Türk Tarım ve Doğa Bilimleri Dergisi 10(2): 431–437, 2023
https://doi.org/10.30910/turkjans.1188052

TÜRK
TARIM ve DOĞA BİLİMLERİ
DERGİSİ

TURKISH
JOURNAL of AGRICULTURAL
and NATURAL SCIENCES

www.dergipark.gov.tr/turkjans

Araştırma Makalesi

Means of Using Renewable Energy Resource: Wind Energy for Controlling Climate in Greenhouses

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Geliş Tarihi: 22.10.2022 Düzeltme Geliş Tarihi: 12.01.2023 Kabul Tarihi: 15.02.2023

ABSTRACT

Use of renewable energy resources might be the solution for electric power shortage in agricultural production. Wind turbines might be used in places with higher wind energy potential to generate electricity, such as coastline of the Marmara Sea and Tekirdağ Province. Generally, natural ventilation used in greenhouses is insufficient. Mechanical ventilation must be used in order to improve ventilation and achieve the desired levels. However, greenhouses are generally located on rural areas and mechanical ventilation cannot be used in such areas because the electricity supply system is not fully available. Wind turbines might be used to overcome this energy shortage in places where wind energy potential is promising. A 12 m^2 pad area is needed for ventilation and cooling system to be installed in a high tunnel located in Tekirdağ Province on a 298 m^2. A 0.2 kWh circulation pump must be used in this system to ensure water circulation. 4 x 0.75 kWh aspirator systems with 9500 $m^3 h^{-1}$ flow rate will be used for providing forced ventilation. A 5 kWh wind turbine system supported with batteries will generate the energy required for the ventilation and cooling system.

Key words: Renewable energy, wind turbine system, ventilation, cooling, fan-pad.

Yenilenebilir Enerji Kaynaklarından Rüzgar Enerjisinin Seralarda İklim Koşullarının Sağlanmasında Kullanılması

ÖZ

Yenilenebilir enerji kaynaklarından yararlanılarak, tarımsal üretimde elektrik enerjisi sorunu çözülebilir. Özellikle Marmara Denizi kıyıları ve Tekirdağ gibi rüzgar enerjisi potansiyelinin yüksek olduğu yerlerde elektrik enerjisi için rüzgar türbinlerinden yararlanılabilir. Seralarda uygulanan doğal havalandırma genelde yeterli olmamaktadır. Havalandırma miktarını istenilen seviyeye çıkarabilmek için, mekaniksel havalandırmanın uygulanması gerekir. Ancak seraların genelde kırsal kesimde olması ve elektrik şebekesinin oralara yetişmemesi nedeniyle, mekaniksel havalandırma uygulanamamaktadır. Rüzgar enerjisi potansiyelinin uygun olduğu yerlerde, rüzgar türbininin kullanımı ile bu enerji sorunu aşılabilir. Tekirdağ'da alanı 298 m^2 olan bir yüksek tünelde kurulacak havalandırma ve soğutma sistemi için, 12 m^2'lik ped alanına ihtiyaç vardır. Bu sistemde suyun dönüşümünü sağlamak için 0.2 kWh'lık sirkülasyon pompasının kullanımı gerekir. Zorunlu havalandırma için, 4 adet 0.75 kWh gücünde ve debisi 9500 $m^3 h^{-1}$ olan aspiratör sistemi kullanılacaktır. Havalandırma ve soğutma sistemi için, akülerle desteklenen 5 kWh'lık bir rüzgar türbini sistemi istenilen enerjiyi sağlayacaktır.

Anahtar kelimeler: Yenilenebilir enerji, rüzgar türbini sistemi, havalandırma, soğutma, fan-ped.

INTRODUCTION

Renewable energy is a type of energy that is available in natural processes and generated from air and water motions. This type of energy is called as renewable energy because generating electricity with water, air and sunrays in the nature do not deplete these sources (Tunus, 2019). However, fossil fuels such petrol, coal and natural gas are commonly used for generating power. Decreasing fossil fuel reserves enforces to go deeper and deeper on earth's surface to extract fossil fuels. (Şenel and Koç, 2015).

Recently, renewable energy has become more important because of its economic advantages and since environmental consciousness focuses protection of the nature, negative impacts of global warming and zero greenhouse gas emission (Tunus, 2019).

Unlike the fossil fuels, wind energy might cause very minimal damage on the environment and it is a key factor for all economies gravitating towards sustainable development. Turkey is a country that highly depends on foreign resources when it comes to energy, and it must convert its available static energy into kinetic energy. Solar energy and wind energy are among the static energies available in the country and they are very important for its economy (Özen et al., 2015).

Wind Energy

Use of renewable energy resources has been increasing gradually since such energy resources do not cause the environmental problems encountered during generation and transformation of energy. The wind energy is one of the most important renewable energy resources and caused by solar radiation warming up ground surfaces at different levels. When warmed at different levels, ground surfaces cause different air temperatures, humidity and pressure levels, and this difference in pressure levels results in air movements. Wind is defined as air flow moving from a high pressure area towards a low pressure area. Initial investment cost of systems generating electricity with the wind energy is high. It has disadvantages such as low efficiency and variable power generation. However, it has a wide range of advantages and these can be listed as follows (Anonymous, 2023):

- It is a renewable and clean source of energy, and it is environment friendly.
- There is no depletion risk or risk of price increase in time.
- The wind turbines can be installed quickly and easily.
- It decreases dependency on foreign energy sources.
- The land used for installation of the wind turbines can be used as an agricultural land with minimum loss (Tunus, 2019).

Our country's geographical position is optimum for installation of wind energy plants. Particularly, some areas in the Aegean, Marmara and Eastern Mediterranean Regions have a substantial wind potential (Bilgili et al., 2010). Therefore, considering our country's geographical position, distribution of the wind energy plants generally focuses on these areas. Here, the advantages are higher levels of electricity consumption in these areas and lower levels of loss in electricity transmission (Çolak and Demirtaş, 2008).

Wind Turbine

The wind energy can be used in remote residential areas, on islands, in rural areas, agricultural businesses, forestlands and mountainsides where the electric supply system is not available. Household-type small wind turbines are optimum for personal use in areas that are far from the supply system and have the advantage of high wind efficiency (Toprak, 2011).

Turbine blades move as the wind hits the blades. The turbine blades start to rotate and the shaft transmits the rotational motion to the power plant (generator). Since this rotational motion must be faster, a gear box fastens this motion. This kinetic energy of the wind turns into mechanical energy and then electric power. The electric power transferred to power converter unit; the power is converted to the standards suitable for the network or consumer and then transmitted to the user (Yaylacı and Yazıcı, 2019).

The wind turbine system has a wind turbine, charge control unit, braking system, battery (power supply) group, turbine tower (post), cables and a control panel (Tunus, 2019).

Use of Wind Turbine System in Greenhouses

The renewable energy sources can be used in agriculture with solar collectors and solar panels. Hot waters collected from the solar collectors can be used to disinfect greenhouse soils in summer.

In winter, hotbeds are heated to increase output in the greenhouses (Yüksel-Türkboyları et al., 2019; Yüksel and Yüksel-Türkboyları, 2020). The electric power generated from solar panels can be used for a variety of purposes in agriculture. The electric power might be used for disinfecting the soil in greenhouses as well as heating the hotbeds, ventilation and cooling (Yüksel-Türkboyları and Yüksel, 2017).

The wind energy is one of the renewable energy sources and it can be used for agricultural purposes and in greenhouses. Here, the key factor is choosing a location or a country with substantial wind potential for the project. Furthermore, the greenhouses are generally located on rural areas and they are far from the electric supply systems. Therefore, use of electric power in greenhouses is very limited. In regions with suitable wind potential, use of electric power in greenhouse growing business might be extended with the wind turbines. The electric power might be used for a wide range of purposes in the greenhouses. These purposes include but are not limited to lighting of greenhouses, mechanical ventilation, operating pumps in irrigation and cooling systems, operating computers and other devices in automated greenhouses and supplying energy to circulation pumps in greenhouses with a central heating system.

Sufficient ventilation cannot be provided in greenhouses located in the rural areas. This impairs efficiency and quality of production in these greenhouses. The sufficient ventilation can be provided only with forced (mechanical) ventilation.

Purpose of this study is to focus on supply of electric power required for forced ventilation in greenhouses by using wind turbines. As a matter of fact, greenhouses are generally located in rural areas and, generally speaking, these areas do not have an electric supply system. The wind turbine system to be installed in the greenhouses can supply energy to ventilation and cooling systems of the greenhouse with fan and wet pad system.

MATERIAL and METHODS

Material

Tekirdag region where the research was carried out is located on the European Side of Turkey and its longitudes are 26˚41′-28˚10′ E, the latitudes are 40˚35′-41˚35′ N and is located in the northeast of Turkey and north of Marmara Sea and its surface area is 6313 km^2. Tekirdağ Province is not generally surrounded by high mountains, steep slopes or valleys. According to the general humidity indexes, it is classified as a hydrographic region and has sub-humid climate, and windy in summer and winter (Anonymous, 2021a).

According to the wind energy potential atlas, our research region and coastline of Marmara Sea have higher wind speed in our country (Tunus, 2019; Karık et al., 2017). Therefore, Tekirdağ has a great advantage in terms of generating electricity using wind energy.

Method

Fan pad system can be used to provide ventilation and cooling in greenhouses. The fan pad system is installed by placing the pad and the circulation pump on one wall of the greenhouse and the fans on the opposite wall. The wind turbine system will also provide the electrical energy needed by the fan pad system. With the operation of the fans, a vacuum is created inside the greenhouse. While the hot air inside the greenhouse is thrown out with the help of aspirators, the outside air passing through the pad fills the inside of the greenhouse. The humidity and partial vapor pressure of the air entering the greenhouse from outside are low. Air passing through the pad comes into contact with the water, evaporating the water and being loaded with moisture. As the water evaporates on the pad, it takes the latent heat of evaporation it needs from the air. The air, whose sensible temperature decreases, gets colder and thus the temperature inside the greenhouse decreases. With this method, the temperature inside the greenhouse is cooled by 6 °C (Yüksel and Yüksel, 2012).

Designing Wind Turbine System in Greenhouses

The structure of wind turbine system depends on the specific application but generally includes components such as wind turbine, accumulator, battery charge control unit (charge regulator), inverter, assorted electronic circuits and control center (Toprak, 2011; Şenel and Koç, 2015). In this system, a wind turbine having a specific level of capacity is used as a source of energy. Batteries are connected to the system due to demand and supply gap of the wind energy, in other words, the energy cannot be generated when needed. The batteries supply energy to the system when there is no wind. A charge regulator is used to prevent overcharging or discharging of the batteries. This extends the operating time of the batteries. Based on the state of the battery, the charge controller directs the current from the wind turbine to the direction it is needed. Depending on condition of a battery, the charge regulator cuts the current coming from the wind turbine or the current pulling the charge. If the system will use an alternating current of 220 V 50 Hz or if current will be supplied to the mains supply, the system must have an inverter (Toprak, 2011; Şenel and Koç, 2015). The fan and wet pad system to provide ventilation and cooling in the greenhouses with a wind turbine system is as shown in Figure 1 (Yüksel and Yüksel-Türkboyları, 2017). In Figure 1, the inverter, charge regulator and battery group have been purchased in a project supported by the Scientific Research Project Office of

T.N.K.U. They have been used in a high tunnel that belongs to Vocational School of Technical Sciences. The picture of wind turbines has been taken at a location close to Hasköy (Edirne).

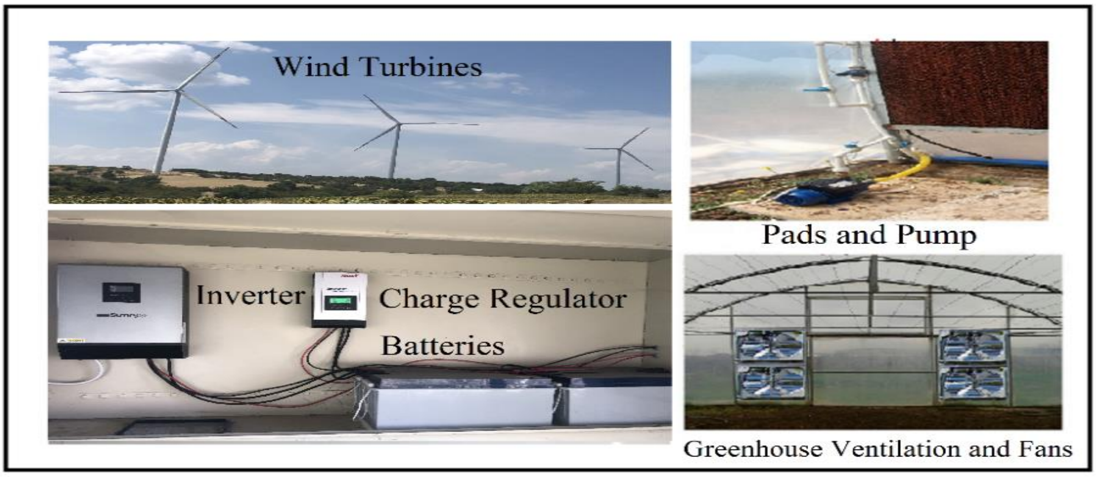

Figure 1. Wind turbine system and components of greenhouse ventilation and cooling system

Cooling Systems in Greenhouses

Temperature is one of the key factors affecting growing crops in the greenhouses. Generally, plants grown in the greenhouses, such as tomatoes, peppers and cucumbers, have the optimum output under 17 °C to 27 °C (Castilla and Hernandez, 2007). Considering the greenhouse effect, the greenhouses must be heated when the daily average exterior temperature falls below 12 °C (Nisen et al., 1998). When the exterior temperature rises above 22 °C, the greenhouses must be cooled (Yüksel-Türkboyları and Yüksel, 2017).

Among all climate factors, high humidity in the greenhouses is the first and foremost cause of plant diseases however; this factor can be easily controlled in ventilated and heated greenhouses. Reduced atmospheric moisture in a greenhouse decreases diseases and harmful effects. Therefore, use of chemicals and pesticides harmful to the environment and human health will be reduced significantly in the ventilated greenhouses (Zabeltitz, 1992).

When we analyze the exterior temperature conditions in Tekirdağ Province (shown in Figure 2), we can see that there are months when greenhouses used for growing crops must be heated, ventilated and cooled (Boyacı et al., 2012; Yüksel and Türkboyları, 2019). The exterior temperature falls below 12 °C in some days of March and November and also in January and February, and the greenhouses must be heated during these periods. Exterior temperature is between 12 and 22 °C in some days of September and March and also in April, May and October, and ventilation is not required in these months. Cooling is necessary in some days of September and Mays and also in June. The exterior temperatures are high in July and August and greenhouse cultivation cannot be performed in Tekirdağ during these months (Yüksel-Türkboyları and Yüksel, 2017).

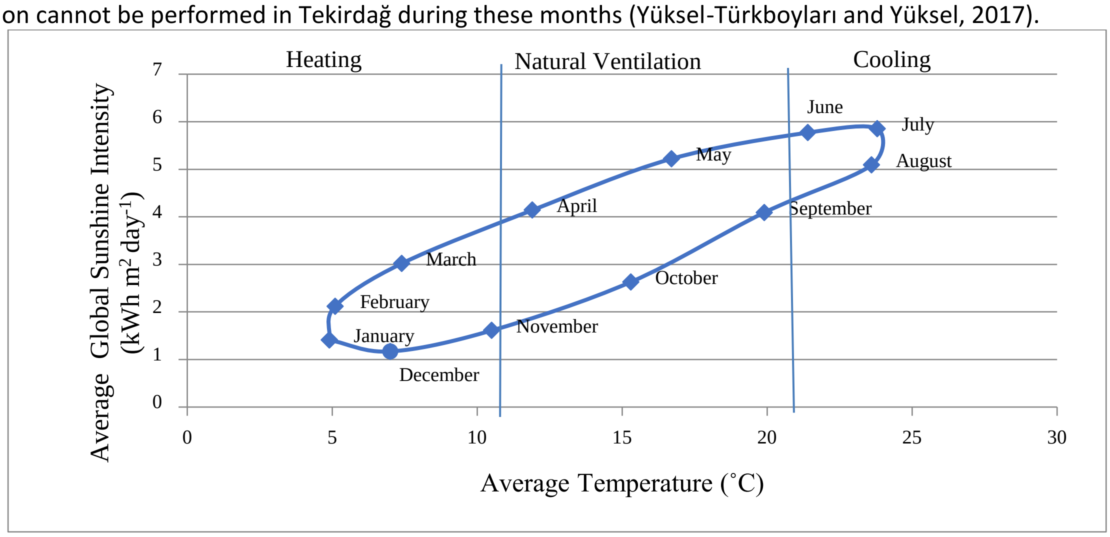

Figure 2. Climatization in greenhouses in the conditions of Tekirdağ in line with the outside air temperature

RESULTS and DISCUSSION

Fan-pad systems are designed for ventilation and cooling in greenhouses. Dimensions of the high tunnel where the fan-pad project is to be installed are as follows; length: 38.2 m, width: 7.8 m and ridge height: 3.6 m and area: 298 m^2.

1 m^2 pad area is required for each 25 m^2 of the greenhouse area (Yağcıoğlu, 2005; Yüksel and Yüksel, 2012; Yüksel and Yüksel-Türkboyları, 2017). Pad area required for the high tunnel is (Eq. 1):

$$298/25 = 11.92\ m^2\ \sim 12.0\ m^2 \quad (1)$$

Daily water need of this wet pad is around 30 to 40 liters per 1 m^2 wet pad area in hot days (Bucklin et al., 1993). Water required for the wet pad per day is between 350 to 500 liters. A small circulation pump with a 0.2 kWh capacity is required for taking this water from the water tank and delivering it to the top section of the wet pad.

Ventilation is based on the greenhouse floor area. Here, ventilation needed per m^2 of greenhouse floor area is between 0.033-0.042 $m^3\ s^{-1}$ or 120-150 $m^3\ h^{-1}$ (Bucklin et al., 1993; Yüksel and Yüksel, 2012). According to the floor area, the ventilation requirement in the high tunnel varies between 35760 to 44700 $m^3\ h^{-1}$.

Aspirators to be used in the high tunnel have a diameter of 60 cm; their rotation speed is 1400 rpm (dd^{-1}) whereas their capacity is 0.75 kWh and ventilating rate capacity is 9500 $m^3\ h^{-1}$ (Anonymous, 2021b). Number of aspirators that can cover the ventilation need determined above as 35760-44700 $m^3\ h^{-1}$ is:

$$35760/9500 = 3.7\ aspirators \quad (2)$$

$$44700/9500 = 4.7\ aspirators \quad (3)$$

In average, we can say that 4 aspirators are required (Eq. 2, Eq. 3).

The calculated values of the elements of the wind turbine and cooling system to be installed for the ventilation and cooling of the greenhouses are given in Table 1.

Table 1. Values of the calculated elements of the ventilation and cooling system designed for the greenhouse

Fan pad area (m^2)	Ventilation amount ($m^3\ h^{-1}$)	Number of aspirators (pieces)	Total energy need of the system (kWh)
12	35760-44700	4	3.2

Efficiency of Pads

When the temperature in a greenhouse is high, cooling systems based on water evaporation become effective, practical and economically feasible. Therefore, it is estimated that water evaporation will be a common method used for cooling greenhouses in the near future.

Efficiency of an evaporative cooling system depends on saturation of air passing through the pads and loaded with humidity. When unsaturated air touches the water surface, a temperature-mass change takes place between these. Vapor pressure of water is greater than air's partial vapor pressure and, thus, humidity is transferred from water surface to the air. At this point, latent heat required for vaporization completely comes from the air. This sensible heat from the air lowers the air temperature and cools the area (Atılgan and Öz, 2007). Therefore, the pads must be wetted as required. Water less or more than the required quantity impairs efficiency of the pads.

Energy Requirement of the System

Calculations of the wind turbine and greenhouse cooling system to be installed were completed. According to these calculations, 4 x 0.75 kWh aspirators and a 0.2 kWh circulation pump will be used for a fan-pad system to be installed for changing the air in the high tunnel as well as humidifying and cooling it.

Total energy requirement of the system that will meet the ventilation need of the high tunnel subject to this study is (Eq. 4):

$$0.75 \times 4 + 0.2 = 3.2\ kWh \quad (4)$$

A wind turbine system having a capacity higher than the calculated requirement, namely 3.2 kWh, will be required -such as 5-kWh- so that the system might operate efficiently. As a matter of fact, the wind turbines can generate the necessary power only under the optimum conditions. There is a time disharmony when it comes to generating electricity with the turbines. Energy cannot be generated when energy is needed (Tunus, 2019). On the other hand, the system must be supported with a battery group since the wind velocity is unstable.

CONCLUSION

This project studied the means of using a renewable energy source, namely wind energy, in the greenhouses. In greenhouses, the ultimate goal of plant production is to provide optimum environmental conditions for the plants. High or low temperature causes decreases in yield in terms of quality and quantity. Thus, heating, ventilation and cooling must be according to the indoor air temperate of greenhouses in order to have quality and highly productive growing activities in the greenhouses. In hot weathers, fans and pads might be used in the greenhouses for ventilation and cooling operations. Systems such as fans and pads need electricity.

However, the greenhouses are generally located in rural areas and use of electric power is limited in these areas. This problem might be eliminated by using the wind turbine system to generate electricity in the greenhouses.

Wind speed along the coastlines of Marmara Region is sufficient and, therefore, the wind turbine systems can be productively used in Tekirdağ Province. The wind energy investments in our country have been increasing rapidly since the wind energy systems are cost-effective.

Conflict of Interest Declaration: The authors have no conflict of interest concerned to this work.

Contribution Rate Statement Summary: The authors declare that they have contributed equally to the article.

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