

Assessment of Relative Humidity Effect on Wind Power for Electricity Production in Al-Samawa City-Southern Iraq

Abdul-Kareem Mahdi Salih^{a*}, Maha Hatem Kamil^b

^a*Department of Physics, College of Science, University of Thi-Qar, Iraq*

^b*Department of Physics, University of Muthana, Iraq*

^a*Email: karimmahdisalih@yahoo.co.uk, abdul Kareem@utq.edu.iq*

^b*Email: mahaphy17@gmail.com*

Abstract

The relative humidity influence on the percentage of loss in annual rates of wind power in Al-Samawa city-Southern Iraq have been assessed for five years interval (2012-2016) for electricity production object. Data of relative humidity and wind speed, are measured at height of AL-Samawa meteorological Station (11 meters). This data utilized as input to a software computer program which was prepared for this study. The study declare the little reduction in the annual rate of power of moist air. It is noted that the least loss in value occurred at minimum height reached approximately 0.76% at study year 2014, whereas the largest loss at the minimum height reached nearly 0.9% at study year 2015, and the value of loss percentage reduces with height increases. This difference belongs to decrease in air density. The least percentage of air density in 2014 at minimum height reached 0.76% while the largest one reached 0.9% in 2015. Lowering in values of annual rates of density was noted as height increases.

Keywords: Physics; Renewable energy; Wind energy.

* Corresponding author.

1. Introduction

An energy sources is called renewable if it can be renewed and sustained without any significant effect on the environment and depletion. It is also called an alternative, sustainable, or green source. Fossil fuels such as oil, coal, and natural gas are not renewable, and they are depleted by use. They also emit harmful pollutions [1]. Rapidly growth in renewable energy sources in many developing countries. Growth in two common renewable energy sources wind and solar photovoltaics (PV) has been significant in recent years. Due to increasing energy demand, the renewable energy technologies has grown dramatically to be compatible with this demand. Therefore the role of these technologies in different perspectives of energy issues with various techniques has been investigated in some studies [2, 3]. Iraq has promising renewable sources of energy such as wind and solar. The relative humidity is important climatic variable that effect on the wind density which effected on the power. The previous papers [4,5] deal the wind power potential as a renewable energy source for electricity mass production and the evaluation of the percentage of loss in wind power annual rates by temperature influence in Al-Samawa city situated in southern Iraq on latitudes (31.316) and longitude (45.283). This study deal the effect of relative humidity on the wind power which can be utilized for electricity production in this city for interval 2012-2016. The results of the study are complementary to the results which is obtained in reference [4,5], because the city location close to “Euphrates” river, and Sawa lack, sometimes that is lead to humid climate features . The data of relative humidity measured only at 11 meter height (height of meteorological Station of AL. Samawa). Software program prepared for this study to solve the set of equations in section 2 and estimates the relative humidity at deferent heights and simulates its effect on wind power as a function of height. .

2. Theory

Humidity is the quantity of water vapor present in air, and there are many varied ways of expressing it such as an specific humidity, absolute humidity, and relative humidity. Relative humidity is the amount of water vapor in the air relative to the maximum amount possible, thus it is at all temperature and pressure defined as the ratio of the water vapor pressure to the saturation water vapor pressure, and it is mathematically defined by the following expression[6,7]:

$$RH = \frac{e_a}{e_s(T)} \times 100\% \quad (1)$$

Where RH is the relative humidity, e_a is the actual water vapor pressure, it is contributes to the total atmospheric pressure, defined by the Antoine equation [8] as the following:

$$\log_{10} e_a = A - \left(\frac{B}{C + T} \right) \quad (2)$$

Where $A = 8.07131$, $B = 1730.63$, $C = 233.426$, actual vapor pressure e_a is in mmHg

(1mmHg=133.322 Pascal), T is the temperature. $e_s(T)$ is the saturation vapor pressure (Pascal) at the same temperature (T) in degrees Celsius (C^0), When air enclose above an evaporating water surface, an equilibrium is reached between the water molecules escaping and returning to the water reservoir. At this moment, the air is saturated since it cannot store any extra water molecules. Many formulas for estimating the saturation vapor pressure [9]. Herman Wobus developed Albeit formula for estimating saturation vapor pressure [10] as the following expression:

$$e_s(t) = \frac{e_{s0}}{P^8} \tag{3}$$

Where: $P = (C_0 + T * (C_1 + T * (C_2 + T * (C_3 + T * (C_4 + T * (C_5 + T * (C_6 + T * (C_7 + T * (C_8 + T * (C_9))))))))))$

$C_0=0.99999683$, $C_1=-0.90826951E-02$, $C_2=0.78736169E-04$, $C_3=-0.61117958E-06$, $C_4=0.43884187E-08$, $C_5=-0.29883885E-10$, $C_6=0.21874425E-12$, $C_7=-0.17892321E-14$, $C_8=0.11112018E-16$, $C_9=-0.30994571E-19$.
 $e_{s0} = 6.1078$

The mixture density of dry air molecules and water vapor molecules may be written as the following[10]:

$$\rho = \left(\frac{P}{R * T}\right) \left(1 - \frac{0.378 * e_a}{P}\right) \tag{4}$$

Where ρ is the moist density (Kg / m^3), $P = P_d + e_a$ is the total pressure, P_d is the pressure of dry air (partial pressure), R is the gas constant for dry air ($J / Kg.K^0$), T is the temperature in (K^0). The most important atmospheric parameters effect on the wind density is the temperature, pressure, and humidity [11]. Coupled physical relation between these parameters. The relationship between the temperature and the pressure can be expressed by Poisson equation [12]:

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{R}{C_p}} \tag{5}$$

Where $\frac{R}{C_p} = 0.286$, C_p is the constant –pressure specific heat of air, P_1 and T_1 are the pressure and temperature at site(1), T_2 and P_2 are the temperature and pressure at site(2). The formula which is assessment the temperature as a function of height express as the following [13]:

$$T(z) = T_g - R_a(z - z_g) \tag{6}$$

Where $T(z)$ the temperature at height z in meter above sea level, T_g is the temperature at ground level z_g , and R_a is the laps rate of temperature ($0.0065\text{C}^\circ\text{m}^{-1}$), $(z - z_g)$ is the height above ground level. Air density can be calculated in pressure and temperature terms by the following equation [13]:

$$\rho = \left(\frac{P_o}{RT}\right) * \exp\left(\frac{-G * z}{RT}\right) \quad (7)$$

Where P_o is the std. sea level atmosphere pressure (101325 pascals), G is the gravitational constant (9.8 m/s). The density of dry air as a function of height ($\rho(z)$) calculated by the following equation [14]:

$$\rho(z) = \rho_o e^{-\left(\frac{0.297 * z}{3048}\right)} \quad (8)$$

Where (ρ_o) is the air density (1.255 Kg/m^3), (z) is the height. The wind speed calculated by the following equation [13, 14].

$$v = v_o \left(\frac{Z}{Z_o}\right)^\alpha \quad (9)$$

Where (z_o), (z) are represents the lower height and other height under study respectively, v and v_o are the wind speed at height (z) and (z_o) respectively, α is the ground surface friction coefficient, can be calculated as the following equation [15]:

$$\alpha = \frac{0.37 - 0.088 \ln v_o}{1 - 0.88 \ln z_o} \quad (10)$$

The net power of a practical wind turbine can be calculated by the following equation [16]:

$$P_w = \frac{C_p \rho A v^3}{2} \quad (11)$$

Where A the swept area of turbine blades in m^2 is, v is the wind speed in m/s . C_p is the power coefficient, it's maximum theoretical value is a brooch to 0.59, but in practical designs the maximum value below 0.5 [13]:

3. Results and Discussion

A software computer program has been prepared in this study. Monthly mean of measured data of wind speed, temperature and relative humidity converted to daily mean and used as input into the program. All equations mentioned in section 2 have been solved in the program using the values of air density equal 1.225 kg/m^3 , $C_p = 0.5$, $p_o = 101325 \text{ pas.}$, and for power density calculation used swept diameter $r = 10 \text{ m}$.

Fig.s (1-A,B,C,D,E) shows the nature of relation between values of daily rates of temperature and relative humidity where calculated in the study for the interval of study (2012-2016) respectively. The figures (1) demonstrates the reverse (opposite) relation between the two factors affecting wind power, while the figure (2-A,B,C,D,E) shows the physical behaviour of annual rates of temperature, relative humidity in terms of height for the of study period (2012-2016) alternately. It is noted that values of relative humidity increases whenever height increases, but the inverse for temperature. Figures (3-A,B,C,D,E) indicates relative Humidity effect on air density for the study period (2012-2016), where a reduction in the annual rates of moist air density on its value of dry air at same height and the difference of both values of density remain approximate at the different heights, attributable to the reduction in temperature degrees and air pressure when the height increases. Figures (4-A,B,C,D,E) shows the effect of relative humidity on power obtained from wind for the study years (2012-2016) respectively. Little reduction in the annual rate of power of moist air is observed due to the decrease in air density of moist air as compared to dry air. Figure (5) shows power loss percentage resulting from humidity effect. It is noted that the least loss in value occurred at minimum height reached approximately 0.76% at study year 2014, whereas the largest loss at the minimum height reached nearly 0.9% at study year 2015, and the value of loss percentage reduces and the height increases. This difference belongs to decrease in air density which humidity causes as shown in figure (6) which shows that the least percentage of air density in 2014 at minimum height reached 0.76% while the largest one reached 0.9% in 2015. Lowering in values of annual rates of density was noted as height increases.

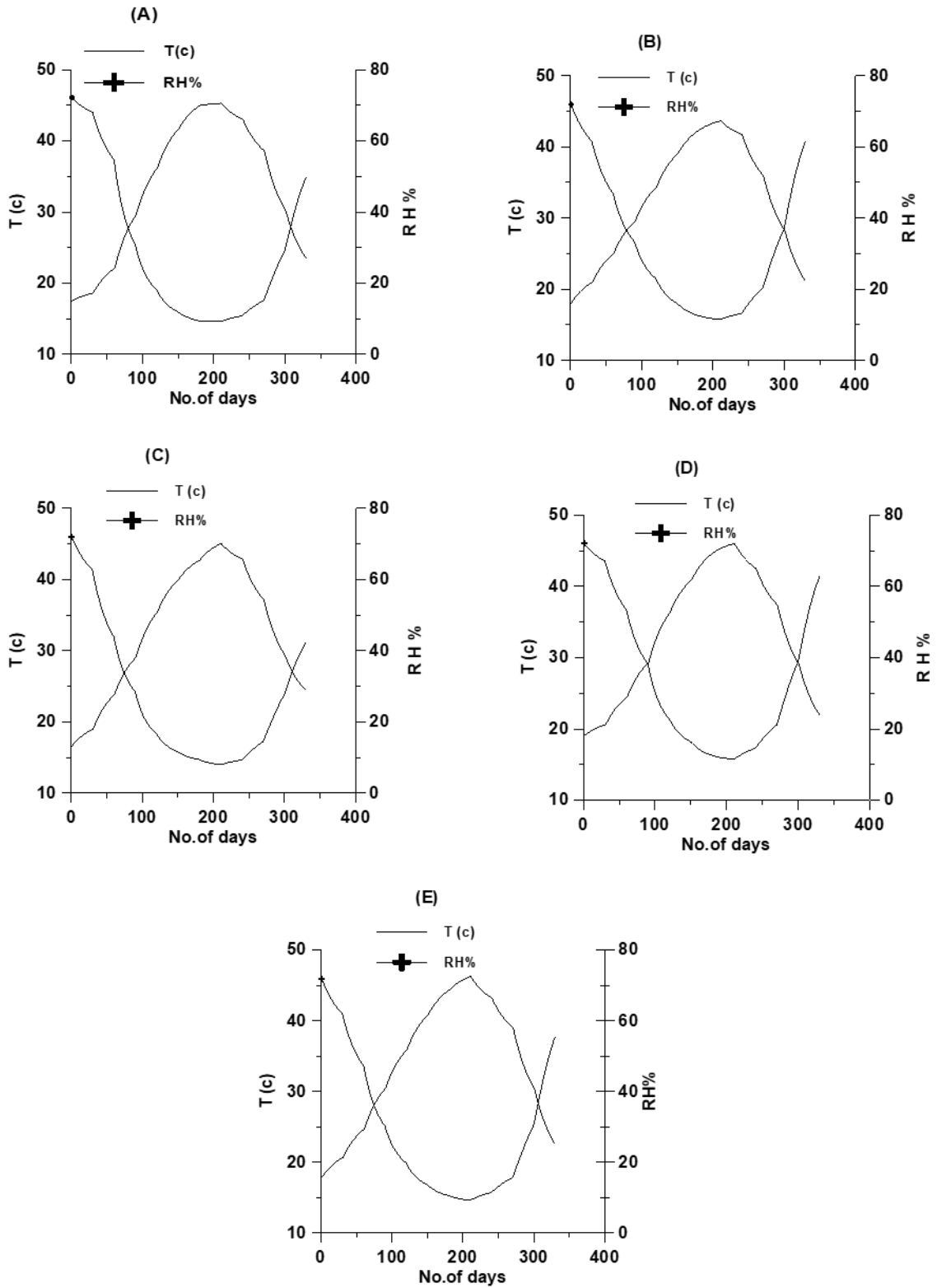


Figure 1: The behaviour of daily average for temperature and relative humidity for interval of study (A for 2012, B for 2013, C for 2014, D for 2015, E for 2016)

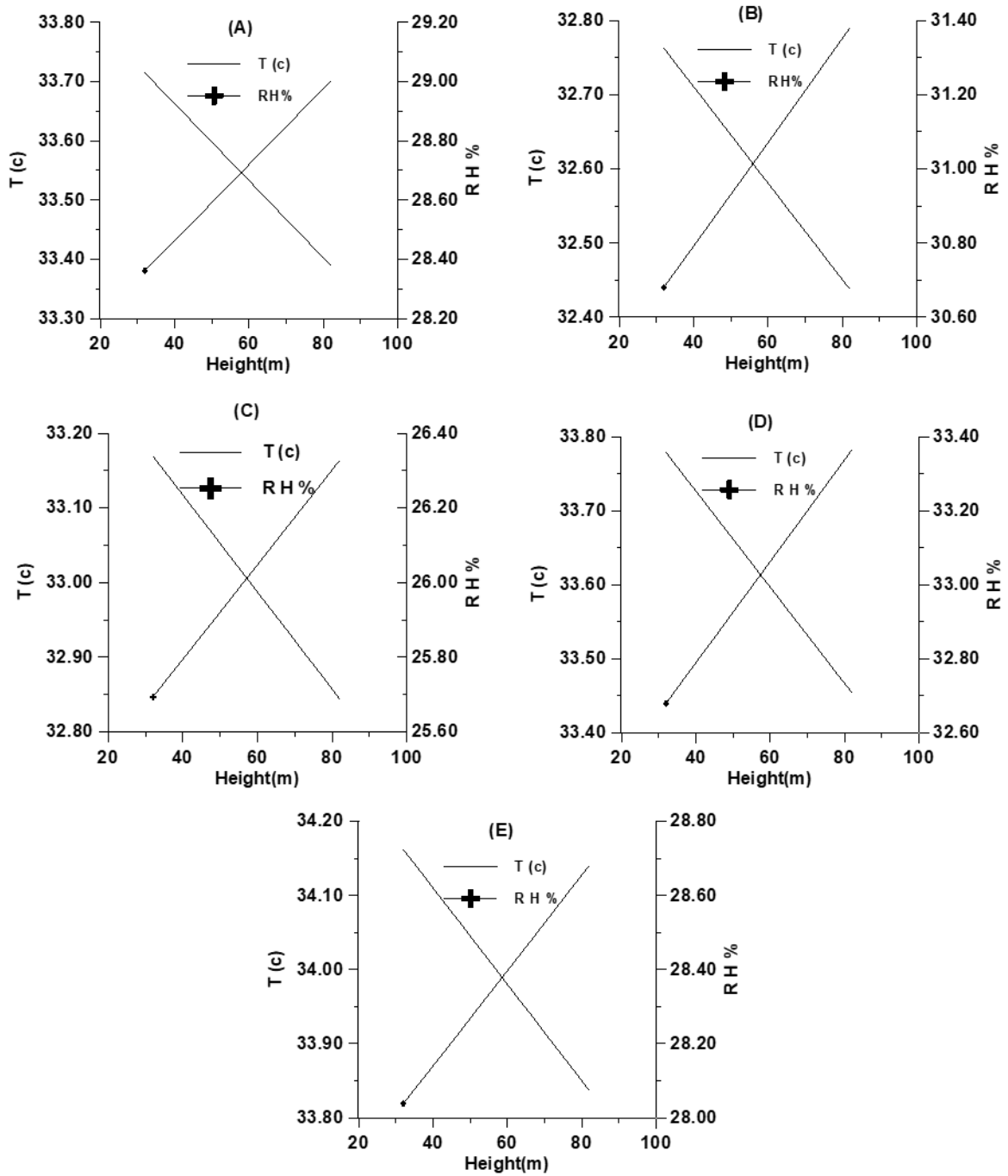


Figure 2: The behaviour of annual mean of temperature and relative humidity for interval of study (A for 2012, B for 2013, C for 2014, D for 2015, E for 2016)

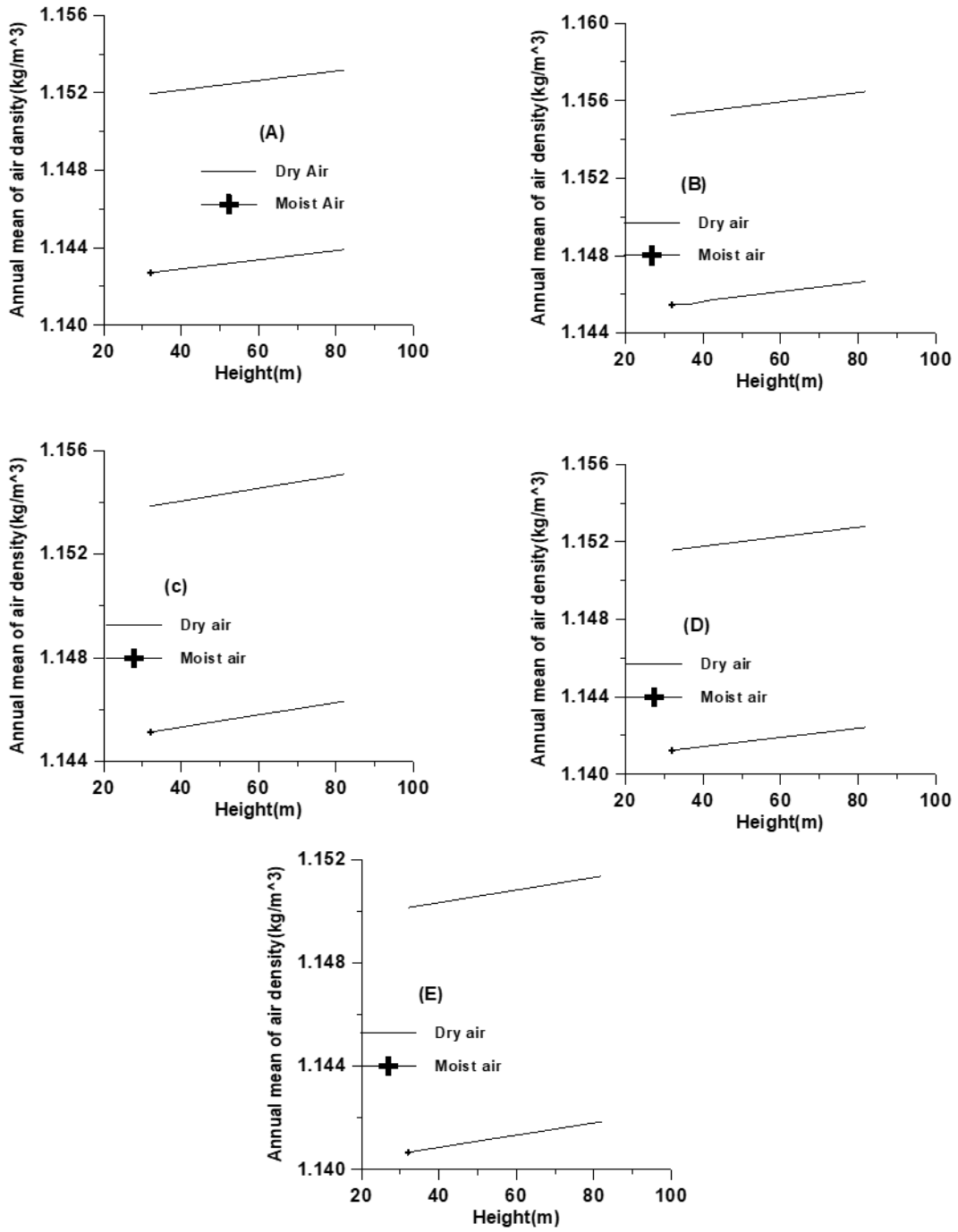


Figure 3: The behavior of annual mean of density for dry and moist air as a function of height humidity for interval of study (A for 2012, B for 2013, C for 2014, D for 2015, E for 2016)

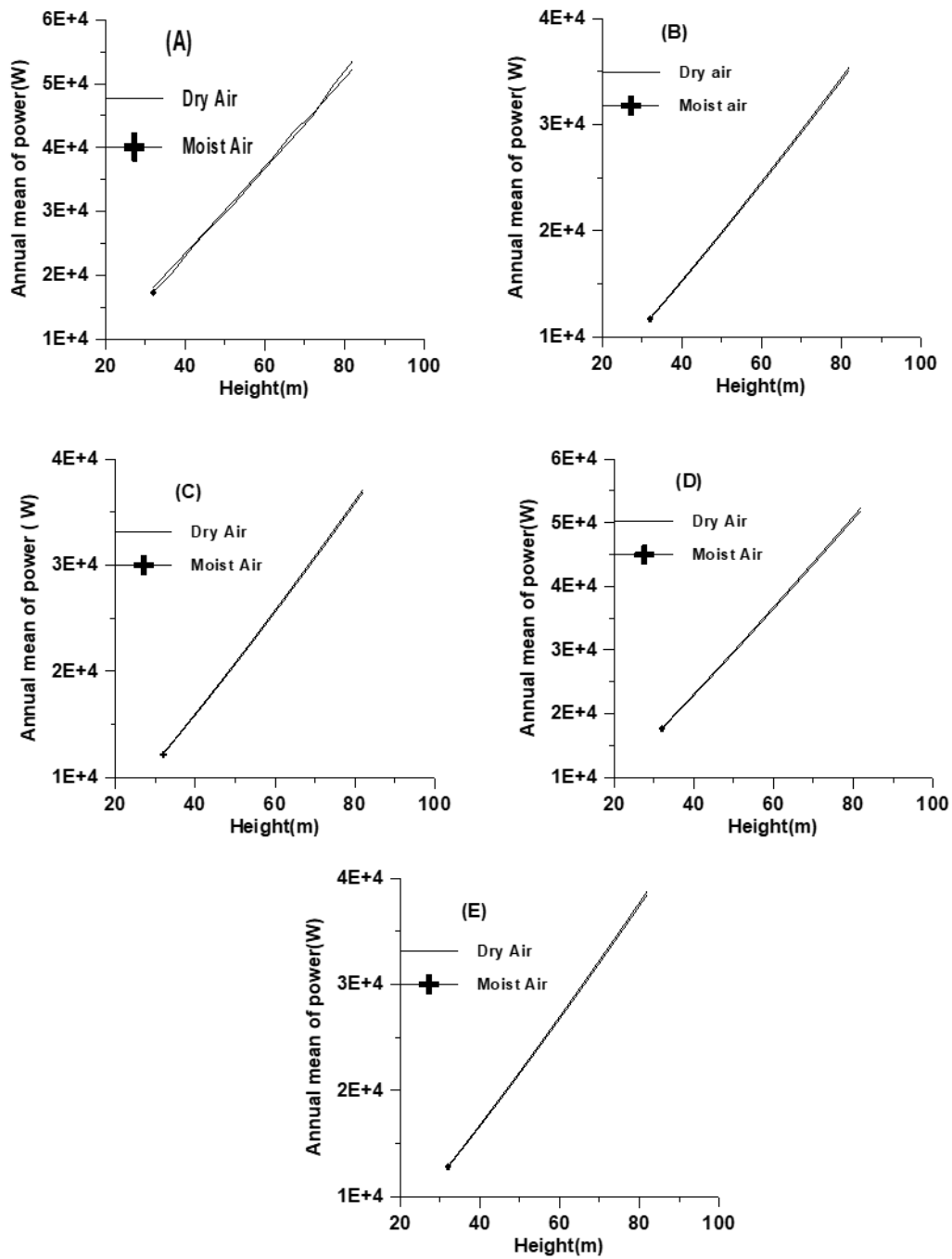


Figure 4: The profile of annual mean of power for dry and moist air as a function of height for interval of study (A for 2012, B for 2013, C for 2014, D for 2015, E for 2016)

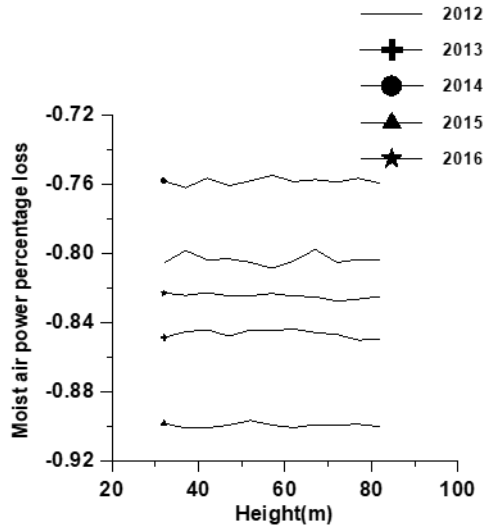


Figure 5: The percentage of loss of the annual mean of power for moist air as a function of height for interval(2012-2016)

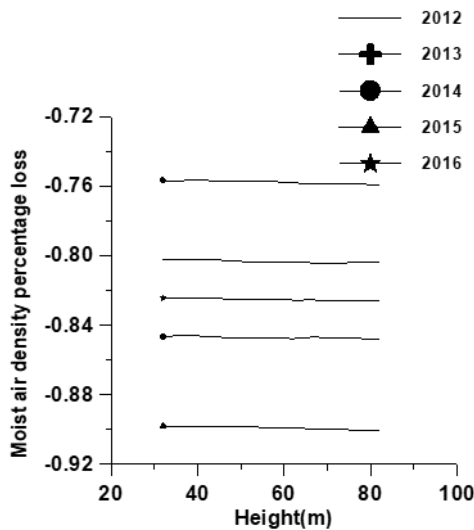


Figure 6: The percentage of loss of the annual mean of density for moist air as a function of height for interval (2012-2016)

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