T.C.
BOLU ABANT İZZET BAYSAL UNIVERSITY
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DETERMINATION OF WIND ENERGY POTENTIAL IN BOLU ABANT İZZET BAYSAL UNIVERSITY CAMPUS

MASTER OF SCIENCE

ERCAN ÇİÇEK

BOLU, NOVEMBER 2019

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THE DEPARTMENT OF PHYSICS

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APPROVAL OF THE THESIS

DETERMINATION OF WIND ENERGY POTENTIAL IN BOLU ABANT IZZET BAYSAL UNIVERSITY CAMPUS submitted by **Ercan ÇİÇEK** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in the **DEPARTMENT OF PHYSICS, The Graduate School of Natural and Applied Science of Bolu Abant Izzet Baysal University in** 26/11/2019 by,

Examining Committee	**Members Signature**
Supervisor **Prof. Dr. Haluk DENİZLİ** **Bolu Abant Izzet Baysal University**	....
Member **Assoc. Prof. Dr. Aliekber AKTAĞ** **Bolu Abant Izzet Baysal University**	....
Member **Asist. Prof. Dr. Ali YILMAZ** **Giresun University**	....

Prof. Dr. Ömer ÖZYURT ....

Director, Graduate School of Natural and Applied Sciences

To My Family

DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Ercan ÇİÇEK

ABSTRACT

DETERMINATION OF WIND ENERGY POTENTIAL IN BOLU ABANT IZZET BAYSAL UNIVERSITY CAMPUS
MSC THESIS
ERCAN ÇİÇEK
BOLU ABANT IZZET BAYSAL UNIVERSITY GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF PHYSICS
(SUPERVISOR: PROF. DR. HALUK DENİZLİ)
BOLU, NOVEMBER 2019

Today, most of the energies consumed in many countries of the world are finite amounts and consumable energy types obtained from petroleum and coal such as fossil-derived gasoline, natural gas, and diesel. The harm that these types of energy cause to the atmosphere and the environment is destroying the balance in nature, increasing unrest among societies, and threatening many living beings. On the other hand, with the increasing world population and technological advances, the need for energy is increasing. This has forced countries to seek new sources of energy to meet their energy needs. In addition to fossil-derived energies, renewable, theoretically endless, the use of energy from sources has become compulsory, such as the generation of electrical energy through the use of advanced and emerging technologies, such as wind and sun. However, geographically, it is necessary to investigate and analyze whether a location or region has the potential to generate sufficient energy before generating electricity from wind or sun.

In this study, wind data obtained for 12 months from a location neighboring the Abant Izzet Baysal University Campus in Bolu were analyzed and wind potential was determined.

Keywords: Wind Energy, Wind Speed, Reneaweble Energy, Energy Sources

ÖZET

BOLU ABANT İZZET BAYSAL ÜNİVERSİTESİ YERLEŞKESİNİN RÜZGAR ENERJİSİ POTANSİYELİNİN BELİRLENMESİ
YÜKSEK LİSANS TEZİ
ERCAN ÇİÇEK
BOLU ABANT İZZET BAYSAL ÜNİVERSİTESİ FEN BİLİMLERİ ENSTİTÜSÜ
FİZİK ANABİLİM DALI
(TEZ DANIŞMANI: PROF. DR. HALUK DENİZLİ)
BOLU, KASIM - 2019

Günümüzde dünyanın birçok ülkesinde tüketilen enerjilerin çoğu, fosil kaynaklı benzin, doğal gaz, dizel gibi petrolden ve kömürden elde edilen sonlu miktarda ve tükenebilir enerji türlerindendir. Bu enerji türlerinin atmosfere ve çevreye verdiği zarar doğadaki dengeyi bozmaya, toplumlar arasındaki huzursuzluğu artırmaya ve ayrıca birçok canlı varlığı tehdit eder düzeye varmaktadır. Diğer yandan, dünya nüfusunun her geçen gün giderek artması ve teknolojik ilerlemelerle birlikte enerjiye duyulan ihtiyaç da gittikçe artmaktadır. Bu durum, ülkeleri enerji gereksinimini karşılamak için yeni enerji kaynakları arayışlarına zorlamıştır. Fosil kaynaklı enerjilerin yanı sıra, teknolojileri gelişmiş ve gelişmekte olan rüzgâr ve güneşten yararlanarak elektrik enerjisi üretilmesi gibi yenilenebilir, teorik olarak sonsuz, kaynaklardan enerjinin kullanılması zorunlu hale gelmiştir. Ancak, jeografik olarak herhangi bir konum veya bölgenin rüzgâr veya güneşten elektrik enerjisinin üretmesi öncesinde, o bölgenin yeterli düzeyde enerjisi üretebilme potansiyelinin bulunup-bulunmadığının araştırılıp analiz edilmesi gerekmektedir.

Bu çalışmada, Bolu Abant İzzet Baysal Üniversitesi Yerleşkesi yakınında bulunan bir konumdan alınan 12 aylık rüzgâr verilerinin analizleri yapılmış ve rüzgâr potansiyeli belirlenmiştir.

Anahtar Kelimeler: Rüzgâr Enerjisi, Rüzgâr Hızı, Yenilenebilir Enerji, Enerji Kaynakları

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1. INTRODUCTION

Human beings have needed food resources to survive since its inception. Today, the need for every aspect of our lives is in the form of energy and is met directly or indirectly from different sources. If the energy needs are not met, it becomes almost impossible to maintain the basic needs of our social life such as transportation, working life, heating and the like. Suppose the rate of world consumption of energy does not grow with time but stays at its present level. The confirmed global oil reserve will last about 35 years. It is 60 years for natural gas, 170 years for coal, and 60 years for uranium. If our consumption rate increases by only 3% a year, the projected energy consumption will deplete the fossil fuel reserves even sooner. Although new reserves may be discovered from time to time, there is the additional problem of global warming (greenhouse effect) caused by the emission of carbon dioxide from burning fossil fuels. It would be foolhardy not to aggressively conserve energy and develop renewable energy sources such as solar cells. Despite the fact that known energy resources are limited and the vital resources have almost reached the end, the more energy resources are needed since there is a continuous increase of the population. Due to the increase in energy demand, countries should change their current life attitudes and seek compulsory explorations. Measures to be taken; step-by-step, reducing the degree of energy generation of oil and its sub-petroleum derivatives in energy from basic sources; the actual use of energy reserves, the strong use of energy assets, and the techniques of rapidly shaping and exploiting the advantage of vital assets. They must act quickly and directly. Today, energy sources used are fossil-based and unsustainable sources such as coal, oil, petroleum gas and wood. Despite our demands, our existing energy resources have to end in a not too distant future. The efforts to meet the needs of modern life with the consumption of non-renewable energy sources due to the ozone layer damaging substances causes a rise in temperature around the world and brutal atmospheric changes, desertification and so on. Major issues considering the new and clean energy resources have gotten obligatory. Wind, sun, water power, geothermal, biomass, marine vitality sources assets are considered as sustainable power sources (Nelson, 2013).

Our study was initiated in 2008 with a wind power plant (WPP) in order to examine the renewable wind energy source at the university and to use it as electricity in Bolu Abant Izzet Baysal University campus. It was decided that the appropriate point for wind measurement having to be analysed is in the location: G27.d.01.d pafta, 137 parcel in Gölköy Village. A 45 meter hight wind measurement mast has been mounted at this point. A wind vane with the measurement equipments of one anemometer (wind speed meter), one pyranometer (light intensity meter), one humidity sensor, one pressure sensor and one temperature sensor are installed 30 m and same equipments in 40 m, respectively. Data acquisition via an NRG Datalogger has been done without interruption.

1.1 Historical Wind Use

Windmills are utilized for something like 3000 years, for the most part to granulate grain or siphoning water, then again, in cruising ships the wind has been a fundamental wellspring of intensity for significantly more. From as right on time as the thirteenth century, flat pivot windmills were a coordinated piece of the provincial economy and just fell into neglect with the approach of shoddy fossil-fuelled motors and afterward the spread of rustic zap. The utilization of windmills (or wind turbines) to deliver power return to the late nineteenth century with the 12 kW DC windmill generator built by Brush in the USA and the exploration made by LaCour in Denmark. Be that as it may, for a significant part of the twentieth century there was little interest in utilizing wind energy other than for battery charging for remote residences and these low-control frameworks were immediately supplanted once access to the power matrix ended up accessible. One striking special case was the 1250 kW Smith–Putnam wind türbine developed in the USA in 1941 (Fleming, 2016).

This essential machine had a steel rotor 53 m in measurement, full-length pitch control and fluttering sharp edges to diminish loads. In spite of the fact that a sharp edge fight flopped disastrously in 1945, it remained the biggest wind türbine built for somewhere in the range of 40 years (Fleming, 2016).

Golding (1955) and Shepherd and Divone in Spera (1994) give an interesting history of early wind turbine advancement. They record the 100 kW 30 m width Balaclava wind turbine in the then USSR in 1931 and the Andrea Enfield 100 kW 24 m breadth pneumatic structure developed in the UK in the mid 1950s. In this turbine empty cutting edges, open at the tip, were utilized to draw air up through the pinnacle where another turbine drove the generator. In Denmark the 200 kW 24 m distance across Gedser machine was worked in 1956 while Electricite' de France tried a 1.1 MW 35 m measurement turbine in 1963. In Germany, Professor Hutter developed various creative, lightweight turbines during the 1960s. Despite these specialized advances and the excitement, among others, of Golding at the Electrical Research Association in the UK there was minimal supported enthusiasm for wind age until the cost of oil climbed drastically in 1973 (Fleming, 2016).

1.2 Wind and Wind Potential

1.2.1 Wind

Wind is air in flat movement over the Earth's surface. All wind are created by contrasts in pneumatic stress between two locales. Contrasts in weight result from differential warming of the outside of the Earth. Warming, obviously, is brought about by daylight striking the Earth's surface (Chiras, 2010). Wind is a characteristic marvel brought about by the relocation of tourist and cold air. Wind, sun powered radiation brought about by the distinctive surface warming of the ground surface. Diverse warming of the ground surface causes the temperature, stickiness and weight of the air to appear as something else and this weight causes the development of the air. Roughly 2% of the sun oriented vitality that ventures the Earth transforms into wind vitality.

The qualities of the breeze change contingent upon the neighborhood topographical contrasts and the inhomogeneous warming of the earth, transiently and locally. The breeze is communicated by two parameters: speed and bearing. The breeze speed increments with tallness and its hypothetical power changes in relation to the speed shape. (Mathew, 2006).

1.2.2 Wind potential

Above all else, wind speed at the conceivable breeze power plant area ought to be in a satisfactory range. Areas with a breeze speed of 3 m/s are suitable for wind power plant establishment. Exact and solid breeze speed information is required for better appraisal of the area. In Turkey Renewable Energy General Administration (EİE) and Turkish State Meteorological Service (DMI) are the two major government organizations that give wind information data just to coastal areas (Chiras, 2010).

1.3 Wind Energy Systems

Wind-electric frameworks fit into three classes: (1) network associated, (2) lattice associated with battery reinforcement, and (3) off-matrix. In this part, we'll inspect every framework and talk about the upsides and downsides of each. We'll likewise analyze half and half frameworks, comprising of a breeze turbine in addition to another type of sustainable power source. Data will enable you to choose which framework suits your needs and way of life. Two of the principle segments of wind frameworks wind turbines and towers will be investigated. Ensuing parts contain increasingly definite exchanges of these and different segments (Chiras, 2010).

1.4 Wind Parameters

1.4.1 Wind Speed

Albeit cleared area could without much of a stretch contrast with thickness, wind speed is impressively dynamically basic in choosing the yield of a breeze turbine. That is on the grounds that the power open from the breeze increments with the 3D square of wind speed (v). This relationship is conferred in the power condition as v^3 wind speed duplicated with no other person's data on different events (Chiras, 2010).

1.4.2 Different Wind Flows

Winds are especially influenced by the ground surface at heights up to 100 m. The breezes are sponsored off by the world's surface disagreeableness and tangles. There may be basic differences between the heading of the worldwide or geostrophic curves because of the world's turn (the Coriolis oblige), and the breeze course near the surface. Close to the outside of the earth, the going with effects sway the stream case of wind (Wagner et al., 2018).

(a) Sea Wind

Land masses are warmed by the sun more quickly than the sea in the daytime. The air rises, streams out to the sea, and makes a low weight at ground level which attracts the cool air from the sea. This is known as a sea wind. At nightfall there is every now and again a period of calm when land and sea temperatures are equal. During the night the breeze blows the other way. The land wind during the night generally has lower wind speeds, in light of the fact that the temperature qualification among land and sea is smaller around night time. The rainstorm (express time when the greater part of precipitation occurs) in India and all of South-East Asia is when in doubt a considerable scale kind of the sea wind and land wind, contrasting toward its between seasons, since land masses are warmed or cooled more quickly than the sea (Wagner et al., 2018).

(b) Mountain Wind

Mountain locale show many interesting atmosphere plans. One model is the valley wind which begins on South-going up against inclinations (North-looking in the Southern side of the equator). Exactly when the slopes and the neighboring air are warmed, the thickness of the air reduces, and the air moves towards the best after the outside of the inclination. During the night the breeze heading is exchanged, and changes into a down-incline wind. If the valley floor is inclined, the air may go down or up the valley, as a crevasse wind. Winds spilling down the leeward sides of mountains can be entirely mind boggling (Wagner et al., 2018).

(c) The Wind Rose

It might be seen that strong breeze generally begin from a particular bearing. To show the information about the scatterings of wind speeds, and the repeat of the fluctuating breeze orientation, one may draw a supposed breeze rose as showed up in Fig. 1.1 dependent on meteorological view of wind speeds and wind headings (Wagner et al., 2018).

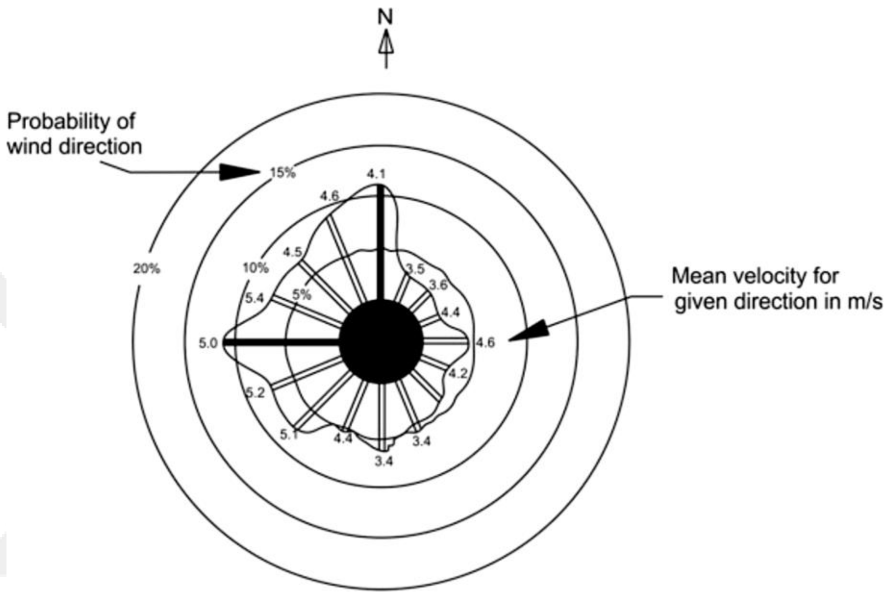


Figure 1.1. Case of a breeze rose (yearly all bearings normal speed 4.3 m/s)

The breeze rose shows a summation of yearly wind data. The round space can for instance be segregated in 16 fragments addressing huge heading from which wind may come. The amount of bits may be even more yet it makes the chart hard to scrutinize and unravel. The concentric circles having percent regards address the probability of wind beginning from a particular heading. In Fig. 1.1, the polygon in north course adventures out before the 10% circle, along these lines it might be assumed that at this region, the probability of wind starting from the North is commonly 12%. The bars going up to the edge of the polygon have a regard tag with them. This regard addresses the mean speed of wind when it starts from that particular course. Yet again, in Fig. 1.1, the bar in the North bearing says that when wind starts from the North it has an ordinary speed of 4.1 m/s. This diagram shows that the most grounded breeze starts from the westward headings. It should be seen that in standard terms, when we express that some site has 'North wind', this suggests wind is beginning from the North and not setting off toward the North. Further to note is that breeze models may change from year to year, and the vitality substance may vacillate (ordinarily by some 10%) from year to year, so it is perfect to have recognitions from a long time to determine a trustworthy typical. Coordinators of extensive breeze parks will as a general rule depend of neighborhood estimations, and use whole deal meteorological discernments from near to atmosphere stations to change their estimations to get a strong whole deal typical (Wagner et al., 2018).

1.4.3 Wind Speed Variability

The breeze speed is persistently fluctuating, and thusly the vitality substance of the breeze is consistently advancing. Accurately how huge the assortment is depends both on the atmosphere and on close-by surface conditions and deterrents. Vitality yield from a breeze türbine will contrast as the breeze vacillates, despite the way that the most quick assortments will somewhat be compensated for by the lethargy of the breeze turbine rotor. Figure 1.2 shows transient assortments in wind. In numerous territories around the globe it is more stormy in the midst of the daytime than during the night. This assortment is, all things considered, on account of the manner in which that temperature contrasts, for instance between the sea surface and the land surface, will by and large be greater in the midst of the day than during the night. The breeze is also logically savage and will when all is said in done modify course progressively occasionally in the midst of the day than during the night (Wagner et al., 2018).

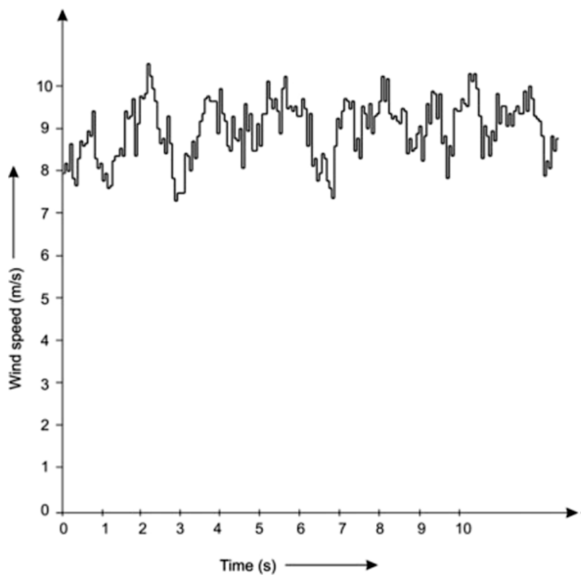


Figure 1.2. Transient fluctuation of the breeze (Wagner et al. 2018).

From the point of view of wind turbine owners, it is influence that most by far of the breeze vitality is conveyed in the midst of the daytime, since power usage is higher than during the night. Many power associations pay more for the power conveyed in the midst of the apex load hours of the day (when there is an inadequacy of decrepit making limit) (Wagner et al., 2018).

At most zones, the breeze may not be satisfactory for conveying power tirelessly for a couple of days and a portion of the time despite for multi week (Wagner et al., 2018).

1.5 Wind Variations

1.5.1 Wind Shear with Height

Expecting that the breeze is blowing at 10 m/s at a stature of 100 m, Fig. 1.3 shows how wind paces vary in agrarian land with specific houses and ensuring hedgerows with some place in the scope of 500 m between times (Burton et al., 2001).

The manner in which that the breeze profile shown in Fig. 1.3 is reshaped towards a lower speed, as one moves closer to ground level, is for the most part called breeze shear. Wind shear may in like manner be basic when arranging wind turbines. It may be seen that for a breeze stature of 50 m, the breeze speed is 9 m/s while for a 100 m height it is 10 m/s in our model case. With the help of the formula for force of wind discussed previosly in this section, it might be resolved that on account of the dependence of force with 3D square of wind speed, this extension of 1 m/s identifies with about 30% difference in the power available with wind. Moreover, it is observed that if a breeze turbine with a middle height of 75 m and a rotor width of 50 m is thought of one as, one can see that the breeze is blowing at 10 m/s when the tip of the sharp edge is in its most elevated position (100 m stature), and 9 m/s when the tip is in the base position (50 m stature). This suggests the forces following up on the rotor sharp edge when it is in its best position are far greater than when it is in its base pos Fig. 1.2 (Burton et al., 2001).

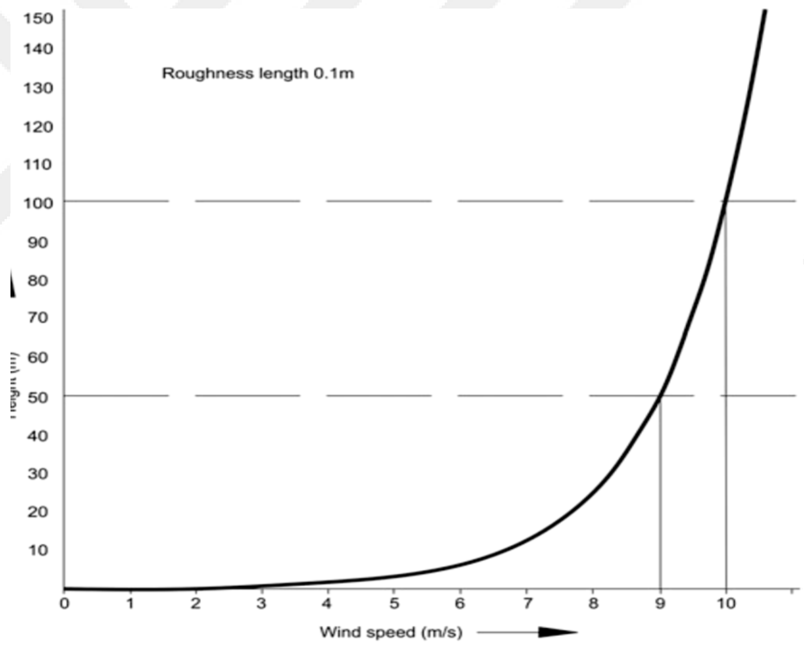


Figure 1.3. Variety in wind speed with height (Burton et al., 2001).

Typical breeze rates are much of the time open from meteorological recognitions assessed at a height of 10 m. Focus point statures of current 1,000–3,000 kW wind turbines are for the most part 80–130 m and that is only the start. Using the recently referenced procedure, one may figure typical breeze speeds at different statures and brutality classes. It is to be seen that the results are not so much generous if there are impediments close to the breeze turbine (or the motivation behind meteorological estimation) at or over the foreordained focus point stature. It should be genuinely seen that there may be invert wind shear on edges in perspective on the incline sway, for instance the breeze speed may truly diminish with growing stature in the midst of a particular height interval over the edge. A mindful examination of wind speed and profile is thus endorsed before arriving at any choices about site (Burton et al., 2001).

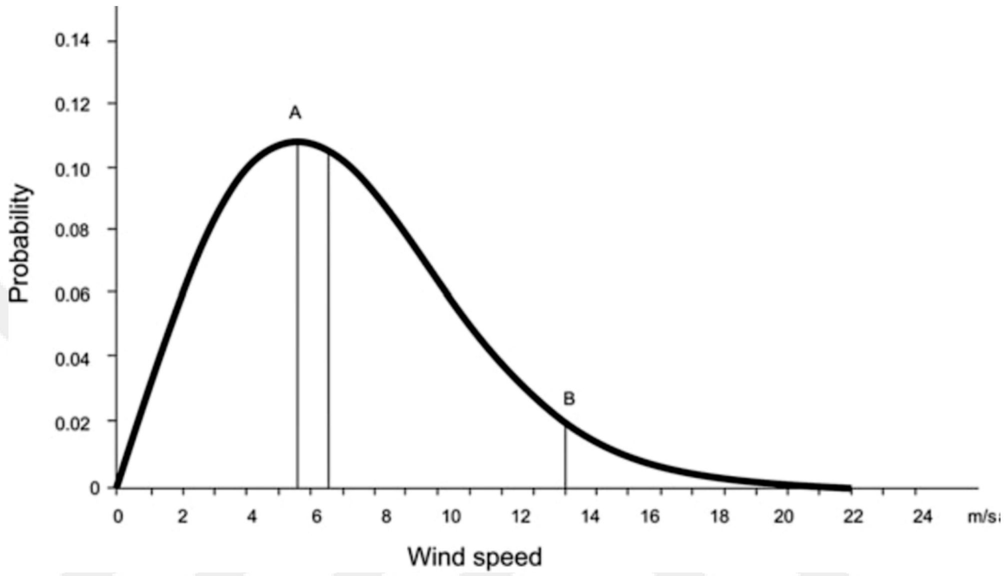


Figure 1.4. Weibull circulation plot between wind speed and likelihood (Burton et al., 2001).

1.5.2 Extreme Wind Speeds

Despite the earlier delineations of the typical real properties of the breeze, it is clearly critical to likely assess the whole deal incredible breeze speeds which may occur at a particular site (Burton et al., 2001).

A probability dispersal of hourly mean breeze speeds, for instance, the Weibull allotment will yield evaluations of the probability of outperforming a particular element of hourly mean breeze speed. Regardless, when used to measure the probability of uncommon breeze, an accurate learning of the high wind speed tail of the course is required, and this won't be really strong since basically most of the data which was used to fit the parameters of the allocation will have been recorded at lower wind speeds. Extrapolating the assignment to higher breeze velocities can't be relied on to give a precise result (Burton et al., 2001).

1.5.3 Extreme winds in standards

The structure of wind turbines must empower them to withstand furthest reaches of wind speed, similarly as responding splendidly to the more 'standard' conditions depicted beforehand. Thusly the various models also decide the limits of wind speed which must be planned for. This joins over the top mean breeze speeds similarly as various sorts of outrageous impact (Burton et al., 2001).

Unprecedented conditions may be proficient about the machine working, ceased or waiting with or without various sorts of fault or system mishap, or in the midst of a particularoperation, for instance, a shut-down event. The phenomenal breeze conditions may be depicted by an 'entry time': for example a multi year impact is one which is extreme to the point that it might be required to happen everything considered only once at normal interims. It is reasonable to envision that a turbine ought to persevere through such an impact, gave there was no fault on the türbine (Burton et al., 2001).

It is always possible that the turbine happens to be shut down as a result of an accuse when an impact occurs. In case the fault blocks the turbine's ability to adjust to an impact, for example if the yaw structure has failed and the turbine is ceased at the off-base edge to the breeze, by then the turbine may need to withstand altogether increasingly significant weights. Regardless, the probability of the most unprecedented shoots occurring meanwhile as a turbine fault is close to nothing. Consequently it is not unexpected to show that a turbine with an accuse need simply be planned to withstand, for example, the yearly over the top impact and not the multi year phenomenal impact. For this to be considerable, it is fundamental that the lacks being alluded to are not compared with exceptional breeze conditions. Network mishap isn't seen as a fault with the turbine, and is entirely at risk to be connected with silly wind conditions. Clearly the phenomenal breeze rates and impacts (both with respect to enormity and shape) may be very site-unequivocal. They may change broadly between level shoreline front districts and intense incline best for example. The IEC (1999) standard, for example, demonstrates a 'reference wind speed' Vref which is on various occasions the yearly mean breeze speed. The multi year exceptional breeze wspeed is then given by 1.4 events Vref at focus point height, and fluctuating with stature using a power law sort of 0.11. The yearly over the top breeze speed is taken as 75 percent of the multi year regard. The standard continues to portray different transient events which the türbine must be proposed to withstand (Burton et al., 2001).

• Extreme working blast (EOG): an abatement in speed, trailed by a precarious ascent, a lofty drop, and an ascent back to the first esteem. The blast abundancy and length fluctuate with the arrival time frame.

• Extreme course change (EDC): this is an upheld modify in turn course, following a cosine-formed twist. The adequacy and term of the change before long depend upon the landing time allotment.

• Extreme judicious impact (ECG): this is an upheld change in wind speed, again following a cosine-shaped curve with the plentifulness and term dependent upon the landing time span.

• Extreme clear impact with course change (ECD): synchronous speed and bearing wanderers like EDC and ECG.

• Extreme breeze shear (EWS): a transient assortment in the level and vertical breeze slant over the rotor. The slant first additions and a while later falls back to the basic measurement, following a cosine-shaped curve.

These transient events are deterministic shoots wanted to address the phenomenal rough assortments which would be depended upon to occur at the foreordained return time span. They are not wanted to occur despite the standard unsettling influence portrayed in advance. Such deterministic clever impacts, regardless, have little reason the extent that genuine evaluated or theoretical breeze characteristics, and are presumably going to be displaced in future measures by something even more immovably related to the genuine properties of unbelievable unsettling influence (Burton et al., 2001).

1.5.4 Wind-speed Prediction and Forecasting

Because of the variable thought of the breeze resource, the ability to figure wind speed some time ahead is as often as possible significant. Such measures fall broadly into two classes:

- foreseeing flashing rough assortments over a period size of seconds to minutes ahead which may be useful for assisting with the operational control of wind turbines or wind farms
- longer-term figures over occasions of two or three hours or days which may be profitable for masterminding the association of other power stations on the framework.

Transient guesses on a very basic level rely upon quantifiable strategies for extrapolating the progressing past, while the more drawn out term measures can make usage of meteorological methods. A blend of meteorological and accurate assessments can give incredibly supportive desires for wind farm control yield (Burton et al., 2001).

1.5.5 Turkey and the world in wind vitality work

The fundamental motivation behind why power from wind vitality is turning out to be far reaching is; change frameworks and the expenses of power age have diminished to a level that can contend with the new fossil-filled power plants. Research on the advancement of wind vitality frameworks; The point of this course is to expand the streamlined and mechanical presentation of turbine frameworks, to improve their sturdiness and weakness life, to display and reproduce wind zones and furthermore to think about the establishment of seaward turbines. The world has arrived at 9839 MW introduced wind control before the finish of 1998. The world's biggest introduced control is situated in Europe with 6469 MW. Germany is driving in 1998 with an expansion of 794 MW. With this expansion, the all out wind intensity of the nation expanded to 2875 MW. With introduced limit of 80.3 thousand MW of introduced limit dependent on various wellsprings of electrical vitality we produce 273 billion kWh of power in Turkey. Antakya in Turkey, Bandırma, Pergamum, Bodrum, Bozcaada, Çanakkale, Çeşme, Çorlu, Gökçeada, İnebolu, Mardin and fiery breeze of Sinop is our rich district. A 55 kW wind generator is utilized in a touristic office in İzmir-Çeşme. The Alaçatı Wind Power Plant, which has a limit of 7.2 MW, began generation in 1998. As of now, created by different private financial specialists, and that can occur in Turkey soon Wind control limit has arrived at 700 MW. (Ataseven M. 2019).

1.6. How Does Wind Energy Form

Power age by wind vitality is acquired by changing over the dynamic vitality of wind into electrical vitality. Producing power productively from wind vitality is given by wind turbines introduced in districts where wind is blowing at ideal level. The ideal breeze level implies that the breeze is blowing at a stature of 10 and 50 meters over the ground and at a speed of in any event 4 m/s.

1.6.1 Wind Vitality Control Count

The territory cleared by the cutting edges of the breeze turbine = rotor range x rotor sweep can be determined with the equation given below. (Gipe, 2003).

$$p = {}^{1}/_{2} \cdot \rho \cdot v^{3} \cdot C_{p} \cdot A$$

Power (P): Shows the power created by the breeze turbine. The unit is Watt.
Consistent: Its incentive as a steady in the recipe is 0.5.
Air Density (ρ): Displays the air thickness. Worldwide Standard Density of air at environmental conditions (ocean level, + 15 °C) is 1,225 kg/m^3.
Wind Speed (v): The estimation of the 3D shape of the normal breeze speed at where the breeze turbine will be introduced.
Power Coefficient (C_p): Percentage of wind turbine proficiency. The most extreme estimation of constant C_p, which is a fixed worth, is roughly 0.5926. This worth is

additionally called Betz limit. This implies the breeze turbine will work at a most extreme productivity of 59.26%.

Cleared Area (A): It alludes to the zone cleared by the edges of the breeze turbine and its unit is square meters. It is conceivable to compute from the rotor span, which is communicated as distance across.

1.7 Wind Turbines

Most wind turbines being used today are level pivot units, or HAWTs, (clarified in the blink of an eye) with three cutting edges joined to a focal center. Together, the cutting edges and the center point structure the rotor. In many breeze turbines, the rotor is associated with a pole that runs flat to the ground, henceforth the name. It is associated with an electrical generator. At the point when the breezes blow, the rotor turns and the generator produces substituting flow (AC) power (Burton et al. 2001).

One of the key segments of a fruitful breeze generator is the sharp edges. They catch the breeze's dynamic vitality and convert it into mechanical vitality (pivot). It is then changed over into electrical vitality by the generator (Burton et al. 2001).

The generators of wind turbines are frequently shielded from the components by a strong lodging produced using fiberglass or aluminum (Figure 1.5a). Notwithstanding, in numerous advanced little wind turbines, the generators are presented to the components (Figure 1.5b) (Burton et al. 2001).

Most wind turbines being used today have tails that keep them indicated into the breeze guarantee greatest creation. Be that as it may, some exceptionally effective turbines like those made by the Scottish organization Proven (articulated PRO-vin) are intended to Orient themselves to the breeze without tails (Chiras, 2010).

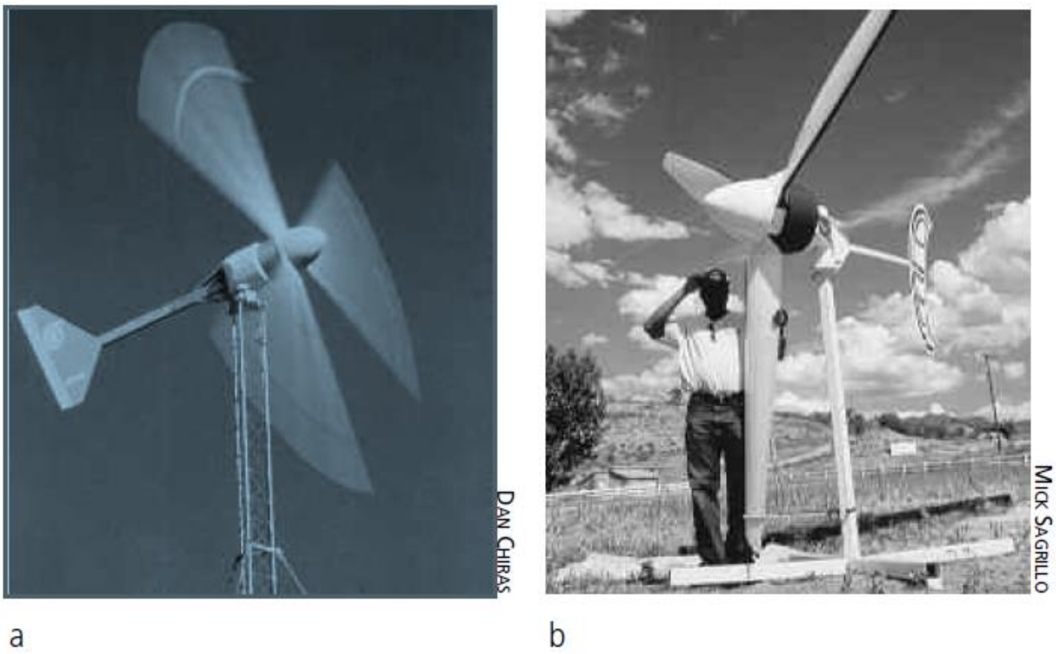


Fig. 1.5a and 1.5b: Wind Turbine Design. (a) The generators in numerous little wind turbines are housed in a defensive case produced using a aluminum or fiberglass. (b) Others, similar to this one, are most certainly not (Burton et al., 2001).

1.7.1 Characterization of Turbines

Wind turbines being used change broadly in measure and type, yet are commonly characterized by the pivot of revolution. These are flat pivot wind turbines and vertical hub wind turbines. Even hub wind turbine types are favored most on the planet.

In wind turbines with flat hub, the hub of turn is parallel to the breeze heading. Their wings make a correct point with the breeze bearing. Business turbines are commonly even pivot. The rotor is put on a pivoting table to get the best wind. A large portion of the level pivot turbines are intended to take the breeze from the front. Turbines that take wind from behind have no regular use. The great side of the breeze turbines that take the front, the pinnacle isn't influenced by wind concealing. The drawback is that the rudder framework is manufactured with the goal that the turbine is continually confronting the breeze. Instances of even hub turbines are propeller wind turbines. The edges of this kind of turbine can be one piece or at least two pieces.

Today, the most generally utilized sort is the three-winged ones. These turbines are utilized to create power. Previously, multi-cutting edge turbines have been utilized to granulate grain, siphon water and cut wood.

Vertical Axis wind turbine; the turbine shaft is vertical and opposite to the heading of wind appearance. There are assortments, for example, Savonius type, Darrieus type. It was delivered generally for test purposes. Business use is exceptionally little.

The upsides of these turbines are as per the following:

- Since the generator and the gearbox are set on the ground, there is no compelling reason to put the turbine on the pinnacle, so there is no pinnacle cost.
- There is no compelling reason to turn the turbine toward the breeze and consequently the rudder framework.
- Maintenance and fix of parts other than turbine shaft is simple.
- The power got is at ground level, making it simpler to move.

The disadvantages are:

- Wind speeds at lower focuses are low since they are near the ground.
- Low yield.
- An engine must be turned over by an engine before it can begin, so it needs an engine.
- To stand, it must be fixed to the ground with wires, which isn't practical (Hemami, 2012).

1.7.2 How Wind Turbines Work

Wind turbine a framework that changes over motor vitality from wind into mechanical vitality and afterward into electrical vitality. The dynamic vitality got from the breeze turbines is changed over into electrical vitality by a generator. Vertical hub wind turbines can take the breeze from each heading. Generators, gear box frameworks can be introduced at the ground level as they needn't bother with an additional pinnacle. In level hub wind turbines, the sharp edges are opposite to the breeze turbine. This sort of turbine must be introduced over the ground level and along these lines needs a pinnacle. Despite the fact that the turbines have altogether different structures, the turbines are for the most part utilized in wind control plants. Vitality generation in the turbine begins with wings. As the liquid air moves towards the turbine, the sharp edges of the turbine start to pivot. With the revolution of the cutting edges, the pole associated with the intersection zone of the sharp edges begins to pivot. Fast shaft transmits. In higher districts, stopping mechanisms are enacted in light of the fact that the turbine is in peril. The estimation of the breeze speed in the turbine is done with an instrument called anemometer. In most enormous breeze turbines, the most powerful age happens when the breeze speed is 15 m/s. At the point when the breeze speed surpasses 20 m/s, the turbines take control and stop for wellbeing. In the generator, vitality creation is performed by electromagnetic enlistment and electrical vitality is transmitted to the ideal system with transformers. (Walker, 1997).

1.7.3 Wind Turbine Effectiveness

Parts, for example, cutting edges, generators and rigging encloses utilized the turbine influence the proficiency of the turbine. The area of the turbine is significant as far as wind effectiveness. With respect to wind control thickness " values in the settlements, the districts that are appropriate for the intensity of the turbine are chosen. The proficiency diminishes when the establishment is done in lower areas as indicated by the intensity of the turbine. The yield intensity of the turbine shifts as per the speed of the breeze and the cutting edge width of the turbine. The estimation of the breeze speed in the turbine is completed with an instrument called anemometer. In most huge breeze turbines, the most powerful age happens when the breeze speed is 15 m/s. At the point when the breeze speed surpasses 20 m/s, the turbines take control and stop for wellbeing. Wind turbines are nearly the main strategy on the planet to utilize wind vitality. Consequently, it would be increasingly fitting to look at the effectiveness of these pinnacle formed three-wing structures. Today, the effectiveness of wind turbines changes between 20-30%. It is marginally settle for what is most convenient option; Rates of 30% are very typical for the greater part of the vitality creation techniques we use today. (Golding, 1955).

1.7.4 Cost of Wind Turbine

160,000 MW in 2012 world wind vitality generation is required to be increment in wind turbine creation costs The impact of the fall. Turbine costs has fallen by 50 percent over the most recent 15 years. A turbine the framework used to satisfy the vitality utilized during development is as short as 3 months. Deterioration of development expenses can take 5 - 7 years. (Tong, 2010).

2. AIM AND SCOPE OF THE STUDY

Today, one of the most important indicators that determine the level of development of countries is their electricity production. While the demand for energy, which is one of the most important inputs in the daily life of the public as well as the industry, is constantly increasing, energy resources are rapidly depleting. In order to achieve a sustainable balance, the introduction of energy resources has gained great importance.

This thesis has been prepared for the Wind Power Plant (Wind Turbine) which is planned to be established in the campus of Gölköy Campus of Bolu Abant İzzet Baysal University.

There is no problem with fossil fuels for wind turbines. Since these turbines use wind as fuel, they do not give poisonous gases to the atmosphere.

According to Betz theorem, wind energy can be converted to mechanical energy with a maximum efficiency of 59.3%. This cycle is done by the wind turbine. Such a turbine must be located on a tower that is too high to obstruct the wind. In addition, large flats for high efficiency are more suitable for these energy sources. The wind direction of the turbine is provided by the mechanism controlling the spring angle between the rotor axis and the wind direction. Potential determination studies related to wind energy in our country are carried out with various software and methods.

3. MATERIALS AND METHODS

Mankind's need for energy is increasing day by day. This energy, which it needs, is mostly supplied from the fuel-derived fuels such as gasoline, natural gas and diesel. However, the fact that these resources are a resource that will be exhausted in the future and that there are many negative effects on the environment indicate that fossil fuels cannot be used so much in the future. This forces people to take various measures to reduce their ever-increasing energy consumption. Although the measures taken provide significant benefits, our need for energy is increasing day by day. For this reason, in addition to fossil resources, it has become compulsory to use systems that generate energy from renewable sources such as wind, whose technologies have been developed to a considerable extent and are continuing to develop. If electricity is to be generated from wind energy in a region, the wind potential of this region should be determined first. All collected data is given in appendices.

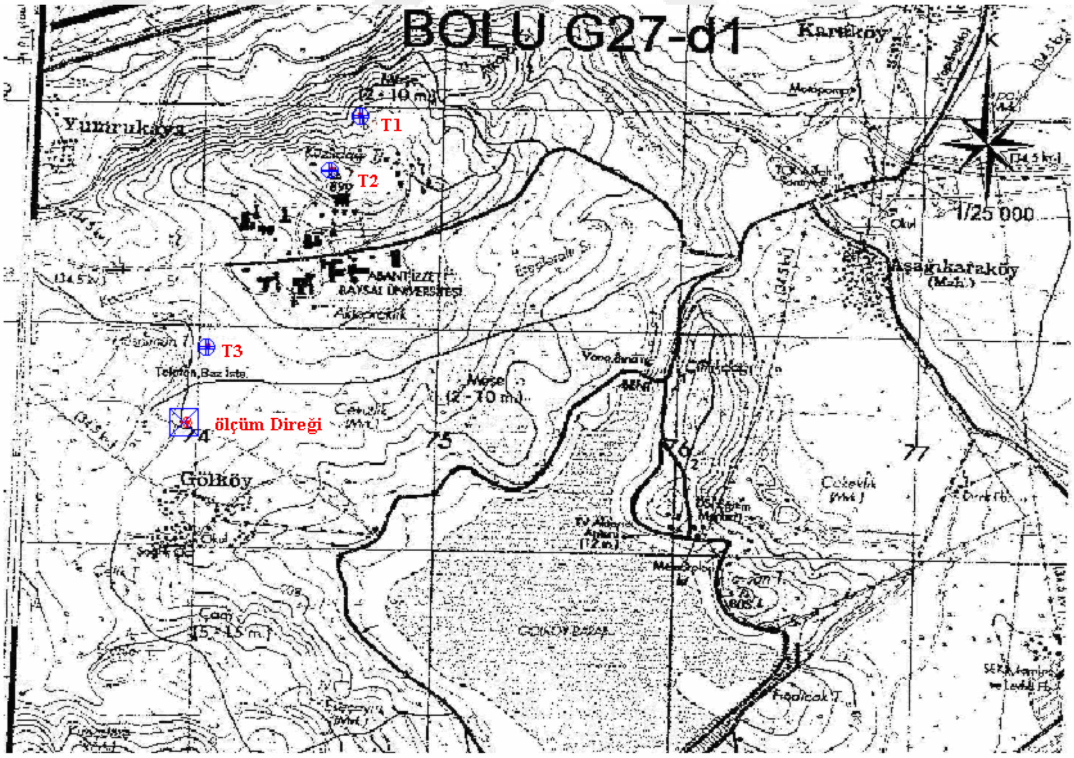
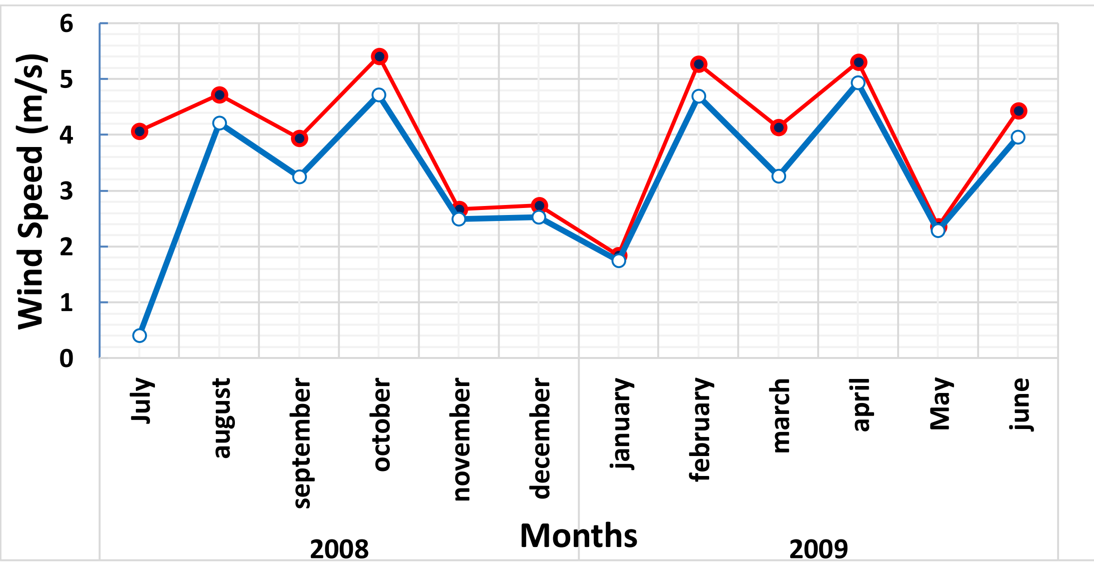


Figure 3.1. Measuring pole on the G27. D. 01. D plot, 137 parcel.

The main material of the study is G27. D. 01. D plot, 137 parcel and belonging to Gölköy village legal entity planted in order to make measurements in the school yard 40.5 m measuring pole 30 m and 40 m in anemometer values taken from the values and data from a Datalogger branded as NRG. The system automatically receives and saves data as minimum, maximum and average values every 10 minutes. Data acquisition from the measuring pole was carried out without interruption for one year from July 2008 to June 2009.

The Vestas V 39 turbine, which is used to determine the wind potential, is a turbine with three blades with a delay of 39.6 m and a sweeping area of 1195 m^2. This turbine has a body height of 40.5 m and the production value of this turbine is 4.0 m/s, while the value of energy production is 25.0 m/s. The optimum energy generation limit is 16.0 m/s.

This study was prepared for the Wind Power Plant (Wind Turbine) planned to be established at the campus of Gölköy Campus of Bolu Abant Izzet Baysal University. Today, one of the most important indicators that determine the level of development of countries is “Energy Production from Renewable Energy Sources”.



Measured values from anemometer at 40 m height.

Measured values from anemometer at 30 m height. (**Colour code applies to all charts**)

Figure 3.2. Average wind speeds (15th day of each month)

The graph in Figure 3.2. is drawn from the anemometers at 30 m and 40 m on the measuring pole with Datalogger recorded every 10 minutes for a year, which shows the average wind speeds on the 15th of each month. When the graph in Figure 3.2 is examined; on the 15th day of July, the average wind speeds and the average wind speed values taken from the 40-meter anemometer were 4.1 m/s, and in August this average was 4.7 m/s. On the other hand, it decreased to 3.9 m/s in September. In October, the average wind speed reached 5.4 m/s, the maximum of 12 months during the year. The decline in average wind speed after October continued until January. In other words, the average wind speed remained below the 4 m/s wind speed on the 15th of November, December and January in this quarter. When the average wind speed values were analyzed after January, one month increase and one month decrease continued and on the 15th day of May the average wind speed remained at 2.3 m/s. When the values taken from the anemometer at 30 meters are examined; we see that average wind speeds have reached sufficient average values only on the 15th of August and February.

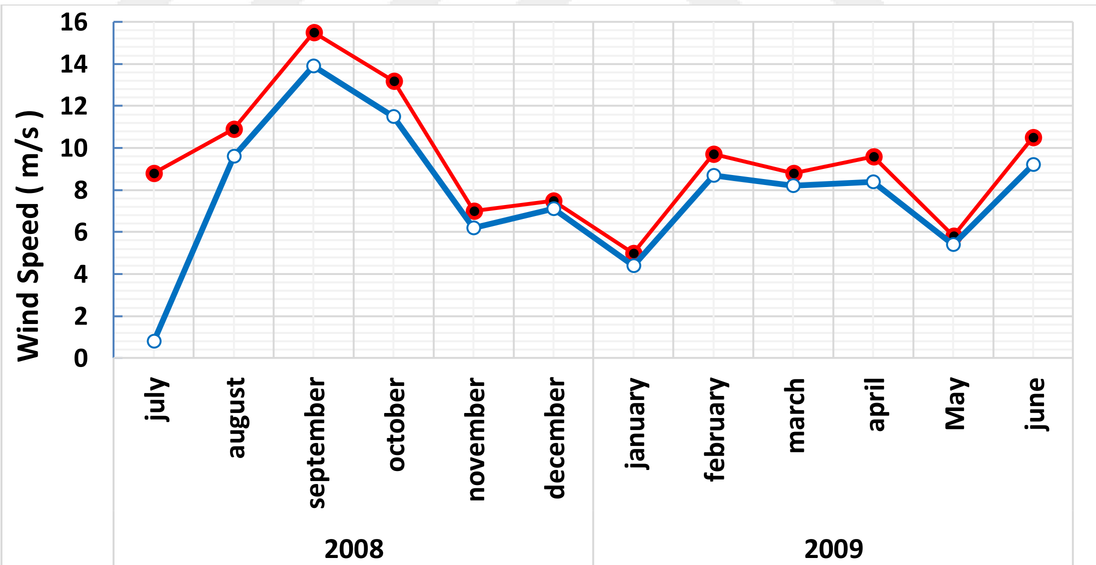


Figure 3.3. Maximum wind speeds (15th day of each month)

When the maximum wind velocity on the 15th day of each month during the year is examined, the garage of the values taken from the anemometer at 40 meters in Figure 3.3. The 15th day of July started with a maximum wind speed of 8.8 m/s and reached its highest value in September with a maximum wind speed of 15.5 m/s. The lowest value was obtained in January with a wind speed of 5.0 m/s.

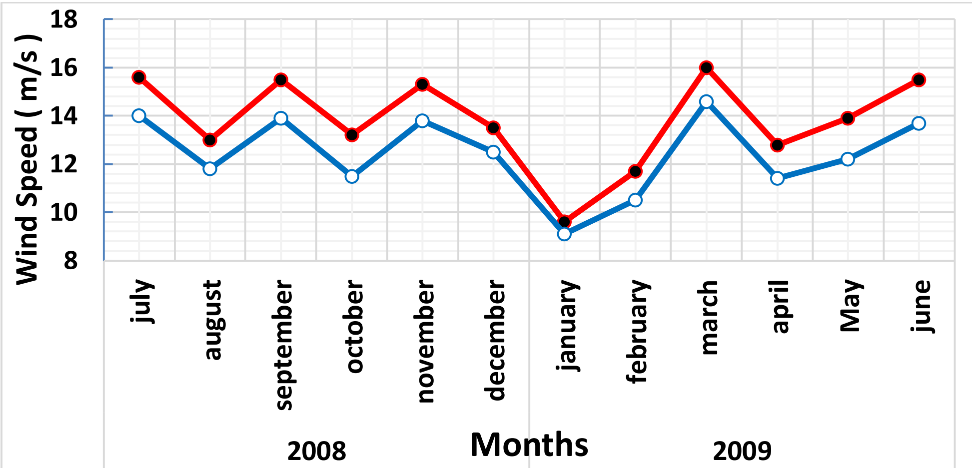


Figure 3.4. Maximum wind speeds (Monthly average)

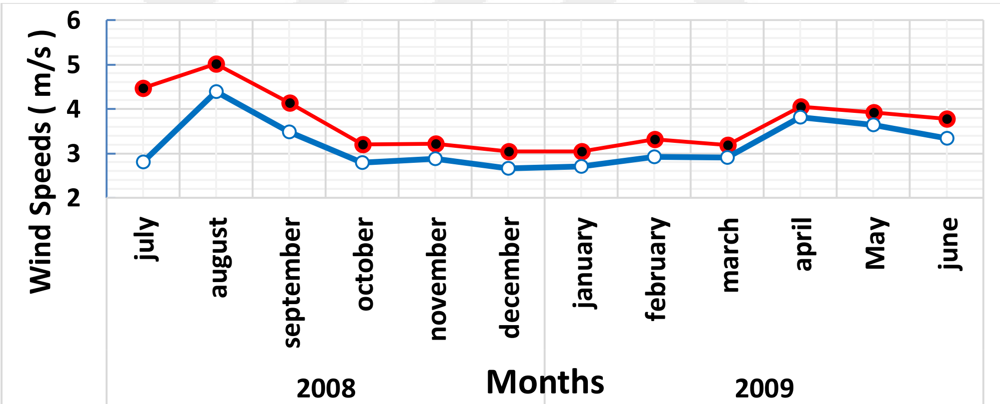


Figure 3.5. Average wind speeds (Monthly)

When the monthly average values of the maximum wind velocities taken from the anemometer at 40 m and 30 m of the measuring pole of the graph in Figure 3.4 are examined, the data from July to December decrease in July and increase in the following month periodically continued. Decrease continued in the period between November and January. In the period between January and March, maximum wind speeds increase in monthly averages. There is a decrease from March to April and an increase in the monthly average of maximum wind speeds is observed in the period from April to June.

If we examine the graph in Figure 3.5. which is drawn with the averages of the maximum blowing speeds of the wind on every day of every month; firstly, looking at the values taken from the anemometer at 40 m on the measuring pole, we see November as the month in which the maximum wind speeds averages the highest value with a value of 17 m/s in the months of the year. The lowest value is 10 m/s in January.

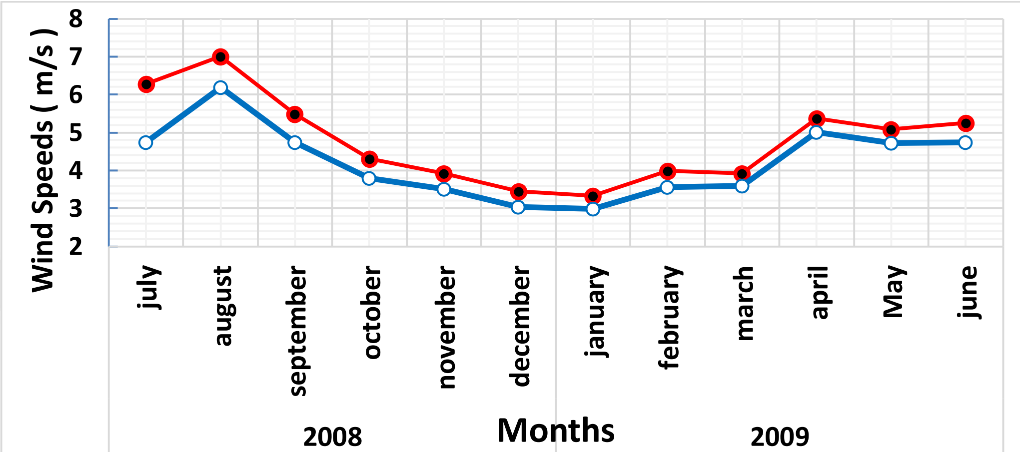


Figure 3.6. Average wind speeds (Monthly 08:00-20:00)

In Figure 3.6. while the average monthly wind speeds are calculated, the averages of each day in the month between 08:00 and 20:00 are calculated and the results obtained from the anemometer at 40 m and 30 m are used in the calculations. The monthly average wind speeds are plotted by showing two different colors on the line graph. If we examine the graph of monthly average wind speeds (08:00 - 20:00) in Figure 3.6. when we examine the values taken from the anemometer at 30 m and 40 m anemometer every 10 minutes throughout the year, It is seen that the most productive hours are between 08:00 and 20:00 in the morning. The average wind speed increased from 6.3 m/s in July to over 7 m/s in August. After August, the decrease in average wind speed continued until January. This decrease, which started in August, decreased to 4 m/s from November to January. From January to April, the average monthly wind speed increases. However, this increase increased to values above 4 m/s after March. After April, the year was completed in May and June with small decreases in average wind speeds.

Between 08:00 and 20:00 in the evening, the monthly averages of the values taken from the anemometer at 30 m and 40 m on the measuring pole are found and the graphs are plotted in two different colors.

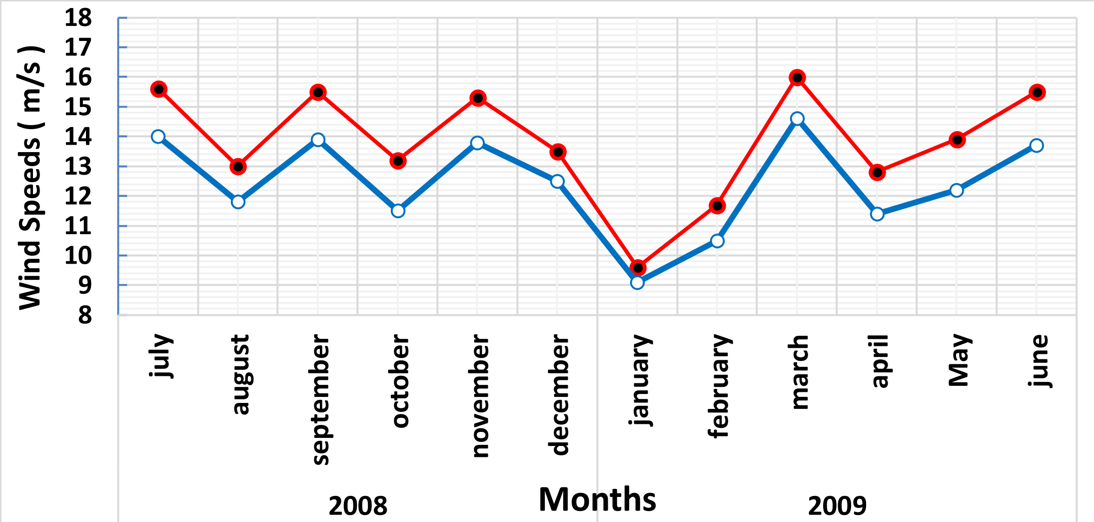


Figure 3.7. Maximum wind speeds (Monthly 08:00-20:00)

If we examine the monthly maximum wind speeds graph, the average maximum wind speed in July has exceeded 15 m/s. January is the month with the lowest average monthly wind speed. In the period from July to January, the monthly max. Wind speed averages increased one month and decreased the following month. From January to March, the monthly maximum wind speed continued to increase. During the month from March to April, the average monthly maximum wind speed decreased. After April, the average monthly maximum wind speed increased. Figure 3.7 shows the increase and decrease in the monthly maximum wind speed graph which is formed by daily maximum wind speed values taken from anemometer at 30 m and 40 m between 08:00 and 20:00 in the morning. Only the anemometer values at 40 m are higher than the anemometer at 30 m.

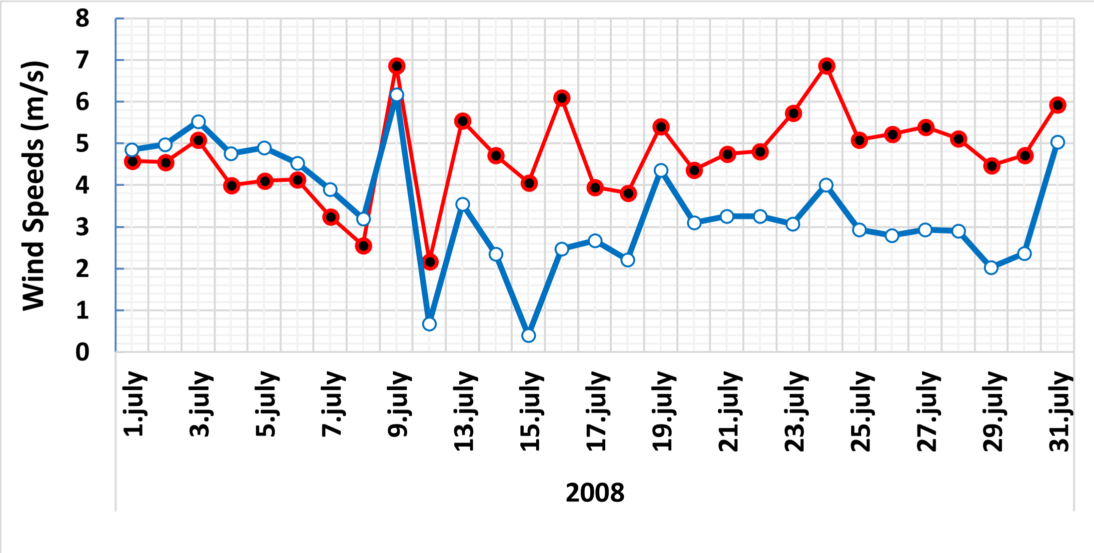


Figure 3.8. Daily average wind speeds (July)

If we examine the average daily wind speeds in July in Figure 3.8 in the first week of July, the values taken from the anemometer at 30 m were higher than the values taken from the anemometer at 40 m. On the days after the first week of July, the anemometer at 30 m was lower than the anemometer at 40 m. The average daily wind speeds in July were recorded at 40 m anemometer with the highest average speed of 6.9 m/s on 9 July. The lowest value in July was recorded on July 12 with a speed average of 2.1 m/s.

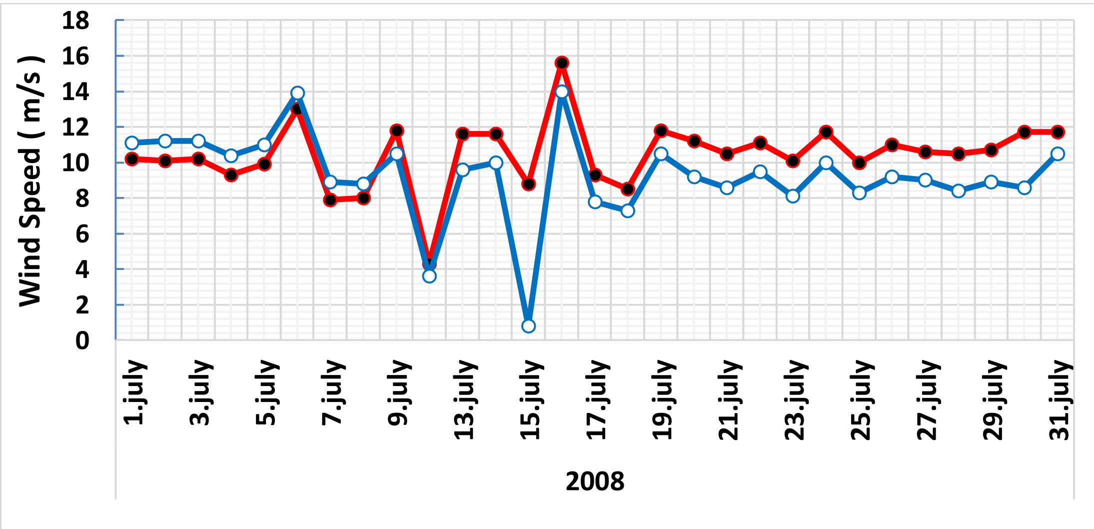


Figure 3.9. Daily maximum wind speeds (July)

If we examine the daily maximum wind speeds in Figure 3.9. for the first week of July, the daily maximum wind speed graph of the measurement pole drawn from the anemometer at 30 m and the anemometer at 40 m as in the July average daily wind speed graph in Figure 3.8. The values taken from the anemometer at 30 m are higher than the anemometer at 40 m. However, after the first week of July, these values returned to normal and the anemometer at 30 m values were lower than the anemometer at 40 m. The line values in the graph drawn with the daily maximum wind speed values in July formed a linear line in the first three days of July, ie at similar maximum wind speeds. In the first three days of the month, the maximum wind speeds taken from the anemometer at 30 m and 40 m were at 11 m/s and 10 m/s. After July 3, there was a decrease in maximum wind speeds for one day. From July 4 to July 6, there was an increase in daily maximum wind speeds. From 6 July to 8 July there was a decrease in the maximum wind speeds per day. After July 8, anemometers at 30 m and 40 m at the mast has daily normal wind speeds. In other words, the values taken from the anemometer at 30 m are lower than the values taken from the anemometer at 40 m. When the maximum daily wind speed data are analyzed in July, the highest value was 15.6 m/s on 16 July. The lowest value was recorded with a maximum wind speed of 3.6 m/s on 12 July. When we examine daily maximum wind speed data taken from the anemometer at 30 m at the measurement pole, the highest wind speed was recorded on July 6 with a maximum wind speed of 13.9 m/s. The lowest value was recorded with a maximum wind speed of 0.8 m/s on 15 July.

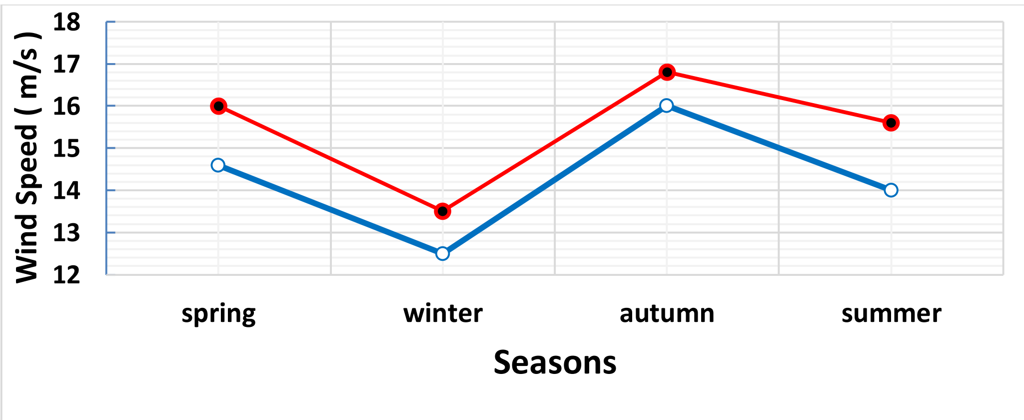


Figure 3.10. Average wind speeds (Seasonal)

When the seasonal average wind velocity graph in Figure 3.10 is examined, we first see that the average wind speed in the spring season is 3.8 m/s according to the averages of the data obtained from the anemometat 40 m on the measuring mast. The winter season is the lowest in all seasons with an average wind speed of 3.3 m/s. It is the autumn season with a value of 3.6 m/s with a slight increase in seasonal average wind speed data after winter season. In the average wind speed data, summer has the highest average wind speed with 4.5 m/s. When we examine the seasonal averages of the data obtained from the anemometer at 30 m at the measuring pole, we see that the average wind speed in spring season is 3.6 m/s. In winter, this value decreased to 2.9 m/s and the winter season is the lowest with the average wind speed. In autumn, the average wind speed reached 3.1 m/s. The summer season has the highest average wind speed at 3.7 m/s among the values taken from the 30 m anemometer on the measuring pole.

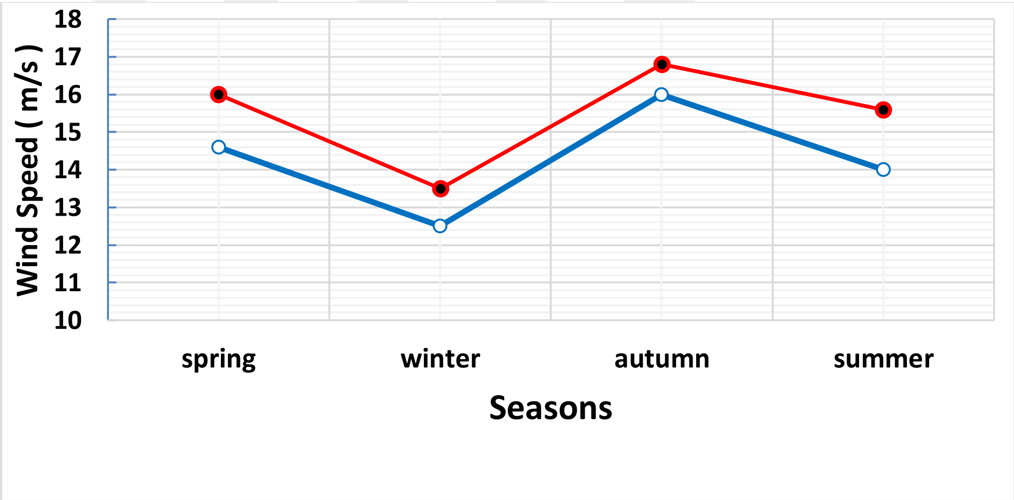


Figure 3.11. Maximum wind speeds (Seasonal)

When we examine the seasonal maximum wind speed graph in Figure 3.11., we see that the maximum wind speed value is 16 m/s in the spring season according to the average values obtained from the anemometer at 40 m on the measuring pole. In winter, the average maximum wind speed value decreased to 13.5 m/s and the winter season had the lowest maximum wind speed. After the winter season, the maximum wind speed values increased and the autumn season was the highest wind speed with 16.8 m/s. In summer, the average value of maximum wind speed decreased to 15.6 m/s. When the average values taken from the anemometer at 30 m on the measuring pole are examined, the average value of max. Wind speed in spring is 14.6 m/s. In winter, as in the anemometer at 40 m, the maximum wind speed decreases to 12.5 m/s, which is the lowest in the winter season. After the winter season, the maximum wind speed value increased and reached to 16 m/s in the autumn season and autumn has the highest maximum wind speed value during the seasons. In summer, the maximum wind speed has dropped to 14 m/s.

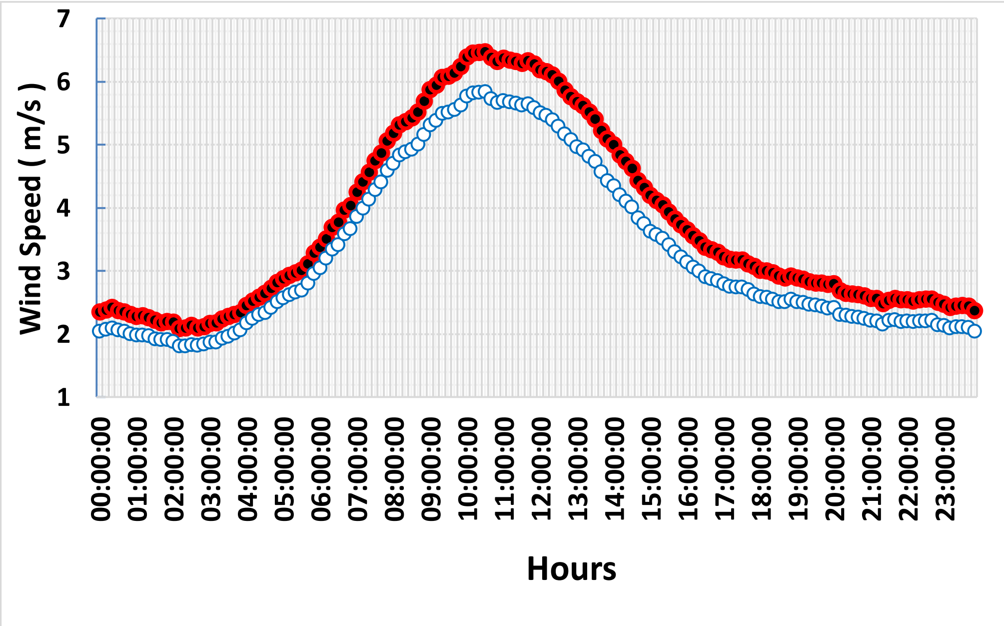


Figure 3.12. Hourly average wind speeds (Yearly)

When the graph drawn from the average hourly wind velocity data in Figure 3.12 is examined, the average wind speed is 4 m/s every day after 06:40 for a year according to the values taken from the anemometer at 40 m on the measuring pole and did not fall below this value until 15:50 in the afternoon. In other words, the average wind speed of 4 m/s for approximately 9 hours per day was higher. According to the values taken from the anemometer at 30 m on the measuring pole, the average wind speed of 4 m/s increased from 7:30 in the morning to 14:30 in the afternoon for a year. Anemometer at 30 m has taken values over the average wind speed value of 4 m/s for 7 hours according to the values obtained. The maximum wind speed during the day reached at 11:00.

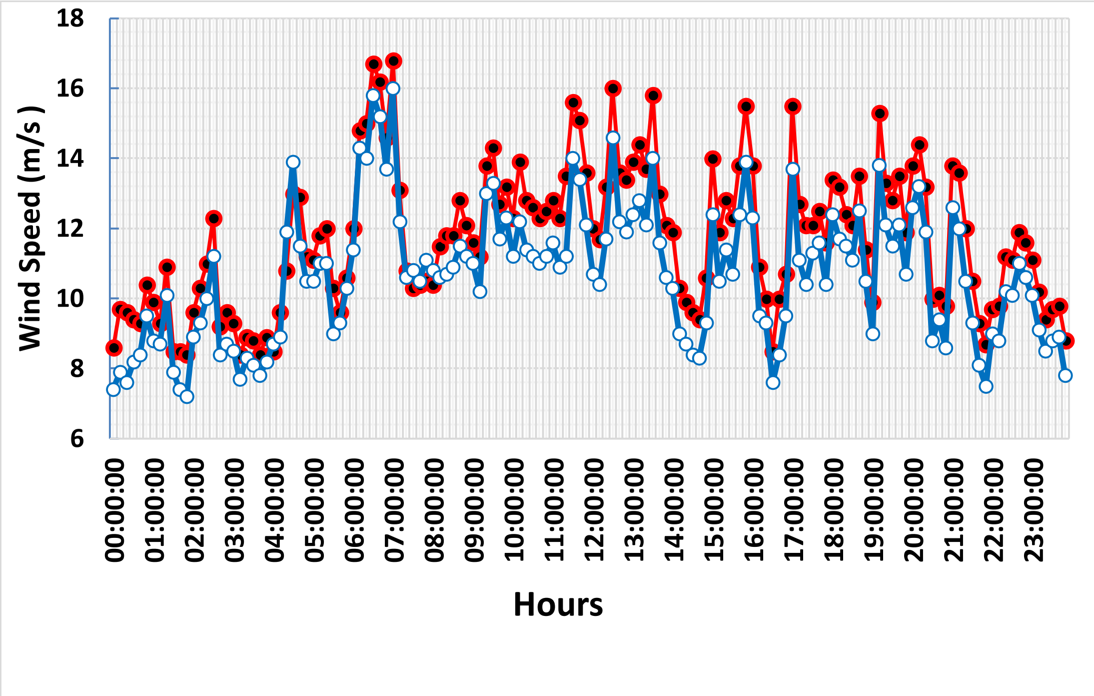


Figure 3.13. Hourly maximum wind speeds (Yearly)

4. RESULTS AND DISCUSSION

Wind energy, which is one of the renewable energy sources, has no harm to nature when it is used for electricity production. There is no problem with fossil fuels for wind turbines. Since these turbines use wind as fuel, they do not give poisonous gases to the atmosphere. Wind energy has an important place in renewable energy sources as an energy source that can be solved in suitable environments with its features such as not polluting the natural environment and atmosphere in order to meet the energy needs of human beings efficiently. Although wind energy is going in parallel with studies to determine the potential ways the world about Turkey, because these studies are not exactly our energy policy on renewable energy sources has been slow. For this, a realistic energy policy should be prepared, and realistic targets should be set for our country which has great potential in energy resources. It should not be forgotten that countries that can use their national resources more technologically will be in a more effective position in the future. The issue of utilizing renewable energy sources, especially wind energy, is one of the steps to achieve this effective position. In order to utilize wind potential, necessary studies should be carried out and incentives should be increased. Only then will such potential analysis work in various regions gain value.

In this study, wind turbine analysis was carried out by using data obtained from anemometers (wind speed meters) at 30 m and 40 m at the measuring pole at Bolu Abant İzzet Baysal University at 10-minute intervals.

When the daily wind speeds taken from the anemometer at 40 m on the measuring pole were examined, the high wind speeds were reached between 06:40 and 15:50 in the afternoon, which means that the average wind speed required for electricity generation is 9 hours per day.

Wind speed values which are high in the measurement area in April, May, June, July, August, September have the lowest values in October, November, December, January, February and March.

5. CONCLUSIONS AND RECOMMENDATIONS

In this study, the wind energy potential of the region was studied by using anemometers at 30 m and 40 m heights at 10 minute intervals at the campus of Gölköy campus of Bolu Abant Izzet Baysal University. As a result of the analyzes and evaluations, the following conclusions were reached.

Wind speed data is measured for 30 m and 40 m altitude, and hourly variations for the selected region during the day were examined. The average maximum wind speed is seen between 07:00 and 15:00 hours while the lowest wind speed is between 12:00 and 03:00 at night was observed. When the data is analyzed on a monthly basis, the average maximum wind speed is calculated for both heights for August and the lowest value for December. Likewise, the highest average wind speed values are observed in autumn season in the seasonal wind data.

As the measurement point determined in the study is surrounded by mountains, it can be said that they are affected by the mountain breezes that occur as a result of different heating of the mountains. According to these results, it can be said that higher yields can be obtained for the plants in this region in autumn season and in the afternoon hours in the morning during the day. Changes during the day and monthly may vary depending on landforms on land, barriers around the measured location.

In this study, one-year results obtained from anemometers at two different heights for 30 m and 40 m were compared. When the average wind speed data are analyzed on a monthly basis, they are the months in which the minimum wind speed value required for electricity generation exceeds 4 m/s in July, August, September and April. In other months of the year, ie in October, November, December, January, February, March, May and June, the average wind speed was below 4 m/s. No electricity was produced efficiently during these months.

When we examine the average hourly wind speed data during the day; During the day, the average wind speed reached more than 4m / s between 06:40 and 15:40 in the afternoon. In other words, electricity was produced efficiently in an average period of 9 hours per day. It should not be ignored that the received wind speed data may vary according to location, years, seasons, months and hours during the day. The obtained annual wind measurement values were taken from a single point measuring pole. In order to make healthier decisions, I believe that evaluations will be made on data from at least 3-4 years from the measurement pole which will be established at several different points.

Although wind energy potential assessment studies in Turkey-Bolu and the world go parallel with existing infrastructure, these studies are progressing slowly due to the lack of an energy policy regarding renewable energy sources. In order to utilize wind potential, necessary studies should be carried out and incentives should be increased. Only then will such potential analysis work in various regions gain value.

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APPENDICES

7. APPENDICIES

Appendix A

12-month wind speed data are collected on a daily basis and given in graphical form.

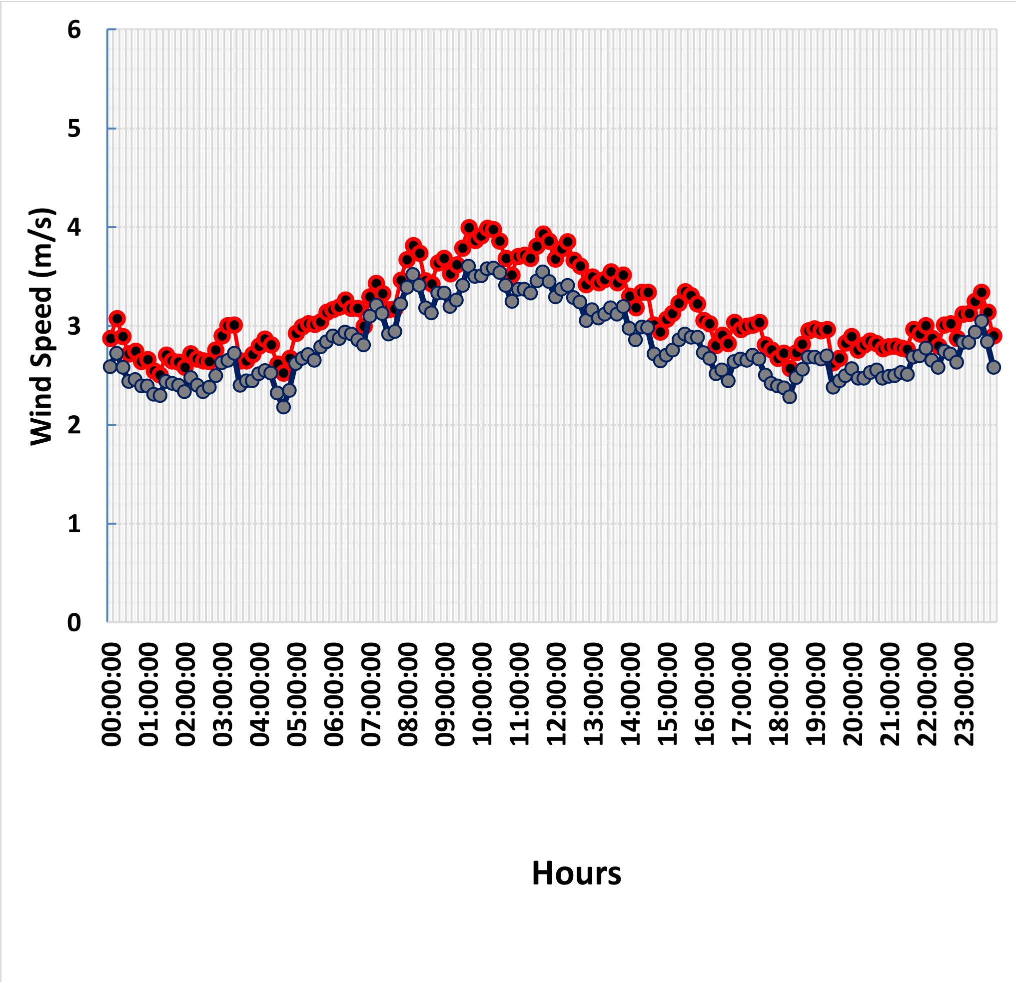

Figure A.1: Hourly average wind speeds (January)

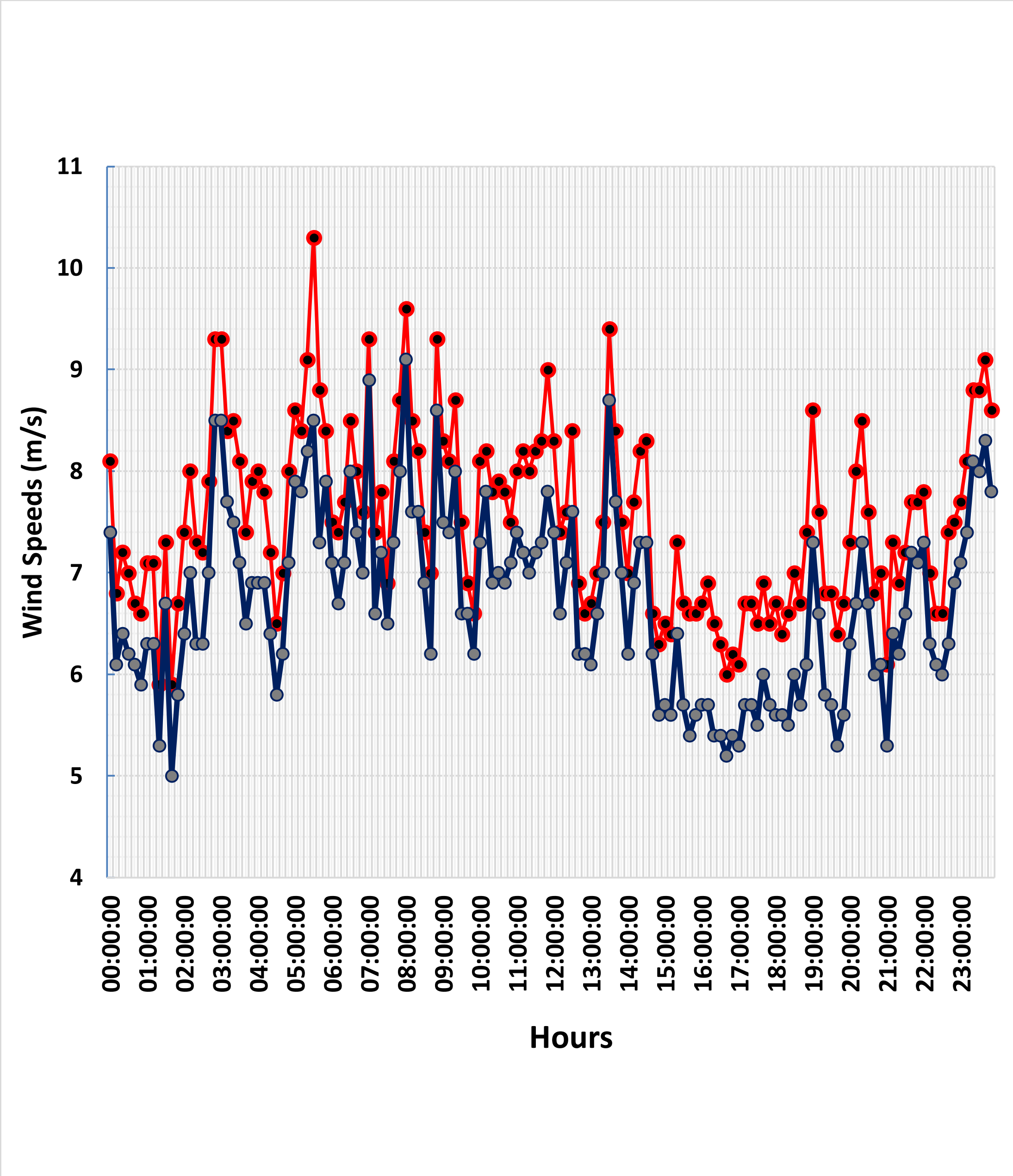

Figure A.2: Hourly maximum wind speeds (January)

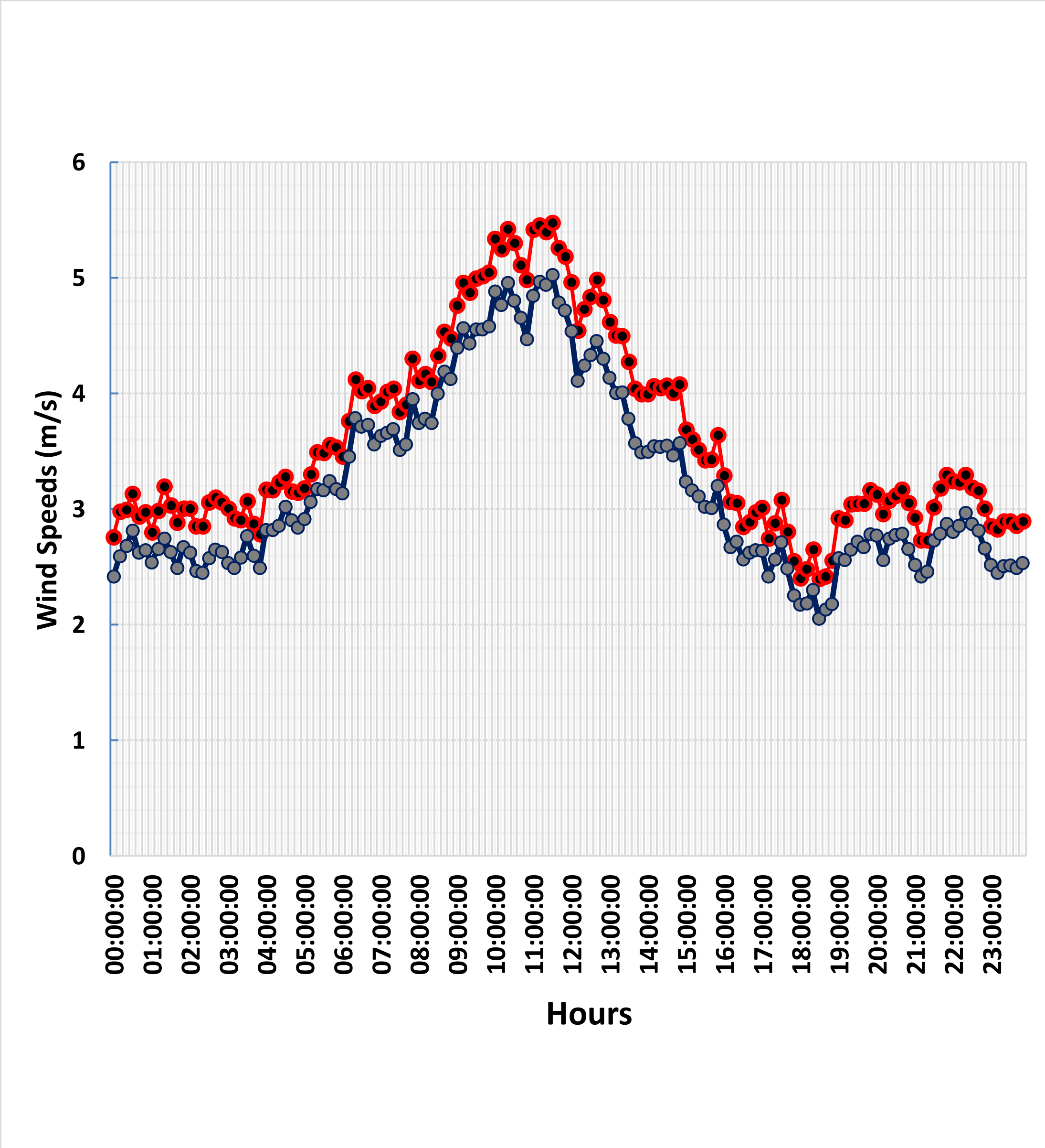

Figure A.3: Hourly average wind speeds (February)

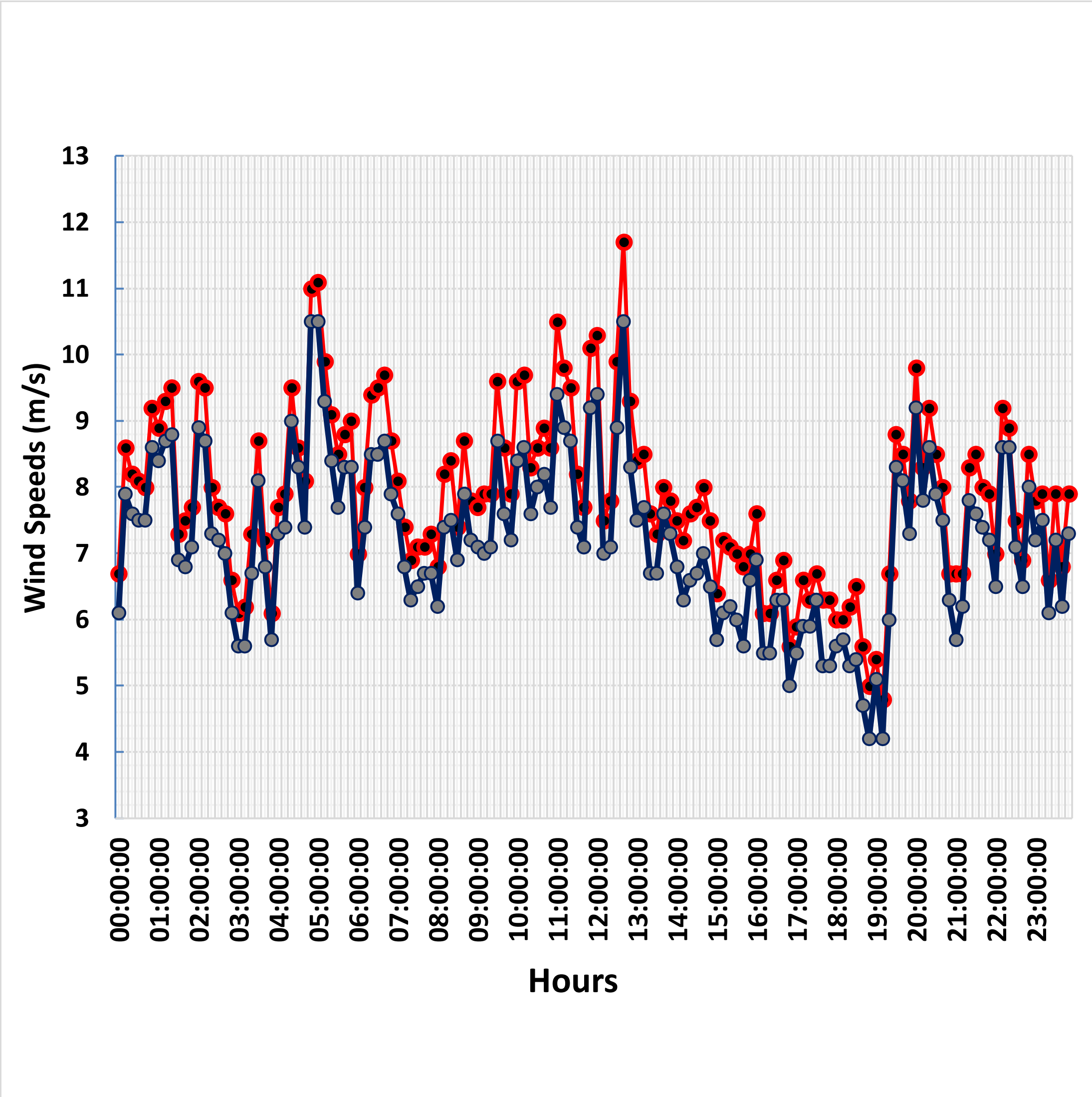

Figure A.4: Hourly maximum wind speeds (February)

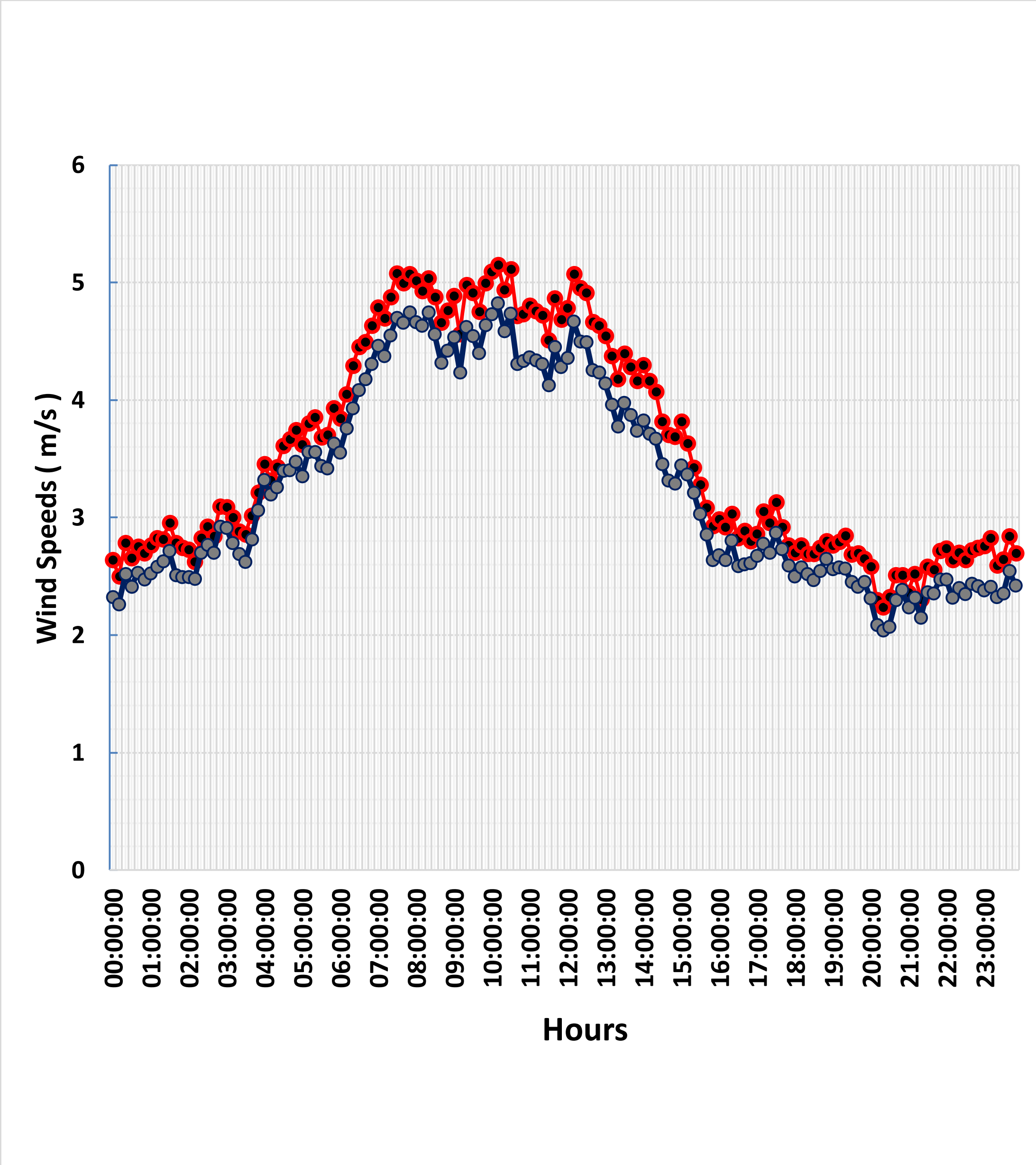

Figure A.5: Hourly average wind speeds (March)

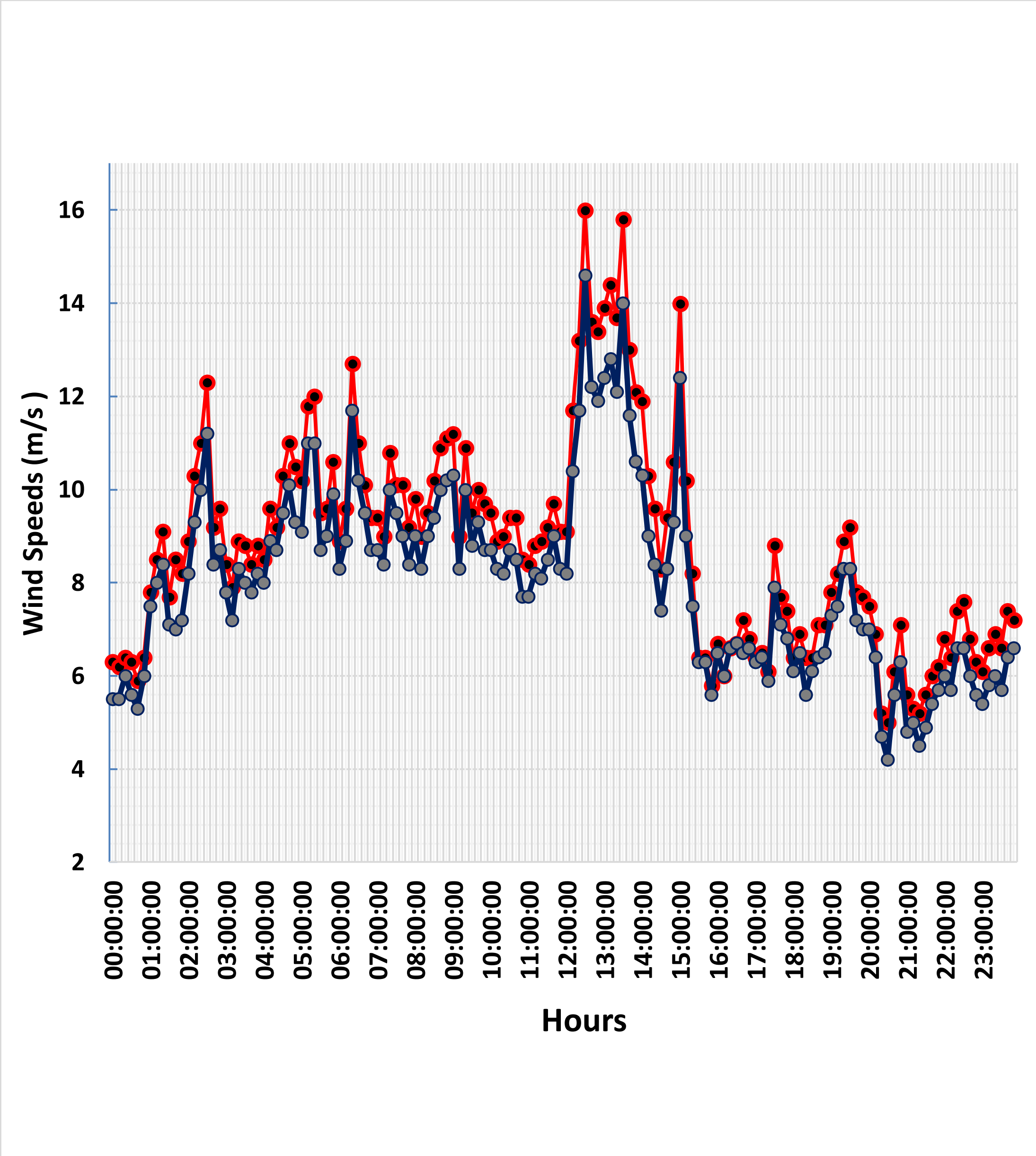

Figure A.6: Hourly maximum wind speeds (March)

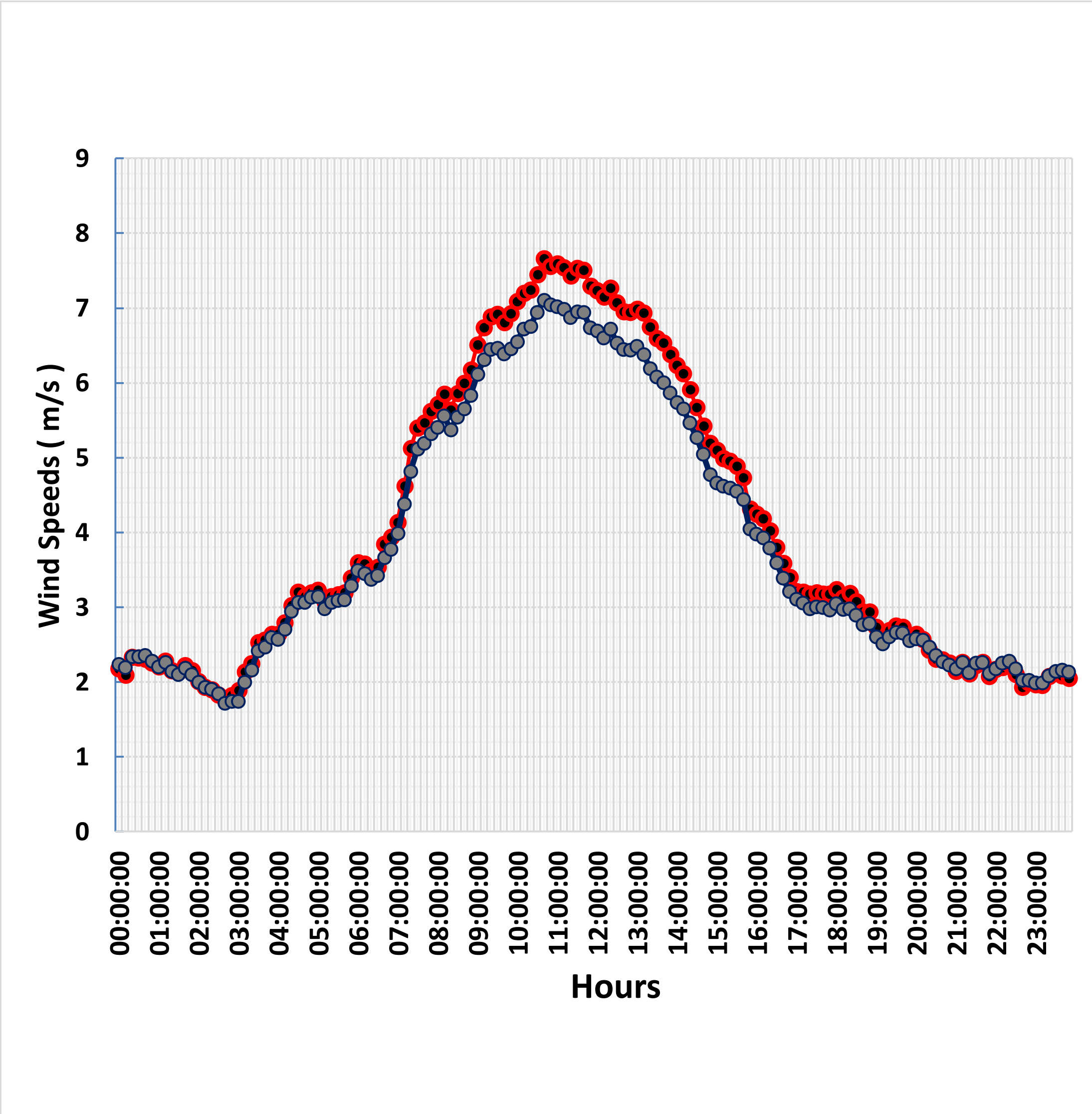

Figure A.7: Hourly average wind Speeds (April)

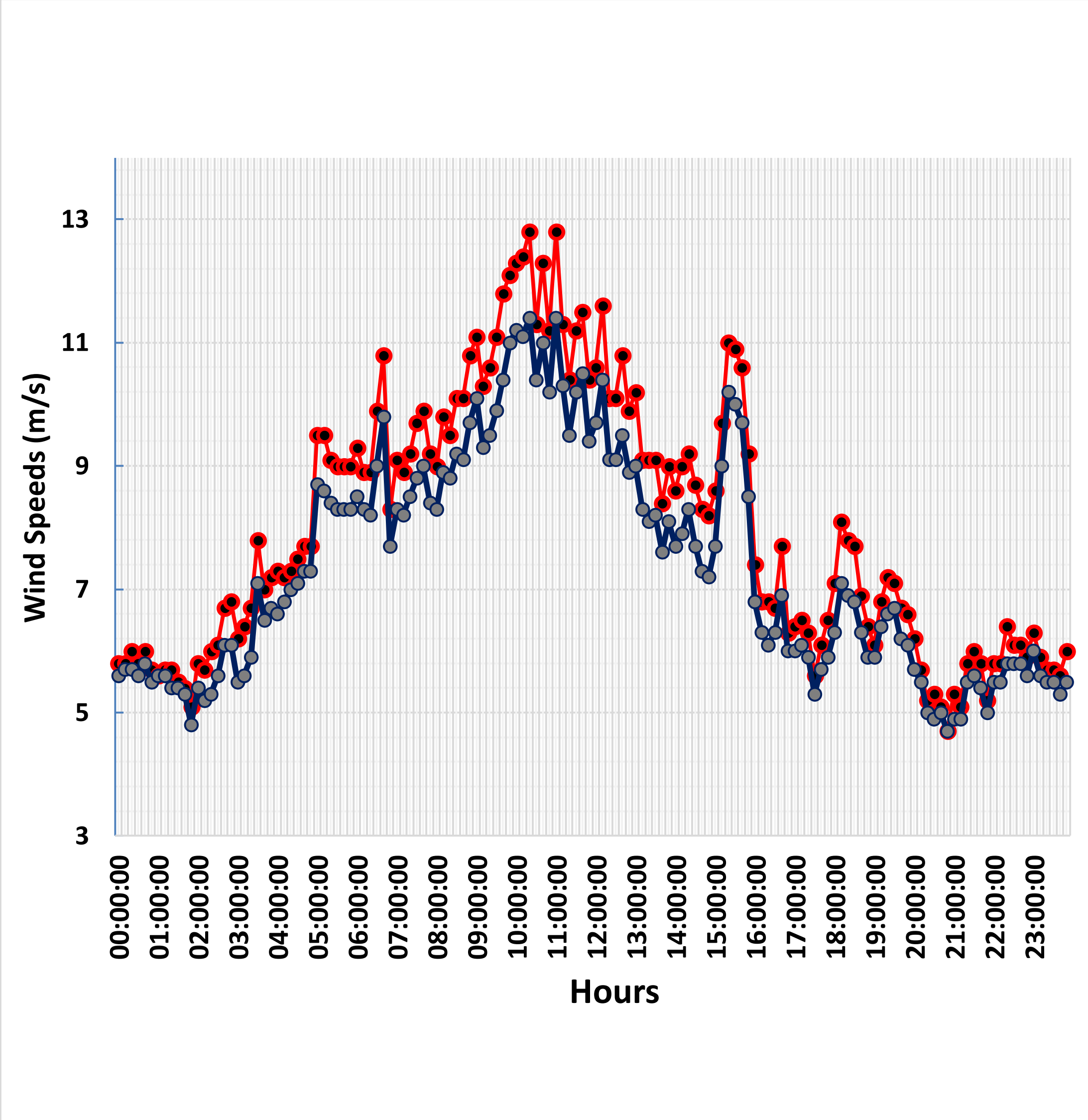

Figure A.8: Hourly maximum wind speeds (April)

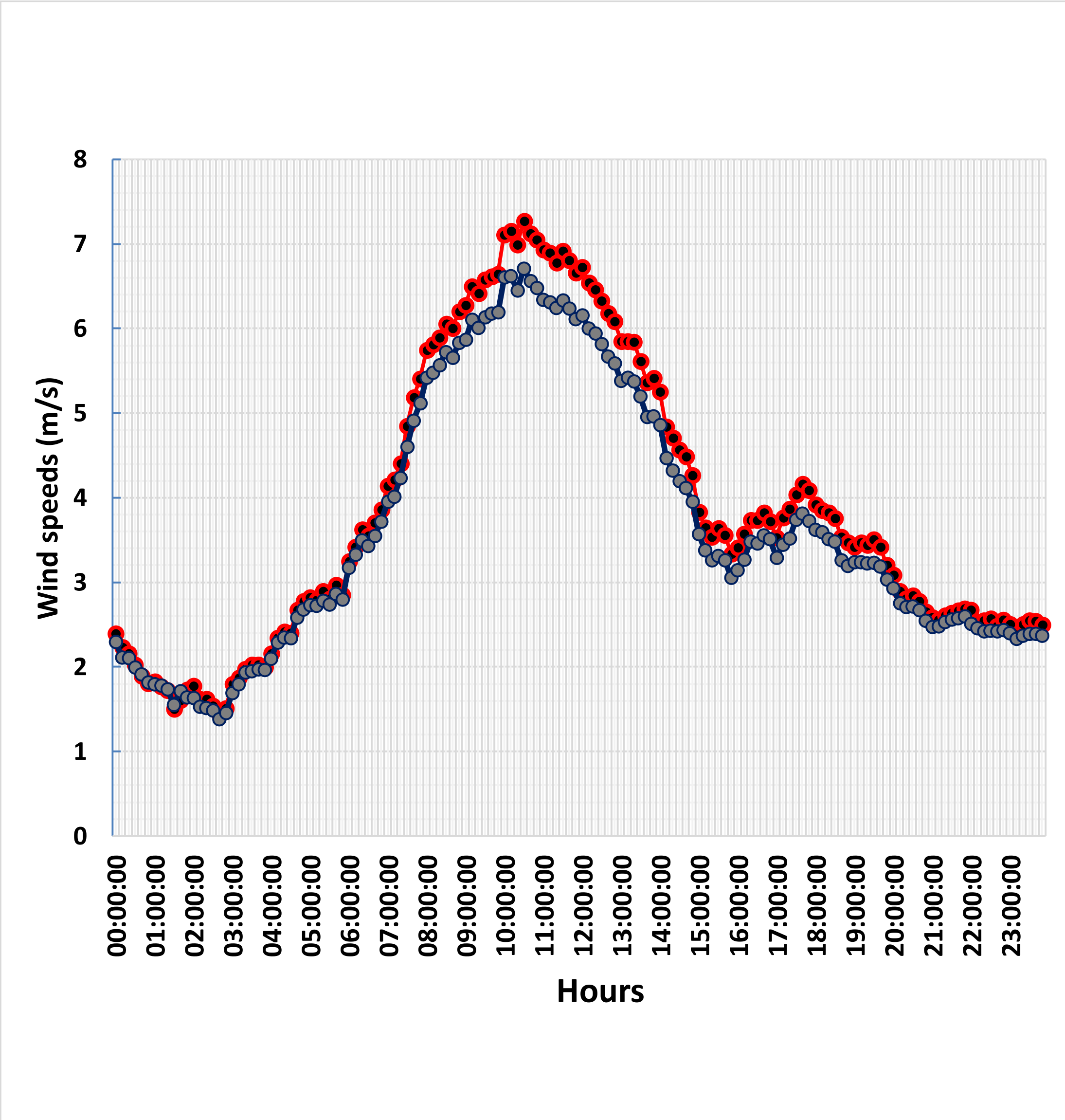

Figure A.9: Hours average wind speeds (May)

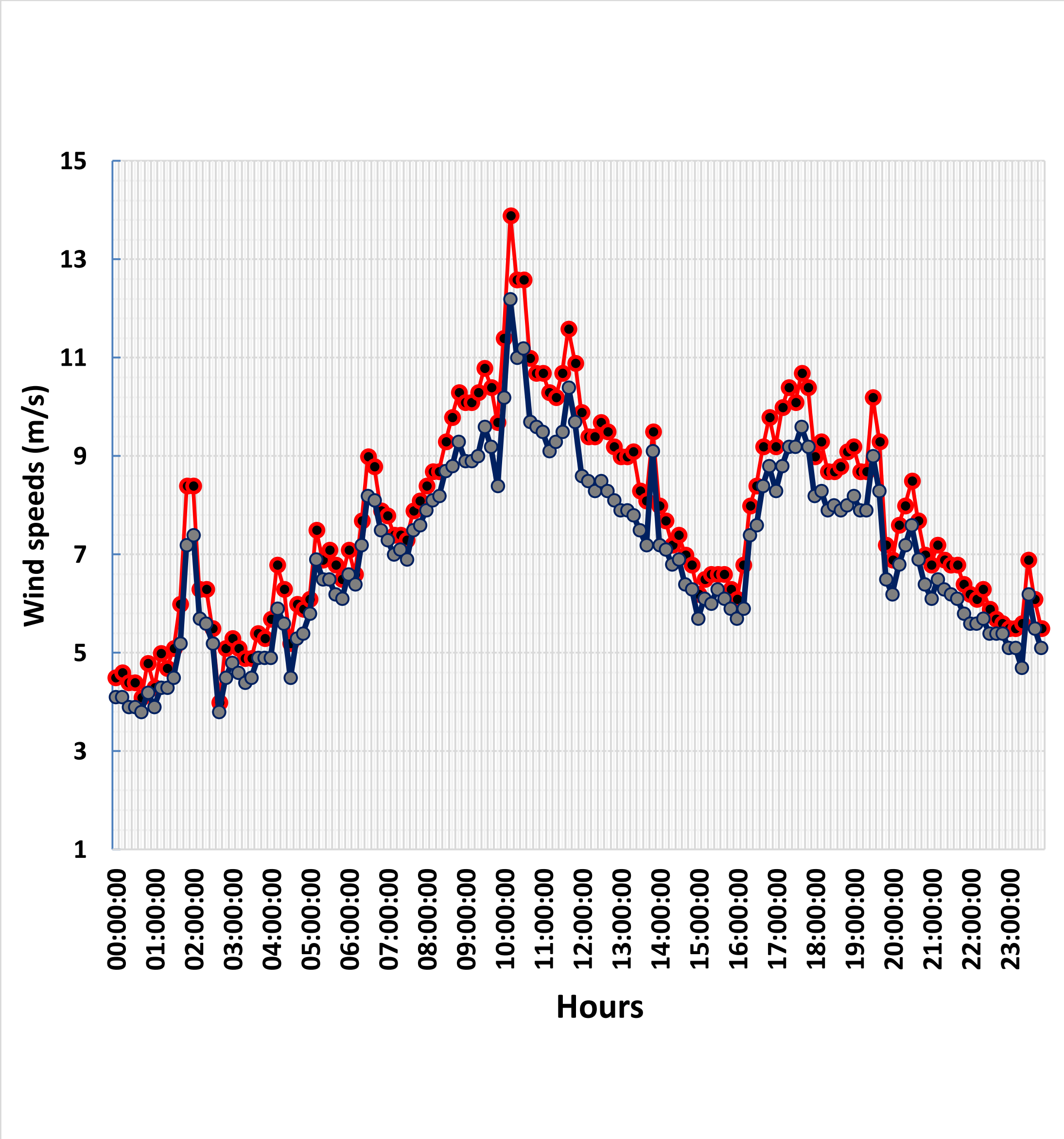

Figure A.10: Hourly maximum wind speeds (May)

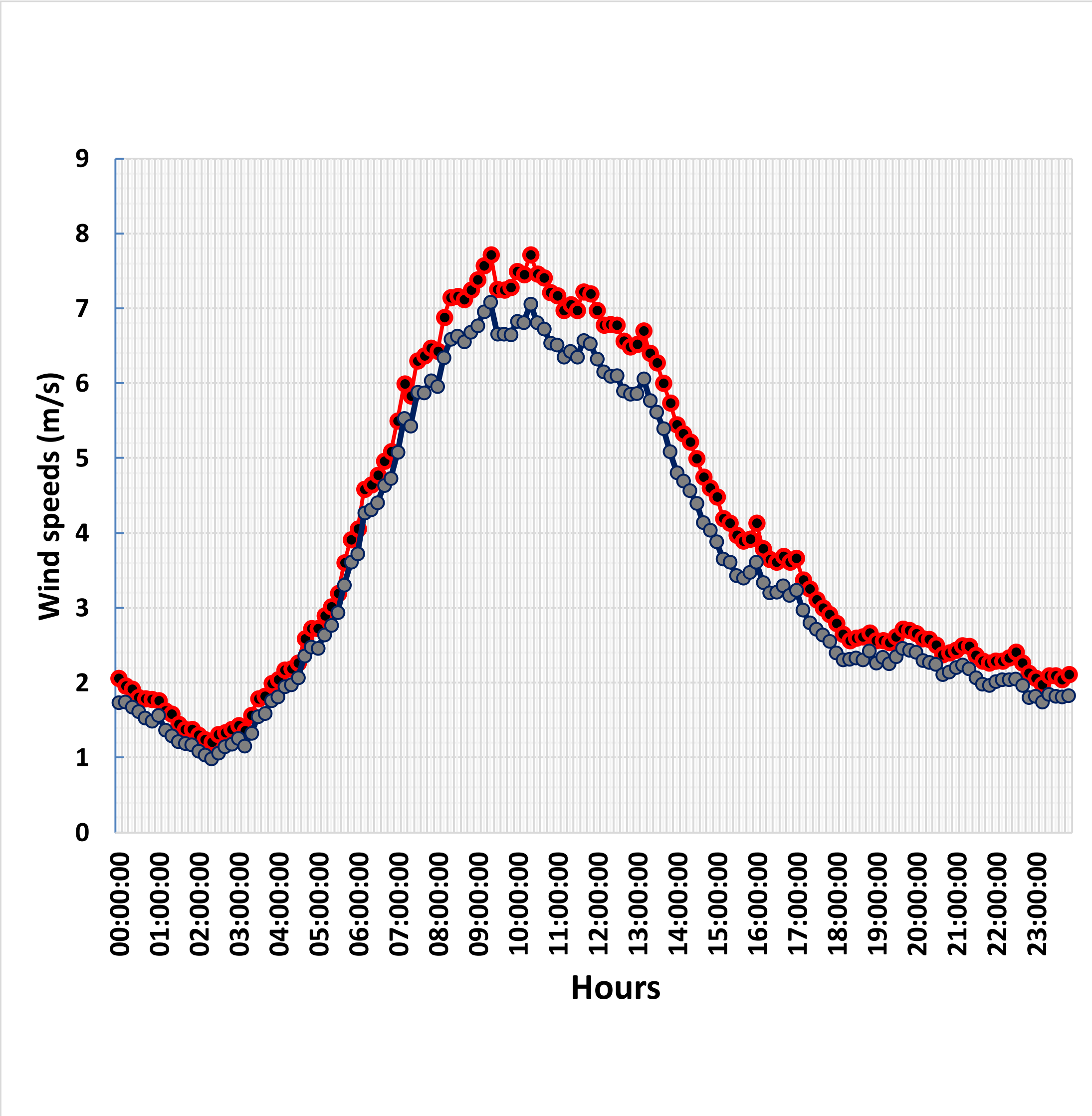

Figure A.11: Hourly average wind speeds (June)

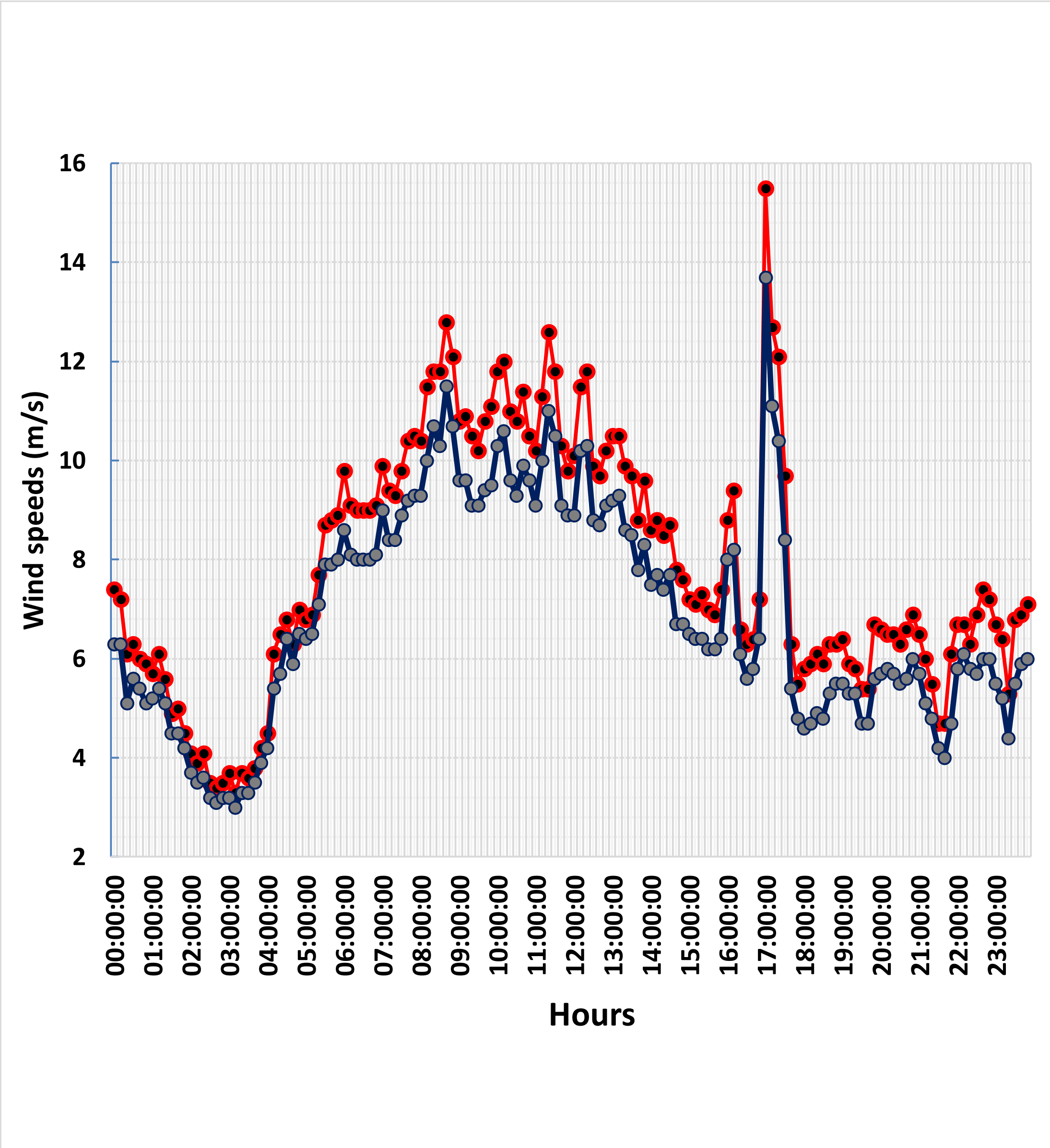

Figure A.12: Hourly maximum wind speeds (June)

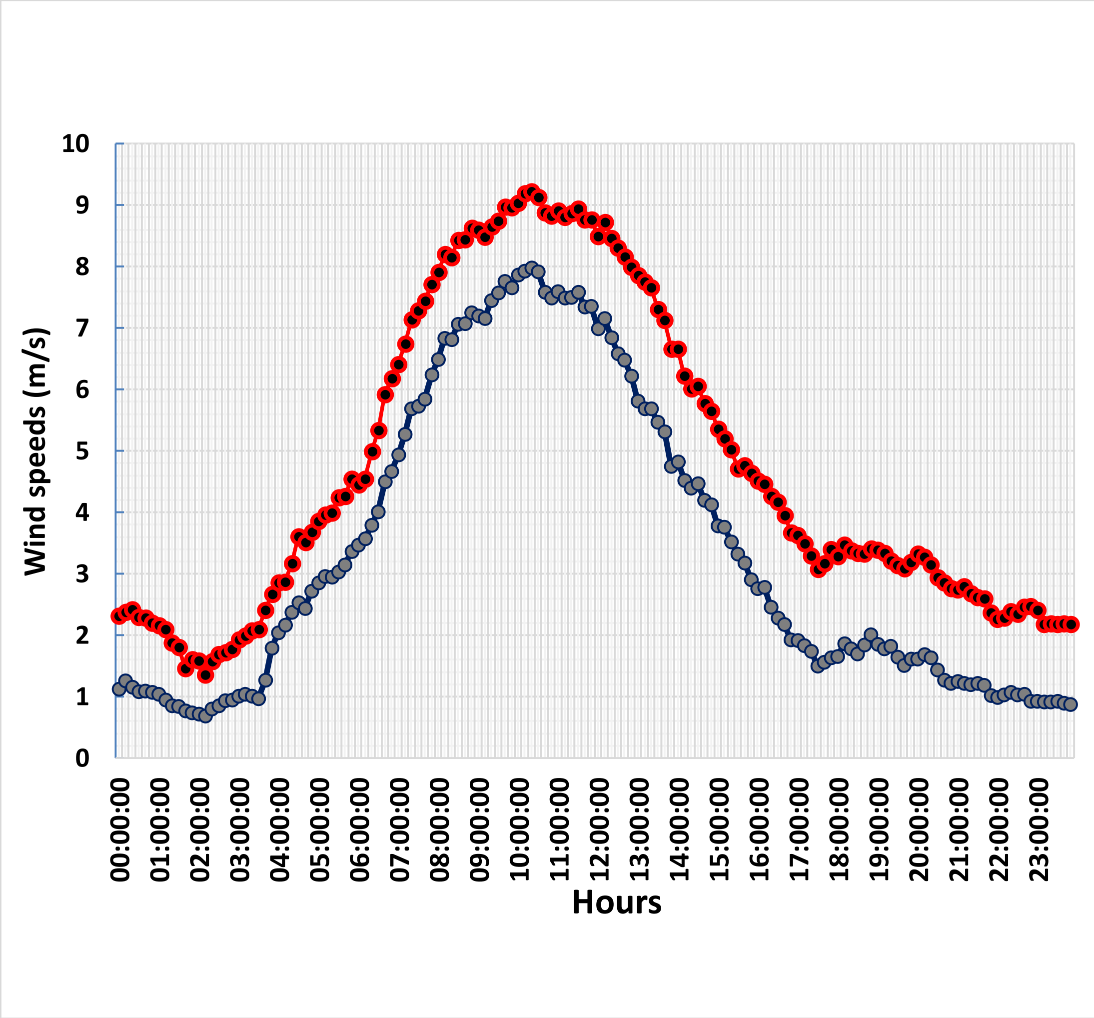

Figure A.13: Hourly average wind speeds (July)

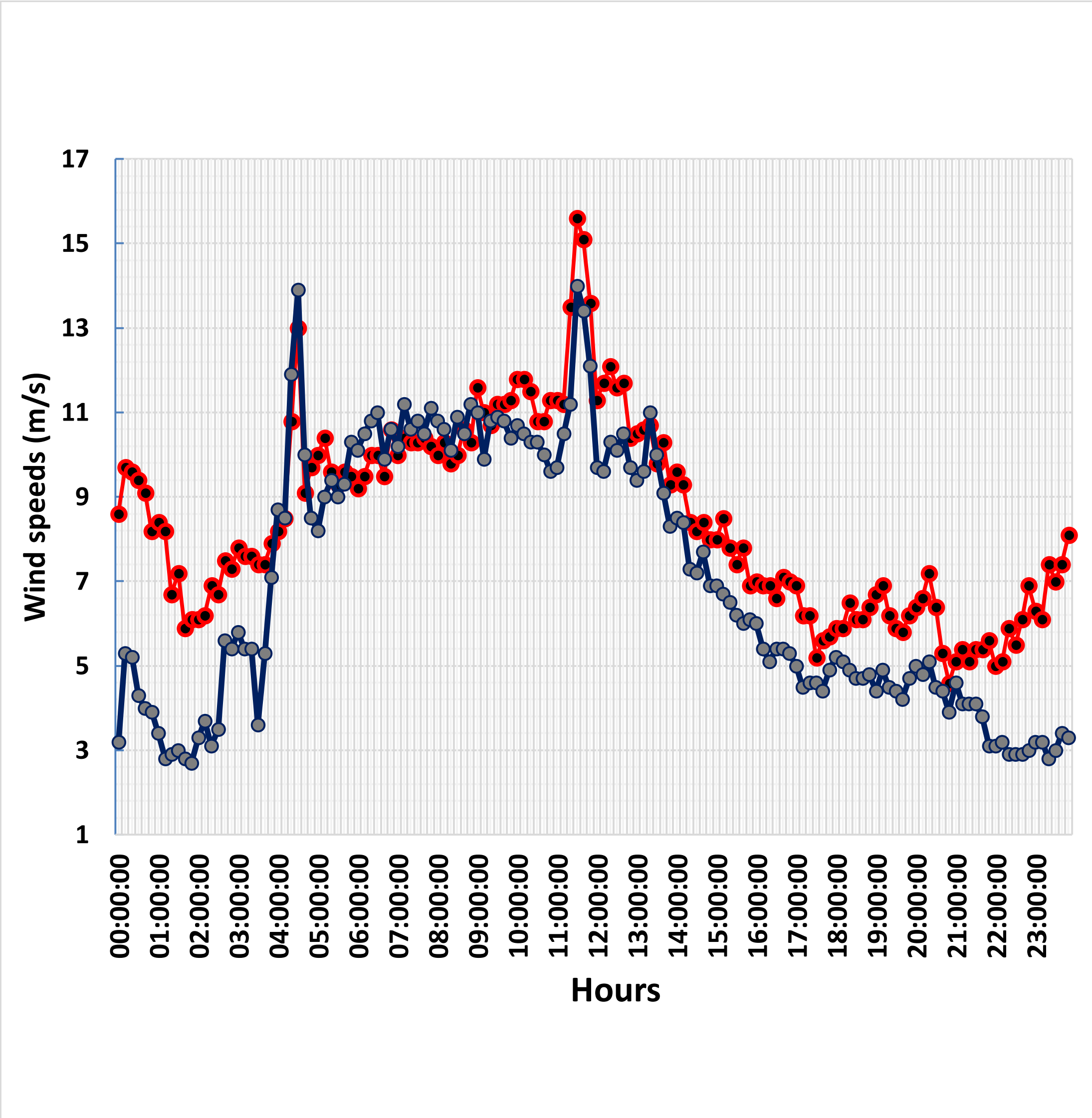

Figure A.14: Hourly maximum wind speeds (July)

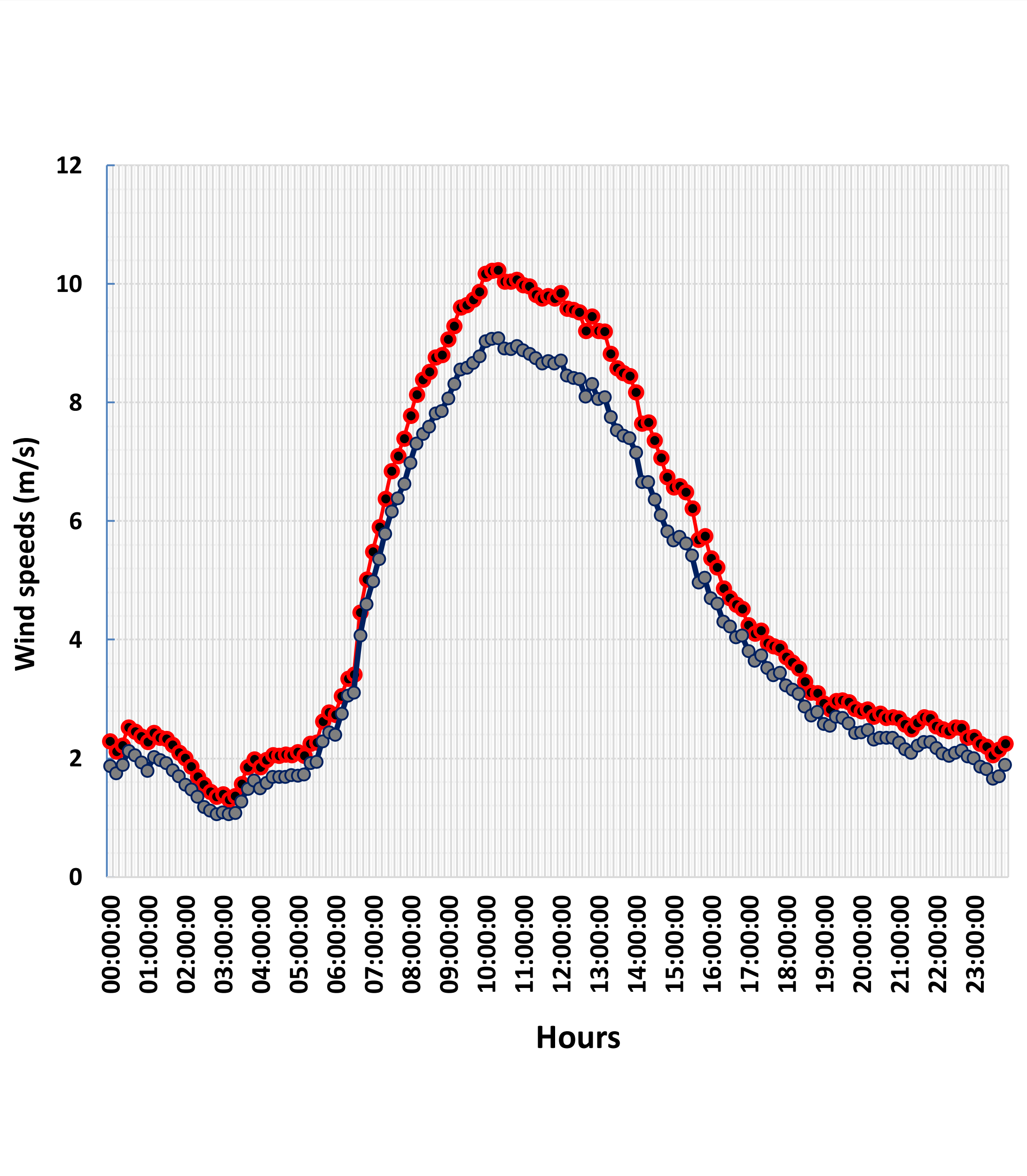

Figure A.15: Hourly average wind speeds (August)

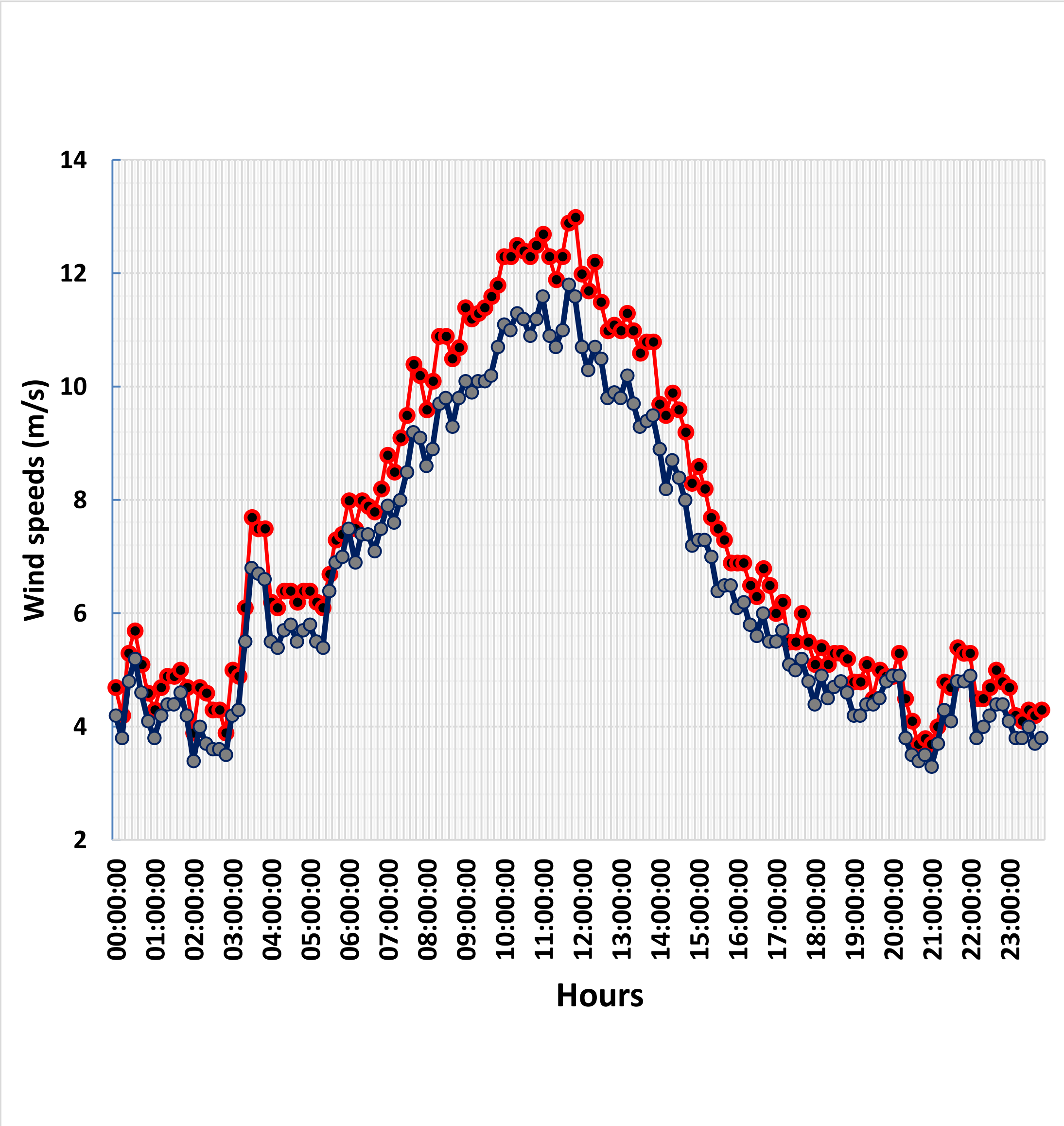

Figure A.16: Hourly maximum wind speeds (August)

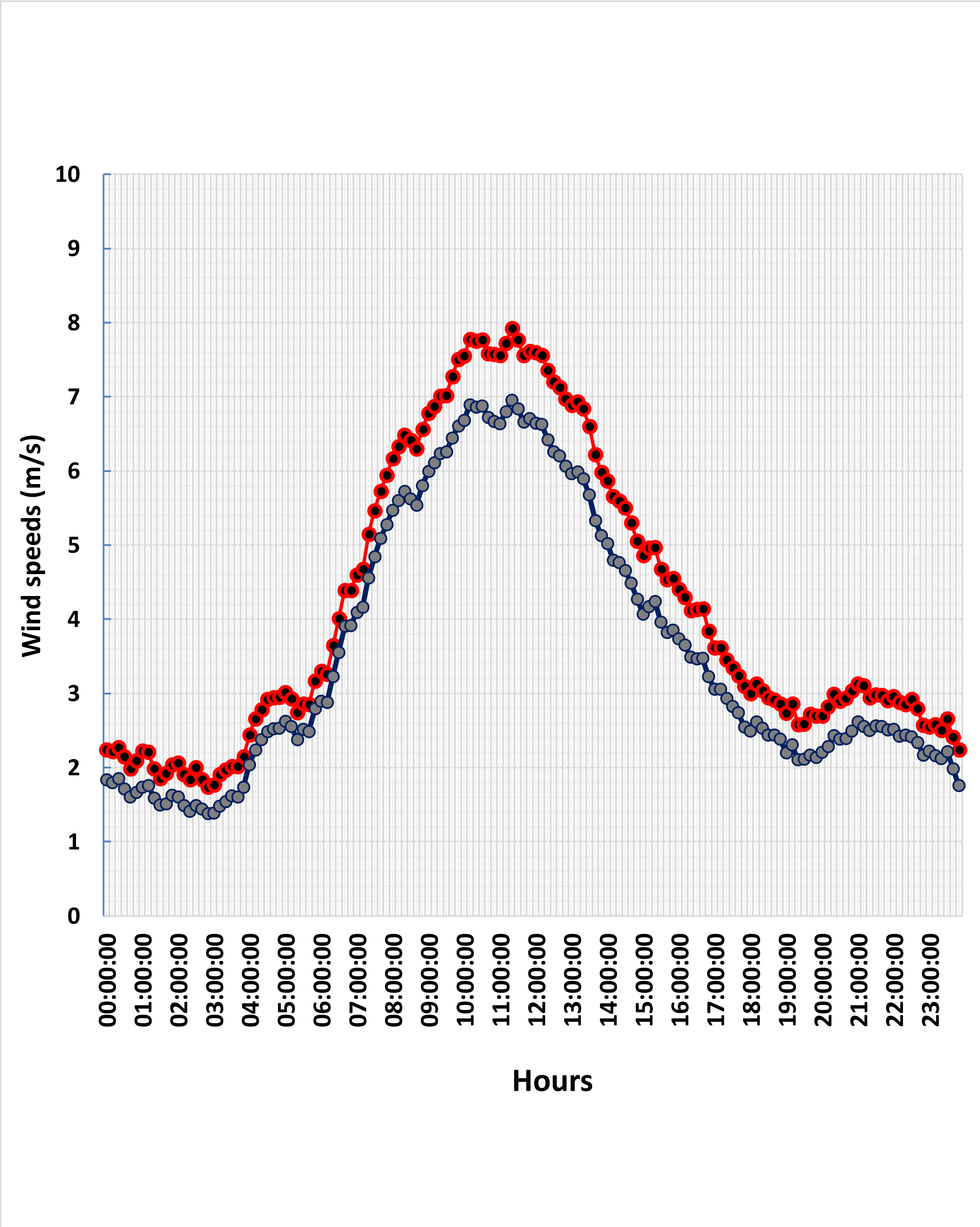

Figure A.17: Hourly average wind speeds (September)

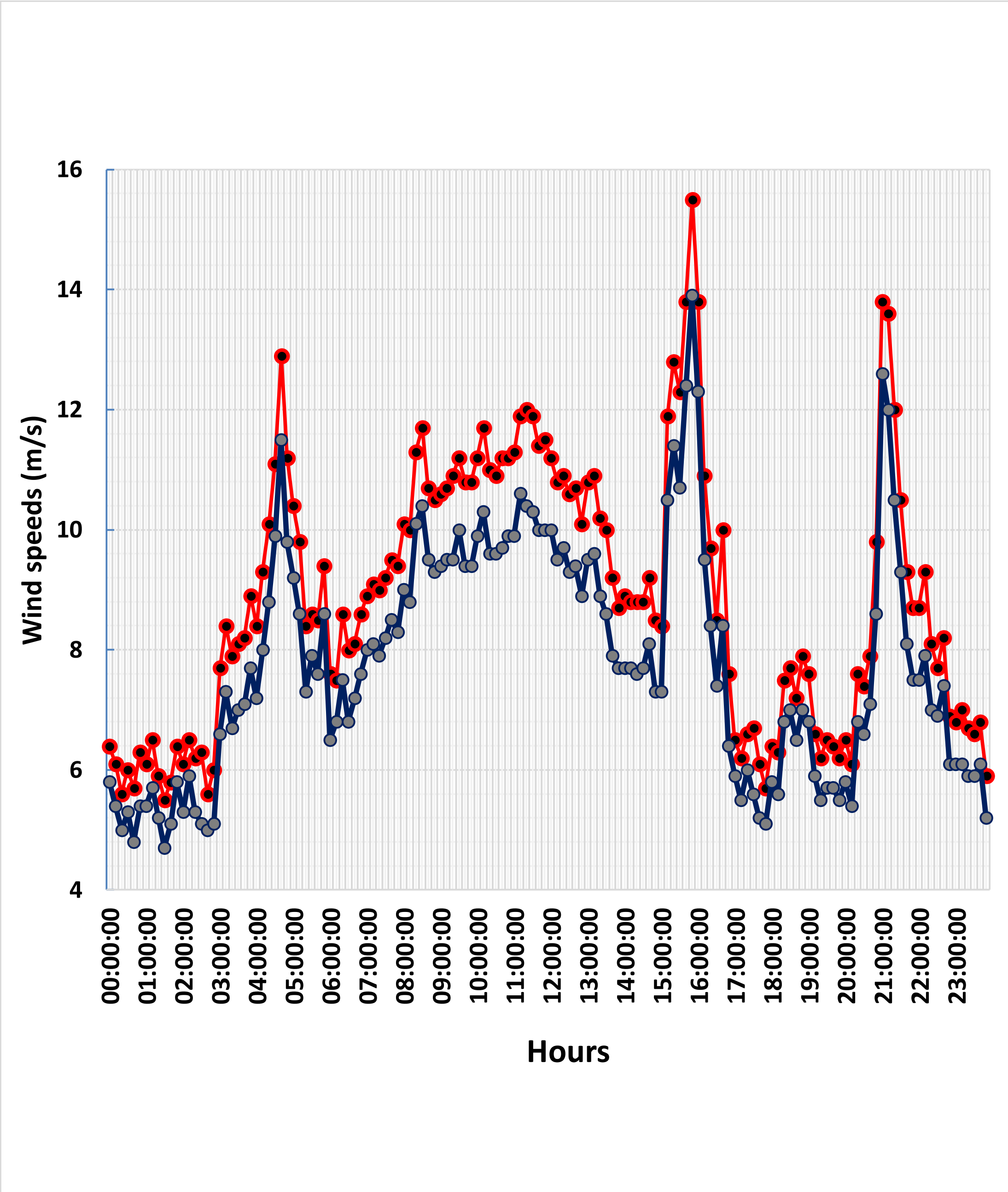

Figure A.18: Hourly maximum wind speeds (September)

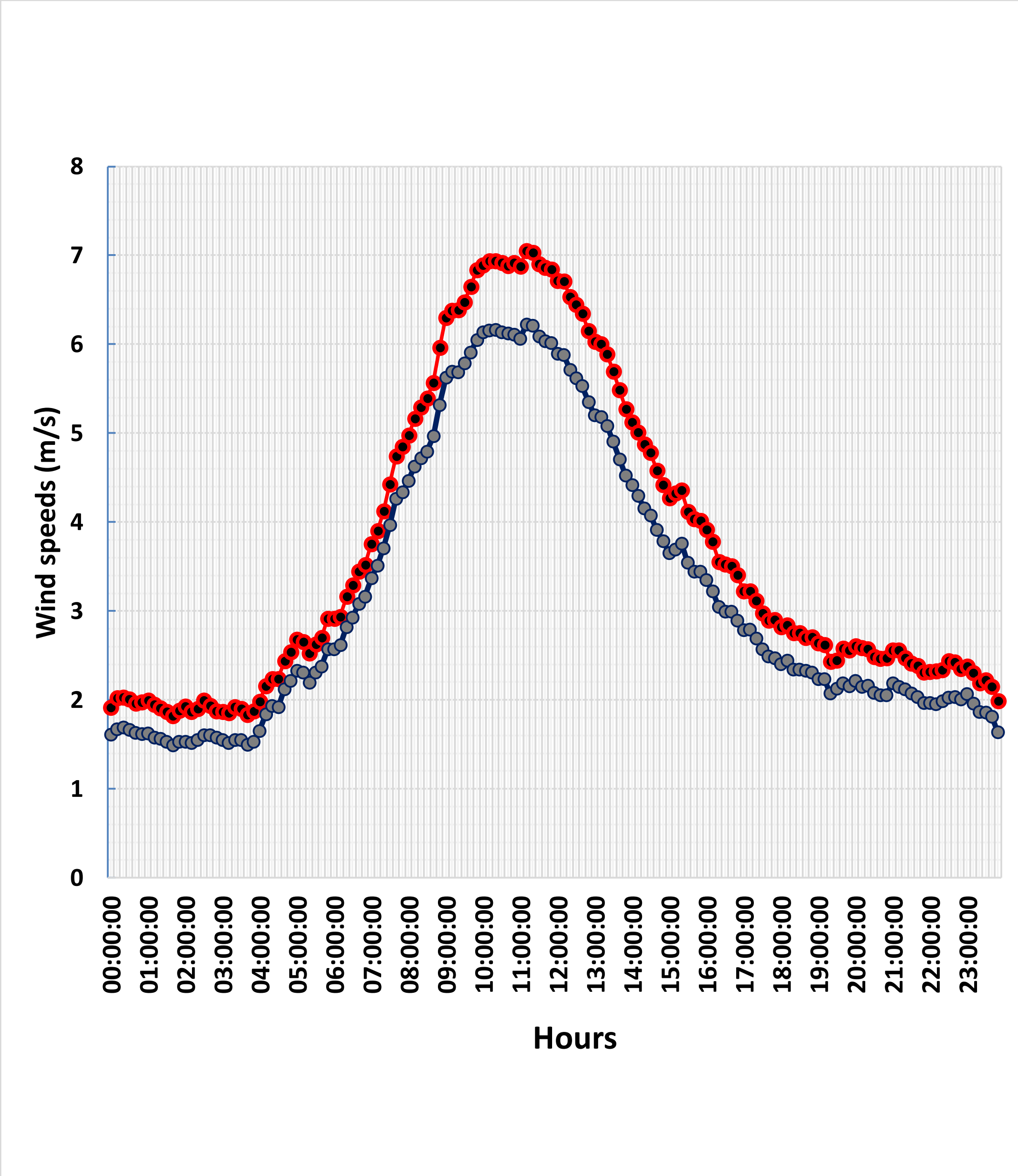

Figure A.19: Hourly average wind speeds (October)

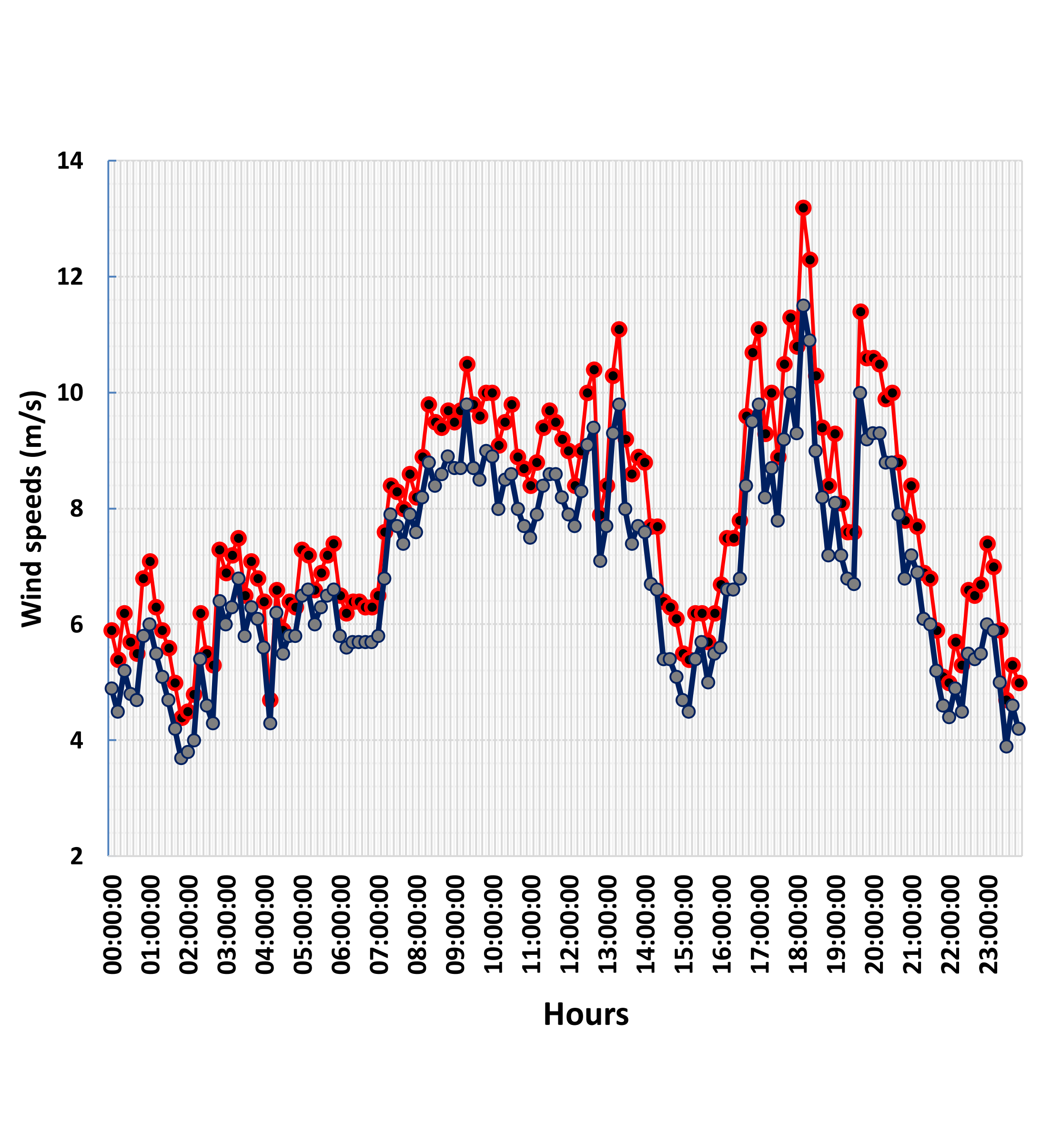

Figure A.20: Hourly maximum wind speeds (October)

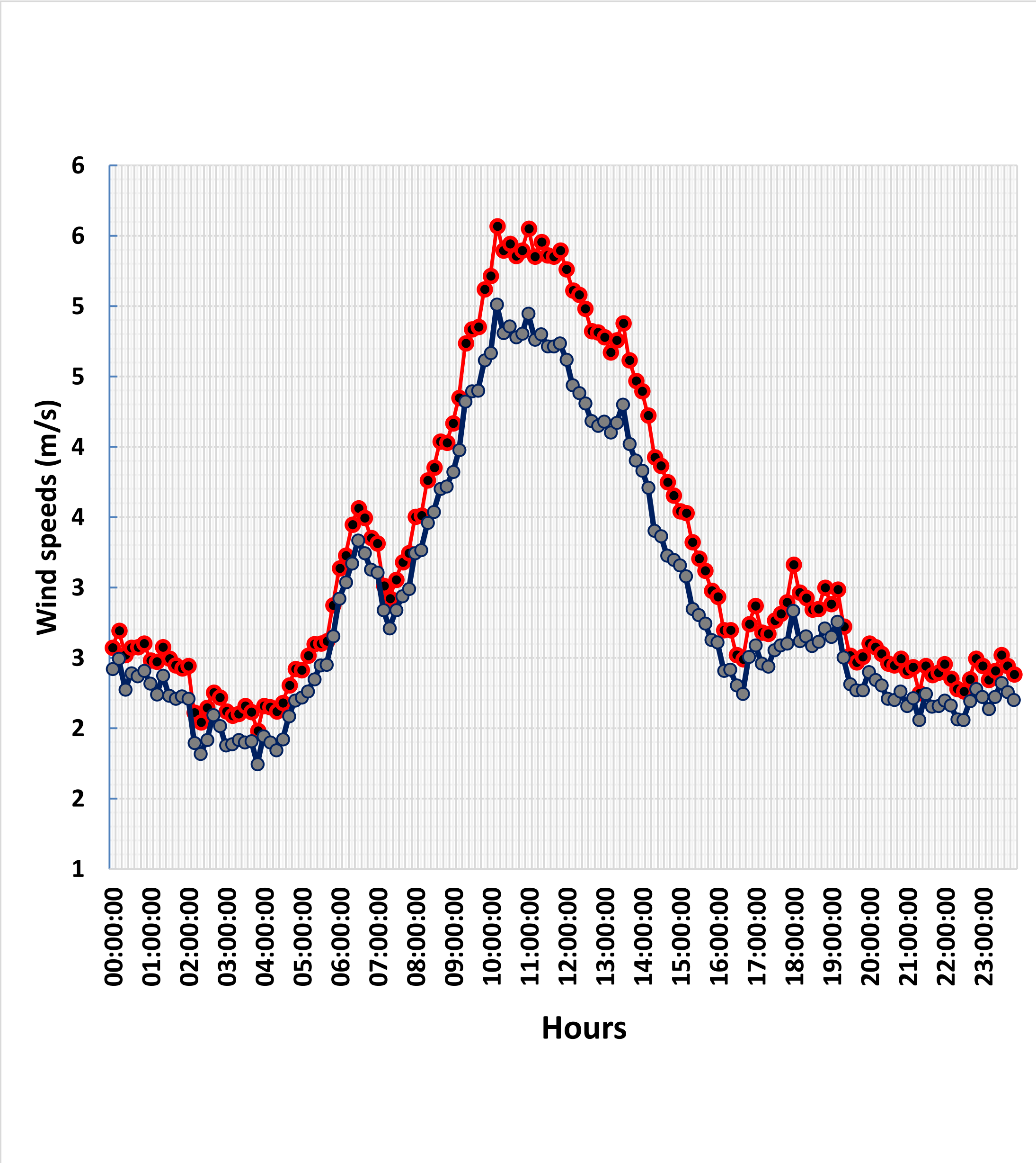

Figure A.21: Hourly average wind speeds (November)

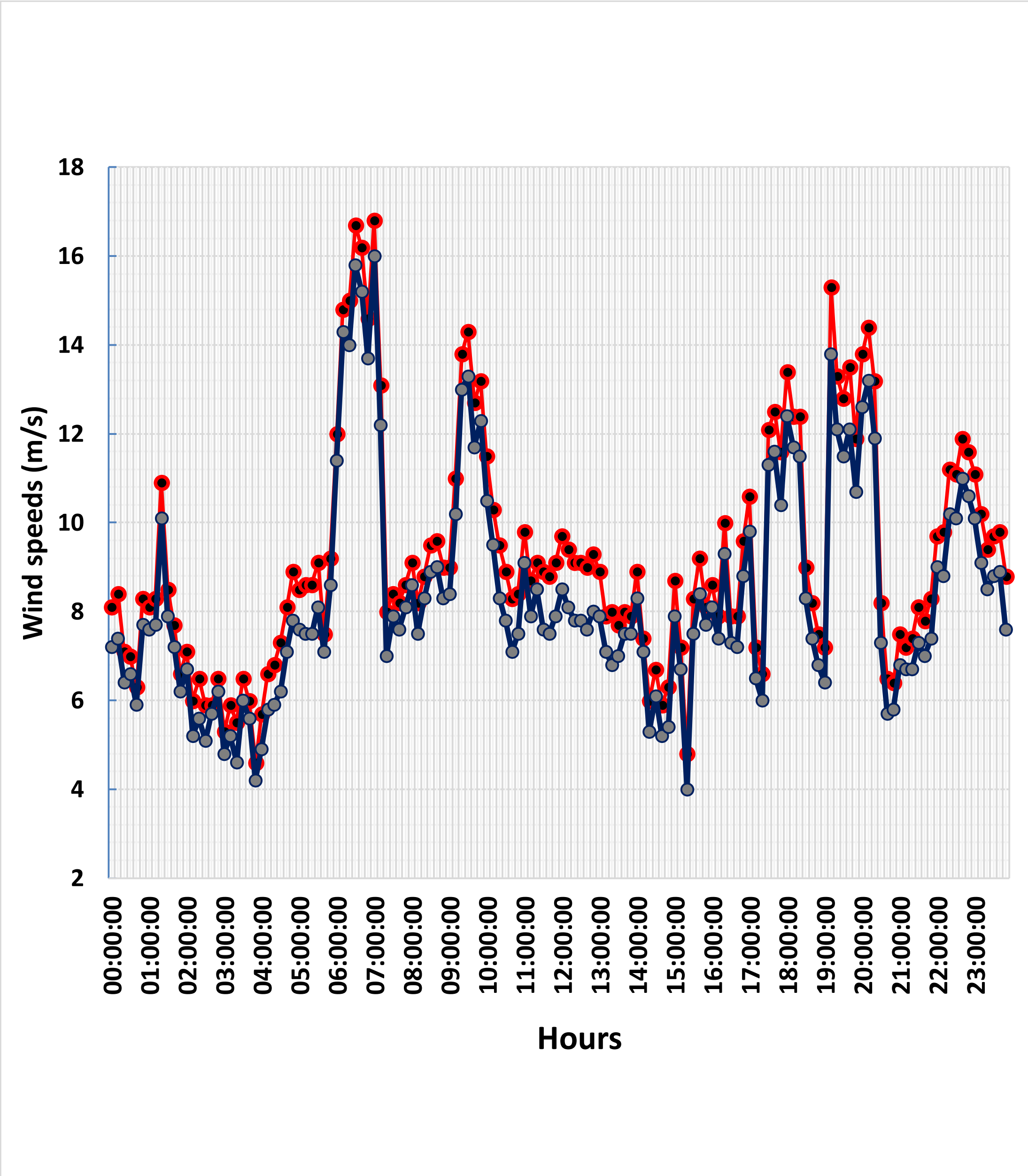

Figure A.22: Hourly maximum wind speeds (November)

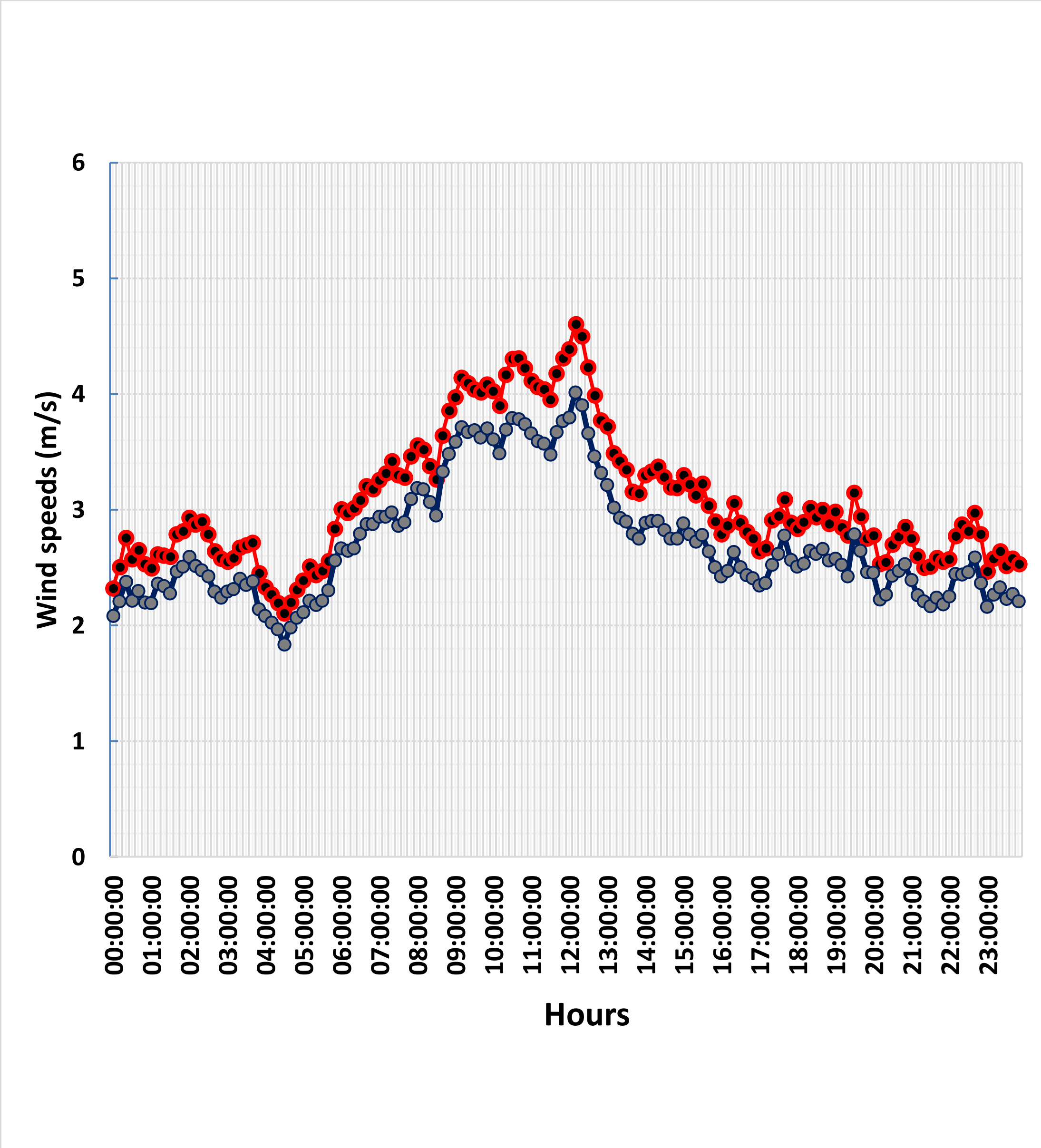

Figure A.23: Hourly average wind speeds (December)

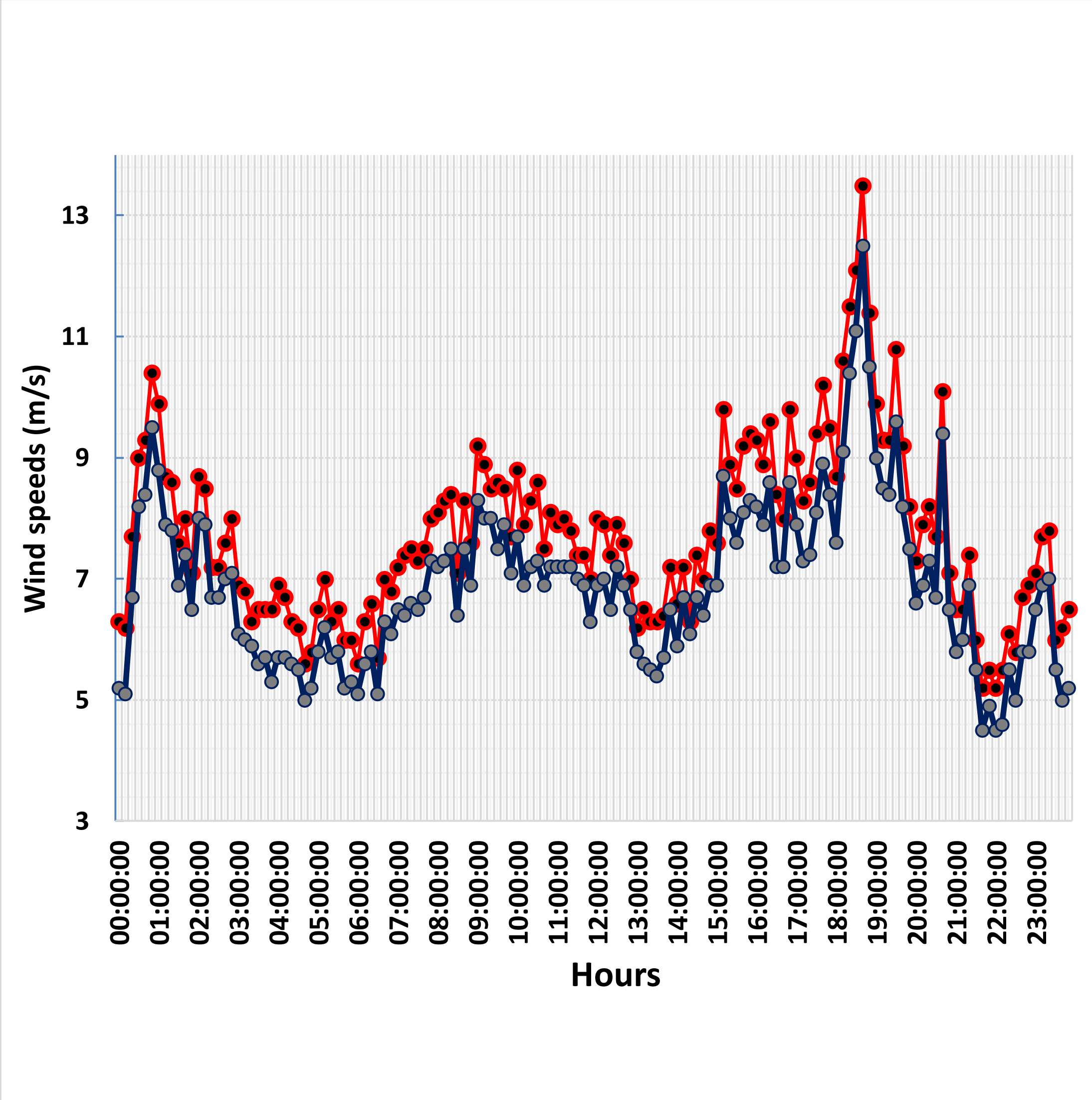

Figure A.24: Hourly maximum wind speeds (December)

8. CURRICULUM VITAE

Name, Surname	**:** Ercan Çiçek
Place and Date of Birth	**:** Denizli, 01.01.1983
Universities	
Bachelor's Degree	**:** Bolu Abant Izzet Baysal University
e-mail	**:** ercancicek8214@gmail.com
Address	**:** İzzet Baysal Mahallesi. Kale sokak. No: 3 D: 2 BOLU