy generation in Libyan coastal regions. In Libya, a contract has been signed to build 25 MW as a pilot project, with the aim of establishing multiple wind turbines and producing wind energy in the future [41].

Professional expertise will be passed to the chosen candidates who will serve in the area of wind power technologies in future projects as a result of this initiative. As a result, the project's key focus is on constructing a wind farm using best technical practices and providing training to local engineers on the projects. Libya has also contracted another project to collect accurate sun and wind data throughout the region, allowing for successful analysis of potential wind and solar energy anywhere in the country [42]. The monthly average wind speed in different cities in Libya as Figure 1.2.

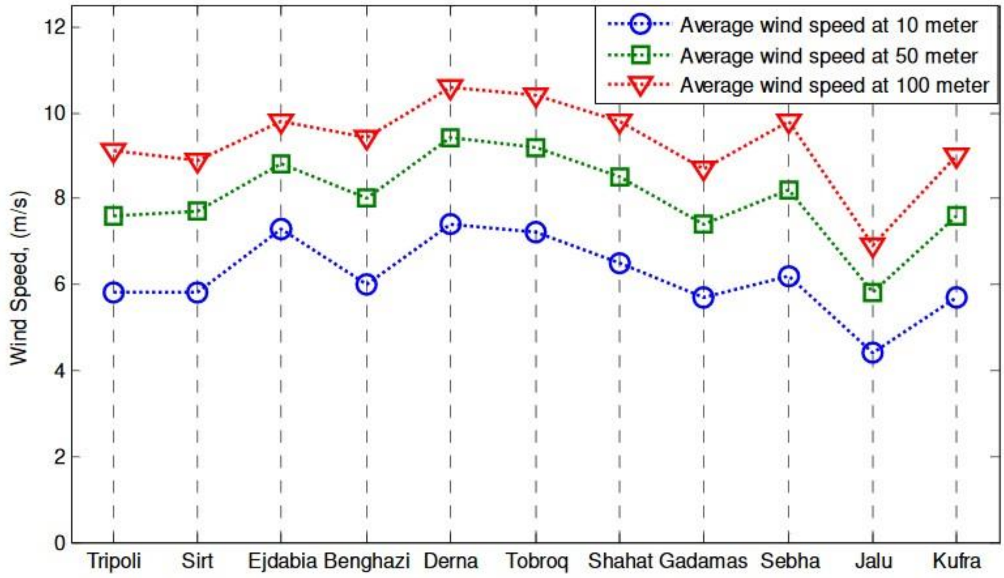

Figure 1.3. The monthly average wind speed in different cities in Libya [13].

In Libya, both projects plan to plan for and produce wind energy. This policy helps Libya to gain required information and expertise for using wind as a renewable energy source, which will help it create a favorable climate for wind energy development in the future. Some projects were begun at various locations in Libya in order to build wind towers. As a result, accountable officials began a study to determine the best locations for erecting wind turbines to produce wind energy. The aim of this project was to collect wind data from 16 meteorological stations in Libya at various elevation levels [43].

1.3. AIM OF STUDY

- This study focuses on the importance of the available and underutilized energy sources (renewable energy), which is wind energy in the city of Tripoli, to be invested in generating electric energy, which is the most important modern energy source that contributes significantly to the various sectors that achieve economic integration in all its branches.
- The use of mathematical equations using the statistical program SPSS version 26 and the use of the EXCEL program in drawing wind speed

1.4. THE STUDY PROBLEM

Libya relies mainly on (fossil) energy sources that have become insufficient to fill the apparent deficit in the supply of electric power with all the requirements of the various sectors of their needs, especially in recent years, as well as its economic cost and environmental pollutants, with the exception of part of the hydropower in the dam Modern, while there are alternative and renewable energy sources that are more appropriate and economically feasible, which can be invested after the technological development

1.5. STUDY HYPOTHESIS

The availability of great potentials of alternative energy sources that can be invested in the production of electric energy in Libya, such as wind energy, to be used as an economic force in sustainable development.

1.6. THESIS ORGANIZATION

This work is organized in the six chapters. The aspects covered by each chapter are shown below.

PART 2

LITERATURE REVIEW

2.1. WIND FARMS

Wind farms or wind turbines, also known as wind turbines or wind turbines,[1] are a body of wind turbines used to generate electricity at the same site. Wind farms range from a few turbines to several hundred wind turbines covering a large area. Onshore or offshore wind turbines may be used.

Many of China, India and the United States are the largest operating onshore wind farms. For example, Gansu Wind Farm in China had a capacity of more than 6,000 MW by 2012 as the world's largest wind farm,[2] with a goal of 20,000 MW [3] by 2020. [4] The Hornsea Wind Farm in the United Kingdom is the largest offshore wind farm in the world in 2020. [5] Specific designs for wind turbines continue to increase their power and fewer turbines are needed for the same overall performance.

Since they need no fuel, wind turbines have less effect on the atmosphere than many other types of power generation. Wind farms have, however, been criticized for their visual impact and impact on the landscape. They typically need to be distributed over more ground than others and installed in wild and rural areas, which can lead to ""campestry industrialization," loss of habitat and a decline in tourism. Certain opponents say that wind turbines do have negative effects on the health of the population, but most investigators consider these arguments to be pseudo-scientific.

2.1.1. The Largest Wind Farms in Europe

The European Wind Energy Association (EWEA) has published a list of the ten largest wind farms in Europe with a total capacity of 3,176 MW with a total of 1,214 wind turbines 2.1. The estimated annual electricity production of these wind farms, when fully completed, is 6.7 TWh, which is enough to cover the consumption of about 2 million households [6].

The largest wind farm in Europe is in Romania, Fantanele & Cogealac, has a capacity of 600 MW. The next four positions on the list are held by offshore wind farms in the UK, and the first on that list is Whitelee, a 539 MW offshore wind farm that uses 215 Siemens wind turbines and is owned by Scottish Power [6].

The top 10 also includes Alto Minho wind farms in Portugal, Andau in Austria, Maranchon in Spain, Jadraas in Sweden, and another wind farm in the United Kingdom [7]

Table 2.1. List of the largest wind farms in Europe (built, under construction or approved) [6].

Location or name	**Earth**	**Capacity (MW)**	**End date**
Hornsea	England, United Kingdom	737	2020
Fantanele & Cogealac	Romania	600	2012
Whitelee	England, United Kingdom	539	2013
Viking	England, United Kingdom	371	2018
Clyde	England, United Kingdom	350	2012
Pen and Cymoedd	England, United Kingdom	256	2016
Alto Minho	Portugal	240	2009
Andau	Austria	237	2014
Maranchon	Spain	208	2007
Jadraas	Sweden	198	2013
Dorenell	England, United Kingdom	177	2018
Total	**740.176**		

2.1.2. Wind Farms in Libya

Wind energy has been used in Libya to pump water from several oases since 1940, but it was not widely used. Since 2001, studies of the feasibility of producing wind energy in Libya have begun, through which five sites on the Libyan coast were nominated to measure wind speed. It is the city of Darnah, Talmitha, Al-Maqron, Misurata and Sirte. These sites were chosen based on several considerations, the most important of which are accessibility to these sites, and the ability to connect to the network [8]

The measurements started in September 2002, and in 2004 studies showed that wind speed measurements showed the existence of great potential for wind energy in Libya, as it reached, on average, in some areas, the wind speed at an altitude of 40 meters between 6-7. 5 m / s, and the estimated availability of wind energy in Libya is about 15 terawatt hours per day[9]

The results of those measurements came out to show that the Darnah site is the most feasible from an economic and technical point of view, as it was distinguished by the following: [10]

- Wind speed is suitable.
- Good website accessibility:
  - Existence of a sea port.
  - The port is 200 km from Benghazi, the second most important city.
  - The coastal road runs through the site.
- A network with good potential.
- Ease of terrain.

Wind energy is a clean energy that does not cause pollution to the environment, and it has the advantage of reducing harmful emissions by reducing dependence on fossil fuels for the production of electrical energy, for example to produce energy of 54 GW hours by wind energy, on reducing harmful emissions by reducing dependence On fossil fuels to produce electric energy, for example to produce 54 GW hours of energy by wind energy, this will prevent the emission of approximately 29,268 tons of carbon dioxide per year, and it also saves about 20,412 m3 of fuel annually, and the cost of kilowatts has decreased. The hourly produced from wind energy greatly, as it reached about 90 cents per kilowatt hour in 1980, and reached an average of only about 10 cents per kilowatt hour in 2010, according to the generating capacity of the turbine, and according to its type in terms of being "coastal, or far from the coast." According to wind speed, Table 2.2 shows the cost of wind energy for the year 2010 [11]

Table 2.2. Cost of wind energy (cents per kilowatt hour) for the year 2010 [2].

Type	**Advantages**	**Cost "kilowatts cent -" hour**
Turbines far from the coast “Offshore”	Turbine size: 1.5-3.5MW Feathers Diameter: 60-100M	5-9
Coastal turbines “ Onshore”	Turbine size: 1.5-5 MW Feathers Diameter: 70-25M	10-14

2.1.2.1. Strategy of Exploiting wind Energy in Libya

Wind energy was developed and exploited in Libya during the period (2010-2020), so that the installed capacity of wind energy in 2020 reached about 1000 megawatts, and there are proposals for the establishment of several wind farm projects in different regions in Libya, as shown in Table 2.3 [12].

Table 2.3. Wind energy projects in Libya during the period (2010-2020) [2].

Project name	**Installed capacity MW**	**The amount of carbon dioxide avoided year / ton**	**Profits $ / Year**
Derna wind station 1-2 Stages	120	336384	3363840
Al-Magron wind station 1-2 stages	240	672768	6727680
Wind stations in the western region	250	613200	6132000
Wind stations in the southern region	320	784896	7848960
White	70	171696	1716960
Total	1000	2578944	25789440

It is evident from the previous table that the installed capacity of wind energy in Libya is about 1000 megawatts, meaning that it will contribute about 4% of the total contribution of energy sources to the production of electricity, and these projects will reduce carbon dioxide emissions by about 2.57 million tons per year, and an expected profit of 25. $ 8 million a year [13].

The construction of "Darnah, the first phase, with a generating capacity of 60 megawatts, and the second phase of Darnah with a generating capacity of up to 60 megawatts, the first phase with a generating capacity of 120 megawatts" has been contracted by six international companies. The results of these stations are expected to be as follows : [8]

Table 2.4. Expected results from the exploitation of wind energy stations in Darnah, the first two phases [2].

Farm	**Company**	**Turbine No**	**Energy GWh/Y**	**Capacity Factor**	**Availability %**
Dernah 1st Stage 60MW	CONERGY Germany	66 WPC 900 KW	214	41	95
	MTORRES Spain	37 TWT 1650 KW	238	44	97
	VESTAS Denmark	20 V90 - 3000KW	210	40	97
Dernah 2nd Stage 60MW	EWT Holland	66 EWT 900KW	226	43.5	95
	SIEMENS Germany	26 SWT 2300KW	251	47	95
	MTORRES Spain	26 TWT 1650 KW	228	37.5	97
AlMaqrun 1st Stage 120MW	SIEMENS Germany	53 SWT 2300 KW	452	42.3	95
	EWT Holland	133 66 EWT 900KW	304	29	95
	VESTAS Denmark	40 V90 - 3000KW	367	35	97
	MTORRES Spain	37 TWT 1650 KW	372	35	97

- Total energy produced 2862 GW/ hours per day.
- The average capacity factor was 39. 43%, and the available capacity for each project was about 96%. Table 2.4 shows the results of establishing the stations in Adrianople, the first phase, the second phase, and the first phase of Al-Maqrun.

2.2. WIND ENERGY CONCEPT

Wind is the air that flows horizontally with respect to the earth's surface. Due to the uneven heating of the Earth's surface at different latitudes, air masses move in the atmosphere. The air is heated indirectly through the ground. Earth's poles receive less energy from the equator, and the Earth heats up faster than the sea. Due to the temperature differences in the air layers, pressure differences are created which are transformed into the kinetic profile of the wind energy [2].

Wind is the result of the action of forces and they are: [6]

- Pressure gradient,
- Coriolis force,
- Gravity and Centrifugal force
- frictional force [11].

The pressure gradient (PG) is greater when the pressure difference is larger and the distance is smaller. Wind speed is proportional to this gradient. Since it is in the direction of the largest change in pressure, and the gradient is always perpendicular to the isotropic lines, the units of force of the pressure gradient are Pascals per meter (P m-1). (ib) and is directed from higher pressure to lower pressure.

Although the winds blow from the high pressure region to the low pressure region, they do not blow directly from the shortest path, that is, they do not blow parallel to the direction of the pressure gradient. The wind is not the same as the pressure gradient perpendicular to isothermal lines, but it closes at a certain angle with it. This angle is greater on land than over the sea, and as the latitude increases, it decreases. From this we can conclude that the wind direction (v) is determined by some other force besides the force of the pressure gradient, that is, the forces that also deflect the wind and affect it, which are the friction force ($\vec{F}$) and the Coriolis force (Co), as shown in Figure .2.1 and Figure 2.2 [12].

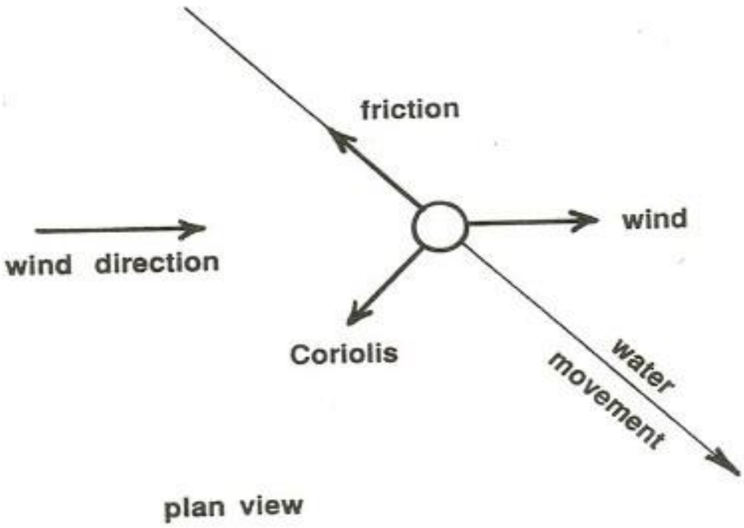

Figure 2.1. Balance of forces on a surface water element under a wind [2].

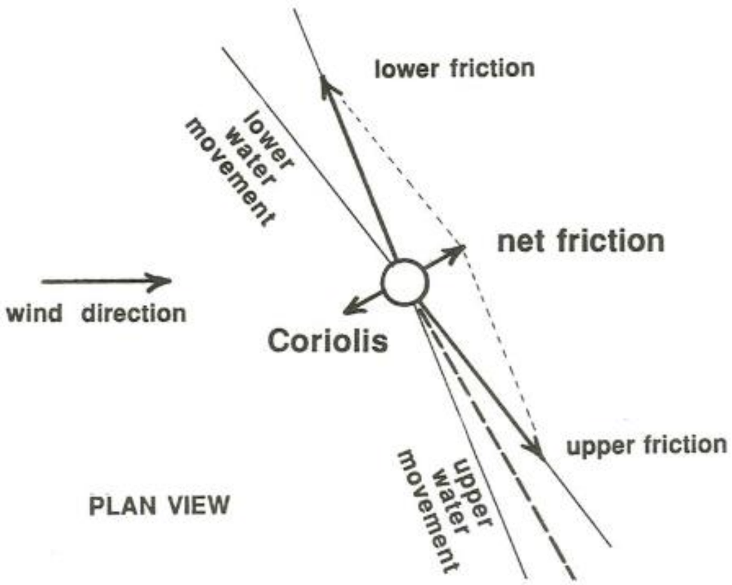

Figure 2.2. Balance of forces on a subsurface water element under a wind [2].

Due to the roughness of the surface, at low altitudes, the frictional force always acts. The friction between the air and the substrate, as well as between the different layers of air, opposes the movement that started and reduces its speed, and changes its direction somewhat [12].

Coriolis force affects the wind velocity vector. The Coriolis component is created by eddy currents as a result of Earth's rotation [2]. The effect of this deflection force is to shift the wind path so that the winds in the northern hemisphere shift to the right and the southern hemisphere to the left Figure 2.3 [13].

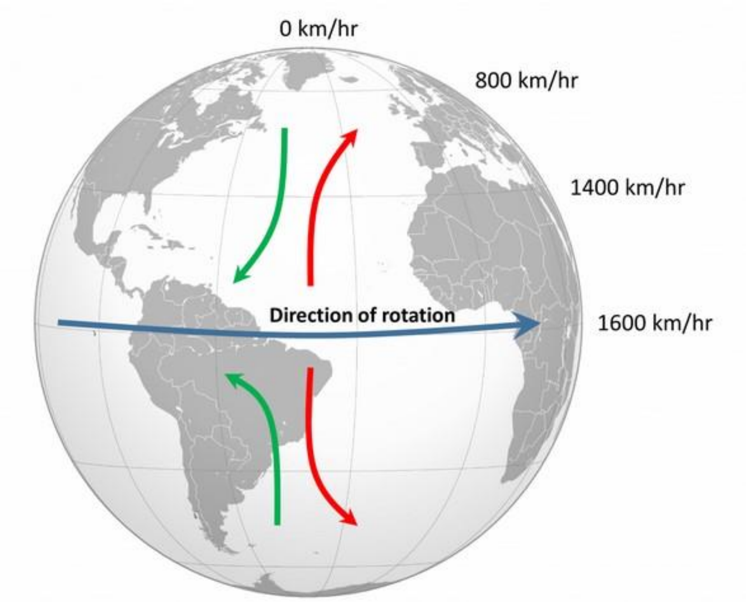

Figure 2.3. Wind as Consequence of the action of the Coriolis force [14].

Atmospheric particles moving eastward in the northern hemisphere will be deflected due to the Coriolis force heading south . Similarly, particles moving west will be deflected to the north. In contrast, in the southern hemisphere for eastward movements, the deviation is to the north, and for westward movements, the deviation is to the south as Figure 2.4 [11].

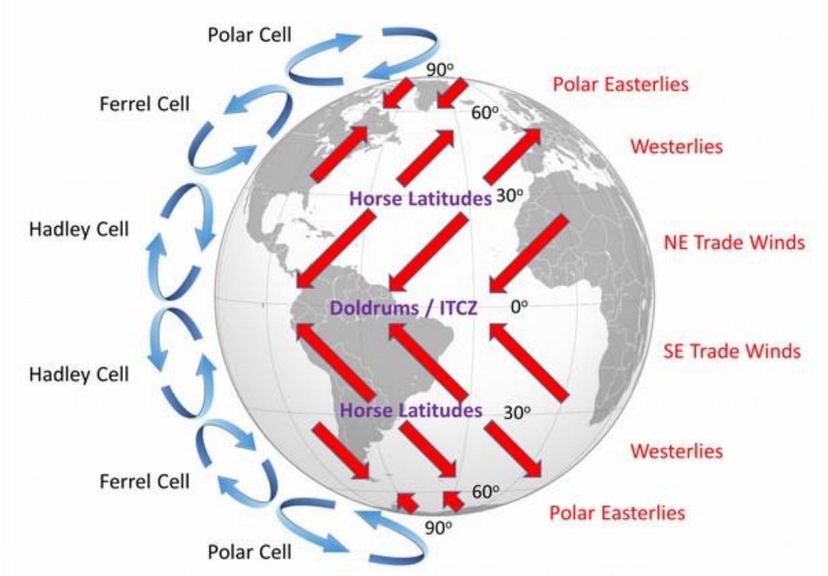

Figure 2.4. The direction of atmospheric particles in the northern and southern hemispheres by the action of the Coriolis force [14].

PART 3

METHODOLOGY

3.1. WIND TURBINES

Today's wind energy utilization systems are predominantly wind turbines. A wind turbine is also known as a wind turbine and a wind generator. A wind turbine is a rotating machine that converts the kinetic energy of the wind into mechanical and then through electric generators into electrical energy. The wind turbine rotor and the electric generator rotor are located on the same shaft [15].

The wind rotates the wind turbine blades attached to the shaft connected to the gearbox. In the gearbox, the gearbox rotation speed is increased by means of a gearbox. The gearbox is connected to the turbine shaft on one side and to the high speed shaft on the other. The shaft rotates the generator rotor and thus produces electricity. Not every wind can be used in this way to produce electricity, As Figure 3.1 [16].

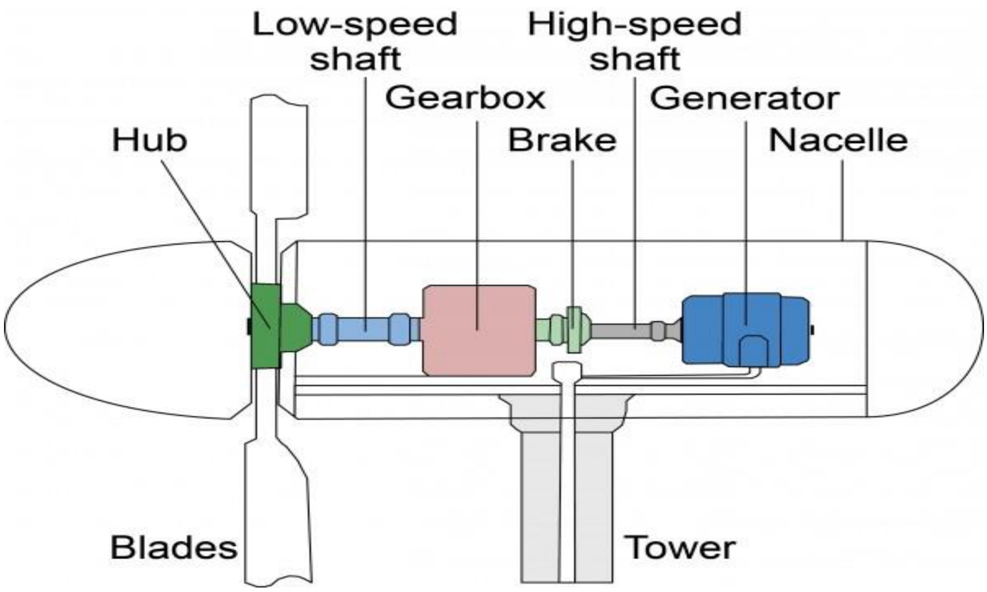

Figure 3.1. Wind turbine parts [16].

The main characteristic of wind as a driving fluid is its reproducibility. After the air leaves the system to which it has delivered energy, it returns to the environment with unchanged physical and chemical properties [2].

3.1.1. Wind Turbine Operation Features

Moving air molecules have kinetic energy, so the amount of air molecules passing through an area over a period of time determines wind energy [18].

Since the turbine blades describe an imaginary circle of surface A during rotation and if a cylinder of length L is taken, then the total mass of particles coming to the turbine blades can be calculated using volume and air density, and kinetic energy is obtained using mass and velocity Figure 3.2 [18].

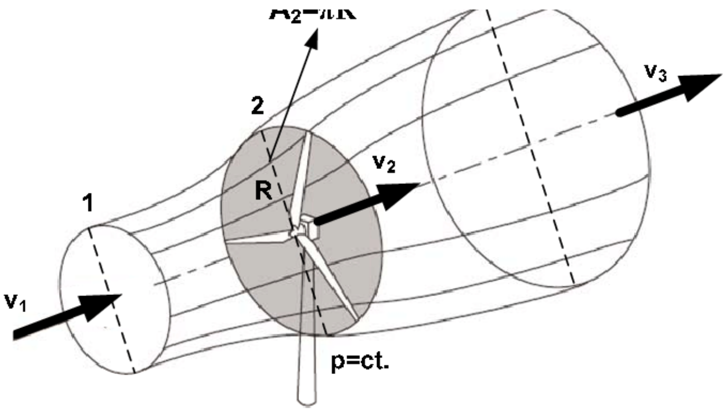

Figure 3.2. An imaginary cylinder describing the wind at the turbine inlet [41].

$$E_k = \frac{1}{2}\, m \cdot v^2 \tag{3.1}$$

The mass of air is determined by the density, the surface through which it flows, as well as the speed and time:

$$m = \rho \cdot V = \rho \cdot A \cdot L = \rho \cdot A \cdot v \cdot t \tag{3.2}$$

$$E_k = \frac{1}{2}\, \rho \cdot A \cdot v^3 \cdot t \tag{3.3}$$

Wind power is the derivative of kinetic energy over time,

$$\frac{dE_k}{dt} \tag{3.4}$$

$$P_v = \frac{1}{2}\,\rho \cdot A \cdot v^3 \tag{3.5}$$

where is:

Ek - kinetic energy
m - mass
v - speed
ρ - density
V - volume
A - surface
L - length
t - time
Pv – power

It is important to note the following important facts:

- Wind power is proportional to air density. For standard conditions (sea level, temperature 15 ºC) the air density is 1,225 kg / m^3.
- The wind power is proportional to the imaginary surface described by the rotor.
- Wind power is proportional to the cubic potential of wind speed. If the wind speed increases twice, the power increases eight times [18].

Formulas (2.3) and (3.3) give the maximum theoretical energy or power contained in the wind. When the air behind the turbine stopped, the turbine would take over all that energy or power. The total kinetic energy of the air cannot be used up all because the air has to move on flow to make room for the incoming one, energy is partially lost to friction, and the turbine can use only a portion of that energy that is proportional to the difference in kinetic energies of the air in front of and behind the turbine [18].

The expression for the mechanical power of a turbine is:

$$P_t = \frac{1}{2} \cdot \dot{m} \cdot (v_1^2 - v_2^2) \quad (3.6)$$

Where is:

- $\dot{m}$ - mass flow (kg / s), depends on the average speed,
- v1 - wind speed at the turbine inlet,
- v2 - speed at the turbine outlet [18].

The electric power output curve shows the dependence of the produced electric power on the wind speed. It is common for wind turbines to start operating at speeds of 3-5 m / s, their rated power is at 12-15 m / s, and the shutdown occurs at wind speeds between 20 and 25 m / s due to the possibility of mechanical damage Figure 3.3. [19].

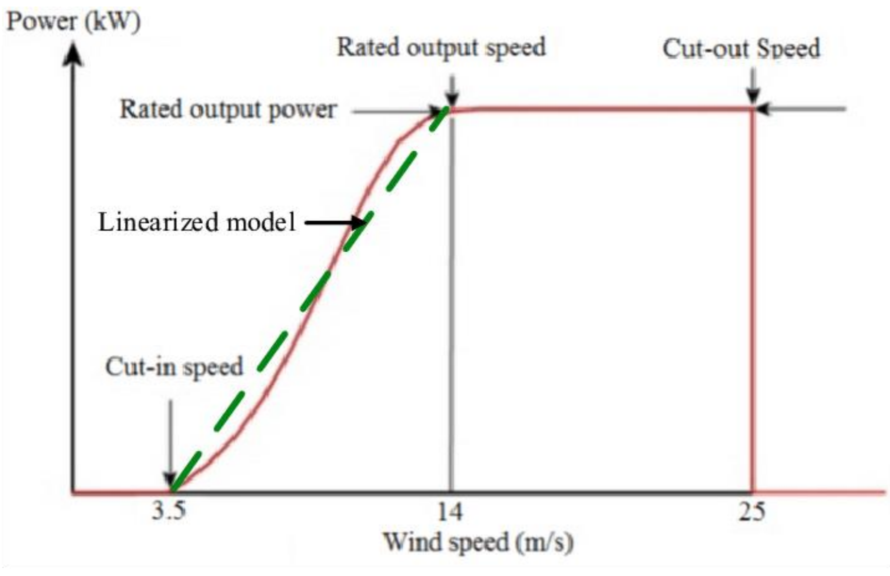

Figure 3.3. Dependence of wind turbine power on wind speed [42].

3.1.2. Betz's Law

The theoretical degree of wind energy conversion efficiency shows what is the maximum energy that can be achieved by a free-flow wind turbine. The theory that defines the maximum degree of wind turbine efficiency is called Betz's law according to the German physicist Albert Betz (1885-1968) [2].

Unfortunately, part of the total kinetic energy of the wind is unusable because the wind must continue to flow to allow the wind to come behind it. It is mathematically represented by the degree of aerodynamic conversion equal to the ratio of the power on the shaft of the wind turbine and the available power in the free wind current [19]:

$$C_p = \frac{P_t}{P_v} = \frac{P_t}{\frac{1}{2}\rho \cdot v^2} \qquad (3.7)$$

Where is:

- cp - degree of aerodynamic conversion (≈ 0.45 for modern wind turbines, and on some wind turbines it goes up to 0.5),
- Pt - transformed power,
- Pv - wind power.

The highest possible degree of aerodynamic conversion is the so-called. Betz limit and it is 0.593. No currently available modern wind turbine can have an efficiency greater than [19]:

$$N = \frac{d^2 \cdot w^2}{k} \; [kW] \qquad (3.8)$$

Where is:

- N - windmill power [kW],
- d - diameter of rotor circuit [m],
- w - wind speed [m / s],
- k - power coefficient (consists of two partial coefficients that take into account thermodynamic and hydrodynamic conditions) [20].

3.2. CONSTRUCTION FORMS OF WIND TURBINES

Wind turbines (WT) can be divided according to the axis of rotation. Conventional wind turbines have a horizontal axis of rotation and are therefore called "Horizontal-axis wind turbines" (HAWT). Lesser known wind turbines have a vertical axis of rotation and are called "Vertical-axis wind turbines" (VAWT).

3.2.1. Wind Turbines with Horizontal Axis of Rotation or WTHAR

Turbines with a horizontal axis of rotation are those whose axis of rotation is parallel to the direction of the wind current and the ground. Most commercial turbines are of this type.

The rotor of these turbines is placed horizontally at the top of the column. The blades that catch the wind must be directed into it. The generator of these turbines is usually placed on top of the column in the fuselage together with a multiplier if needed (depending on the type of electric generator). The multiplier increases the speed if the speed of the blades is too low to produce electricity [2].

The shaft height of a wind turbine is about 1.5 to 2 blade diameters so that the turbine can pick up high speed winds at higher altitudes. These wind turbines must be able to rotate the structure due to trapping winds from different directions, so smaller versions have simple wings that direct the wind turbines in the right direction while larger turbines have a servomotor attached to the sensor [2].

WTHAR turbines can be divided into those that are directed towards the wind and those that are projected from the wind Fig. 4.3. The vast majority face the wind, as this avoids the effect of turbulence behind the turbine. The main advantage of WTHAR turbines that consider the opposite direction of the wind flow is that they do not need to be equipped with turbine rotation mechanisms, but they are not as reliable and durable as "normal" WTHAR turbines [2].

Figure 3.4. Sections of wind turbines [43].

The number of blades in horizontal versions of wind turbines greatly affects their characteristics. Figure 19 shows several designs with different numbers of blades. The three-bladed version, the classic Danish concept, proved to be the most effective, and it is the most commonly used. That is, an odd number of blades compared to an even one proved to be a better solution due to the balance of the structure [2].

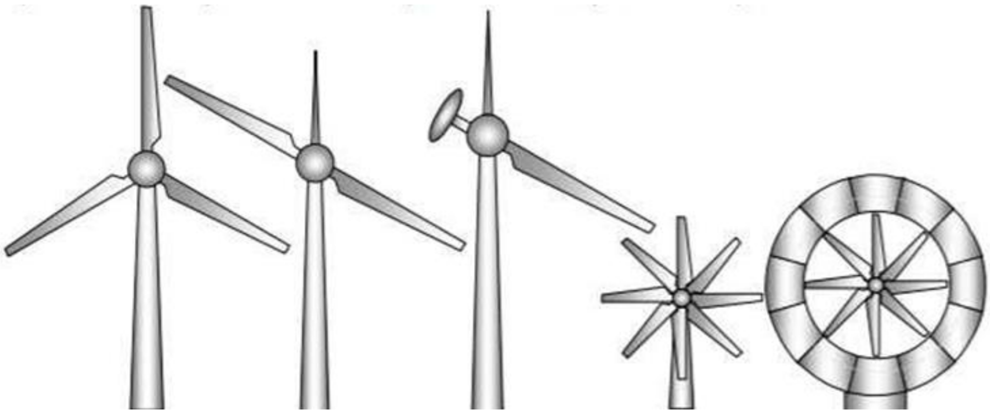

Figure 3.5. Performances according to the number of blades [44].

Two-bladed wind turbines require a higher rotational speed to develop the same amount of energy as a three-bladed version. Due to the increase in speed, noise also increases, so this design is less popular. There are also single-blade wind turbines, but such performance has not proven to be good due to the additional increase in speed, and thus noise, for the same amount of energy [21].

Rotors with a larger number of blades are most often used on farms to drive water pumps, and due to their low speed, they also have low efficiency. Examples of such rotors are American (Figure 20) with a large number of blades or Danish windmills Figure 3.6 with four large blades. Due to their low efficiency and speed, they are very rarely used as wind turbines [21].

Figure 3.6. American wind turbine [45].

Figure 3.7. American wind turbine [46].

3.2.2. Wind Turbines with Vertical Axis of Rotation or WTVAR

The main feature of this design is the vertically mounted axis of rotation. Since the rotor is placed vertically there is no need to direct it towards the wind because from whatever direction the wind blows, the wind turbine is equally efficient. This is especially useful in locations where the direction of wind blowing is variable [21].

WTVAR do not need a high pole and are placed closer to the ground, which makes them easier to maintain. Also, the generator and other equipment can be placed in the base making the tower less loaded. The downside of lower installation is that wind speeds at lower altitudes are lower, and turbulence occurs, especially if there are other facilities in the vicinity of the wind turbine. Turbulence causes a number of problems such as the occurrence of vibrations and faster bearing wear [21].

WTVAR can be divided into Darrieus and Savonius. None of them are in wider commercial use today, and recently new concepts of vertical wind turbines have become more common.

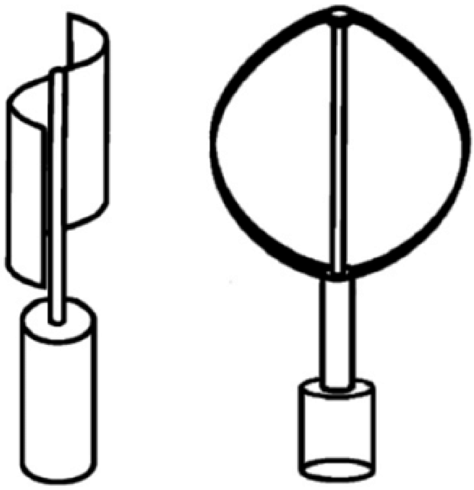

Figure 3.8. WTVAR can be divided into Darrieus and Savonius [47].

3.2.2.1. Darrieus Wind Turbine

The basic design of this wind turbine appeared in 1927. The French aviation engineer Georges Jean Marie Darrieus patented a vertical wind turbine Figure 8.3 according to which other designs were later created [2].

Aerodynamic profile blades are arranged around the rotating shaft. This design is equally efficient, regardless of wind direction, compared to conventional wind turbines. The rotational speed of this design is generally much higher than the wind speed. This type of wind turbine needs start-up assistance because they have to reach a certain speed before they start spinning on their own. At low speeds, the Darrieus turbine has a very low torque, so it stops very easily due to friction in the system [2].

In addition to the vertical versions, there are also horizontal versions of the Darrieus wind turbine Figure 8.3, which greatly facilitates and expands their range of applications. The advantage is that the bearings are better placed on the structure and thus are less axially loaded. With this design, the structure is placed at a certain height at which it catches a uniformly distributed wind speed, thus avoiding the problem of low speeds on the part of the turbine that is near the ground. The negative aspect of this performance is the inability to capture wind from all directions, so the range of their application is reduced [2].

3.2.2.2. Savonius Wind Turbine

The Savonius turbine was developed by Finnish engineer S. J. Savonius in 1922. There are many different designs of this type of turbine, and in the simplest design it consists of two halves of a drum or cup attached in opposite directions to the central shaft. Looking at the cross section from above, the turbine has the shape of the letter "S" [21].

Modern Savonius turbines have evolved into more advanced designs in which the blades are spirally rotated lengthwise. In such turbines, buoyancy is partly used, which increases efficiency and reduces vibrations [21].

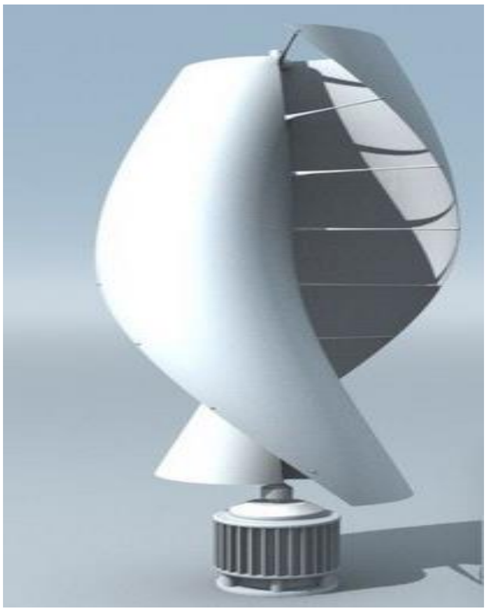

Figure 3.9. Savonius wind turbine [48].

This type of turbine is used when cost and reliability are more important than efficiency, as is the case with wind speed measuring instruments (anemometers), and are also used to drive water pumps or smaller generators [21].

3.2.3. Small Wind Turbines

The nominal power limit below which wind units can be considered small cannot be precisely determined [7]. There are basic divisions of a system in which smaller wind turbines operate [27]:

3.2.3.1. According to the Mode of Operation

- independent work
- combination with other energy sources

3.2.3.2. According to the Systems in Which they Work

- stand-alone network
- combination with other energy converters (hybrid systems)
- connection to the public electricity network

3.2.3.3. By purpose

- production of electricity for general needs
- water pumping
- electricity supply of navigation, telecommunication and signaling devices
- other uses such as seawater desalination [27].

Classification of wind turbines where the mean velocity interval represents annual average velocity quantities on the wind turbine axis under which it is not recommended to install wind turbines of a particular class. The site selection column provides a recommendation for the budget selection process. To determine a location for an accurate wind turbine, it is not necessary to perform wind potential calculations, but it is necessary to obtain the opinion of experts (meteorologists) and obtain monitoring data near the place of their installation (Beaufort scale, wind rose). To determine the location of a miniature wind turbine, it is necessary to calculate the wind potential. In the case of small wind turbines, a study is necessary, and in the case of medium and large wind turbines, in addition to the study, measurements of at least one year of wind potential are necessary at the exact location [27].

Figure 3.10. Use of small wind turbines to supply electricity to a house [49].

Small wind turbines mainly use multi-blade rotors for pumping water and watering. Rotors with more blades have lower aerodynamic efficiency, but due to the larger surface of the blades, they are suitable for lower wind speeds, ie they enable higher torque for starting wind turbines Figure 10.3 [2].

Figure 3.11. Use of small wind turbines to pump water [50].

These wind turbines are self-propelled, slow moving, durable and easy to build and maintain, and therefore cheaper, but with a relatively lower wind energy utilization factor [7].

“In the global market, one can notice a significant increase in the supply of small wind turbines intended for urban areas and residents. These wind turbines are used for installation in homes, on public lighting poles and in yards, and a combination of all this can be seen in some of the new settlements striving for Energy independence from the electricity grid "[29].

While large wind turbines are almost exclusively used to build larger or smaller wind farms whose primary goal is to sell electricity to the end customer, with certain exceptions to the rule, small wind turbines have and can have greater freedom and applicability [29].

There are many advantages to installing small wind turbines in urban and populated areas. On-site consumption, lighting installation, private investment, low power grid load and relatively small overall investment are the details that small wind turbines share with rooftop PV installations (Fig. 27). Its advantage is also a greater possibility of installing energy per unit area, especially in the case of wind turbines with a vertical axis of rotation. There are also places where the use of wind energy is more than that of the sun because of the proportion of sunny days and the amount of wind.

In places where there are many energy sources, solar energy can be used for space heating/cooling using much cheaper installations with solar heat collectors, and electricity can be simultaneously produced from small wind turbines on the rooftop or in the yard [30].

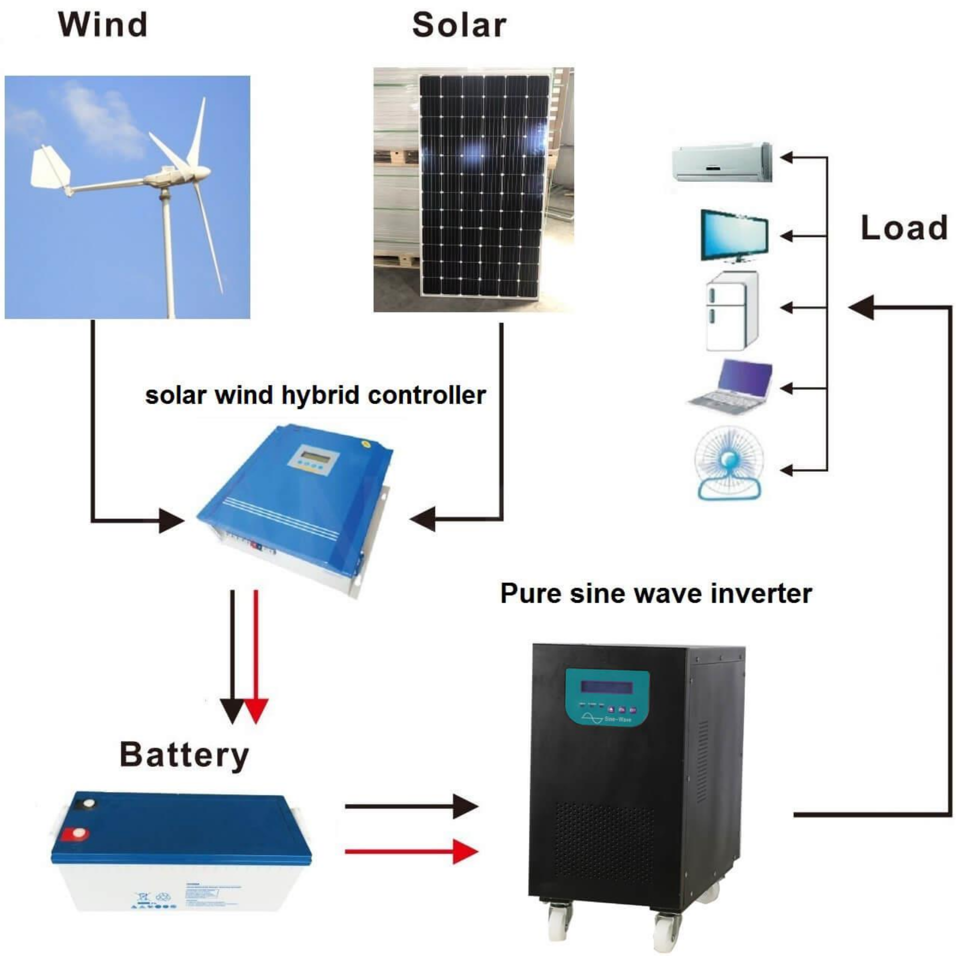

Figure 3.12. U wind turbine hybrid system [50].

PART 4

METHODOLOGY

4.1. WIND ENERGY POTENTIAL IN LIBYA

“Measurements of wind direction and speed are made in Libya in Derna and in the area of Tripoli International Airport, and this is often done within the work of the network of stations of the Governmental Institute of Meteorology. At these stations, wind strength measures were developed taking into account the recommendations of the World Meteorological Organization to the greatest extent possible. The World Meteorological Organization (WMO) installed wind speed and wind direction meters at a height of 10 meters above the exposed area. Open space means the area in which the distance between the wind direction and velocity gauge and surrounding obstacles is at least ten times greater than the height of these obstacles. However, rarely what obstacle-free area is available for placement of the anemometer column. Therefore, the locations of stations for which a position permit can be obtained and where it is possible to appoint a reliable observer should often be used, endeavoring to meet the requirements of the World Meteorological Organization as closely as possible" [32]. In order to properly assess the effect of winds on structures, it is essential that the data measured at wind velocity and wind direction used fulfill the following conditions [33]:

- That it is measured with instruments that comply with the regulations of the World Meteorological Organization and the State Institute of Hydrometeorology, and as a result gives values of mean wind speed for 10 minutes, that the data measured at each site are complete, homogeneous and at least 10 years,

- The spatial distribution of the measurement site allows an insight into all the diversity of the current system of the area [33].

4.2. POWER CONTROL TECHNOLOGY FOR WIND TURBINES

Wind turbines have a power control system from the start (to the turbine stopping, rated speed) and the rated speed is the smallest speed the turbine reaches to the greatest power. There are two types of control systems for turbines, which are:

4.2.1. Stall Regulated

In which the distribution of the gradient angle along the blade is constant for all wind speeds, and it is simple and does not require any control system.

4.2.2. Pitch Regulated

The blades can rotate about a diagonal axis during the operation of the turbine as the wind speed changes, so it is possible to reach the optimum gradient angles almost at all wind speeds and to obtain a rather low starting speed and a high shutdown speed In some designs, only the outer part of the blades is movable, the step system is very expensive and requires a somewhat complex but more efficient control system than the breakdown, and to model the power out of the turbine assembly.

4.3. MATHEMATICAL MODEL

To calculate the wind turbines to generate electricity in the Tripoli Airport area, which is located south of the city of Tripoli, about 20 km, shown in Figure 4.1, taken from the reference map of Libya, and the monthly average of the 2008 and 2009 wind speed data will be used at an altitude of (10m) above the ground level obtained from the National Center of Meteorology. Air Libya 2014, shown in Figure 4.2 and in Figure 4.3, the study site was chosen for its surface roughness ($Z_0 = 0.12\ m$), which represents agricultural land with buildings and barriers shown in Table 1.4, specifications of horizontal axis wind turbines that have been implemented [13]

Figure 4.1. Map of Tripoli airport in Libya [51].

Figure 4.2. The monthly average wind speed in the Tripoli port area for the year 2008 [52].

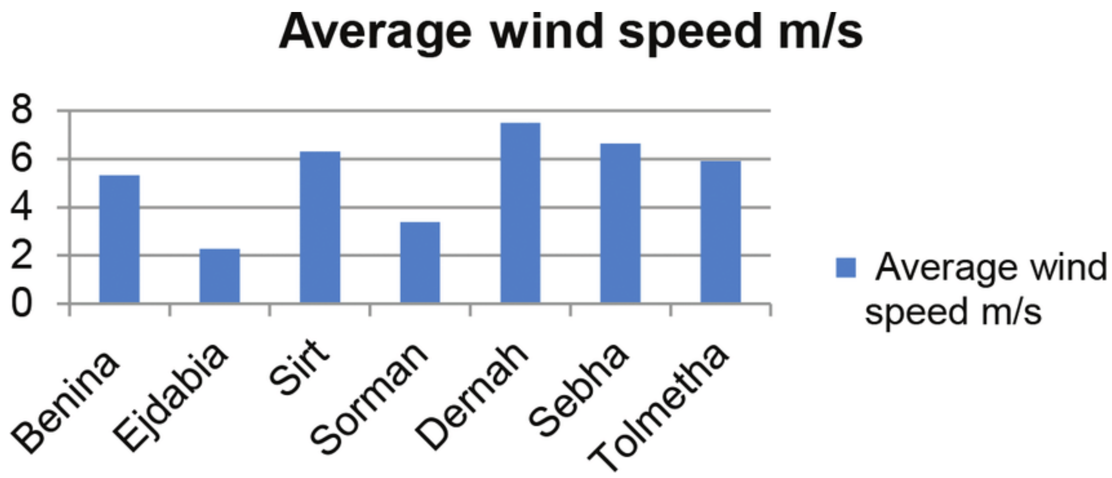

Figure 4.3. Average wind speed in Diffetent cities in Libya [52].

Table 4.1. Specifications of horizontal wind turbines [52].

Power control technology	**V_r m/s**	**V_{co} m/s**	**V_{ci} m/s**	**H_{hub} M**	**P_{rated} KW**	**Wind turbine**	**The manufacture company**
Step	1MW, 24, 2M	1000	54.2	60	4	25	20
Collapse	300KW MK II	300	33	40	4	25	13.43
Collapse	N50/800	800	50	60	4	25	139.9
Step	N70/1500	1500	70	75	4	25	13
Step	12	20	4	75	1500	N77/1500	Nordex
Step	11	25	3	72	64	1000	Suzlon

There are many ways to calculate the availability of wind turbines, the most important of which is the manuel used

Converting the wind speed from the reference height (the height of the atmospheric device) to the height of the wind turbine axis using the logarithmic function (logarithmic law) from the equation

$$\frac{V_{(z)}}{V_{(zr)}} = ln\left(\frac{Z}{Z_0}\right)/ln\left(\frac{Z_r}{Z_0}\right) \tag{4.1}$$

Where is:

- $V_{(z)}$Wind speed at altitude Z
- $V_{(zr)}$Wind speed at reference altitude Z_r
- where ($Z_{r=}$10 m) and Z_0 the length of the surface roughness which depends on the study site
- According to Table 4.2, it is shown in general, knowing that the value that was used is ($Z_{0=}$0.12 m)

Table 4.2. The wavelength of the surface roughness to calculate the vertical distribution of wind speed [52].

Surface Type	**Surface Roughness Length (m) z_0**
Water area	0.001
Open land and some surface features	0.05
Agricultural land with buildings and barriers	0.12
Agricultural land with many trees and forests	0.3

The average wind speed at the height of the wind turbine axis$\bar{V}_{(z)}$

It is calculated by the following equation

$$\bar{V}_{(z)} = \frac{\div\sum_{i}^{N}=1\ V_{(z)i}}{N} \tag{4.2}$$

Where

- N : Wind speed data number
- $V_{(z)t}$ Wind speed at the height of the wind turbine axis to read
- Standard deviation of wind speed at turbine axis height$\sigma v_{(z)}$It is calculated by the following equation

$$\sigma v_{(z)} = \sqrt{\frac{1}{N-1}[\sum_{i=1}^{N} V(z)i^2 - N\overline{N}^2\ (z)]} \tag{4.3}$$

The dimensionless form factor () for the average wind speed is calculated from the following equation

$$K = \left[\frac{\sigma V_{(z)}}{\overline{V}_{(z)}}\right] - 1.086 \tag{4.4}$$

Scale parameter (C) is calculated with the equation, the measurement factor, or the characteristic characteristic of wind speed, is the speed variable that depends on the average wind speed at the study site

$$\mathrm{C} = \overline{\mathrm{V}}_{(\mathrm{z})} \left[0.568 + \frac{0.433}{\mathrm{K}}\right] \tag{4.5}$$

4.4. EXAMPLE FOR CALCULATING WIND VOLTAGE IN THE TRIPOLI AIRPORT AREA

Due to the erratic winds, windmills are designed based on average wind speeds. The Tripoli airport area is taken as a numerical example and a wind energy calculation is presented based on the average measured wind speeds (m/s) for the period from 2010, Table 4.3. Wind power can be calculated using the expression, where the available windmill power is proportional to the third power of the wind speed and the second power of the windmill's diameter [52].

Table 4.3. Measured values of average wind speed (m/s) in the period (2010) [52].

		From (2010)
Station	Anemometer height (m)	Mean wind speeds Wsr (m / s)
Tripoli Airport	40	6.2
Darnah	40	8.0

According to the following equation and the power of wind as Figure 4.3.

$$N = \frac{d^2 w^2}{k} [kW] \tag{4.6}$$

Where is

- N - windmill power [kW],
- d - diameter of the rotating circle [m],
- w - wind speed [m / s],
- K - power factor.

It follows that in the same diameter of the mill wheel, at twice the wind speed, eight times the power is achieved according to the cubic law.

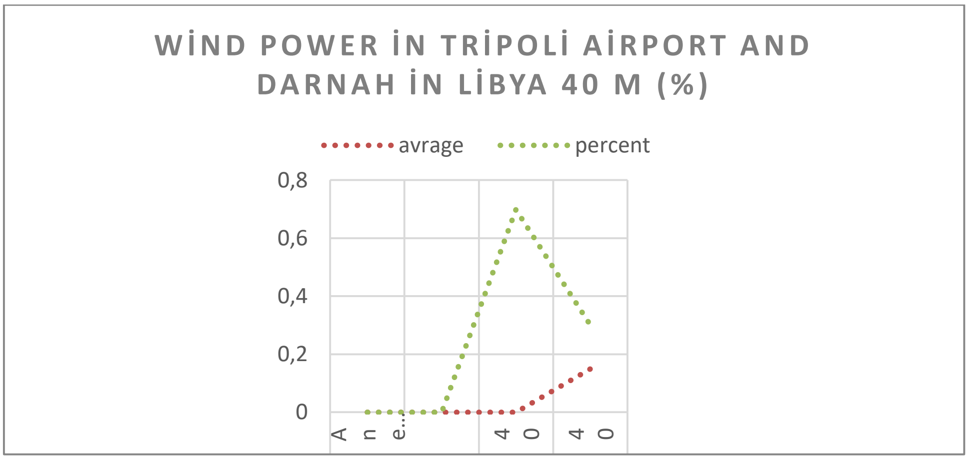

Figure 4.4. The wind power in Tripoli airport and Darnah.

The power factor (k) of a windmill consists of two partial factors that take into account thermodynamic and hydrodynamic conditions [20]:

$$k = k_1 x k_2 \tag{4.7}$$

$k_1 = f\ (p_0, t_0) -$ thermodynamic coefficient depending on the state of the surrounding atmosphere

$k_2 = f\ (\eta) -$ hydrodynamic coefficient depending on the degree of action of the windmill whose theoretical maximum value is 59% [20].

For the calculation of windmill power, the power coefficient k was used, which under standard conditions (temperature = 0, air pressure = 1013.25 mb) is 3414. The amount of power coefficient is taken from the literature [20]

Dependence of the coefficient (k) on pressure and temperature [20].

For an easy comparison

- The diameter of the windmill circle (d) is one meter, and the weather conditions are taken according to the literature [20] where the temperature is zero and the air pressure is 1013.25 megabytes, although some different conditions can be taken according to the work.
- Hourly wind power for arbitrarily selected sites will be:
- For the Tripoli region, the average wind speed is 2.39 m/s, which means that the wind energy per hour is:

$$\boldsymbol{N_{Tripoli}} = \frac{d^2 x W_{sr}^3}{3414}$$

$$\boldsymbol{N_{Tripoli}} = \frac{1^2 x 6.2^3}{3414}$$

$$N_{Tripoli} = 0{,}0698[kW] \qquad (4.8)$$

In the Darnah region, the average wind speed is 2.04 m / s, which means that the wind energy per hour is:

$$\boldsymbol{N_{Darnah}} = \frac{1^2 x 8.0^3}{3414} \qquad (4.9)$$

$$N_{Darnah} = 0.1500[kW]$$

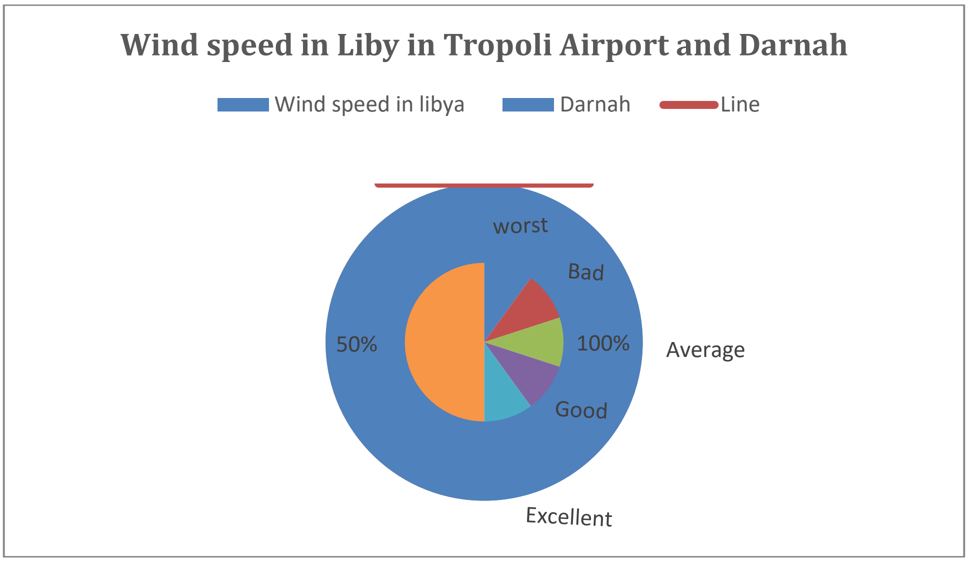

Figure 4.5. Wind speed in Liby in Tripoli Airport and Darnah.

The calculation of wind energy was performed by the method of arithmetic mean speed, and the energy is obtained as follows

$$E_{sr} = 24xN_{sr}E_{sr} \quad (4.10)$$

$$= 24x\ \frac{d^2xw_{sr}^3}{3414} \quad (4.11)$$

$$E_{sr} = \frac{24}{3414}xd^2x\ \left[\frac{1}{24}\sum_{i=1}^{24} wi\right]^3\ [kWh] \quad (4.12)$$

Where is:

Esr - energy in one day (kWh)

Nsr - hourly power based on medium speed (kW)

wsr - average wind speed for a period of 24 hours (m / s)

wi - measured hourly wind speed (m / s)

d - diameter of the rotor circuit (m)

24 - a period of one day [20]

Wind energy in one day for the area

Tripoli Airport Area

$$\mathrm{E_{sr}} = \frac{1}{142} \text{ x } 6.2^3$$

$$E_{sr} = 1.6784 \ [kWh]$$

Darnah Area

$$\mathrm{E_{sr}} = \frac{1}{142} \text{ x } 8.0^3$$

$$E_{sr} = 3.6056 \ [kWh]$$

4.5. ECOLOGICAL CHARACTERISTICS AND CONTRIBUTION TO ENVIRONMENTAL PROTECTION

The production of electricity in thermal power plants using fossil fuels emits pollutants generated in the combustion process, while the production of electricity in wind power plants is not accompanied by this harmful phenomenon for humans and the environment [7].

The amount of pollutant depends on the type of fuel and the type of thermal power plant. For coal, these quantities are significantly higher than for natural gas, and vary depending on the performance and age of the plant itself. In addition to air pollution, as a negative consequence of combustion, there is water consumption, ie. water heating in the cooling part of a thermal plant [7].

4.5.1. Aspects of Noise

There is aerodynamic and mechanical noise. During the operation of wind turbines, noises are generated due to air flow around the blades and columns (aerodynamic noise) and noises during the movement of gears (mechanical noise) [7].

The strength of the noise generated during the operation of wind turbines depends on:

- design and size of wind turbines
- wind speed
- distances from wind turbines
- noise in space (background noise) [7].

Noise reduction is a priority for many wind turbine research teams. The largest companies have also achieved the best results, highlighting the low noise level produced by their wind turbines. Specially shaped blades and wind turbines without a toothed multiplier contribute to this. This feature in wind turbine operation is particularly important for a unit or smaller number of wind turbine units operating in the vicinity of a settlement. Relative noise reduction from wind turbine can also be considered a natural noise that is heard at higher wind speeds, and which is relatively higher than the noise of the wind turbine [7].With the distance from the wind turbines, the noise intensity decreases as shown in Figure 4.6 [35].

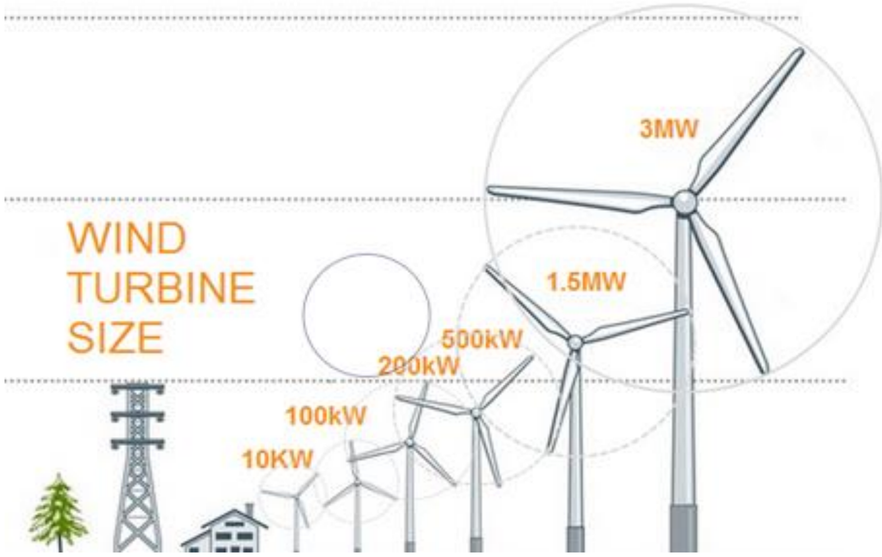

Figure 4.6. Wind turbine noise intensity at different distances from the wind turbine shaft [35].

According to Danish regulations, the minimum distance for individual turbines from the nearest residential house should be 200 m, which corresponds to a noise level of 45 dB, while this distance for wind farms is 500 m [7].

By careful selection of the site, and placing the wind turbines in locations sufficiently far from settlements and other facilities, it is possible to avoid noise consequences [7].

4.6. ELECTROMAGNETIC INTERFERENCE

Wind turbines can cause interference to radio and microwave reception used to transmit radio and television signals, communications and navigation. Due to the reflection of electromagnetic signals on the wind turbine blades, unwanted interference can occur, and the effect is more pronounced for metal that strongly reflects electromagnetic waves compared to glass plastic and wood [7].

When choosing the location of the wind farm, it is necessary to avoid transmission lines between the transmitter and receiver, that is, it is necessary to place the wind farm at the specified distances from individual facilities [7].

4.7. VISUAL DEGRADATION OF SPACE

The visual impact of a wind farm on the environment depends on the perception of the observer, the landscape in which the plant is located and the visual characteristics of the plant (number, size, layout of wind turbines, color, shaft design, etc.). A specific wind power plant (a certain number and size of wind turbines) will visually affect the environment in one way or another depending on the characteristics of the environment in which it is located. Wind turbines, depending on the rated power, have a shaft height of 30 to 65 meters and therefore can be seen in a wider area. Depending on the type, size, color, number and distribution of the wind turbines as well as the openness of the space, it will be somewhat noticeable [7].

The locals, ie. Public opinion greatly influences the acceptance or rejection of a wind farm. Therefore, when constructing the access road and roads between wind farms, care must be taken when choosing the location of the station, as well as when choosing the size of the modules, the color of the blades and columns [7].

4.8. SOIL EROSION EFFECT

Soil erosion occurs during construction work during the construction of wind farms. Therefore, when constructing the access road and roads between wind turbine units, it is necessary to take into account and minimize this effect [7].

4.9. DANGERS FOR BIRD SPECIES

The impact of wind farms on the animal world is very small, perhaps only slightly greater during the construction of the power plant, while in its operation we can only talk about the effect on birds [7].

The impact on birds can be considered through direct impact such as collision hazards and indirect impact which includes visual and audible disturbances to birds. For migratory birds, they generally fly at altitudes higher than the height of the turbine, but it is recommended to exclude them. Locations on bird migration routes. It is also recommended to exclude sites known as the habitat of a large number of birds. Studies have shown that the impact of wind farms and transmission lines is equal to that of bird species [7].

4.10. LAND TRANSFER

When choosing a potential site for the operation of wind farms, the areas intended for the construction of residential and commercial buildings are excluded, i.e. areas designated for cities, settlements, facilities construction areas and tourism activities that cannot be carried out in the immediate vicinity of wind farms [7].

Wind farms are usually located in uncultivated areas, ie. Areas unsuitable for other activities or in meadows, pastures and agricultural lands. Also, they occupy much smaller areas compared to other power plants of the same capacity (Table 8) [7].

Table 8. The average area required to produce 1 GWh of electricity in different types of power plants [7].

4.11. WASTE GENERATION

During the construction of wind farms, non-hazardous and hazardous waste is generated from the remains of construction and packaging materials, as well as municipal waste as a result of the work and stay of people on the construction site. Waste disposal at the project site may have negative impacts on soil, water and the environment as a whole. For all types of waste that will be produced during use, it is necessary to ensure compliance with the Waste Act, the Waste Types Act and the Waste Management Act adopted on its basis [16].

As for dismantling the wind farm, it includes [7]:

- Dismantling and dispatch of wind turbine generators, removal of foundations and auxiliary facilities,
- Landscaping.
- Generators that are no longer used are disassembled into basic parts and shipped to appropriate locations. Some parts can be reused or recycled. Lubricants and oils from hydraulic systems that must be collected and can be used as fuel in thermal power plants also appear as waste materials. Landscaping, after all wind farms have been removed, can be achieved by growing suitable plants [7].

4.12. ASSESSMENT OF WIND ENERGY IN LIBYA IN THE EASTERN AND CENTRAL REGIONS

In order to discover potential locations for wind energy applications, wind characteristics information will be useful and then increase the chance of contributing to diversifying energy savings and reducing increasing environmental stress. In this study, renewable energy was studied in Derna and Al-Maqron, and Sirte was studied by studying wind characteristics based on the average daily wind speed. Statistical analysis of SPSs and Weebol factors were performed to assess wind characteristics based on the overall acceptance of the Weebol distribution for predicting the frequency of wind speed.The distribution of Whippool for the three regions chosen for the investigation shows that the Whippool model and data is very well agreed. Weibull factors were also achieved that characterize the wind properties of portion of the coastal areas of Libya in the Mediterranean.

4.12.1. The Information Used

The average wind speed for the cities of Derna, Al-Maqron and Sirte have been picked from the database of the National Center of Renewables, Tripoli for analysis. Areas chosen. The geographical length and width of each of the three cities as Figure 4.7.

Figure 4.7. The selected sites are east and central of the Libyan coast, namely, Derna, Al-Maqron and Sirte [51].

Table 4.4. Latitude and longitude plans for the geographical locations of the selected cities.

Site	Latitude	longitude
Dernah	$22^{\circ\prime}E$	$22^{\circ}38'E$
Al-Maqron	$31^{\circ}35'N$	$19^{\circ}59'E$
Sirte	$31^{\circ}12'N$	$16^{\circ}35'E$

4.12.2. Relationships Used

The wind speed available for the three selected cities (Durna, Al-Maqron, Sirte) was analyzed for the study in Libya for the year 2003, form factor (k) and speed Wind potential (Lab view) and maximum wind speed in addition to the wind energy density WPD at 80m and 10m above sea level, the mean wind speed and standard deviation for two months of data for each city were calculated using the relationship 1 and 2 as follows:

$$F(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^{\kappa}\right] \quad (4.13)$$

$$wind\ speed\ = f(v) \quad (4.14)$$

Weipol scaling factor $c = "m\ /s"$

Dimensional loipol form factor (without unit)

Cumulative distribution function for observation of wind speed

$$P = \frac{1}{2}\rho c^3 \left(1 + \frac{3}{k}\right) \quad (4.15)$$

Wind power density

$$P = "W/m^2" \quad (4.16)$$

Wind density of the site

$$\rho = " 1.23kg/m^2 \quad (4.17)$$

wind power density P_2 at height h_2 it can be calculated if the power P_1at height h_1 is known using the relationship

$$\bar{V} = \frac{1}{n}\ (\sum_{i=1}^{n} \bar{V}_{\mathrm{i}}) \quad (4.18)$$

$$\sigma = \left[\frac{1}{n-1} \sum (v_i - \bar{V})^2\right]^{\frac{1}{2}}$$

The Weibel distribution variables k and c for data were calculated using the following trade

$$k = \left(\frac{\sigma}{\bar{v}_i}\right)^{-1.86} \quad (4.19)$$

$$c = \left(\frac{1}{n} \sum_{i=1}^{n} v_i^k\right)^{1/k} \quad (4.20)$$

The variables k and c represent the inherent wind characteristics of the locations studied. The scale factor c indicates whether, the wind is high or low at the given location while k is a form factor indicating wind stability. The Whippool distribution function is generally an acceptable method for predicting the frequency distribution of wind speed. The probability mass function as the Weibull function uses the distribution of wind speed for a wind-abundant location during the relationship. The relationship is known as the Whippool function

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1}\ \exp\left[-\left(\frac{v}{c}\right)^{k}\right] \quad (4.21)$$

cumulative mass function (CDF) knowledge of the relationship

Table 4.5. Monthly average speed of the month ($\bar{v}$), standard deviation (SD), form factor (K), scale factor (C), potential wind speed (Vmp), maximum wind speed (V max), wind energy intensity at a height of 10 m (WPD) and wind intensity at a height of 80 m (WPD) for the city of Derna.

Dernah	$\bar{v}$	**SD**	**K**	**C**	**Vmp**	**V max**	**WPD on 10m**	**WPD on 80m**
January	5.1091	2.2147	4.734072	5.7723	4.69	7.33	261.44	637.4
February	9.445	9171	2.78E-06	10.6833	7.69	15.03	1880.6	4584.97
March	9.3913	4.8554	3.411075	10.6243	7.66	14.82	1818.36	4433.2
April	8.8379	3.9021	4.575034	9.9762	8.02	12.77	1364.5	3326.69
May	8.4327	3.8011	4.402169	9.5196	7.56	12.31	1200.48	2926.8
June	9.3353	2.9501	8.522014	10.3742	8.64	10.84	986.11	2366.61
July	10.8926	2.2991	18.05374	11.8176	11.38	12.52	1577.23	3785.27
August	9.9013	2.6423	11.6708	10.8457	10.17	11.9	1345.29	3228.63
September	8.7495	3.6103	5.188697	9.8413	8.19	12.23	1258.64	3068.6
October	7.6548	3.3956	4.535365	8.6576	6.94	11.11	894.31	2180.36
November	6.7603	3.4568	3.48179	7.6471	5.56	10.6	673.27	1641.46
December	9.0212	4.3422	3.896291	10.165	7.78	13.67	1545.1	3766.99

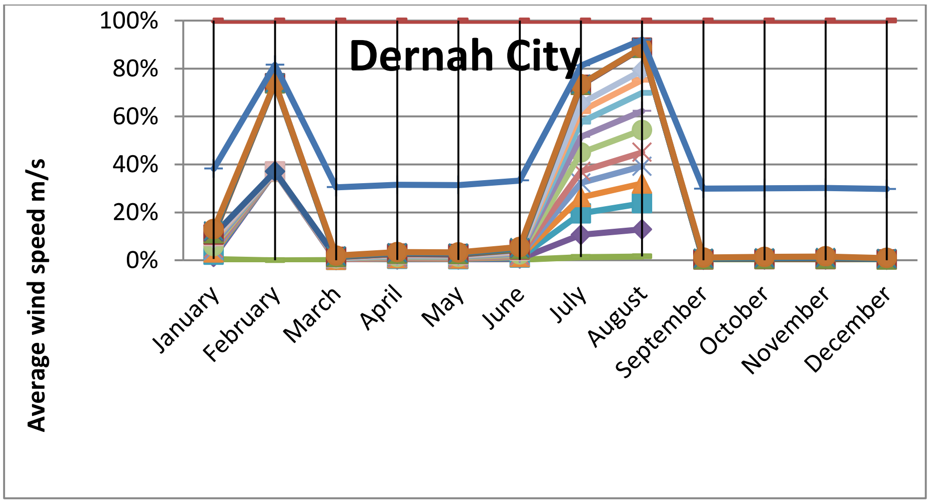

Figure 4.8. Monthly average speed of the month, Derna City.

Table 4.6. Monthly average speed of the month ($\bar{v}$), standard deviation (SD), form factor (K), scale factor (C), potential wind speed (Vmp), maximum wind speed (V max), wind energy intensity at a height of 10 m (WPD) and wind intensity at a height of 80 m (WPD) for the city of Al Maqron.

Maqron	$\bar{v}$	SD	K	C	Vmp	V max	WPD on10 m	WPD on 80m
January	6.9903	3.436	3.74717	7.9104	5.94	10.71	726.71	1771.75
February	9.0023	5.1847	2.79069	10.1539	6.55	15.26	1704.69	4156.08
March	8.1347	4.8077	2.659695	9.1362	5.71	14	1263.78	3081.12
April	8.3503	3.9441	4.03555	9.4467	7.29	12.51	1207.2	2943.19
May	7.9645	3.3878	4.903518	9.0086	7.38	11.34	982.71	2395.86
June	7.544	3.4182	4.359893	8.5309	6.76	11.06	866.67	2112.97
July	7.7301	3.8261	3.699113	8.7424	6.53	11.88	985.31	2402.21
August	7.0751	3.549	3.608323	8.0016	5.91	10.96	761.89	1857.51
September	7.0822	3.4772	3.755136	8.0159	6.02	10.84	755.63	1842.25
October	5.9304	2.5282	4.883228	6.6938	5.48	8.43	403.68	984.19
November	6.4463	2.7039	5.032862	7.2743	6	9.1	513.17	1251.12
December	7.8361	4.3151	3.033493	8.8495	6.01	12.87	1095.11	2699.91

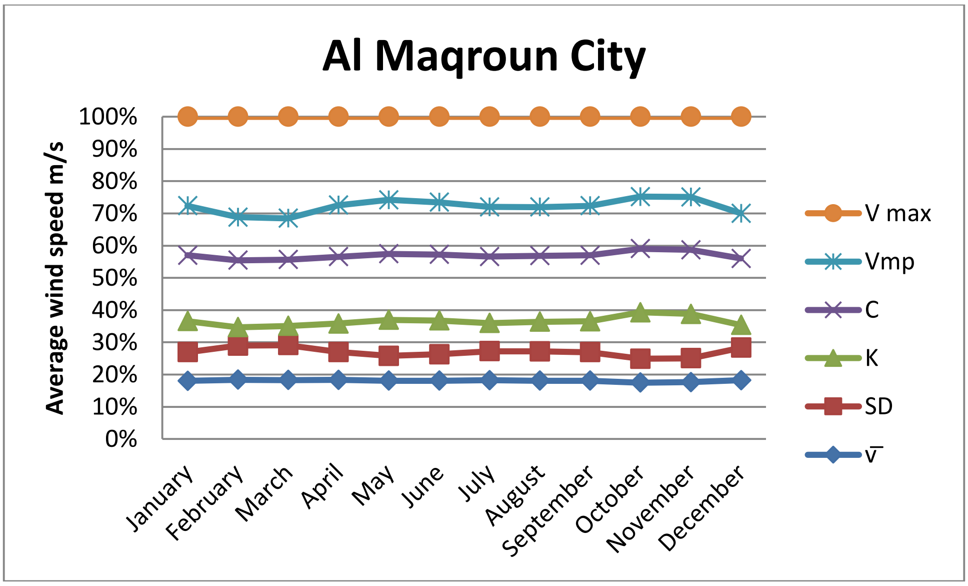

Figure 4.9. Monthly average speed of the month, Al Maqroun City.

Table 4.7. Monthly average speed of the month ($\bar{v}$), standard deviation (SD), form factor (K), scale factor (C), potential wind speed (Vmp), maximum wind speed (V max), wind energy intensity at a height of 10 m (WPD) and wind intensity at a height of 80 m (WPD) for the city of Sirt

Sirt	$\bar{v}$	SD	K	C	Vmp	V max	WPD on 10m	WPD on 80m
January	7.4245	3.2939	4.534189	8.3954	6.73	10.77	815.57	1988.38
February	8.4495	4.2663	3.564594	9.5595	7.03	13.14	1304.62	3180.69
March	7.1796	3.7825	3.293651	8.1188	6.18	10.88	776.51	1893.15
April	7.7374	3.7328	3.879736	8.7601	6.66	11.73	975.44	2378.14
May	7.2827	2.9291	5.441746	8.1927	6.89	10.07	715.5	1744.41
June	6.0175	2.7768	4.214257	6.8035	5.33	8.9	444.54	1083.79
July	5.6871	2.4871	4.657014	4.4043	5.18	8.16	358.93	875.09
August	5.2291	2.3138	4.556466	5.8958	4.73	7.56	282.02	687.57
September	6.4005	2.6567	5.131931	7.2365	6	9.01	502.13	1224.21
October	6.1653	2.4219	5.685705	6.9543	5.91	8.47	431.78	1052.69
November	7.0595	3.0707	4.703899	7.9838	6.47	10.15	693.16	1689.94
December	8.2718	3.58	4.748032	9.3421	7.59	11.85	1107.26	2699.53

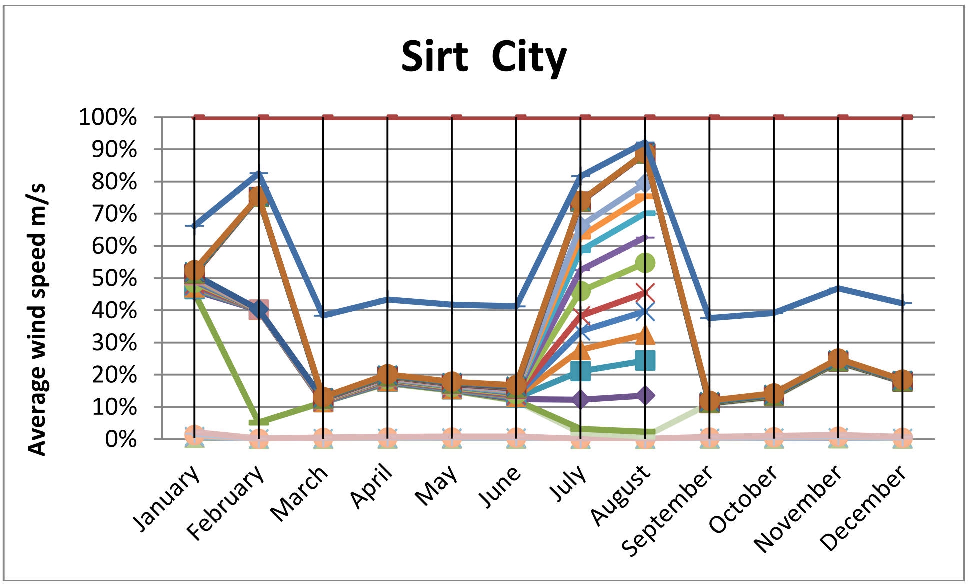

Figure 4.10. Monthly average speed of the month, Sirt City.

Cumulative distribution function If the wind speed is 4 m/s (and used as the starting speed to generate electricity) for wind turbines, the city of Derna will have a possibility of operating 100% in the months of July and August, and the lowest possibility of operating 87% in November, and the city of Al-Maqron will be It has the highest operating potential of 94% in May and the lowest operating potential of 87% in the months of June and July. As for the duration and speed curves, it is a graph of the wind speed in the months of the year, and from these graphs we conclude that the winds in the three cities are suitable for the application of wind electricity on a large scale. Broad, this study may be a reference due to the scarcity of studies on wind sources in Libya, and the same study can be conducted on other cities in Libya.

The wind speed for 3 cities was calculated on the spss program and the average wind speed, maximum and minimum speed, and ANOVA analyzed using the spss program and the results were according to the Table 4.8 and Figure 4.10, Figure 4.11 and Figure 4.12.

Table 4.8. Statistics For 3 cities wind Dernah, Al – Maqron and Sirt on spss programme.

		Dernah(V)	Al-Maqron(V)	Sirt(V)
Mean		8.6211	7.5905	6.9920
Median		8.9295	7.6371	7.1196
Mode		5.11[a]	5.93[a]	5.23[a]
Minimum		5.11	5.93	5.23
Maximum		10.89	9.35	8.45
Sum		103.45	91.09	83.90
Percentiles	25	7.8493	7.0115	6.2241
	50	8.9295	7.6371	7.1196
	75	9.4176	8.0922	7.6592
a. Multiple modes exist. The smallest value is shown				

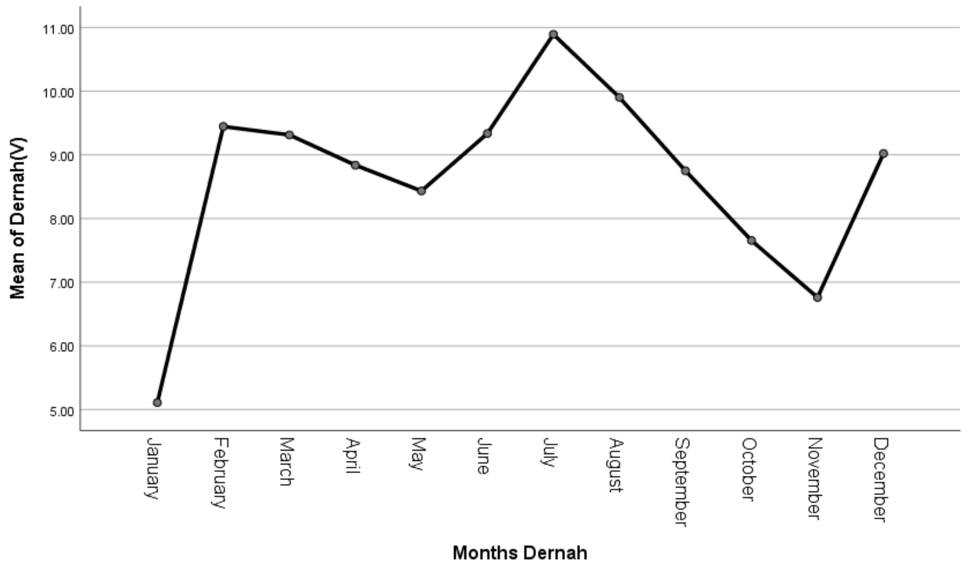

Figure 4.11. Analysis of variance (ANOVA) of monthly wind speed in the city of Dernah.

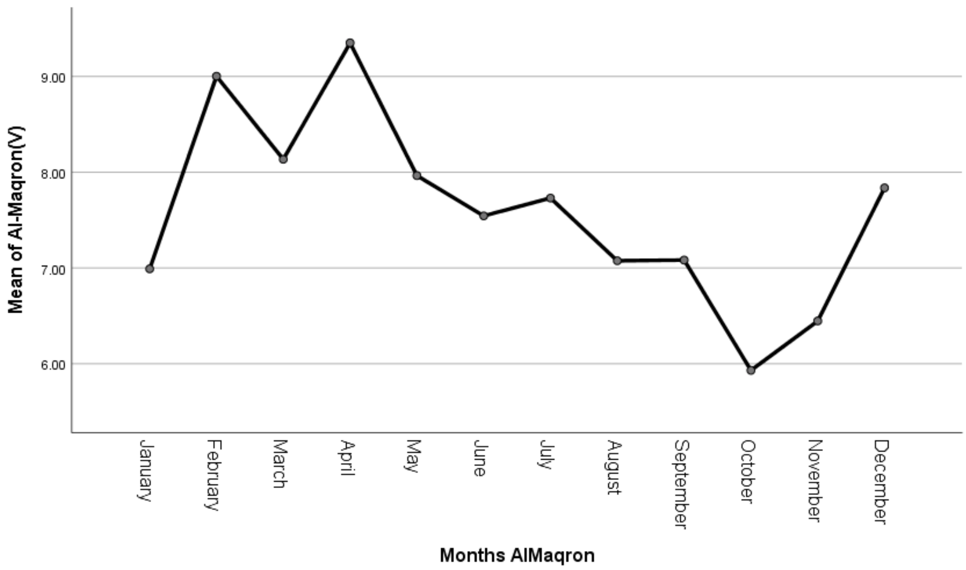

Figure 4.12. Analysis of variance (ANOVA) of Monthly wind speed in the Al Maqroun City.

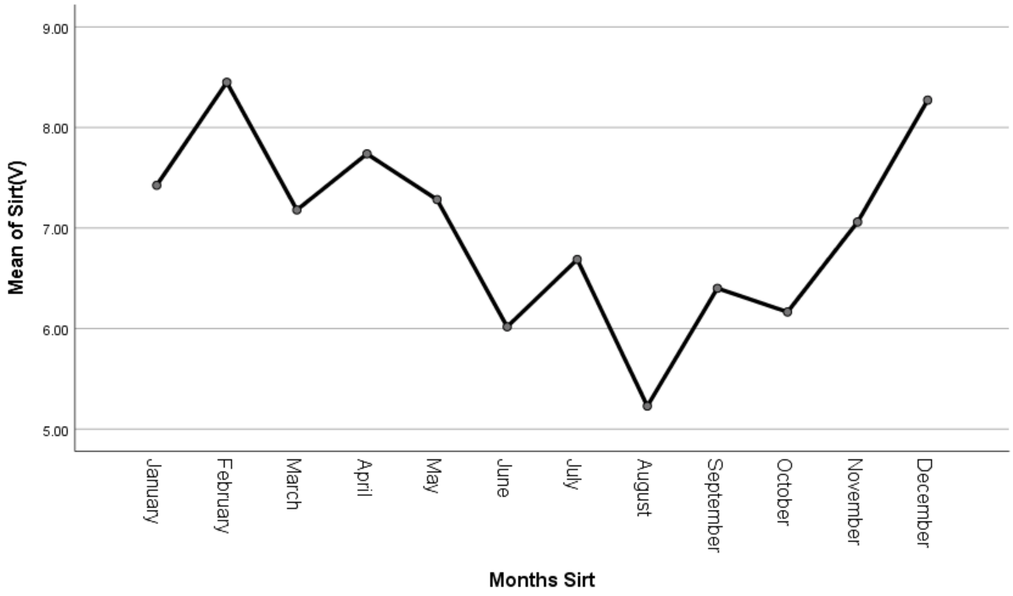

Figure 4.13. Analysis of variance (ANOVA) of Monthly wind speed in the Sirt City.

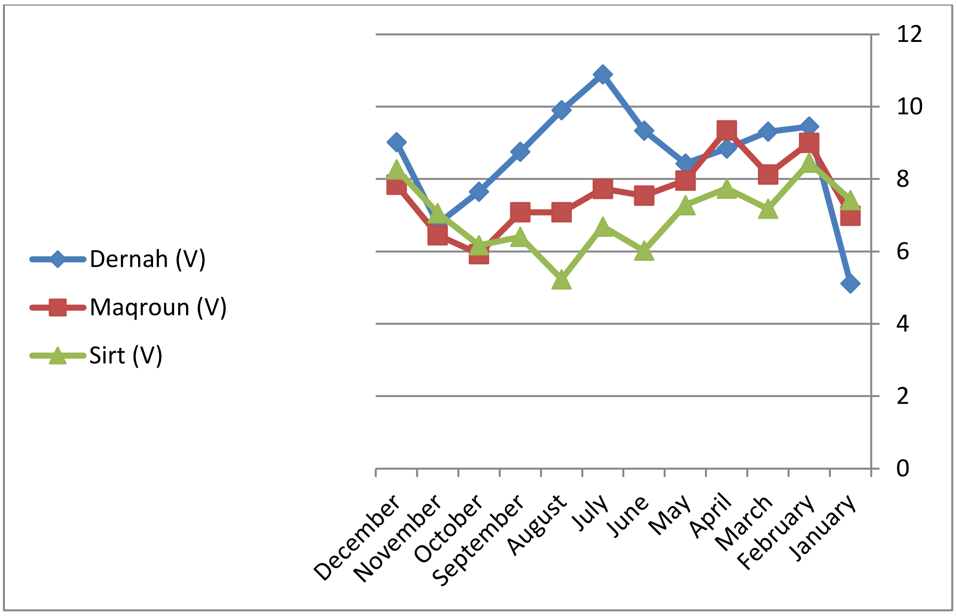

Figure 4.14. Analysis of variance of Monthly wind speed for three cities Dernah, Al Maqroun, and Sirt.

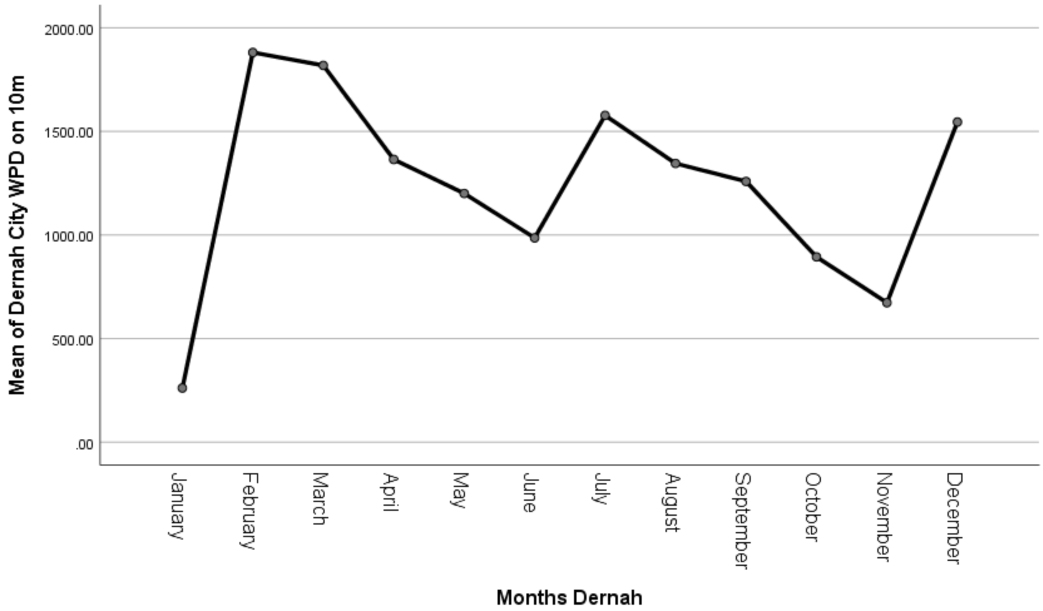

Figure 4.15. Analysis of variance (ANOVA) of Wind energy intensity at an altitude of 10 m for the Dernah city.

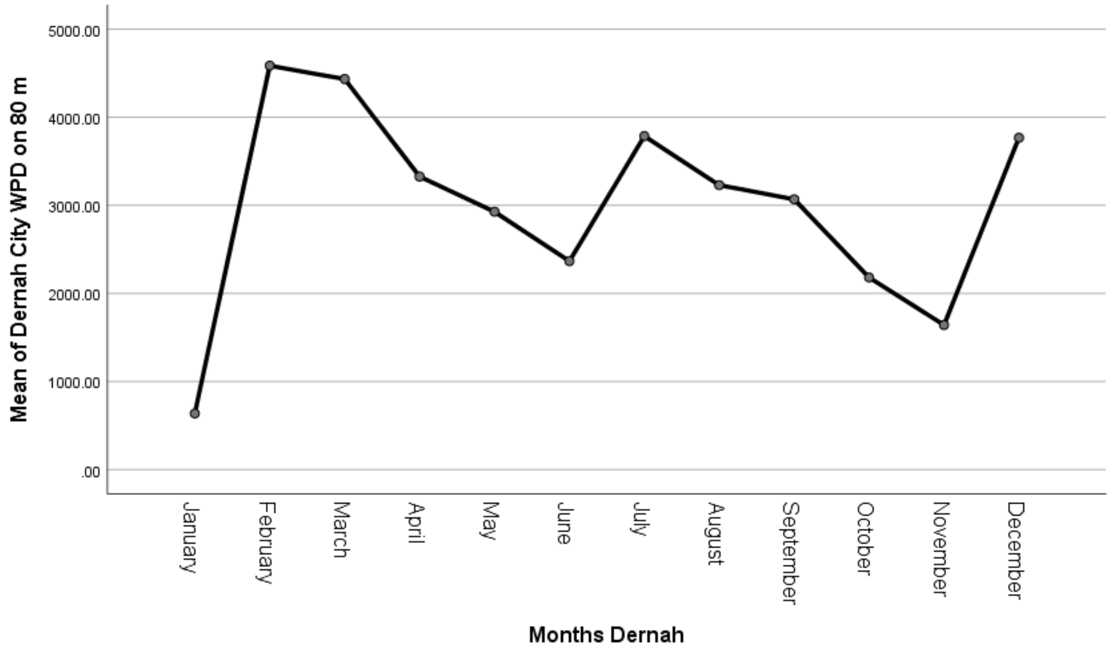

Figure 4.16. Analysis of variance (ANOVA) of Wind energy intensity at an altitude of 80 m for the Dernah city.

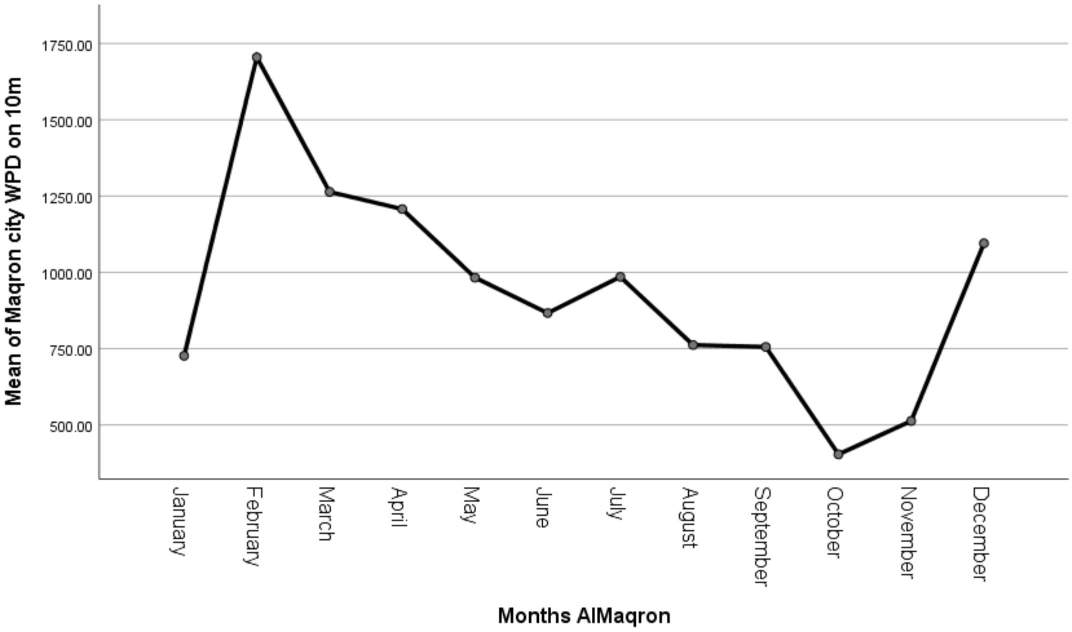

Figure 4.17. Analysis of variance (ANOVA) of Wind energy intensity at an altitude of 10 m for the AlMaqroun city.

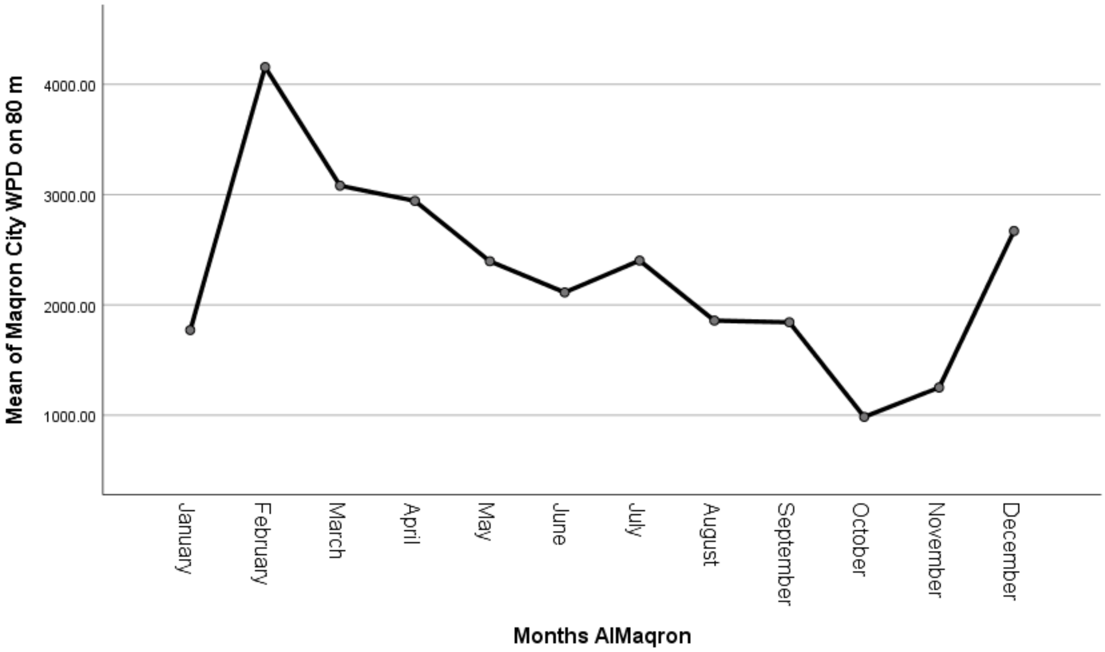

Figure 4.18. Analysis of variance (ANOVA) of Wind energy intensity at an altitude of 80 m for the AlMaqroun city.

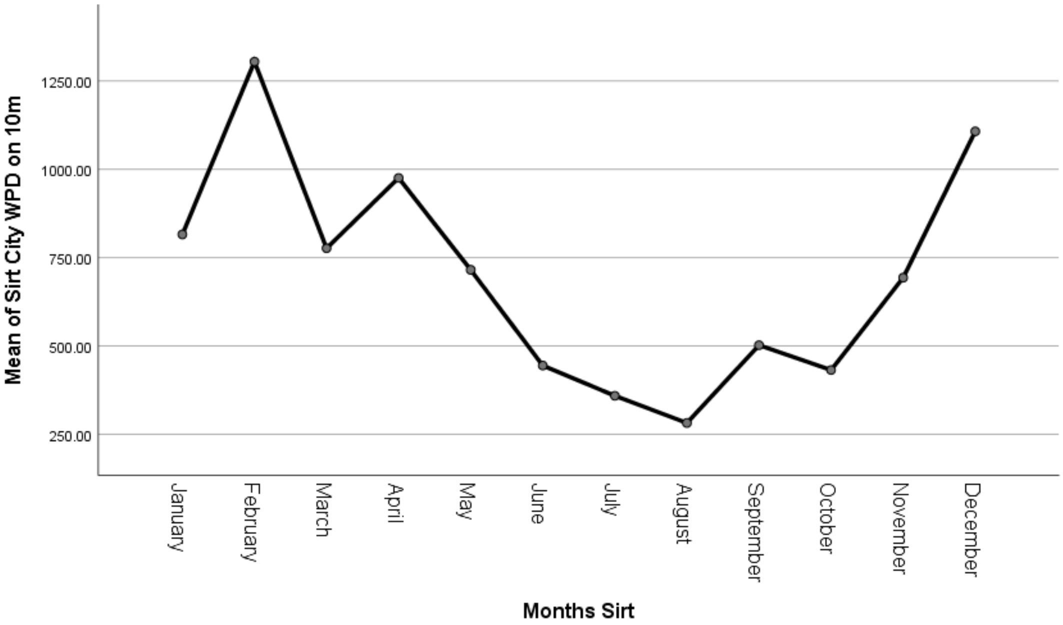

Figure 4.19. Analysis of variance (ANOVA) of Wind energy intensity at an altitude of 10 m for the Sirt city.

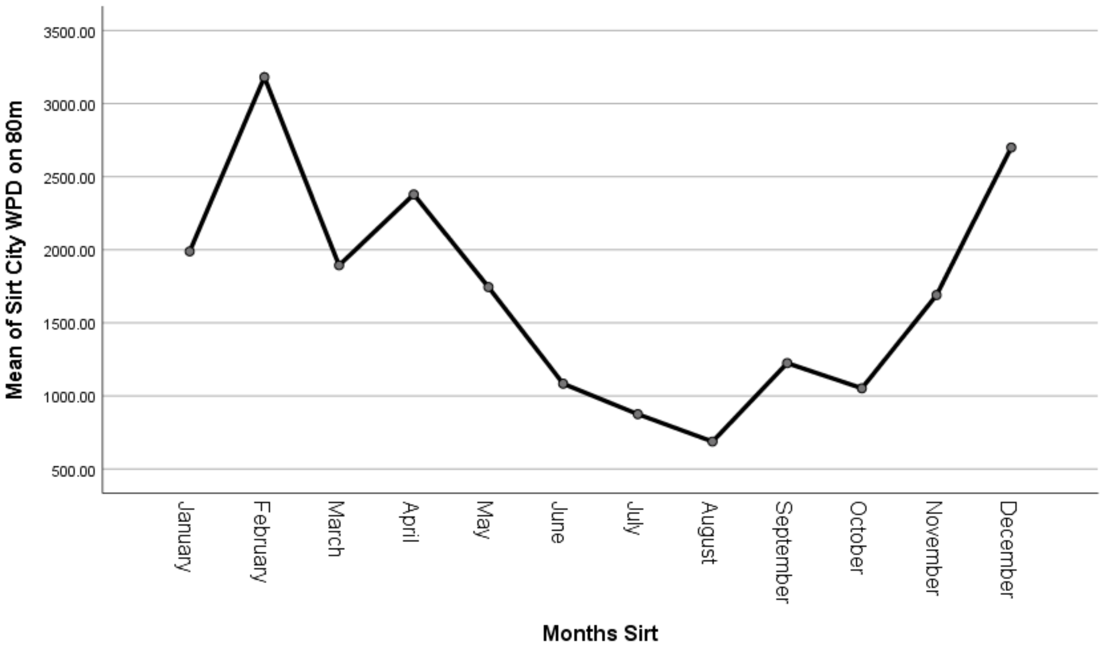

Figure 4.20. Analysis of variance (ANOVA) of Wind energy intensity at an altitude of 80 m for the Sirt city.

4.13. DISCUSSION

Thesis entitled The most suitable location for the construction of wind farms on the Red Sea coast in the Kingdom of Saudi Arabia, by Al-Khalif and Siam, for the year 2018 submitted to the Department of Geography, King Saud University in Riyadh, originally, this test tried to repeat the test No. 4.5, but Because the parameters were entered differently, it was not possible to obtain results equal to wind power in the test 2.5.Although the results obtained are not the same, the results are very useful for making a comparison with what has already been done. The results are found in the Table 4.9 these results used spss to analysis it

Table 4.9. The most suitable locations for setting up wind farms on the Red Sea coast in the Kingdom of Saudi Arabia [52].

Alwajeh station	$\bar{v}$	**SD**	**K**	**C**	**V max**
January	8.29	4.27	18.64	9.60	25.01
February	9.24	4.24	20.35	10.48	35.30
March	9.59	4.94	21.25	10.94	38.28
April	9.51	4.90	20.8	10.71	37.50
May	9.59	4.94	20.75	20.75	10.69
June	9.62	4.95	20.79	20.79	10.71
July	8.74	4.50	19.12	19.12	9.85
August	9.20	4.74	20.07	20.07	10.34
September	9.59	4.94	20.52	20.52	10.57
October	8.27	4.26	18.59	18.59	9.57
November	7.56	3.89	17.66	17.66	9.09
December	7.68	.96	17.13	17.13	8.82

PART 5

CONCLUSION

The aim of this paper was to analyze the potential of wind energy in the region of Libya by comparing the characteristics of wind in several cities, including the Tripoli airport area, the city of Derna, the city of Al-Maqron, and the city of Sirte. And the tuber region, to estimate the strength of the wind. The average wind speed is 40 m above the ground, in the Tripoli airport area 6.2 m / s, and in the Derna area 8.0 m / s. Using these data, the energy potential was calculated, by the method of the mean value of the wind speed of one meter in diameter, for the two sites. Accordingly, the annual achieved energy, which increased by 40% for the Tripoli airport area, is 31 kWh/year and 49 kWh/year in the Derna area. Based on the results obtained, it can be concluded that the potential of strong wind energy in the Derna region, due to the relatively high wind speeds, there is the possibility of using slow-moving wind turbines, but with significantly less economic effects.

Wind speed is the primary criterion to start from when designing all the wind turbines that will be located on the site, their number and their spatial distribution. In order to be able to make a better assessment, it is important to know the directions from which the wind is blowing (the wind rose) and the distribution of wind speed. Other important wind data are the long-term air density at the site and the intensity of the wind turbulence at the site, which affects the determination of the load on the rotor blades and the life expectancy of the wind turbines themselves.

The wind characteristics were compared in terms of speed in each of these cities, using monthly data for them, between 2003 and 2010, and Excel and Spss were used to apply statistical methods and analyze the available climate data, and the results of the study showed that there is a possibility of energy production. Electricity in this city of Derna, for example, where wind speeds are favorable for the production of wind energy and it turns out that wind speed is promising in the production of electrical energy in the month of June and August.

5.1. RECOMMENDATIONS

Wind energy, as a form of sustainable energy, is the future of electricity generation. However, the cost of early research and development is a serious problem for enterprises. Fortunately, this study recommends support from the authorities responsible for wind power generation as the wind energy industry enjoys healthy growth and becomes more important in the global economy.

Another important issue to focus on is recycling. Nowadays some waste can be reused or recycled but not much of it can be treated as resources. The trend of the wind energy industry is that more and more wind turbines will be installed. However, the problem of how to deal with more and more waste from wind farms must be resolved. This is the goal that drives governments, companies and scientists to collaborate to find feasible ways to choose materials and treat waste. This way wind energy can be truly sustainable energy.

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RESUME

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