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APPLIED SECOND LAW OF THERMODYNAMICS ON THE WIND ENERGY OVER IRAQ

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Abstract: Although Iraq is an oil country, but it's have very large sources of renewable energy. This study was discussed the results of the wind energy and exergy for six regions in Iraq at three different turbine heights. The highest exergy efficiency was in Basrah then Anbar, Tikrit, Najaf, Baghdad, and smallest in Mosul. The exergy efficiency was increase by 60 % at height 50 m, while it's increasing by 70 % at height 100 m. The highest exergy destruction was in Mosul, Najaf, Tikrit, Baghdad, and smallest in Anbar and Basra. The exergy destruction decreasing by 33 % at height 50 m, while its decreasing by 68 % at height 100 m. The high energy efficiency was in Basra, then Anbar, Tikrit, Najaf, Baghdad, and the smallest in Mosul, the energy efficiency of a turbine increase by 52 % at height 50 m, while it's increasing by 66 % at height 100 m. And the highest output useful energy was in Basra, then Anbar, Tikrit, Baghdad, Najaf, and it's very small in Mosul, it is found that the output energy from turbine increase by 85 % at height 50 m, while its increase by 94 % at height 100 m

Keywords: *Wind Turbine, Wind Energy, Energy Efficiency, Exegy Efficiency, Exergy Destruction.*

الخلاصة: بالرغم من أن العراق هو بلد نفطي ولكن له مصادر كثيرة جدا للطاقة المتجددة، و في هذه الدراسة تمت مناقشة نتائج الطاقة والاكسيرجي للرياح لستة مناطق في العراق وعلى ثلاثة ارتفاعات مختلفة. وكان أعلى كفاءة للاكسيرجي في البصرة ثم الأنبار وتكريت و النجف و بغداد وأصغر قيمة كانت في الموصل، ازدادت كفاءة الاكسيرجي بنسبة 60% على ارتفاع 50 متر، بينما ازدادت بنسبة 70% على ارتفاع 100 متر. أعلى طاقة مدمرة كانت في الموصل ثم النجف و تكريت و بغداد وأصغر قيمة كانت في الأنبار والبصرة والطاقة المدمرة تناقصت بنسبة 33% على ارتفاع 50 مترا، بينما تناقصت نسبة 68 في المائة على ارتفاع 100. وكان أعلى كفاءة للطاقة في البصرة ثم الأنبار وتكريت و النجف و بغداد وأصغر قيمة في الموصل وكفاءة الطاقة ازدادت بنسبة 52% على ارتفاع 50 مترا، بينما ازدادت بنسبة 66 في المائة على ارتفاع 100 متر. وكان أعلى طاقة خارجة من التوربين في البصرة ثم في الأنبار و تكريت و وبغداد والنجف واصغر قيمة كانت في الموصل، و الطاقة الخارجة من التوربين ازدادت بنسبة 85% على ارتفاع 50 مترا، بينما ازدادت بنسبة 94% على ارتفاع 100 متر.

1. Introduction

The renewable energy resources have been significantly important in later years because the increasing environmental pollution, large request of energy required and exhausting fossil fuel resources. Many sources of renewable energy include wind, solar, geothermal, hydro, biomass and ocean energy have pulled in increasing attention due to their almost boundless and non-polluting characteristics. Among these resources wind energy has proved to be a cheaper elective energy resource and hence broad research efforts have been put to improve the technology of electricity generation through wind [1].

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The energy available in the wind is basically the kinetic energy of large masses of air moving over the earth's surface. The blades of the wind turbine receive this kinetic energy, which is then transformed into mechanical or electrical forms, depending on our end users. Wind energy is one of the important sources, its most suitable, most effective and inexpensive sources for electricity generation as a result, people beings have been using the wind energy to work for a very long time, and the stationary machines that converted the wind energy into work were first created in the Near East. As early as 1700 BC, Hammurabi used windmills for pumping water the plains of Mesopotamia. The horizontal-axis windmill was developed later, circa 1100 AD, and then it spread from England and France via Holland, Germany (1200s) and Poland to Russia (1300s) [2]. Currently, a wind energy product, approximately 2 % of global electricity, is already the world driving to green technology among sources of renewable energy [3].

At the end of 2001, the total wind power through the world was 23,270 MW. 70.3% was generated in Europe, followed by 19.1% in North America, 9.3% in Asia and the Pacific, 0.9% in the Middle East and Africa and 0.4% in South and Central America [4]. On being the wind energy used to generate electric power or for water pumping, but now it is a low cost generation technology, and it is likely to provide 10 % of the world's electricity by the year 2020 [5]. The term exergy comes from the Greek words ex and ergon, meaning from and work. The exergy or available energy of a system is the maximum work that could be derived if the system were allowed to come to equilibrium with the environment.

Unlike energy, exergy doesn't deal with the conservation law. The exergy consumed through the process is proportional to the entropy generated due to the irreversibility. This analysis is used to identify the causes, locations and magnitudes of wasteful aspects of the processes [6]. A. Ahmadi and M.A. Ehyaei [7] studied approach for exergy analysis of the wind turbine that it was installed in Tehran. The results show that wind power is increased by 20% and the entropy generation is decreased about 76.9%, if the cut in, rated and furling velocity was varying from 3.1, 13.8 and 15.6 (m/s), to 2.53, 11 and 12.43 (m/s), respectively. K. Pope et al. [8] studied the first and second laws were used to compare the performance of wind systems.

The results showed a 50-53% difference in first and second law efficiencies of the two different geometry for aerodynamicists airfoil systems (NACA63 (2)-215 (National Advisory Committee for Aeronautics) and Wortman Airfoils FX 63-137) this two type of airfoil is commonly used in wind turbine, and 44-55% of the vertical axis wind turbines and proved that exergy methods was better site determination and the design of the turbine was improve system efficiency, reduce cost, and rising capacity of wind systems. S. A. Ahmed et al [9] studied the analysis of wind speeds at Azmar Mountain in Sulaimani region. The averaged wind speed at a height of 5m was found from 4.65 to 11.86 (m/s) and at 50m found from 6.41 to 16.36 (m/s). The Weibull distribution's parameters (c and k) were found between 5.21 and 13.46 (m/s) and 1.60 to 3.47 respectively, with power density from 70.89 to 1559.16 (W/m2) at 5m while at 50m from 186.71 to 4096.20 (W/m^2).

A. F. Hassoon [10] investigated the wind energy potential in the north of Iraq for five regions (Tikrit, Tuz, Biji, Kirkuk and Mosul). The highest wind speed was found in

Tuz and Tikrit stations. In Tuz the range (2.5-3.0 m/s) taken about 45% from the total wind, In Tikrit the high ranges of wind (3.5-4.0 m/s) taken about 40.9% of wind speed, but the low wind speed is found at Biji, Kirkuk and Mosul. This is affected on the maximum energy output (13.5 kW/h) at Tikrit station. O. T. Al-taai et al. [11] studied the analysis of winds to produce electricity in Iraq for fifteen regions at three heights (12,50,100 m) and the results shows that the maximum values of wind power and the wind power density and Weibull parameters at Basra, the medium values at Baghdad and the lowest values in Mosul.. E. Asgari and M.A. Ehyaei [12] investigated mathematical modeling of wind energy, results proved that genetic algorithm is a more productive method than searching method.

The genetic algorithm shows the output power, first and second law efficiencies, increased by 61%, 56.5%, and 62.2%, respectively, at cut-in, rated, and furling speeds (u_c = 1.27, u_r = 12.19, u_f = 15.73) m/s. And the searching shows the output power, first and second law efficiencies, increased 8.4%, 8.5%, and 8.4%, respectively, at cut-in, rated, and furling speeds (u_c = 2.99, u_r = 13.31, u_f = 15.05) m/s. K. S. Heni et al. [13] compute wind power density for the horizontal and vertical wind turbine in Karbala City, and the results shows that the total power density, wind speed, Weibull parameters (c) and (k) at 10 m height are (102 W/m2), (4.1 m/s), (4.6 m/s), and (1.64) respectively, at 30 m height are (167 w/m2), (4.9 m/s), (5.5 m/s), and (1.69) respectively, and at 80 m height are (279 W/m2), (5.89 m/s), (6.6 m/s), and (1.74) respectively.

A. M. Rasham (2016) [14] investigated the analysis of wind speed for three sites in Iraq (Basra, Amara, and Nasiriya) in height (60 ,90,120 m), the results show that wind energy for Amara at (60, 90, 120 m) were approximate (100-300 W/m^2), for Nasiriya at (60, 90 m) were approximate (100-300 W/m^2) but at 120 m were approximate (300-700 W/m^2) and in Basra at (60, 90, 120 m) were approximate (300-700 W/m^2). So, Basra is acceptable for connecting to wind turbine power grid and Nasiriya at height 120 m.

This paper was discuss the results of the exergy and energy analysis of the wind turbine in different regions over Iraq, studies the effect of differences heights on the performance of the wind turbine and selected the suitable zone to builds this system.

2. Case Study

The data of annular wind speed at height 12 m that used in this work was obtained from the Iraqi Meteorological Organization and Seismology and from reference [5] for six locations distributed of different regions in Iraq show in Fig. 1, the regions are (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) as shown in Table 1 [11].

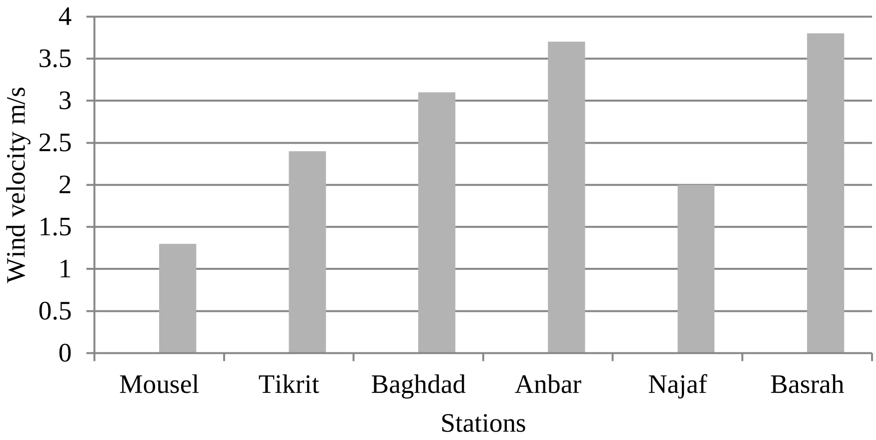

Figure (1) Wind Speed of regions at height (12 m) [5].

Table (1) six locations distributed in different regions in Iraq [11]

Stations	Latitude (N)	Longitude (E)	Sea Level Altitude (m)
Mosul	36.4	43.3	228
Tikrit	34.6	43.6	116
Baghdad	33.3	44.2	30
Anbar	33.2	43	45
Najaf	31.5	44.3	19
Basra	30.1	47.04	7

The Weibull distribution parameters *k*- Shape parameter and *c* (m/sec) scale parameter in three high (12, 50, 100 m) for six regions was obtained from [11] as shown in Table 2.

Table (2) Weibull distribution Parameters (c and k) at high (12, 50, 100 m) for six Stations [11]

Stations	12 m		50 m		100 m	
	c	k	c	k	c	k
Mosul	1.993	2.6	2.523	2.68	2.651	2.65
Tikrit	3.27	2.84	4.14	3	4.47	2.639
Baghdad	2.3	2.84	2.8	3	3.19	2.639
Anbar	3.19	2.57	4.05	2.45	4.47	2.72
Najaf	2.05	1.875	2.59	1.875	2.651	1.88
Basra	4.6	2.56	5.9	2.68	6.5	2.6

And the characteristics of wind turbine (3 kW) that using in this study as shows in Table (3) [11].

Table (3) characteristics of wind turbine [11]

Power	3 kW
Diameter	4.5 m
Swept area	15.89 m2
Maximum power	4 kW
Rated wind speed	10 m/s
Started wind speeds	2 m/s
Maximum wind speed	45 m/s
Number of blades	3
Rated rooter speed	220 r/min
Furling speed	15 m/s

3. Energy and Exergy Analysis

This section deals with the first and second law of thermodynamics, the energy efficiency (η) is defined as the ratio of useful output work to the kinetic energy of wind stream [1]

$$\eta = \frac{W_o}{E} \tag{1}$$

While the exergy efficiency (ψ) refers to the ratio of useful output work to the exergy flow of the wind [1]

$$\psi = \frac{W_o}{Ex_f} \tag{2}$$

The electrical energy that generated from the wind turbines is considered as the useful work output of the wind turbine. The useful output work of the wind turbine depends on. The model that used for useful work output of the wind turbine *(W_o)* is given by Abdel Hamid (2009) [15] this model is depended on cut-in speed (u_c), rated wind speeds (u_r), furling speed (u_f) and on specific site, such as the Weibull distribution parameters k- Shape parameter and c (m/sec) scale parameter:

$$W_o = P_{out} * \left(\frac{e^{\left(-\frac{u_c}{c}\right)^k} - e^{\left(-\frac{u_r}{c}\right)^k}}{\left(\frac{u_r}{c}\right)^k - \left(\frac{u_c}{c}\right)^k} - e^{\left(-\frac{u_f}{c}\right)^k} \right) \tag{3}$$

Where

P_{out} is output energy and can be calculated from [15]

$$P_{out} = P_{mech} * Cp * \eta_m * \eta_g \tag{4}$$

Where
P_{mech} is the mechanical energy
Cp is the power coefficient of a wind turbine
η_m and η_g are the mechanical and alternator efficiency, that's equal to 0.98 and 0.97 respectively [4]
The mechanical energy can be calculated from [8]

$$P_{mech} = \frac{1}{2} * \rho_a * A * (V_1^3 - V_2^3) \quad (5)$$

Where
A is the swept area of the turbine
ρ_a is the density of air
V_1 is the upwind velocity of turbine
V_2 is the final velocity of turbine
The density of air depended on temperature and pressure of air and was calculated using the ideal gas law Equation [15]

$$\rho_a = 3.4837 * \frac{P}{T} \quad (6)$$

Where
P is the pressure of air
T is the temperature of air
The final wind velocity (V_2) is equal to one third of the upwind velocity (V_1) [16]

$$\frac{V_2}{V_1} = \frac{1}{3} \quad (7)$$

The power coefficient of a wind turbine (Cp), was determined as a function of the tip speed ratio (λ), number of blades (Nb) [15]

$$Cp = \left(\frac{16}{17}\right) * \lambda * \left[\lambda + \frac{1.32+\left(\frac{\lambda-8}{20}\right)^2}{N_b^{2/3}}\right]^{-1} - \frac{0.57*\lambda^2}{\frac{C_L}{C_D}*\left(\lambda+\frac{1}{2*N_b}\right)} \quad (8)$$

The power coefficient of turbine Cp will be decreased if the number of blades was reduced at the same tip speed ratio. The wind turbines that have two blades must operate at a higher tip speed ratio than three bladed turbines to maintain the same power coefficient. While the tip speed ratio can be expressed in terms of tip speed and free stream wind velocity [15]

$$\lambda = \frac{\omega * R}{V} \quad (9)$$

Where
ω is the angular velocity (rad/s)

R is the radius e of the turbine
V is the stream wind velocity
The Energy of the wind stream (E) describes the total kinetic power of a wind stream and can be found [1]

$$E = \frac{1}{2} * \rho_a * A * V^3 \quad (10)$$

Where
ρ_a is the density of air, can be estimated from equation (6)
A is the swept area of the turbine
V is the wind velocity
The exergy of flow Ex_f, is the maximum achievable work gained as the air flows through the turbine. This term includes physical exergy (Ex_{Ph}) and kinetic exergy (Ex_{Ke}) [8]

$$Ex_f = Ex_{Ph} + Ex_{Ke} \quad (11)$$

Physical exergy incorporates the enthalpy and entropy changes related to the turbine operation as [8]

$$Ex_{Ph} = \dot{G} * \left[c_{pa} * (T_2 - T_1) + T_o * \left(c_{pa} * \ln\left(\frac{T_2}{T_1}\right) - R_a * \ln\left(\frac{P_2}{P_1}\right) - \frac{c_{pa} * (T_o - T_{av})}{T_o}\right)\right] \quad (12)$$

Where
$\dot{G}$ is the mass flow rate of the air through the turbine
c_{pa} is the specific heat of air
T_2 and T_1 are the wind chilled temperature of outlet and inlet to turbine respectively
T_o is the ambient temperature
R_a is the general gas constant
P_2 and P_1 are the air pressure of outlet and inlet to turbine respectively
T_{av} is the average temperature of the outlet and inlet to the turbine
The mass flow rate of the air through the turbine is represent as

$$\dot{G} = \rho_a * A * V_1 \quad (13)$$

Where
ρ_a is the density of air, can be estimated from equation (6)
A is the swept area of the turbine
V_1 is the upwind velocity of the air
The outlet and inlet wind chilled temperature can be found as [17]

$$T_2 = 33 - 0.0454 * \left[10 * {V_2}^{0.5} + 10.45 - V_2\right] * (33 - T_o) \quad (14)$$

$$T_1 = 33 - 0.0454 * \left[10 * {V_1}^{0.5} + 10.45 - V_1\right] * (33 - T_o) \quad (15)$$

Where
T_2 and T_1 are the wind chilled temperature of outlet and inlet to turbine respectively
V_1 is the upwind velocity of turbine
V_2 is the final velocity of turbine
T_o is the ambient temperature
The air pressure of outlet and inlet to turbine can be found as [8]

$$P_2 = P_o - \frac{\rho_a}{2} * {V_2}^2 \quad (16)$$

$$P_1 = P_o + \frac{\rho_a}{2} * {V_1}^2 \quad (17)$$

Where
P_2 and P_1 are the air pressure of outlet and inlet to turbine respectively
P_o is the atmospheric pressure
V_1 is the upwind velocity of turbine
V_2 is the final velocity of turbine
Kinetic exergy represent the maximum net velocity of the flow stream that converted into power that drives the turbine [1]

$$Ex_{Ke} = \frac{1}{2} * \rho_a * A * (V_1^3 - V_2^3) \quad (18)$$

The exergy destruction ($Ex_{dest.}$) is a representative measure of the irreversibility of the process. It offers a helpful elective measure of turbine efficiency that incorporates the irreversibility, which were not included in the first law analysis. The specific exergy destruction can be defined as [8]

$$Ex_{dest.} = \dot{G}\left[T_o * \left(c_{pa} * \ln\left(\frac{T_2}{T_1}\right) - R_a * \ln\left(\frac{P_2}{P_1}\right) - \frac{c_{pa} * (T_o - T_{av})}{T_o}\right)\right] \quad (19)$$

Where
$\dot{G}$ is the mass flow rate of the air through the turbine
T_o is the ambient temperature
c_{pa} is the specific heat of air
T_2 and T_1 are the wind chilled temperature of outlet and inlet to turbine respectively
R_a is the general gas constant
P_2 and P_1 are the air pressure of outlet and inlet to turbine respectively
T_{av} is the average temperature of the outlet and inlet to the turbine
Since the values of velocity at a height of 12 m, so can be use the following equation to calculate the wind velocity at other heights (50 and 100) m [12]:

$$\frac{V_{(z_2)}}{V_{(z_1)}} = \left(\frac{z_2}{z_1}\right)^{\beta} \quad (20)$$

$$\beta = a - b * \log_{10}(V_{(z_1)}) \quad (21)$$

Where
z_1 is the reference height (m),
z_2 he turbine height (m),
$V_{(z_1)}$and $V_{(z_2)}$ is the wind velocity at heights z_1 and z_2, respectively,
a and b are coefficients, typical values of (a) and (b) is 0.11 and 0.061 in the daytime and 0.38 and 0.209 at night are recommended [12].

4. Results and Discussion

This section was presented the results of the first and second law analysis, the results of two Weibull parameters, wind velocity, wind chill temperature, air pressure, wind energy, output energy of the turbine, energy efficiency, exergy destruction, and exergy efficiency were discussed at different height (12, 50, 100 m) for six regions in Iraq (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra). The results obtained from this study can be summarized as follows.

Fig. 2 and 3 shows the two Weibull parameters the scale parameter (c) and shape parameter (k) for six regions in Iraq at different height. The values of k and c are drawing according to table (2) [11] to show the behavior of two parameter (c and k) at different height for all selected six regions, the higher value of parameter (c) lead to higher output energy. It is obvious that the average value of the parameter k has a much smaller than the average value of the parameter c. The smallest value of c was 1.993 (m/s) in Mosul at (12) m and the highest value was 6.5 (m/s) in Basra at (100) m, also can be noted that the c value of Mosul and Najaf was same at (100) m. While the smaller value of k was 1.875 in Najaf at (12 and 50) m and the highest value was 3 in Baghdad and Tikrit at (50) m, also can be noted that k value of Baghdad and Tikrit was same at (12 and 50) m.

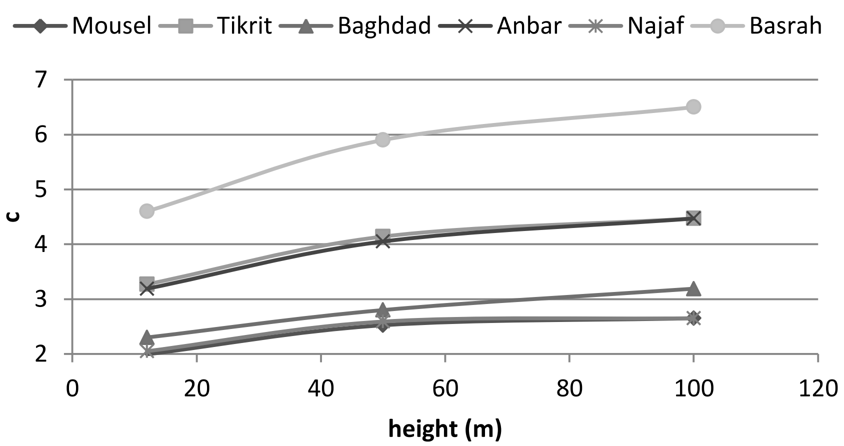

Figure (2) scale parameter (c) of six regions at different height

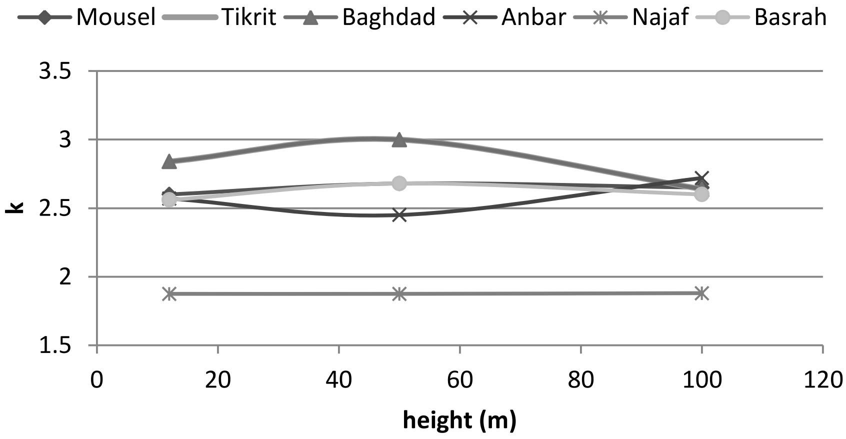

Figure (3) shape parameter (k) of six regions at different height

Fig. 4 presented the distribution of wind velocity for six regions at different height. The value of velocity at height 12 m was obtained from the Iraqi Meteorological Organization and Seismology and from reference [5] for six locations, while the velocity at height 50 m and 100 m was estimated from equation (20). The output energy of the wind turbine was increase as the velocity increase so that the second and first efficiency will be increase. It is can be seen that the smaller value was 1.3, 1.94, and 2.35 (m/s) in Mosul at (12, 50, and 100) m height respectively, while the highest value was 3.8, 5.76, and 6.88 (m/s) in Basra at (12, 50, and 100) m height respectively, also the wind velocity value of Basra and Anbar was close together. The wind velocity increasing by 33% when the turbine height become 50 m for all regions, while its increasing by 45% when the turbine height become 100 m for all regions.

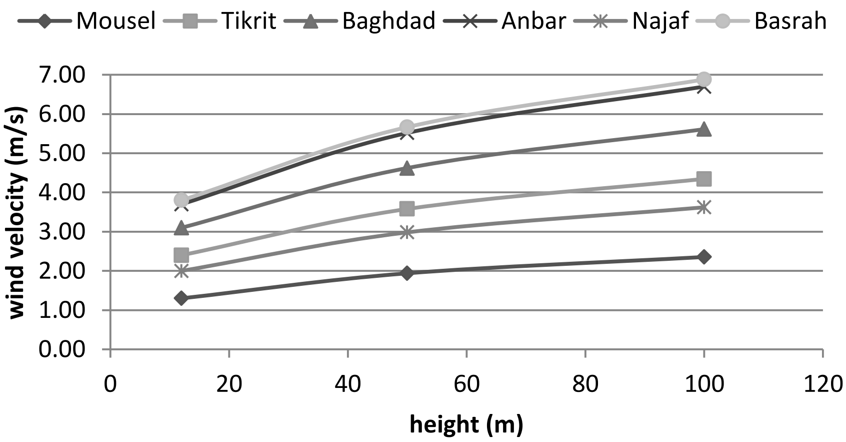

Figure (4) wind velocity of six regions at different height

Fig. 5 shows the relationship of wind chill temperature for six regions at different height. The value of average wind chill temperature can be obtain from equations (14) and (15), as the different between inlet and outlet wind chill temperature was increase due to increase in exergy flow and causing to decreases in exergy efficiency according to equation (2). It is can be seen that the smaller value was 27.07, 26.51, and 26.24 (°C) in Basra at (12, 50, and 100) m height respectively while the highest value was 28.33, 27.91, and 27.68 (°C) in Mosul at (12, 50, and 100) m height respectively, this result represent the equation (14) where at wind velocity increase led to decrease in wind chill temperature, also can be notes that wind chill temperature value of Basra and Anbar was close together.

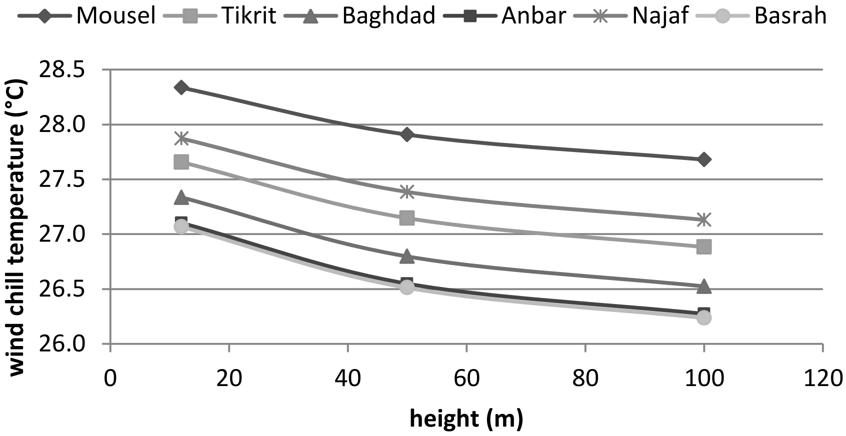

Figure (5) wind chill temperature of six regions at different height

Figure 6 shows the relationship of air pressure for six regions at different height. The value of average air pressure can be calculated by using equations (16) and (17), as the ratio of (P_2/P_1) was increase due to converted to useful energy and lead to reduce the exergy flow and causing of increase in exergy efficiency. It is obvious that the smaller value was 92.57, 81.97, and 72.83 (kPa) in Basra at (12, 50, and 100) m height respectively while the highest value was 100.22, 98.98, and 97.91 (kPa) in Mosul at (12, 50, and 100) m height respectively, this result represent the Bernoulli equation where at velocity increase the pressure should be decrease, and the pressure for same regions was decrease as the height increase , also can be notes that air pressure value of Basra and Anbar was close together.

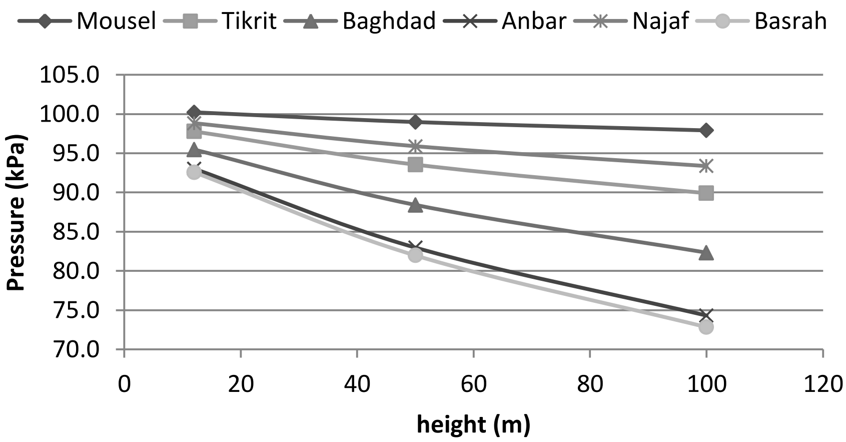

Figure (6) air pressures of six regions at different height

Figure 7 shows the relationship of wind energy for six regions at different height. The value of wind energy was calculated from equation (10), as the wind energy increase lead to converted more energy to turbine and due to increase the energy and exergy efficiency. It is obvious that the smaller value was 20.95, 69.46, and 124.33 (W) in Mosul at (12, 50, and 100) m height respectively, while the highest value was 523.15, 1734.8, and 3105.37 (W) in Basra at (12, 50, and 100) m height respectively, wind energy generation can be higher in the south region as the wind speed are strongest for all heights.

The maximum values in Basra , the medium values in Najaf, Tikrit, Baghdad, Anbar and the lowest values in the northern region Mosul because of this region locates between mountain while in the south is an opening lands area. The wind energy is increasing by 69% at when the turbine height become 50 m for all regions, while its increasing by 83% when the turbine height become 100 m for all regions.

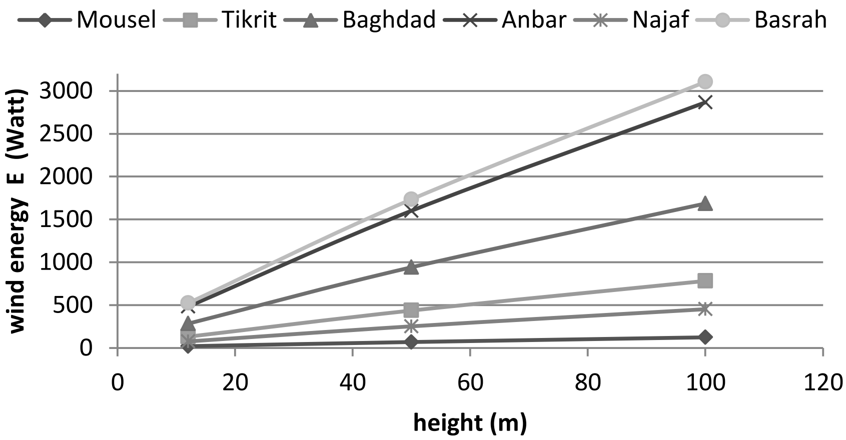

Figure (7) wind energy of six regions at different height

Figure 8 shows the relationship of output energy for six regions at different height. The output energy of the turbine was estimated by equation (3), the output energy of the wind turbine was increasing as the velocity of the air and the c-parameter was increase, the energy efficiency of the turbine was increase as the output energy increase. It is can be seen that the smaller value was 0.05, 0.47, and 1.07 (W) in Mosul at (12, 50, and 100) m height respectively, while the highest value was 29.59,182, and 427.47 (W) in Basra at (12, 50, and 100) m height respectively, this result represents the equation (3) where it is mainly depended on the Weibull distribution parameters *k*- Shape parameter and *c* (m/sec) scale parameter.

The output energy from the turbine, increasing by (88,84,84,87,86, and 83) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively, when the turbine height become 50 m, while its increasing by (94,94,96,93,93, and 93) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively when the turbine height become 100 m.

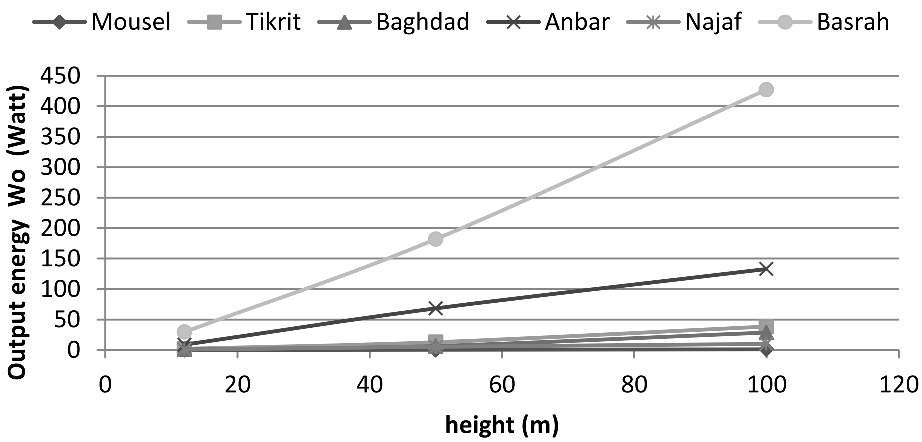

Figure (8) output energy of six regions at different height

Figure 9 shows the relationship of energy efficiency for six regions at different height. The value of energy efficiency was estimated by using equation (1), it is obvious that the smaller value was 2.56, 6.77, and 8.57 (%) in Mosul at (12, 50, and 100) m height respectively, while the highest value was 28.28, 52.46, and 68.79 (%) in Basra at (12, 50, and 100) m height respectively, this result represents the equation (1). The energy efficiency of the turbine, increasing by (62, 48, 48, 57, 54, and 46) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively, when the turbine height become 50 m, while its increasing by (70, 69, 78, 60, 56, and 58) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively when the turbine height become 100 m.

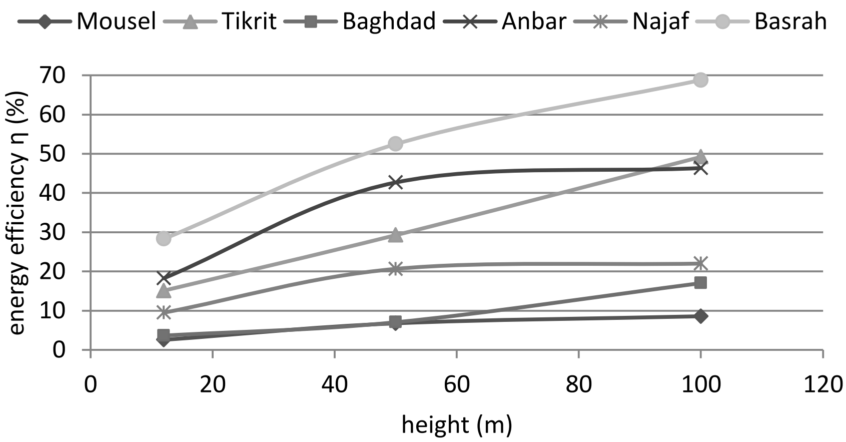

Figure (9) energy efficiency of six regions at different height

Figure 10 shows the relationship of exergy destruction for six regions at different height. The exergy destruction was found according to equation (19), the exergy destruction represented the losses in energy (work) so the energy and exergy efficiency increase as the exergy destruction decreases. It is can be seen that the smaller value was 262.64, 176.12, and 34.65 (W) in Basra at (12, 50, and 100) m height respectively, while the highest value was 1084.96, 727.57, and 529.33 (W) in Mosul at (12, 50, and 100) m height respectively, this result represents the equation (17).

The exergy destruction of turbine decreasing by (32, 38, 41, 52, 33, and 50) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively, when the turbine height become 50 m, while its decreasing by (51, 60, 70, 83, 56, and 86) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively when the turbine height become 100 m.

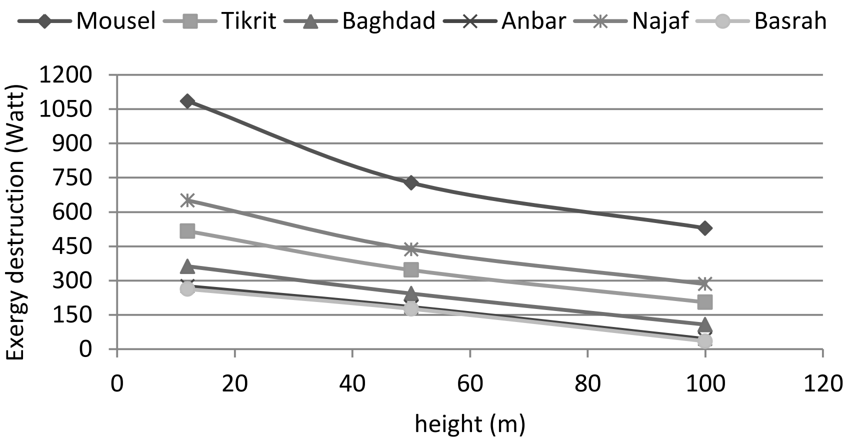

Figure (10) exergy destructions of six regions at different height

Figure 11 shows the relationship of exergy efficiency for six regions at different height. The exergy efficiency can give a better understanding of the losses in energy that happening in the wind turbine due to irreversibility. Targeted efforts can then be made to overcome these losses. It is can be seen that the smaller value was 0.57, 2.1, and 3 (%) in Mosul at (12, 50, and 100) m height respectively, while the highest value was 24.36, 49.63, and 66.98 (%) in Basra at (12, 50, and 100) m height respectively, this result represents the equation (2).

The exergy efficiency of the turbine, increasing by (72, 56, 54, 61, 63, and 50) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively, when the turbine height become 50 m, while its increasing by (81, 75, 81, 65, 67, and 63) % in (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively when the turbine height become 100 m.

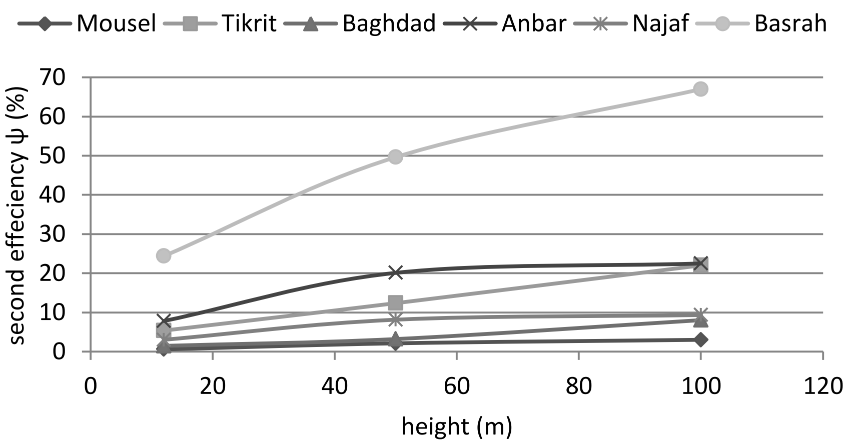

Figure (11) exergy efficiency of six regions at different height

5. Conclusions

The wind energy in Iraq is very limited. The main aims of this study were to recognize the wind characteristics such as (Weibull parameters c and k, wind velocity, wind chill temperature, air pressure, wind energy, output energy of the turbine, energy efficiency, exergy destruction, and exergy efficiency) for six regions in Iraq. This regions located at Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) at three different turbine heights (12, 50, 100) m. The following important conclusions can be drawn from the present study:

1- The highest exergy efficiency was in Basra, then Anbar, Tikrit, Najaf, Baghdad, and smallest in Mosull
2- The exergy efficiency of the turbine, increasing by (72, 56, 54, 61, 63, and 50) % at height 50 m, while its increasing by (81, 75, 81, 65, 67, and 63) % at height 100 m, for (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively
3- The highest exergy destruction was in Mosul, Najaf, Tikrit, Baghdad, and smallest in Anbar and Basra
4- The exergy destruction of turbine decreasing by (32, 38, 41, 52, 33, and 50) % at height 50 m, while its decreasing by (51, 60, 70, 83, 56, and 86) % at height 100 m for (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively
5- The high energy efficiency was in Basra, then Anbar, Tikrit, Najaf, Baghdad, and the smallest in Mosul
6- The energy efficiency of the turbine, increasing by (62, 48, 48, 57, 54, and 46) % at height 50 m, while its increasing by (70, 69, 78, 60, 56, and 58) % at height 100 m, for (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively
7- The highest output energy was in Basra, then Anbar, Tikrit, Baghdad, Najaf, and it's very smaller in Mosul
8- The output energy from the turbine, increasing by (88,84,84,87,86, and 83) % at height 50 m, while its increasing by (94,94,96,93,93, and 93) % at height 100 m for (Mosul, Tikrit, Baghdad, Anbar, Najaf, and Basra) respectively
9- As the results that obtain from applied first and second law of thermodynamics on the wind turbine, it is note that the suitable location to installation the wind turbine system in south regions of Iraq.

6. Abbreviations

A	Swept area of the turbine (m^2)
c	Scale parameter (-)
C_D	Drag coefficient (-)
C_L	Lift coefficient (-)
CP	Power coefficient of a wind turbine (-)
C_{pa}	The specific heat of air (kJ/kg.K)
E	Energy of the wind stream (W)

Ex_{dest}	Exergy destruction (W)
Exf	Exergy flow (W)
Ex_{Ke}	Kinetic exergy (W)
Ex_{Ph}	Physical exergy (W)
$\dot{G}$	Mass flow rate of the air through the turbine (kg/s)
k	Shape parameter (-)
Nb	Number of blades (-)
P	Pressure of air (kPa)
P_1	Inlet air pressure (kPa)
P_2	Outlet air pressure (kPa)
P_{mech}	The mechanical energy (W)
P_o	Atmospheric pressure (kPa)
P_{out}	Output energy (W)
R	Radius of turbine (m)
R_a	General gas constant
T	Temperature of air (^oC)
T_1	Inlet wind chilled temperature (^oC)
T_2	Outlet wind chilled temperature (^oC)
T_{av}	Average temperature (^oC)
T_o	Ambient temperature (^oC)
u_c	Cut-in speed (m/s)
u_f	Furling speed (m/s)
u_r	Rated wind speeds (m/s)
V_1	Upwind velocity of turbine (m/s)
V_2	Final velocity of turbine (m/s)
$V_{(z_1)}$	Wind velocity at heights z_1 (m/s)
$V_{(z_2)}$	Wind velocity at heights z_2 (m/s)
W_o	Useful output work (W)
z_1	Reference height (m)
z_2	Turbine height (m)
η	Energy efficiency (-)
η_g	Alternator efficiency (-)
η_m	Mechanical efficiency (-)
λ	Tip speed ratio (-)
ρ_a	Density of air (kg/m^3)
ψ	Exergy efficiency (-)
ω	Angular velocity (rad/s)

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