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Simulation of Wind Power Dynamic for Electricity Production in Nassiriyah District

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Abstract: *In this paper, wind speed in Nassiriya district (south of Iraq) has been measured for four years period (2010-2013) at 10 m altitudeand then, simulated mathematically to study and predict the important wind energy dynamic parametersas a necessary step to utilize the windenergy for electricity production job.The study concludes that the wind speed is feasible for power production at minimumaltitude equal to 44m for ,* $\alpha = 0.3$ *and 32m for* $\alpha = 0.4$ *As best knowledge no previous study investigated thewind energyas a renewable source in Nassiriyah district.*
Keywords: *Physics energy, renewable energy, wind energy*

I. Introduction

The energy sources can be divided into three categories: fossil fuels, renewable sources, and nuclear sources. The combined effect of the depletion of fossil fuels and the gradually emerging consciousness about environmental degradation have given priority to the use of conventional and renewable energy sources such as wind, hydro, geothermal, and solar sources. The rapid development in wind energy technology has made it an alternative to conventional energy systems in recent years and wind power as a potential energy has grown at an impressive rate.The potential benefits of wind power is a clean (does not causes acid rain or atmospheric heating, no CO2 emission, no harm to nature and human health, no radioactive effect), renewable, and economic energy source. This reduction in wind energy cost is the result of improved aerodynamic designs, advanced materials, improved power electronics, advanced control strategies and rigorous component testing [1-6].Wind turbines have continued to evolve over the last years and the overall cost of energy required to produce electricity from wind is now competitive with traditional fossil fuel energy sources [3,4].However, for power grid operators, the advancement of wind energy holds many challenges. Wind power is unsteady, unpredictable, and harnessed in relatively small quantities at points spread over a large area.If it is not properly controlled, wind farms cannot be tied directly to the power grid without devices to help regulate and control their output. However, the most technologically advantageouswind energy conversion systemfeatures a superb electronicpower interface to the external power grid to which it is connected.This system, which is referred to as direct drive synchronous, features a synchronous generator whose AC output is immediately rectified to DC, and is then inverted back to an AC voltage that is compatible with the grid into which it is being fed. This system is highly advantageous because the inverter can control both the reactive power content and the frequency of the electricity being put onto the grid. 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 those parameter [7].

This paper will focus on renewable sources (specifically wind energy) to study important parameters such as the variation of the annual mean speed ,annual mean power density of the wind as a function of altitude for two different values of the ground surface friction , the aim of the above studies to estimate the minimum altitude to obtain feasible wind speed for electricity power production optimal, also the Weibuall distribution has been studied to know the percent of day/year which is distinguishable by mean wind speed equal or more than 5 m/sec (the literatures consider the wind speed value become suitable to this purpose at least when it is approach to (4.5-5) m/sec [8])for chosen altitudes. The region of study is Nassiriya district which is located in south of Iraq, 4.5 meter above sea level, 31(east) with 46 (north) intersection lines [9].

II. Theory

The kinetic energy in joule of air mass (m) moving with speed (v) is given by

$$K.E. = \tfrac{1}{2} m v^2 \qquad (1)$$

While the mechanical power in watt of air mass flow rate per second moving with speed ((P)) is given by

$$P = \tfrac{1}{2}(\rho A v) v^2 = \tfrac{1}{2}\rho A v^3 \qquad (2)$$

Then the amount $(\rho A v)$ represents the mass flow rate of the air in kilograms per second, (ρ) is the air density (Kg/m3), $(A = \pi D^2 / 4)$ is the area swept by the rotor blades (m2), (D) is the rotor diameter. The amount (Av) is the volumetric flow rate.
By using Eq.(2),the actual power extracted by the rotor blades (P_o) (the difference between the upstream and the downstream wind power) can be formulated as the following expression :

$$P_o = \tfrac{1}{2}(\rho A)[v^3 - v_o^3] \quad (3)$$

Where $(v),(v_0)$ are the upstream wind speed (at the entrance of the rotor blades) and the downstream wind speed (at the exit of the rotor blades) respectively. The air speed is discontinuous from (v) to (v_o) at the plane of the rotor blades, however it is suitable to use the average speed [10] and rearrange Eq. (3) as the following expression.

$$P_o = \tfrac{1}{2}(\rho A v^3)[\tfrac{1}{2}(1 + \tfrac{v_o}{v})(1 - (\tfrac{v_o}{v})^2]$$

Then,

$$P_o = \tfrac{1}{2}\rho A v^3 C_p \quad (4)$$

Where represents the power coefficient of the rotor efficiency, equation (4) reflects that the wind turbine cannot take all of power from the moving air , Albert Betz in 1919 provedthat, for any turbine, the optimum power extraction occurs when the wind speedbehind the turbine is 1/3 the incident wind speed[10], the value of depends on the ratio of the downstream to the upstream wind speed and the theoretical maximum value of is 0.59, while in practical designs the maximum value below 0.5[11-13],The air density at sea level, one atmospheric pressure (14.7psi) and temperature of 60oF is Kg/m3. The temperature and pressure both in turn vary with the altitude to make combined effect on the air density is given by the following expression [11].

$$\rho = \rho_o e^{-(\frac{0.297 H_m}{3048})} \quad (5)$$

Where is the site elevation in meters.There are several density functions that can be used to describe the wind speed frequency curve. The most common are the Weibull and Rayleigh function [11]. TheWeibull function is a two parameter distribution while the Rayleigh function has only one parameter. This makes the Weibull function somewhat more versatile and the Rayleigh function somewhat simpler to use;Weibull probability distribution of wind speed being during any time interval is given by[11,13] .

$$h(v) = (\frac{k}{c})(\frac{v}{c})^{(k-1)} \exp(-(\tfrac{v}{c})^k \text{ for } v \rangle 0, k \rangle 0, c \rangle 0 \quad (6)$$

Where $h =$ (number of hours in which the wind is between v and $(v + \Delta v)) / \Delta v$,(k) is the shape parameter, and (c) is a scale parameter mile/hour(mph=0.446 m/sec) ranging from 10 to 20 mph (about 5 to 10 m/sec) [10].The distribution of wind speed can often be approximated by wiebull-raylieighdistribution $f(v) \approx v \exp(-v^2)$ [14], the normalized constantfor this distribution so that .
The wind shear at ground surface causes the wind speed increase with height in accordance with the following expression [11,12] $v_1(\frac{h_2}{h_1})^\alpha = v_2$ (7)

Where is the wind speed measured at the reference height h_1, v_2 is the wind speed estimated at height h_2 , and α is the ground surface friction coefficient determined empirically, The typical values for terrain classes are given in Table (1) [11].

Table (1) : Friction coefficient of various terrain

Terrain type	Friction coefficient (α)
Lake, ocean and smooth hard ground	0.1
Foot high grass on level ground	0.15
Tall crops, hedges, and shrubs	0.2
Wooded country with many trees	0.25
Small town with some trees and shrubs	0.3
City area with tall buildings	0.4

Mode speed is defined as the speed corresponding to the hump in the distribution function. Mean wind speed over the period is defined as the total area under the $h-v$ curve integrated from v =0.0 to ∞, divided by the total number of hours in the period (8760 if the period is one year). The annual mean wind speed is therefore the weighted average speed and is as follows: $v_{mean} = \frac{1}{8760}\int_0^\infty hv\,dv$ (8)

The speed every hour averaged over the day, which in turn was averaged over the month and over the year, the averaging was done as follows: $v_{avg} = \frac{1}{n}\sum_{i=1}^{n} v_i$ (9)

Where is the number of observations in the averaging period, is the wind speed at the ith observation time. The wind power is proportional to the speed cube, and collected over the year (equivalent the integral of (hv^3dv), therefore, defines the root mean cube (rmc) speed in the manner similar to the root mean square (rms) value

$$v_{rmc} = \sqrt[3]{\frac{1}{8760}\int_{0.0}^{\infty} hv^3 dv}$$

$$v_{rmc} = \sqrt[3]{\frac{1}{n}\sum_{i=1}^{n} v_i^3} \quad (10)$$

Eq. (10) does not take into account the variation in the air mass density which is a parameter in the wind power density. Therefore a better method of collecting the wind power data is to digitize the yearly average power density (watt/m2) as follows:

$$P_{rmc} = \frac{1}{2n}\sum_{i=1}^{n} \rho_i v_i^3 \quad (12)$$

III. Calculations, Results, and Discussion

The data of the wind speed in Nassiriya district has been measured for four years ago (2010-2013) at 10 m altitude (the tower altitude of meteorology Nassiriya station), this data has been fed into a software program set up in this study to know or predict the wind dynamic parameters by computations. The following input data was used in the study such a blade radius (r) =10m, air density (ρ_o) (Kg/m^3) =1.225, power coefficient $(C_p) = 0.5$,friction coefficient (α = 0.3 - 0.4), shape factor (k) =2 m/sec , scalar factor(C) =7 m/sec.

The air density sweeping the blades was corrected with the altitude in computations. The daily mean wind speed, annual mean wind speed, mean power density, and the wind distribution function areanalysed in this study for the time interval (2010-2013).

Figures(1-a) and (1-b) showsimilar behavior of the variation of the annual mean of wind speed as a function of the altitude;theyrevealed that the annual mean speed increased with the increasing of altitude, but the values of the annual mean of wind speedin case of fig.(1-b) is greater than in fig.(1-a) for the same altitude that is related to the increment of friction coefficient value. The aim of this part of the study is to estimate the minimum altitude which is ensure availability to utilize the wind speed in Nassiriya district for electricity production. We can estimate fromfig. (1-a) the values of the annual mean speed which are suitable for electricity production purpose; they are approach to 5 m/sec at the altitudes (44 m, 44 m, 44 m, 40 m) for the years 2010, 2011, 2012, 2013, respectively when the friction coefficient $(\alpha) = 0.3$ .While we can consider from the fig.(1-b) the annual mean speed approach to 5m/sec at the altitudes (32m, 32 m, 32 m, 28 m) for the same interval, that is related to the increment of friction coefficient value $(\alpha = 0.4)$. Figures(2-a) and (2-b) show the annual mean power density as a function of the altitude for two different values of friction coefficient (α =0.3) and(α =0.4) respectively for the same study interval (2010-2013). They revealedthe increase of the annual mean power while the altitude increasewith the increase in the wind speed values with the altitude.Concerning Weuibuall distribution study, the last years have been selected as a function of friction coefficient and altitude. Figures (3-a) , (3-b) and(3-c) show thepercent of day/year which is distinguishable by mean wind speed equal or more than 5m/sec at arbitrary altitude (44m,60m, and 76 m) respectively to the case of $\alpha = 0.3$ for year 2012 . It appears from fig.(3-c) that the rang of percent ratio of day/year which has mean wind speed is equal or more 5m/sec greater than what appears in fig.(3-b) and fig.(3-a), also fig.(3-b) shows this percent ratio is greater than obtained from fig.(3-a), that is related to the increasing in the wind speed values while the altitude increasing. Figures(4-a),(4-b) and (4-c) show the percent of day/year which distinguishable by mean wind speed equal or more than 5m/sec at arbitrary altitudes (32m,60m, and 76 m) respectively to the case of $\alpha = 0.4$ for year 2012. The percent ratio of day/year which is distinguishable by this mean wind speed is greater than obtained from the study of case ($\alpha = 0.3$), that is related to the increasing of friction coefficient (α). It appears from fig.(4-c) the rang of percent ratio of day/year which distinguishable by mean wind speed equal or more than 5m/sec greater than appears from each in fig.(4-b) and fig.(4-a), also fig.(4-b) appears this rang of percent ratio greater than obtained from fig.(4-a), that is also related to the increasing in the wind speed values while the altitude increasing.Figures(5-a),(5-b) and (5-c) show thepercent of day/yearwhich are distinguishable by mean wind speed equal or more than 5m/sec at arbitrary altitudes (40m,60m,and 76m) respectively to the case of $\alpha = 0.3$ for year 2013 . Also Itappears from fig.(5-c) the percent ratio of day/year which are distinguishable by wind speed equal or more than 5m/sec greater than appears from each in fig.(5-b) and fig.(5-a),the similar result has been obtained concerning fig.(5-b) and fig.(5-a) that is also related to the increasing in the wind speed values while the altitude increasing. Figs (6-a,6-b,and 6-c) show the percent of day/year which distinguishable by mean wind speed equal or more than 5m/sec at arbitrary altitudes (28m,60m, and 76 m) altitude respectively for the case of $\alpha = 0.4$ for year 2013. The percent ratio of day/year whichis distinguishableby this mean wind speed is greater than obtained from the study of case ($\alpha = 0.3$),that is related to the friction coefficient (α) effect.Then from the distribution function which appears in figs.(3-6) can note that the number of days are distinguishable by mean speed more than 5m/sec and are much and suitable to electricity production.The aim of this part of the study is to estimate the number of days which are useful or encouraging for utilizing wind in electricity production in this district .

IV. Conclusion

The study concludes that the wind speed in Nassiriya districtis suitable to electricity production at minimum altitude equal to 44m and 32m for $\alpha = 0.3$ and respectively. $\alpha = 0.4$

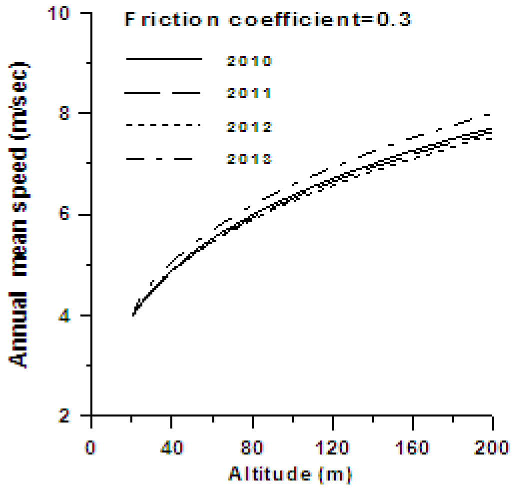

Fig. (1-a) : The variation of annual mean speed as a function of altitude for friction coefficient=0.3

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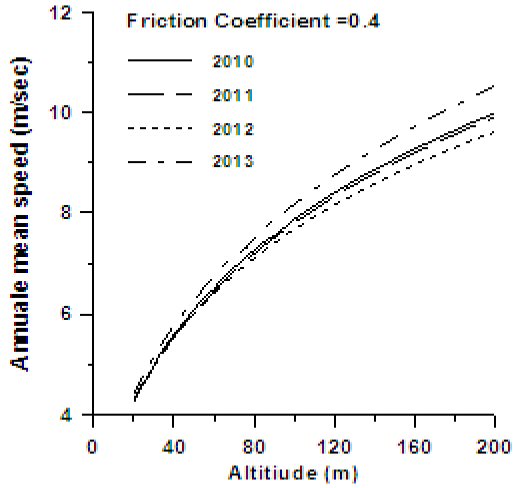

Fig.(1-b): The variation of annuall mean speed as a function of altitude for friction coefficient =0.4

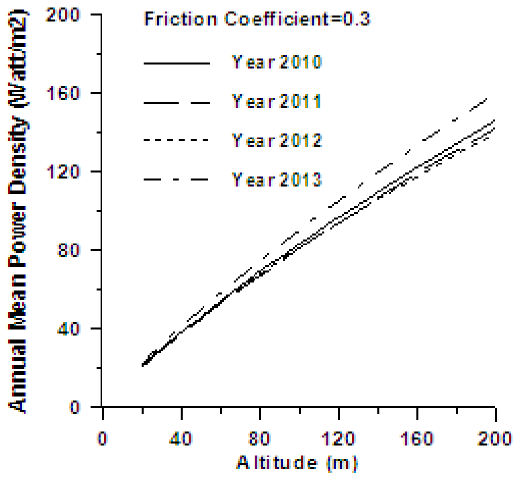

Fig.(2-a): The variation of annual mean power density as a function of altitude for friction coefficient= 0.3

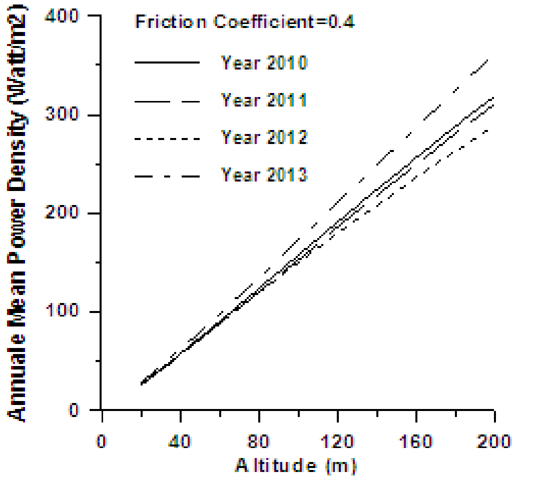

Fig.(2-b): The variation of annual mean power density as a function of altitude for friction coefficient =0.4

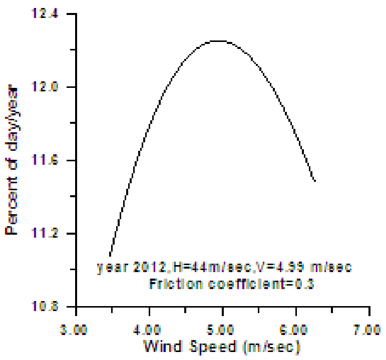

Fig. (3-a): Weibuall distribution of day/year at 44 m altitude for friction coeffiecint= 0.3

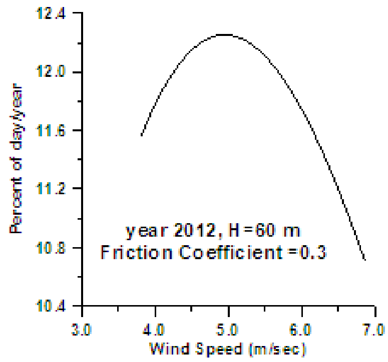

Fig.(3-b): Weibuall distribution of day/year at 60 altitude for friction coefficient= 0.3

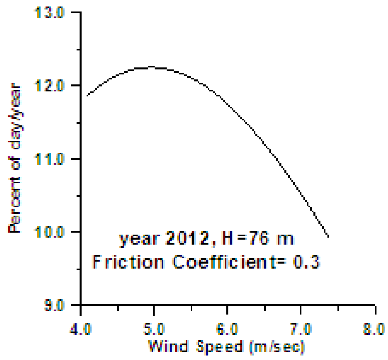

Fig. (3-c) Weibuall distribution of day/year at 76 m altitude for friction coefficient=0.3

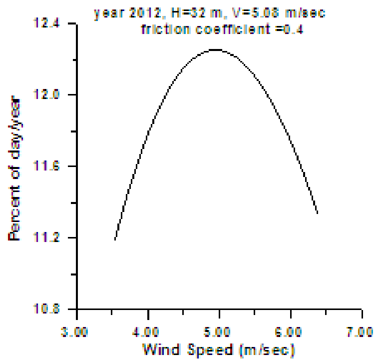

Fig. (4-a) : Weibuall distribution of day/year at 32 m altitude for friction coefficient =0.4

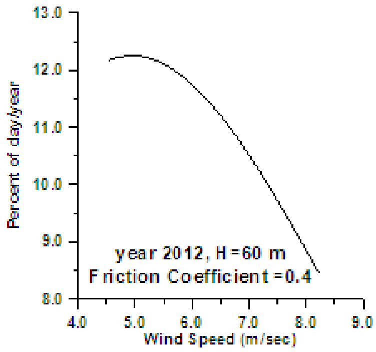

Fig.(4-b):Weibuall distribution of day/yearat 60 m altitude for friction coefficient=0.4

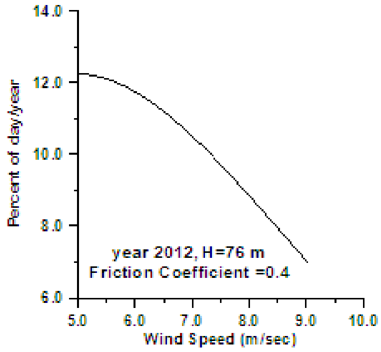

Fig. (4-c) : Weibuall distribution of day/year at 76 m altitude for friction coefficient =0.4

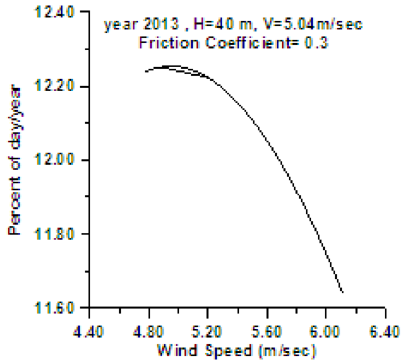

Fig.(5-a): Weibuall distribution of day/year at 40 m altitude for friction coefficient= 0.3

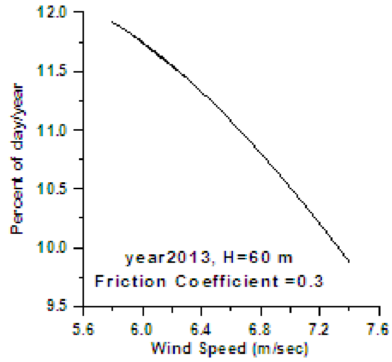

Fig.(5-b): Weibuall distribution of day/year at 60 m altitude for friction coefficient=0.3

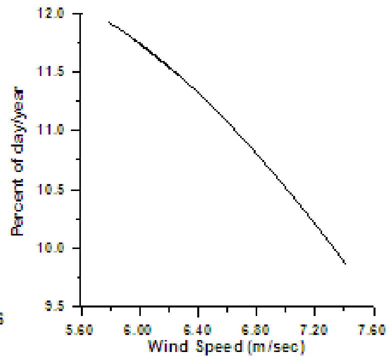

Fig. (5-c): Weibuall distribution of day/year at 76 m altitude for friction coefficient =0.3

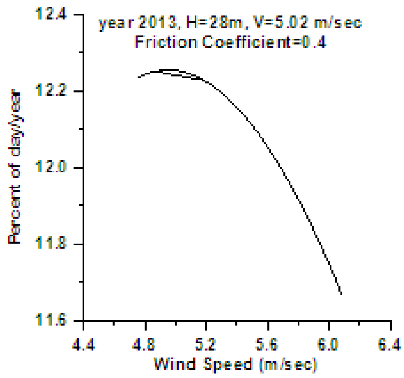

Fig. (6-a) : Weibuall distribution of day/year at 28 m altitude for friction coefficient= 0.4

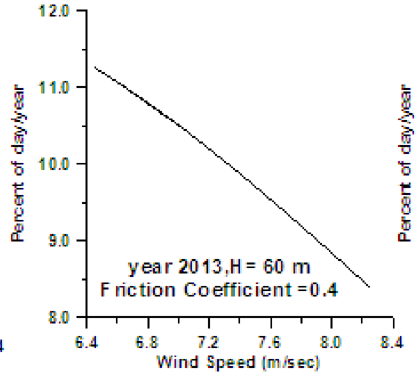

Fig.(6-b) : Weibuall distribution of day/year at 60 m altitude for friction coefficient =0.4

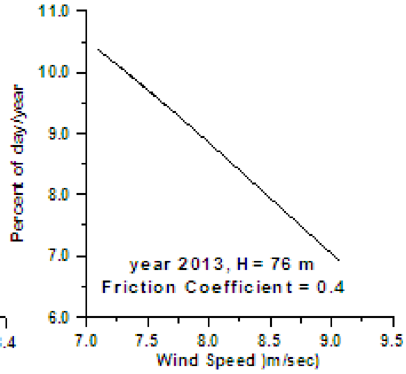

Fig.(6-c) : Weibuall distribution of day/year at 76 m altitude for friction coefficient = 0.4

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