JCBPS; Section D; Feb. 2015 – Apr. 2015, Vol. 5, No. 2; 1958-1966. E- ISSN: 2249 –1929

Journal of Chemical, Biological and Physical Sciences

An International Peer Review E-3 Journal of Sciences

Available online at www.jcbsc.org

Section C: Physical Sciences

CODEN (USA): JCBPAT Research Article

Theoretical study of temperature effect on the wind power extracted as a renewable energy for electricity production in Nassiriyah district

Abdul-Kareem Mahdi Salih

Physics Department, College of Science, Thi-Qar University, Thi-Qar, Iraq

Received: 19 March 2015; **Revised:** 04 April 2015; **Accepted:** 22 April 2015

Abstract: The temperature effect on the wind power extracted as a renewable energy for electricity production in Nassiriyah district – south of Iraq- has been investigated for three years (2011-2013) by theoretical calculations. The study shows that the air temperature in this district affects extract power from the wind, this effect is dependent on the altitude and the value of temperature. The percentage of annual mean power loss decreases with the increasing of altitude. The annual mean power loss values vary between 6.1%Watt at 40 m altitude to 2.6% Watt at 300m altitude for the study time interval.

Keywords: physics, renewable energy, wind energy.

INTRODUCTION

Wind energy is an attractive alternative source of energy. With the use of this resource high rate for growth and development in this field at the last years, is related to no harm to nature and human health, renewable and economic power source[1-3]. The estimation of wind energy capacity is expected to be installed in the European Union (EU) in 2020 between 20 GW and 40 GW. This is increased reliance on deployment of many wind farm[4-6].

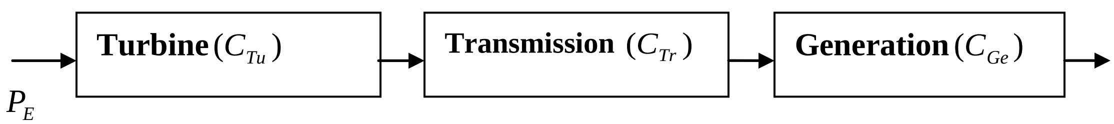
Some factors are a major determinate of power extracted from wind turbines such as wind velocity, humidity, pressure, air density, rain, dust, and temperature[7-9]. These factors have significant physical coupled relations. Mathematical calculation has been used these relations to obtain the essential data about some of these factors because is nonexistence actual measurement data at altitude rather than 10 m at the district under the study. The previous theoretical study[10] has been done to termination the elevation to be satisfying the minimum wind speed is feasible for electricity production in Nassiriyah district which is located in 31(east) with 46 (north) intersection lines[11]. Because of high temperature which distinguished this district for a long time interval through the year. This paper is focusing the study upon the temperature effect on the wind power extracted as a renewable energy in Nasiriyah district. The information are very important to take decision for utilization the wind power for electricity production in the district.

THEORY

The total extracted power from wind turbine can be estimated by taking the derivative of the kinetic energy of the wind. This results in the following equation

$$P_w = \frac{\rho A v^3}{2} \quad \dots (1)$$

Where $(A = \frac{1}{2}\pi r^2)$ the swept area of turbine blades (airflow cross section) in (m^2), r is the rotor radius, (ρ) is the air density $(1.255 Kg/m^3)$, (v) is the wind speed in (m/s). The process of converting wind power to electrical power results in efficiency losses, as illustrated in the diagram below.



The electrical power output of a practical wind turbine can be described using the following equation

$$P_E = \frac{C_p \rho A v^3}{2} \quad \dots (2)$$

Where $(C_p = C_{Tu} C_{Tr} C_{Ge})$ is the overall efficiency. It is called the power coefficient, and depends on the ratio of the downstream to the upstream wind speed. Its theoretical maximum value equal to 0.59[12, 13]. Eq. (2) shows the wind power estimation depended on the rotor blade radius rather than some important factors such a wind speed and wind density. Furthermore these factors are a function of altitude, temperature, humidity, and pressure[13].

The equation which predicts the wind speed as a function of altitude is expressed as:

$$v(z_2) = v(z_1).\left(\frac{z_2}{z_1}\right)^{\alpha} \quad \dots (3)$$

The friction coefficient (α) varies with altitude, time of day, nature of the terrain, and temperature. The average value has been determined is given in **Table-1**[14].

Table 1: Friction coefficient of various terrain.

Terrain type	Friction coefficient (α)
Lake, ocean and smooth hard ground	0.10
Foot high grass on level ground	0.15
Tall crops, hedges, and shrubs	0.20
Wooded country with many trees	0.25
Small town with some trees and shrubs	0.30
City area with tall buildings	0.40

The relationship between the temperature and the pressure can be expressed by Poisson equation [12]

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{R/cp} \quad \ldots (4)$$

Where $R/cp = 0.286$, cp is the constant – pressure specific heat of air, T_1 and P_1 are the temperature and pressure at site 1, $T2$ and P_2 are the temperature and pressure at site 2.The equation which predict the temperature as a function of altitude expresses as the following[13].

$$T(z) = T_g - R_a(z - z_g) \quad \ldots (5)$$

Where $T(z)$ the temperature at altitude z in meter above sea level is, T_g is the temperature at ground level z_g, and R_a is the temperature laps rate $(0.0065C^0 m^{-1})$. Air density can be determined by the following equation

$$\rho = \left(\frac{P_0}{RT}\right) * \exp\left(\frac{-g * z}{RT}\right) \quad \ldots (6)$$

Where P_0 is the std. sea level atmosphere pressure (101325 pascals), g is the gravitational constant (9.8m/s), and R is the universal gas constant for dry air $(287.05 J.Kg^{-1}.K^{-1})$

CALCULATIONS, RESULTS & DISCUSSION

Because of high temperature for a long interval in nassiriyah district in south of Iraq, the effect of temperature on the extract wind power has been simulated in this study. The data of the wind speed has been measured for three years' time interval (2011-2013) in Nassiriyah district at10 m altitude (tower elevation of Nassiriyha station of meteorology).The maximum temperature values which are reported in this station are utilized as a input data, and has been feed to computer program prepared in this study. Other input data used in calculations are as the following:

Fig. (1-A) shows the daily distribution of air density at 40 m altitude for the years 2011, 2012, and 2013. While the **Fig. (1-B)** shows the daily distribution of temperature degree for the same altitude and intervals. From these figures the inverse relation between the temperature and the density is appearing. **Figs. (1-C)** & **(1-D)** are also showing the same relation for the same intervals at 140m altitude.

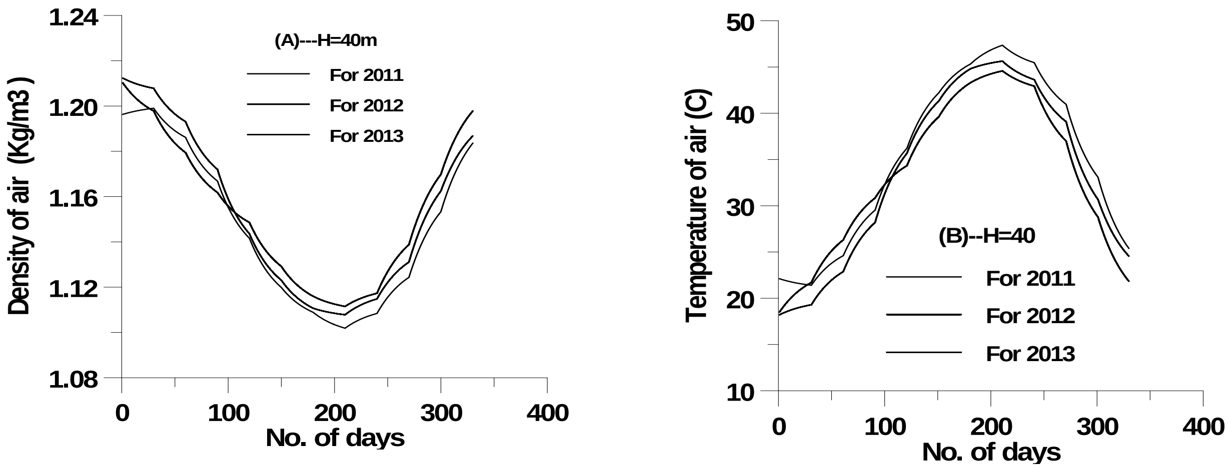


Fig. (1-A, C): The daily air density distribution for altitude (40 m, 140m) respectively through the years (2011, 2012, and 2013).

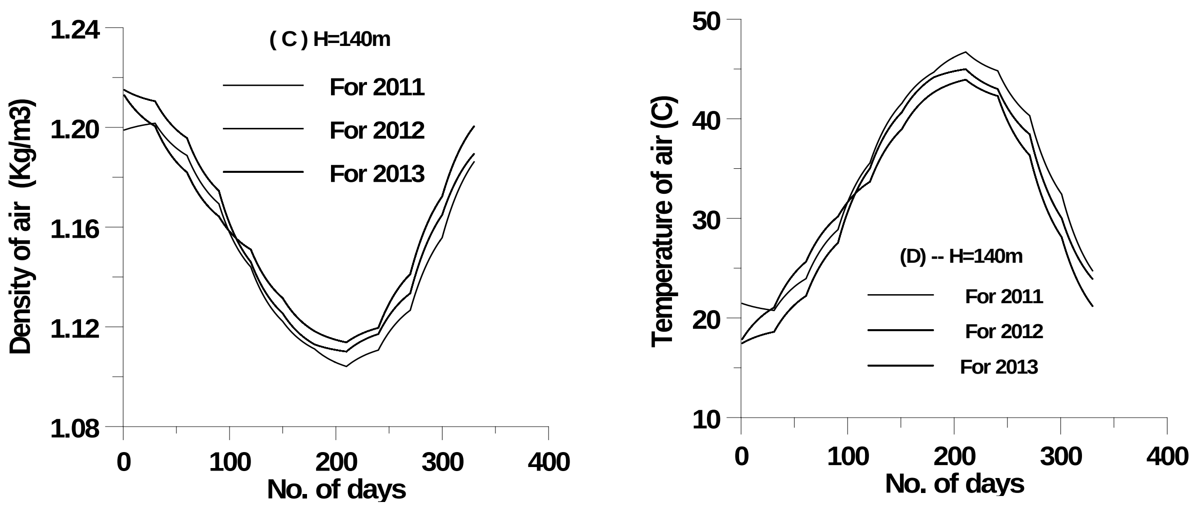


Fig. (1-B, D): The daily air temperature distribution for altitude (40 m, 140m) respectively through the years (2011, 2012, and2013).

There are two coupled types of effects which are affecting the air density. **Fig. (2-A)** shows the first. It is shows the behavior of annual mean density as a function of altitude for the years 2011, 2012, and 2013 under the temperature effect. It is shows small increment in the annual mean density with the increment of the altitude (the relationship is not quite linear), that is related to the volume reduction which is occurring by temperature reduction with altitude increment. The pressure reduction which is associating the altitude increment is the second type of these coupled types of effect. It leads to a decrease in the density as a result of volume expands. But the first type of effect (temperature reduction) is the more important (dominator) than the second type (pressure reduction).

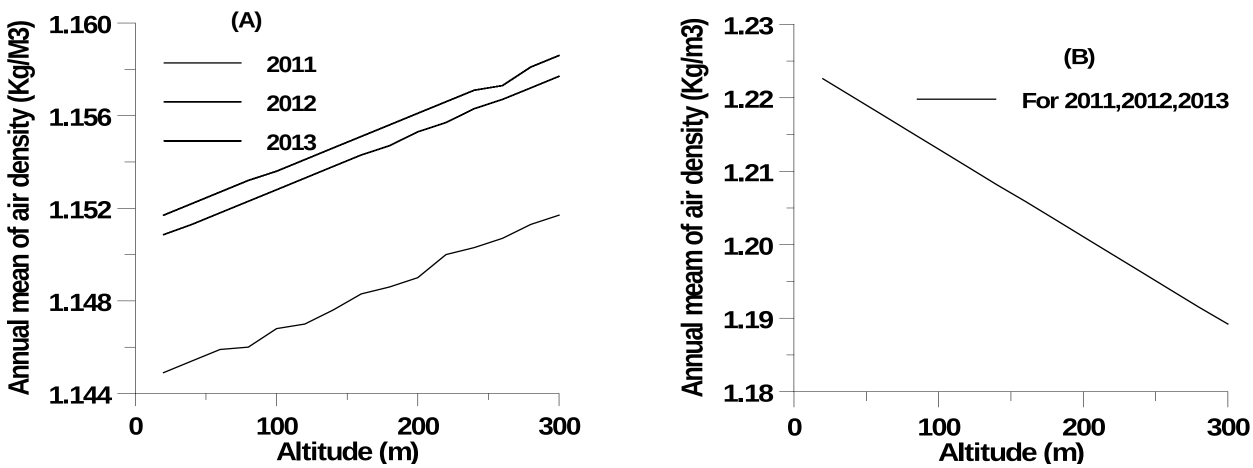


Fig. 2: The behaviour of annual mean wind density as a function of altitude; **(A)** By temperature effect: **(B)** Without temperature effect.

Fig. (2-B) shows the simulation of the annual mean density behavior as a function of the altitude for the years 2011, 2012, and 2013 when neglecting the temperature effect. The figure shows the decrees of annual mean density with the altitude increment. The study explains this behavior to the singlet effect of pressure reduction which is associating with the altitude increment. From the comparison between the **Figs. ((2-A) &(2-B))** it can be confirm that the maximum value of annual mean density simulate with temperature effect(1.1586 Kg/m3) is less than the minimum value of annual mean density which is simulating without temperature effect (1.1892 Kg/m3).

Fig. (2-C) shows the percentage of the annual mean density loss (decreases) as a function of altitude for the years 2011, 2012, and 2013. It appears from the fig. that the loss percentage has the maximum values (6.13%, 5.65%, and 5.5%) at the minimum altitude (40m) for each study year, while having minimum values (3.15%, 2.64%, and 2.57%) at the maximum altitude (300m) for the same intervals. The study refers this results to the density increasing by temperature reduction with the altitude to approach to semi study state of temperature reduction equivalent to the case without temperature effect calculation which is shown in **Fig. (2-B)**. **Fig. (3-A)** shows the variation of the power annual mean (Watt) as a function of altitude for the intervals 2011, 2012, and 2013 whit the temperature effect. It shows that the wind power is increasing when the altitude increases.

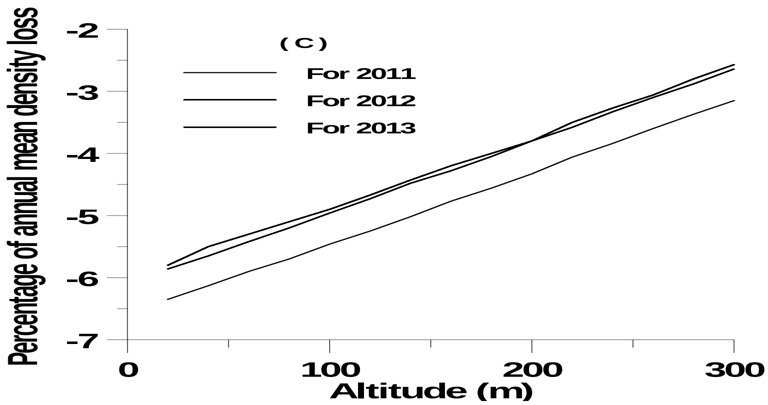


Fig. 2 (c): Percentage of annual mean wind density loss by temperature effect.

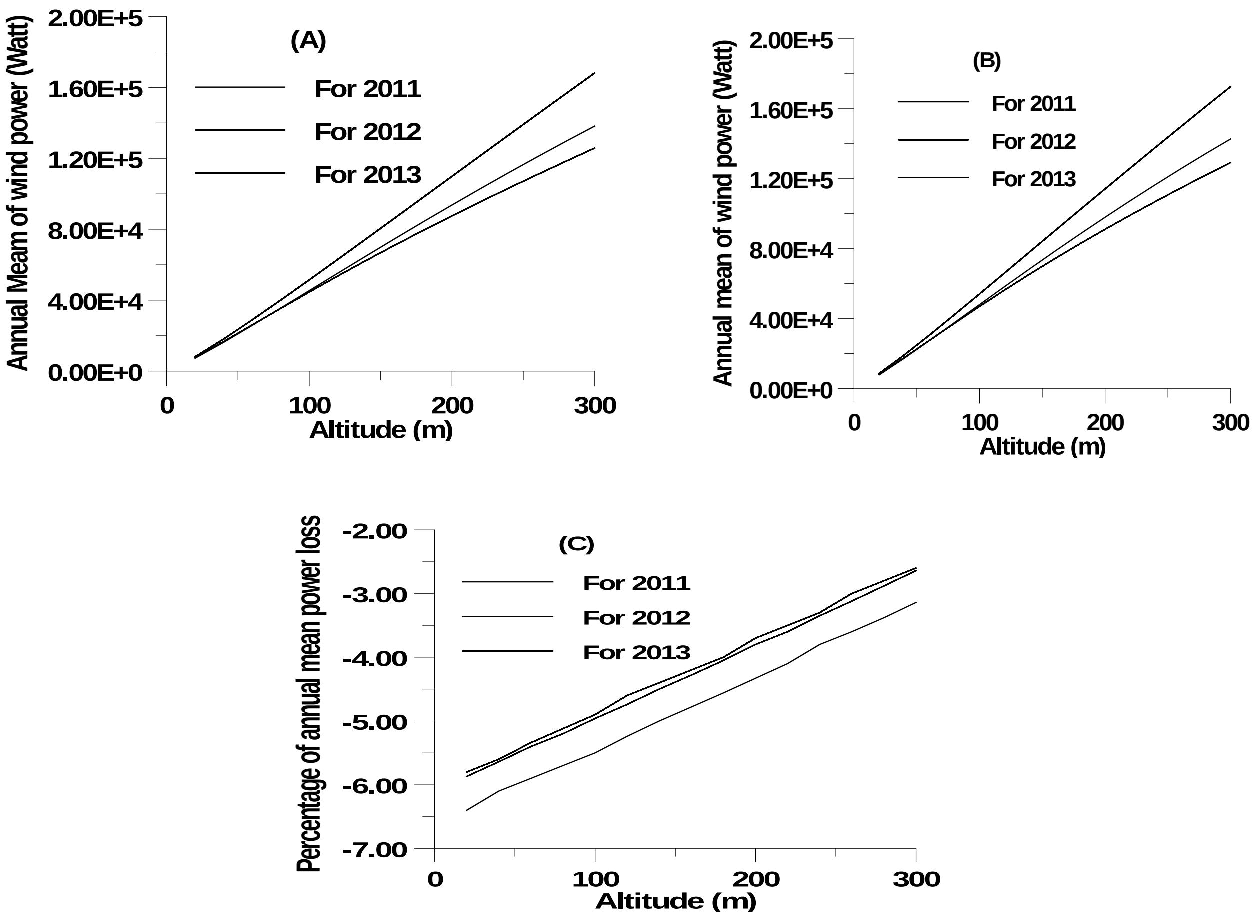
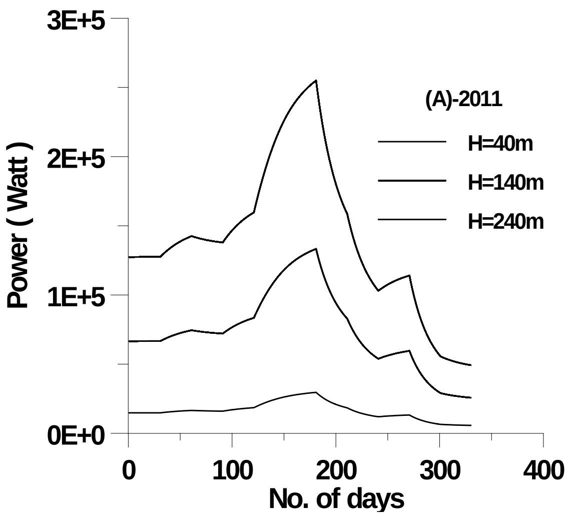
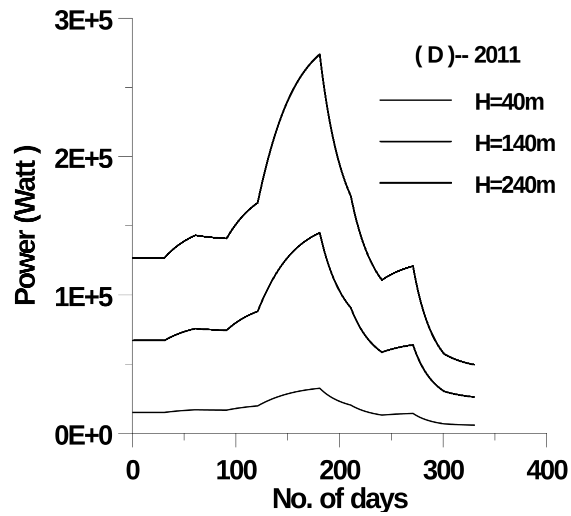
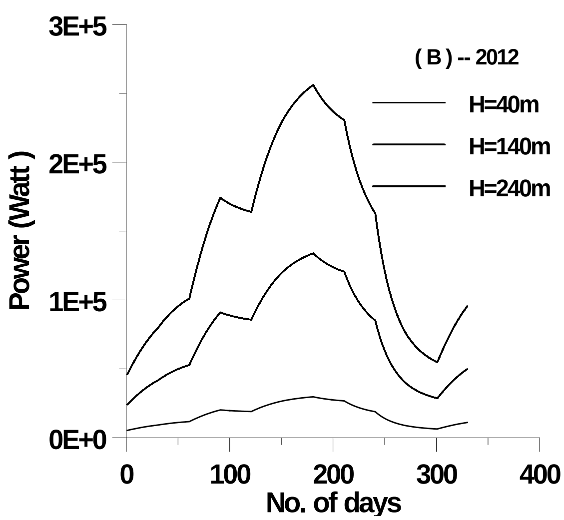


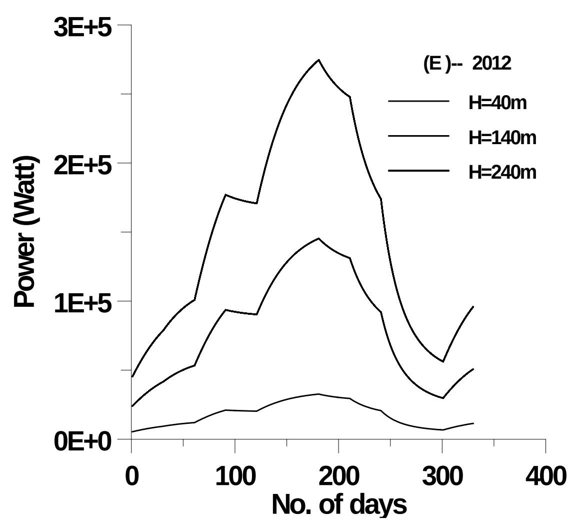
Fig. 3: The behavior of annual mean wind power as a function of altitude; **(A)** By temperature effect: **(B)** Without temperature effect: **(c)** Percentage of annual mean wind power loss by temperature effect.

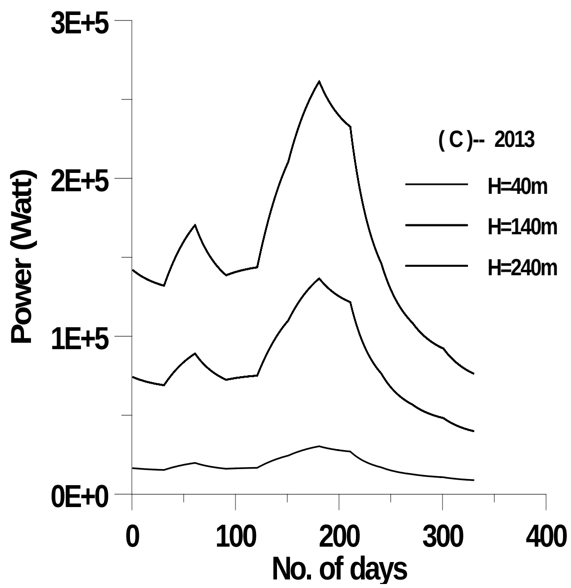
Fig. (3-B) shows the variation of the power annual mean (Watt) as a function of altitude for the intervals 2011, 2012, and 2013 without the temperature effect. It shows the semi of relation which appears in Fig. (3-A), but the values of power are greater than what is shown in **Fig. (3-A)**. This is related to the temperature effect on the density of air. **Fig. (3-C)** shows the percentage of annual mean power loss as a function of altitude for the intervals 2011, 2012, and 2013 with the temperature effect. It shows that the percentage of annual mean power loss decrease with the altitude , , it is appear from the fig. that the loss percentage have the maximum values (6.1%, 5.64%, and 5.6%) at the minimum altitude (40m) for years 2011,2012, 2013 while having minimum values (3.14%, 2.64%, and 2.6%) at the maximum altitude (300m) for the same years respectively. The study refers these results to the density increasing by increasing of altitude.











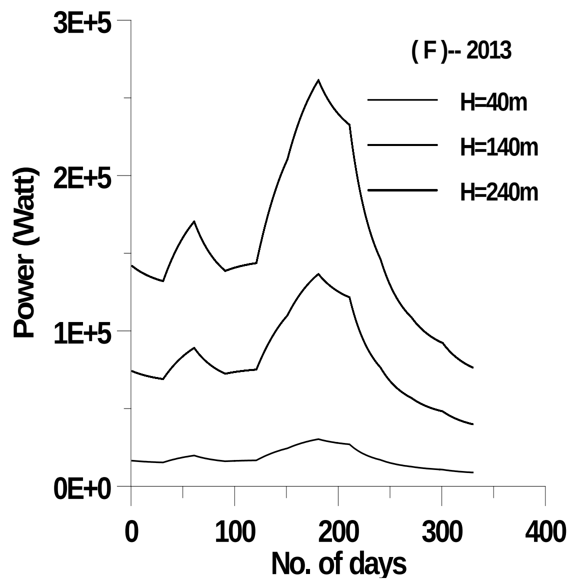


Fig. 4A-C: The daily power distribution for altitude (40 m, 140m, 240m) through the years (2011, 2012, 2013) respectively with temperature effect. **Fig. 4D-F:** The daily power distribution for altitude (40 m,140m,240m) through the years (2011,2012,2013) respectively without temperature effect.

Fig. (4-A, B, C) show the daily power distribution under temperature effect for the years 201, 2012, and 2013 for three different altitudes, while the **Fig. (4-D, E, F)** show the daily power distribution without temperature effect for the same altitudes and years.

The figures show the low power distribution at the low altitude and vice versa for equally cases with or without temperature effect in simulation, but the power distribution was calculated with temperature effect had the minimum values comparing with power distribution was calculated without temperature effect. These behaviors are clear indications of temperature effect on the extract power from the wind in Nassiriyah district.

CONCLUSIONS

The following can be concluded from this study:

1- The air temperature in Nassiriyah district is affected on extract power from the wind. This effect is dependent on the altitude. The extracted power increases with the altitude increase. The study is related or explains that to the associate temperature reduction with the altitude increment which is leading to volume reduction causes increase of air density which finally leads to an increase in the power.

2-The percentage of annual mean power loss decreases with the increasing of altitude because of the temperature effect and leads to small percentage loss to approach to a case of without temperature effect calculation. The annual mean power loss values vary between 6.1%Watt at 40 m altitude to 2.6% Watt at 300m altitude for the study interval (years 2011,2012, and 2013).

REFERENCES

1. Erkan E rdogdu, "On the wind energy in Turkey", *Renewable and sustainable reviews*. 2009, **13**, 1361-1371.
2. Puneet Malhorta, "New method for dual –axis fatigue testing of large wind turbine ", University of Massachusetts, Amherst. 09-2010.
3. Marques AC, Fuinhas JA, Manso JRP, "Motivation driving renewable energy in European countries: a panal data approach ", *Energy Policy*. **38**, 2010.
4. R. J. Barthelemie, S. C. Pryor and S.T. Grandsen "Climatological and meteorological aspects of predicting offshore wind energy", offshore wind energy, Multi-Science Publishing Co. Ltd, 2009.
5. W. Musail "Offshore wind electricity: A viable energy option for the coastal united states", *Technol. Soc. J*.2007, **41**, 32-43.
6. De. E. Vries " 40000 MW by 2020: Building offshore wind in Europe, Renewable Energy World.2008, **11** (1), 36-47.
7. B.C.AL., Dr. C. Klumpner and Dr. D.B. Hann, "Effect of rain on vertical axis wind turbines", International conference on renewable energyeis and power quality *", Las Palmass de Gran (Spain)*, 13th to 15th April, 2011.
8. R. J. Barthelmie, A. M. Sempreviva and S. C. Pryor, "The influence of humidity fluxes on offshore wind speed profiles" *Ann. Geophys*. 2010, **28**, 1043-1052.
9. L. Perkovic, P. Silva, M. Ban, N. Kranjcevic, N. Duic,"Harvesting high altitude wind energy for power production: the concept based on magnus effect" *Applied energy*. 2013, **101**, 151-160.
10. Abdul-Kareem M. Salih " Mathematical simulation of wind speed as a renewable energy in Nassiriyha district: Utilization for electricity product.
11. Meteorological station of Nassiriya city, Thi- Qar, Iraq.
12. E. Hau, "Wind turbines—Fundamentals, Technologies, Application, Economic", Berlin, Germany, Springer. 2000.
13. Gary L. Johnson," Wind energy system "*Manhatta n.* 2006.
14. Mukund R. Patel," Wind and Solar Power System", U.S. Merchent Marine Academy, New York, CRC Press LLC. 1999.

Corresponding author: Abdul-Kareem Mahdi Salih;

Physics Department, College of Science, Thi-Qar University, Thi-Qar, Iraq