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Moisture Impact on Wind Density Power Seasonally

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Abstract

Increased carbon dioxide emissions in the atmosphere and their harmful effects on the atmosphere and humans in general, this increase leads to significant climate changes that continue to affect the coming years. There is an urgent need to develop and increase research on clean energy and find the impact of weather changes, on the turbine's efficiency as a result of density fluctuate. A two-phase flow homogeneous model used to find these changes. The study analyzed the effect of atmospheric conditions, including temperature, humidity and pressure on kinetic energy in the wind through its effect on air density and find the rate of change resulting from these conditions, the air is dry and when the air is humid so the increase or decrease of this energy will affect positively or negatively on the performance of the turbine. The city of Mersin was selected in Turkey for this analysis through the application of air conditions obtained from the General Directorate of Meteorology in Ankara and resolve for accurate and detailed for each season throughout the year 2017, where the temperature varies from 0 to 35 degrees Celsius and humidity of 15 to 99 percent, as well as air pressure from 966.95417 to 1025.9 hPa. The effect of moisture was studied mainly by using thermodynamic laws in this paper.

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1. INTRODUCTION

The wind data analysis assessment is the key requirements to benefit the achievement of wind energy at any location. With the development in the economy and the rising population, human request for energy is increasing rapidly. Fossil energy such as coal and oil are non-renewable as they have to go through hundreds of millions of years of a geological procedure to be generated. The burning of fossil energy with the obstetrics of sulfur dioxide and dust leads to many environmental problems such as acid rain and photochemical smog problem. It also turnover underground solid carbon into gaseous carbon dioxide emitted into the atmosphere, which enhances the greenhouse effect, accelerates north and south polar ice to melt, and leads to a deadly threat to human civilization. There are several studies on wind energy potential and electricity generation (Karlsen, 2009; Carriveau, 2011; Giebel et al., 2011; Ragheb & Ragheb, 2011; Torenbeek, 2013; Salih & Majli, 2015; Clifton et al., 2016; Emeis, 2018). The previous paragraphs have assumed that the air was completely dry. In reality, it is in no way dry (Karlsen, 2009; Carriveau, 2011; Giebel et al., 2011; Ragheb & Ragheb, 2011; Torenbeek, 2013; Clifton et al., 2016; Emeis, 2018). Wind speed and energy maps of Turkey have been presented and the potential areas are identified with the emphasis on their significance, according to Ahmet Öztopal indicated that Along the Aegean and the Black Sea, coastal areas wind energy generation amounts are higher in winter than in summer (Karlsen, 2009). Wind power density is generally under the influence of relief (mountains, hills, valleys), ground thermic (thermal capacity of different soils and water); it is clear that in higher altitude wind is less influential by

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those parameters (Torenbeek, 2013). Wind energy potential assessment is critical factors for the suitable development of wind power application at a given location (Rotronic, 2005).

1.1. Factor Affecting on the Density

Air density is the mass of air molecules in a given volume so any more air mass flowing over wing allows to generate more lift and increasing wings performance. There are three factors are effective on-air density its pressure, temperature and Humidity. Pressure is a weight of column of air any increasing pressure means more air molecules in given volume. Temperature also affects density when temperature increase the air molecules have more energy, so they spread farther apart so when air wormer than stander it's less dense and performance decrease. Humidity also plays an important factor, air is made up of 78% Nitrogen, 21% Oxygen and 1% other gasses. The amount of water vapor in the air varies, but it can contribute up to 1%. Water vapor weighs less than the Nitrogen or Oxygen molecules that make up the rest of the air and, water vapor takes up about the same amount of space. So, when more water vapor in the air, the air has less mass which means it's less dense. thus, all factor affective on-air density also affective on-air power (available power).

2. MATERIAL AND METHOD

2.1. Theory

A mathematical description of the winds is most easily done by considering the momentum balance of the atmosphere thus, in this paper explain the theory for using homogeneous two-phase flow to find the kinetic energy by application the two-phase flow theory to find the density of air and then find the available power in wind, Also, the laws of thermodynamics the ideal gas laws is used to find the density of dry air and through it find the available energy hypothesis when it is dry air only and through these two scenarios the difference between them is found. Be-low is a guiding explanation of the mechanism of work in this research to find the available energy to prepare the laws and find the homogeneous air density and dry air and find the resulting difference in kinetic energy in terms of two conditions. Depending on this theory, was obtain accurate data on the impact of atmospheric changes on wind density power, as well as the extent of the variation of kinetic energy in the wind based on this theory.

2.2. Methodology

When air is wet it means that contains a quantity of water vapors so the atmospheric air in this condition is the two-phase case and considers there is no-slip velocity between air atomics, consider the air in this case a homogeneous state (Wills, 1967). Thus, a single-phase equation for continuity, momentum, and energy can apply by replacing the single-phase property with the mixture property. According to this condition using the weather data got from the General Directorate of Meteorology for Mersin city in 2017 (MGM, 2017), to calculates atmosphere density and other mix properties by using the following equation.

$$\rho_{Atm} = \alpha\, \rho_{dry} + [(1 - \alpha)\, \rho_v] \tag{1}$$

According to the ideal gas law the density of dry air is,

$$\rho_{dry} = \frac{P_{dry}}{R_a\, T_{Atm}} \tag{2}$$

from T_{Atm} find the saturation pressure of vapor from thermodynamics table and then from relative humidity and saturation pressure of vapor find the pressure of vapor,

$$\rho_{dry} = \frac{P_{dry}}{R_a\, T_{Atm}} \tag{3}$$

and from pressure of vapor and atmosphere pressure that obtained from metrology data find the pressure of dry air,

$$P_{dry} = P_{Atm} - P_v \tag{4}$$

then from recent equation find the density of air when R_a represent the constant of dry air. After calculating the density of dry air, it's necessary calculate the vapor density in atmosphere to obtained the density of mixture air (atmosphere) thus from pressure of vapor, temperature of atmosphere and constant of vapor R_v calculate the density of vapor,

$$\rho_v = \frac{P_v}{R_v\, T_{Atm}} \tag{5}$$

There are two way to find the humidity ratio ω the first way used psychrometric chart and second way used Colebrook-White Equation.

$$\omega = \frac{\text{mass of vapor}}{\text{mass of dry air}} \tag{6}$$

$$M_v = \frac{P_v\, V}{R_v\, T} \tag{7}$$

$$M_{dry} = \frac{P_{dry}\, V}{R_a\, T} \tag{8}$$

$$\frac{Ra}{Rv} = 0.622$$

$$\omega = 0.622\frac{P_v}{P_{dry}} \tag{9}$$

Find volumetric concentration from two phase flow equation α The volumetric concentration is defined as the ratio between volumetric vapor flow and total volumetric flow in a given cross-section.

$$\alpha = \frac{Q_v}{Q_v + Q_{dry}} \tag{10}$$

From humidity ratio ω find the ratio between volume flow rate of vapor and dry and substituted it in volume concentration equation.

$$\omega = \frac{\rho_v \; Q_v}{\rho_{dry} \; Q_{dry}} \tag{11}$$

$$\frac{Q_v}{Q_{dry}} \frac{\rho_{dry}\, \omega}{\rho_v} \qquad \text{Substitute in Eq (10)}$$

So, the volume concentration equation is valid now then calculate density of mixture from equation (1).

The power available in the wind can be found from the following equation:

$$P_{in} = ½ \text{ A } \rho \text{ V}^3 \tag{12}$$

Where ρ is the density of the air, A is the swept area, and V is the wind speed. So, through this equation extract the power available in the wind in the first use the density of dry air and in the second use the density of the mixture and through them are extracted the power deviation as rate of change in the kinetic energy from dry air density to the mixture (atmosphere) density according metrology condition

$$P_{in\ dry} = ½ \text{ A } \rho_{dry} \text{ V}^3 \tag{13}$$

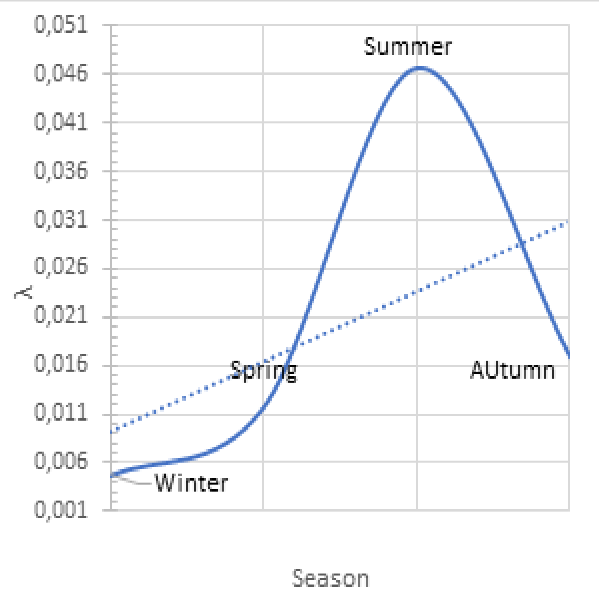
$$P_{in\ atm} = ½ \text{ A } \rho_H \text{ V}^3 \tag{14}$$

$$\lambda = \frac{P_{in\ dry} - P_{in\ atm}}{P_{\ in\ atm}} \tag{15}$$

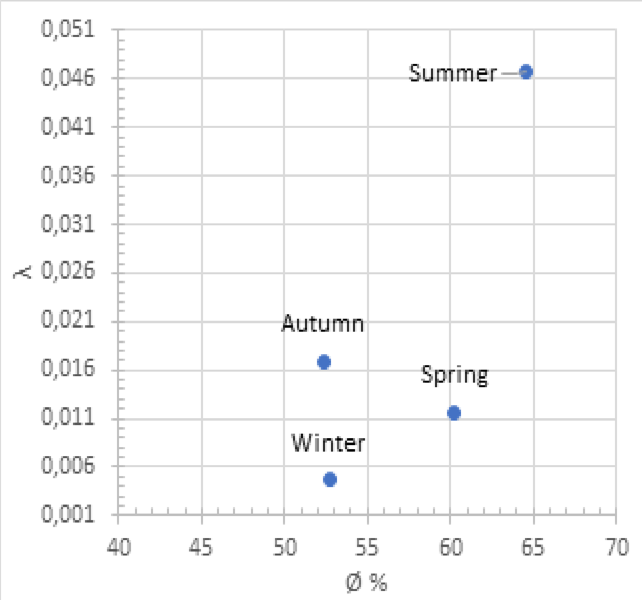
The variability of wind power will be an increasing challenge for the power system as wind penetration grows and thus needs to study, thus from Equation (13) find the deviation of kinetic power of wind when supposition the wind is dry and when the wind is atmospheric according to the homogeneous flow.

3. RESULTS AND DISCUSSION

The statistical characteristics of the wind power have been analyzed by using meteorology data recorded by the General Directorate of Meteorology in Ankara for Mersin city in Turkey for the 2017 year. To decide the best suitable site for installing a wind farm as well as to select the turbine model suited for any site, it is necessary to carry out a careful wind energy resource evaluation. The meteorology data in the Excel program was analyzed by using the equations that were it was concluded in methodology section schedule explaining the change in the rate wind power.



A) Changing of Wind Power Deviation for Each Season

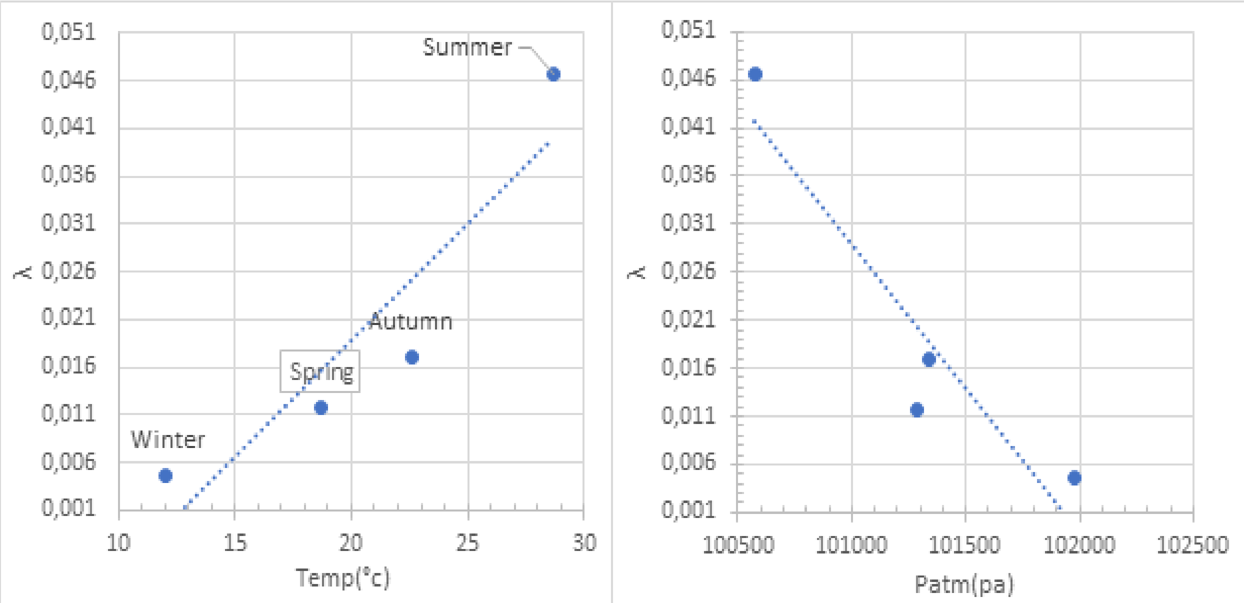


B) Changing of Wind Power Deviation with Relative Humidity

Figure 1. *Wind Power Deviation Change Seasonally*

Table 1. *Wind Power Deviation Seasonally for 2017*

Season	Temp (°C)	Ø %	V (m/s)	P_{atm} (Pa)	P_g (Pa)	P_{dry} (Pa)	P_v (Pa)	Ꞷ	ρ_{dry}	ρ_v	α	ρ_H	λ
Winter	12.054	52.67	1.065	101978	1470.186	101216.801	752.324	0.00469	1277.56	5.7758	0.0000471	1277.50	0.0046
Spring	18.675	60.25	1.465	101282	2211.742	99971.901	2376.355	0.00824	1233.19	9.7160	0.000110	1233.04	0.0116
Summer	28.679	64.52	1.478	100573	3974.871	98032.900	2557.061	0.01623	1169.54	18.2312	0.000516	1169.03	0.0466
Autumn	22.620	52.32	1.056	101341	2876.303	99815.387	1504.923	0.00941	1215.38	10.8248	0.000170	1215.18	0.0169
Average	20.507	57.44	1.266	101293	2633.280	99759.200	1797.670	0.00964	1223.92	11.1370	0.000215	1223.69	0.0199



A) Changing of Wind Power Deviation with Temperature **B)** Changing of Wind Power Deviation with Atmospheric Pressure

Figure 2. *Changing of Wind Power with Meteorology Data*

Table 1 represents a sensitive analysis of the 2017 seasonal wind energy deviation according to a two-phase flow homogeneous model for Mersin, Turkey. Figure 1A shows that the minimum deviation occurs in winter while the maximum power deviation appears in Summer. The deviation of the wind power increases gradually from the winter season through the spring to reach its highest value in the summer and then begins to decrease significantly in the autumn season. Any rising in deviation means decreasing in available wind power in atmospheric. This increasing and decreasing in deviation due to rising or dropping in temperature and relative humidity and atmospheric pressure, during winter the temperature is at low value 12.054°C and relative humidity at 52.6% that makes the moisture content at a low value at 5.77 g/m³ while in the summer the average temperature is 28.6°C and relative humidity at 64.5% makes an in-crease in water vapor content to 18.23 g/m³ which make the air more moisture content in air as known the water vapor has less weight from other content as shown in Figure 2.

4. CONCLUSIONS

Wind energy is important energy globally as it is clean energy used to produce electricity through the turbines. As it is known that a formula used to find the available energy in the air is $P=0.5V^3\rho$, the previous studies im-posed that the air density is constant and took it as dry air, this is a mistake because the atmospheric air density is changeable and depends on the temperature, humidity, and air pressure all of these factors change for every season throughout the year which causes losses are not few in available power if predicate as dry. The current study indicates that there is an energy deviation along each season, and throughout the year. When the temperature and relative humidity increases with decreasing in atmospheric pressure the power deviation increase which leads to a drop in available power.

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CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

NOMENCLATURE

λ : Power deviation between the available power for dry air and for atmospheric air

A : Area m^2

ρ_{Atm} : Density of atmospheric air g/m^3

ρ_{dry} : Density of dry air g/m^3

α : Volume void fraction between vapor area and total area

ρ_v : Density of water vapor g/m^3

P_{dry} : Pressure of dry air pascal

P_v : Pressure of water vapor pascal

P_g : Saturation vapor pressure (Pa)

R_a : Dry air gas constant J/(kg.K)

R_v : Vapor gas constant J/(kg.K)

T_{Atm} : Temperature of atmospheric air ºC

Ø : Relative humidity

ω : Humidity ratio

M_v : Mass of vapor

M_{dry} : Mass of dry air

Q_v : Volumetric vapor flow

Q_{dry} : Volumetric dry flow

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