A Look at the Wind Energy Prospects in Iraq: Review

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***Abstract*— This research provides an overview of Iraq's renewable energy prospects. One of the most important sorts of renewable energy resources in the world is wind energy. Wind energy is considered environmentally beneficial and very economical. These benefits are cited as the primary reasons for using wind turbines to generate power across the world. An assessment of the country's profile has been made, taking into consideration existing energy generation, crude oil production at current levels, gas flares that generate CO2 emissions, as well as industry, human activities, and grid electricity distribution. Iraq has power shortages, and several obstacles must be solved in order to satisfy projected increases in electrical demand. This analysis discovered that solar, wind, and biomass energy are now underutilized, but that they might play a key part in Iraq's sustainable energy future. Wind energy, for example, has become an important aspect in reducing pollution and improving air quality. The usage of tiny wind turbines to generate power under Iraqi meteorological conditions is examined in this study. The research evaluates the wind system that is necessary to provide electric power for highway services including lighting and parking. According to the study's findings, wind turbines can be used effectively for roadway illumination. The efficiency of a maximum wind turbine is determined by the blade design. For the planned use, the wind speed reported in Iraqi winter is pretty acceptable. Alternative and sustainable energy, wind energy, Iraqi climate are all index terms. The Iraqi government recently joined the Paris Climate Agreement and is now starting to encourage the participation of small and large consumers to generate electricity from renewable energy sources. This article analyzes the hybrid electrical system of solar and wind energy for the city of Dohuk, the northern part of Iraq, to find out the feasibility of this system compared to the local electrical network. First, access to solar and wind energy resources in Dohuk were ensured.**

Keywords— Renewable Energy, Wind Energy, Wind Power Density WPD, Wiebull Distribution, Wind turbines.

I. Introduction

It is clear that wind energy density is strongly influenced by the value of wind speed (v) which is the main factor in estimating wind energy density because it is proportional to the cube of wind speed [1], [2]. Then, the wind speed data of the selected site must be accurately recorded and analyzed to get the best result when the site assessment is achieved [3], [4].The wind speed is affected by the obstacles and the roughness of the ground surface of the site [5], [6], atmospheric stability [7], and geographical location of the site [8], the height above ground level is directly proportional to the wind speed [9], [10]. Wind energy extracted from the wind itself is a type of renewable energy, which is sustainable, clean and considered the least expensive type of renewable energy technology. To get the most out of wind speed, a wind map of Iraq must be created. The map of Iraq's winds is very important to know the best locations with the highest wind speeds [3], [11] .

The Iraq Wind Atlas (IWA) was achieved in 2012, through the cooperation between the Directorate of Renewable Energy of the Ministry of Science and Technology (MOST), with the National Center for Renewable Energy of Spain (CENER), IWA shows the distribution of wind speed and wind direction (windflower), Wind energy density distribution maps plus Walpole charts [12]. It covers all regions of Iraq at three altitudes above ground level: 30 m, 50 m, and 100 m. IWA has been approved and published on the IRENA website [13]. Global energy demand, especially clean energy, is growing rapidly. Protecting the environment through pollution control, especially greenhouse gas emissions, has become a major concern worldwide. Although energy from fossil fuels is still available and isn't going away any time soon, the era of low-cost, abundant energy won't last long. Hence, exploring alternative Energy sources, especially renewable energy, and addressing the environmental issues associated with energy sources have become necessary [14].

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By 2040, renewables-based power generation is expected to account for 50% in the European Union, about 30% in China and Japan, and over 25% in the United States and India; By contrast, coal will account for less than 15% of electricity supply outside Asia [15]. Power plants produce baseload energy using coal or conventional gas, which pollutes the environment and contributes to the global warming effect. Concentrated solar power plants (CSPPs) utilize the sun's heat to power an engine and generate heat energy. This technique is linked to typical fossil-fuel-fired power plants, which rely on heat engines to transform thermal energy into electrical energy. Solar thermal energy is not a new concept [14], [16], [17]. In 1907, Germany was the first country to harness solar power. The sun was first used as a heat source for electricity generation in the United States after World War II, and 1973 was the year of the oil crisis. In the late 1980s, California's first commercial radio station was formed. Policy support and investment in renewable energy has been mostly focused on the energy sector around the world. As a result, renewables are valued for an increasing share of new electricity generation capacity installed every year around the world [18].

Wind power is the least expensive of the renewable energy options, but it is a great resource; According to some studies, the total potential of wind energy alone can provide 20 times the global electricity demand In Iraq, wind energy is divided into three regions: 48 percent have a low annual wind speed, 35 percent have an annual wind speed of 3.1 to 4.9 m/s, 8 percent have a reasonably high annual wind speed, and the rest has calm values [19], [20]. Electric energy demand is increasing at a rapid rate over the world. Furthermore, the price of oil has risen significantly, as has the pollution created by the use of fossil fuels. Oil sources may run out. As a result, research into other options, such as using renewable energy resources such as solar and wind energy to generate electricity, is receiving increased attention [21], [22]. Jordan is a country in the north of the Arabian Peninsula, with an area of 89,342 square kilometers. Jordan's climate is semi-arid in winter and mild in summer. Among the concerns of the Jordanian energy sector is the rapid growth in energy demand, as well as the country's limited domestic resources to meet this demand [23].

The primary benefit of wind energy, unlike many other sources of energy, is that it does not disrupt natural processes or harm the environment. A wind farm is a group of windmills spread across a large area that generates electricity on a large scale. A wind speed of 15 km / h is required in such areas. As a result, the import of crude oil and natural gas has had a great impact on the country's economy. Iraq's demand for energy is rapidly increasing [24]. For example, energy demand growth was 7.4% from 2008 to 2020, which means that 4,000 megawatts of new generation capacity will be required by 2020, averaging 300 megawatts annually. While primary energy demand is expected to increase by 5.5 percent during the same period, total primary energy demand in 2020 is expected to reach 15 million tons of oil equivalent, up from 7.5 million tons of oil equivalent in 2008 [25]. Because of its great speed, wind, or flowing air, has some kinetic energy. Because land heating causes air movement, the wind is a product of solar energy. Kite flying is arguably the most prevalent application of wind! Even paragliding, sailing, and other water sports are available.

These challenges will put additional strain on Jordan's power system in the future years. To meet the rapidly rising demand for electricity shortly, Jordan's government has initiated several energy-related programs aimed at increasing the contribution of renewable energy resources to the country's overall power supply. Renewable energy resources might contribute 8% and 9% of the total energy mix by 2020 and 2025, respectively, including various wind and solar projects, notably 300-600 MW of solar energy projects [26], [27].

The most serious challenges facing humanity today and in the future are air pollution, global warming and climate change. All of these dangers are related to human activities, the most important of which are electricity generation and the operation of vehicles using fossil fuels (coal, oil and natural gas) [28]. The combustion of fossil fuels produces hazardous pollutants, especially carbon dioxide, nitric oxide and sulfur. These pollutants, along with unburned hydrocarbons, are the main cause of acid rain and chemical clouds, among other things. Excessive burning of fossil fuels is causing higher levels of carbon dioxide in the upper atmosphere, leading to global warming with worldwide repercussions. Climate change, drought and rising ocean water levels are just a few of the dangers this phenomenon has brought to humanity[29], [30]. The growing number of small and large automobiles emitting pollution from their exhausts has exacerbated the problem [31]. especially in countries with fewer electricity processing hours, inhabitants are forced to rely on gasoline or diesel generators to make up for power outages. For the residents of these countries, these generators with insufficient specifications caused an environmental calamity. The worst aspect of the air pollution threat is that the rich northern industrial countries are sending their pollution to the impoverished southern countries, which lack the resources to combat it [32], [33], [34].

II. MATHMETICAL FORMULATION OF WIND POWER

In this section, the whole mathematical formulations are presented to determine the wind power density to measure the capacity of wind resources in specified site. The following formulas can be used to find the wind power density [21]:

$$WPD = \frac{1}{2}\rho V^3 \tag{1}$$

Where WPD is wind power density, ρ is the density in (kg/m^3) and V is the wind speed (m/s). The wind power density based on Weibull distribution can be calculated by [35]:

$$WPD_W = \frac{1}{2}\rho c^3 \tau(1+\frac{3}{k}) \tag{2}$$

Where WPD_W is wind power density based on Weibull, c is scale factor and K is form factor.

The intensity of wind energy (WED) can be measured by multiplying the power by times as the following [36]:

$$WED = WPD^{*}T \tag{3}$$

The Wiebull distribution can be characterized using the probability density function (PDF) and the cumulative distribution function (CDF) as follows [37]:

$$f(U) = \frac{k}{c}(\frac{U}{C})^{K-1} \quad exp(-(\frac{U}{C})^{K}) \tag{4}$$

$$F(U) = \int_0^U f(U)dU \tag{5}$$

$$F(U) = 1 - e^{-(\frac{U}{c})^k} \tag{6}$$

Where,

$$F(U) \geq 0, U \geq 0; \; k > 0, c > 0$$

There are more than seven methods to calculate the Weibull parameters [4] such as the Standard Deviation Method (SDM). The forms of the Standard Deviation Method (SDM) are [36]:

$$k = (\frac{S.D}{Um})^{-1.086} \tag{7}$$

$$Um = cT\left(1 + \frac{1}{k}\right) \tag{8}$$

The ratio of the total power available in the wind to the power corresponding to the mean wind speed is called the Energy pattern factor method (E_{pf}) [38]:

$$E_{pf} = \frac{1/n \sum_{i=1}^{n} U_i^2}{(1/n \sum_{i=1}^{n} U_I)^2} \tag{9}$$

Where,

$$k = 3.957\, E_{pf}^{-0.898} \tag{10}$$

Usually, the data of wind speed are available in most cases on a height of 10m above the ground level. Since the wind speed tends to increase with height in most locations. The height of the hub in the energy generation systems is more than 10m, therefore it's necessary to estimate the wind speed at the range of elevations that corresponding with the wind turbine which possible to install in the selected site. In order to transfer the anemometer height to the standard level or other desired heights, it should be used the power law equation as follows [39], [40]:

$$U_2 = U_1(\frac{z_2}{z_1})^{\propto} \tag{11}$$

The scale factor c and form factor k of the Weibull distribution will change as a function of height as the following expressions [41]:

$$c(h) = c_{\circ}(\frac{h}{h_{\circ}})^{\alpha} \tag{12}$$

$$k(h) = k(h_{\circ})\left[\frac{1-0.0881\, ln(\frac{h_{\circ}}{10})}{1-0.0881\, ln(\frac{h}{10})}\right] \tag{13}$$

$$n = \frac{[0.37-0.088\ln(c(h_{\circ}))]}{\left[1-0.0881\, ln(\frac{h}{10})\right]} \tag{14}$$

Where n total number of data

III. Performance Characterization of Wind Power

In Iraq, the amount of electricity generated is insufficient to meet the needs of the domestic and industrial sectors, also and the climatic change that causes global warming, therefore renewable energy demands rapid attention. A hybrid system as a renewable power generating resource for grid-connected applications in three Iraqi cities have been presented with meteorological data for the selected sites and the sizes of PV and wind turbines as input parameters for the solver [42], [43], [44]. Among the various deserts in the region, the western Iraq desert has the highest solar electricity generation power, with a global average of 170 W⁄m^2 . The Iraqi deserts generate a mean power density of 270-290 W⁄m^2 , with a peak power density of 2310k wh⁄m^2 year [45].

This has given Iraq a leg up in terms of remaining an energy supplier in the future as well as a current fossil fuel supply. The use of electrical heaters in homes and their replacement with solar water heaters is a critical step that must be addressed, as well as used in other applications [46], [47]. Due to electricity shortages and other issues in Iraq, researchers have looked into using solar and wind energy to generate enough power for some desert or rural villages. On the other hand, AL-Riahi and AL-Kayssi [48], [49] attempted to analyze and examine various areas of radiation climatology that are significant in solar energy utilization.

The criteria of using wind power is the best solution in terms of investment in such a power system in order to save money instead of investing large amounts of money in both oil and gas power generation, where solar power and its storage facilities are a solution to reduce CO2, maintain a clean power for the future, and save money. This analysis discovered that solar, wind, and biomass energy are now underutilized, but that they might play a key role in Iraq's sustainable energy future. Furthermore, the offshore wind energy potential in the Gulf (near Basrah in southern Iraq) should be examined. They've talked about, debated, and assessed the Iraqi government's efforts to use renewable energy [50].

Wind energy is a clean renewable, locally produced energy source, and wind farm building has increased dramatically in several nations in recent years. The kinetic energy created by air in motion has been used for electricity generation using wind. Wind turbines and wind energy conversion devices have been used to convert this into electrical energy. The turbine blades are the first to be hit by the wind, causing them to rotate and turn the turbine to which they are linked. The kinetic energy has transformed to rotational energy by rotating a shaft coupled to a generator and producing electrical energy through electromagnetism [51].

Wind energy resources in Iraq are plentiful enough to offer a large quantity of electricity capacity to meet the country's needs if properly invested. Because of its low MWh cost, wind power capacity has grown by more than 20% every year over the past five years. Wind energy could be combined with adequate reactive power compensations to improve energy distribution network operational voltage stability during fast load changes. The following are some of the most frequently reported benefits [52]:

It does not contaminate, it is inexhaustible and reduces the use of fossil fuels, which are the origin of greenhouse gasses that cause global warming. Furthermore, wind energy is "native" energy because it is found almost everywhere on the planet, helping to reduce energy imports while also providing wealth and local employment. As a result, generating power from wind energy and putting it to good use contributes to long-term sustainability.

Wind power calculations are based on the equation of kinetic energy (KE); kinetic energy exists anytime an item of a given mass is moving at a translational or rotational speed. When a parcel of air is in motion, its kinetic energy can be calculated as [53]:

$$KE = \frac{1}{2} m v^2 = \frac{1}{2} (\rho A x) v^2 \quad (15)$$

Where KE in Joules, m is the air mass in kg, v is the wind velocity in m/s, ρ is the air density (1.225 kg/m^3 dry air at 1 atm. and15°C), x is the thickness of the parcel in m and A is the swept (rotor) area of blades in m^2, as shown in Fig. 1. Wind power can be calculated by varying the kinetic energy in the wind with relation to time [53]:

$$P_w = \frac{dKE}{dt} = \frac{1}{2} \rho A v^2 \frac{dx}{dt} = \frac{1}{2} \rho A v^3 \quad (16)$$

This calculates the amount of power in the region swept by the wind turbine rotor, P_w measured in watt. The following conclusions can be made from Eq. 16. [20]:

- More wind power necessitates more wind speed.
- Increasing the length of the blades will boost the power gain. Finally, increased air density results in increased wind power.

The quantity of wind power available per unit of area perpendicular to the wind flow is known as wind power density. In reality, once the area swept by wind turbine rotors and the power system efficiency are determined, wind power density is used to estimate the potential electrical output of a wind farm. The wind power density (WPD) is calculated by dividing the wind power Eq. 16. by the area, or [53]:

$$WPD = \frac{1}{2} \rho v^3 \quad (17)$$

The best wind capacity is density of wind capacity (Wind Power Density), because it shows how to distribute wind speed on average (mean) and this quantity can be estimated in practice using Weibull Distribution, which is dependent on two parameters (c) scale and (k) shape parameters, where Gamma function [54]:

$$WPD = \frac{1}{2} \rho c^3 \Gamma(\frac{1+3}{k}) \quad (18)$$

The yearly average wind speed of the country is an important component in calculating energy yield and evaluating wind energy systems. Based on the annual average wind speed at 50 meters above the ground, the power curve, which displays the output of electric power as a function of hub height and wind speed, can be used to explain the wind turbine's performance. Without knowing the characteristics of the turbine and its components, the power output and energy production of a wind turbine can be estimated using this graph [35]. Two types of wind turbines (ATB Riva calzoni 500kw and Enercon3 500kw) were chosen for this investigation because they fit the average wind speed of the selected sites. The annual energy production (AEP) was determined in hours by multiplying the value (8760) by the probability density function and the power curve of the selected wind turbines [36].

Because wind output power is proportional to the cubic power of the mean wind speed, a small change in wind speed can result in a large change in wind power. However, the power of the wind is not completely converted into mechanical form, as this would decelerate the air mass flow to zero and block the rotor area for following air masses. As a result, several additional terms must be included to obtain a practical equation for wind turbine power (wind turbine mechanical power), as shown in [38]:

$$P_T = \frac{1}{2} \rho A c_p v^3 \quad (19)$$

Where c_p stands for power coefficients of wind turbine.

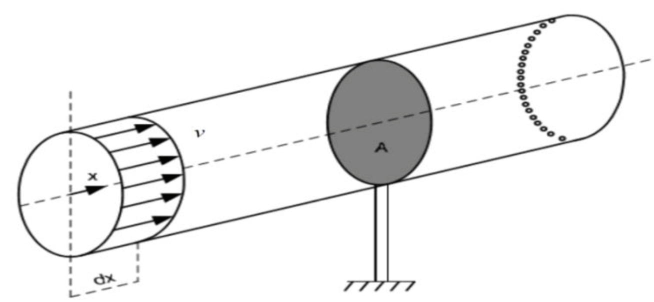

Fig. 1. Wind mass flow over the cross sectional area A of a wind turbine [54]

The power and energy production of any wind turbine increases considerably as the wind speed increases. As a result, the most cost-effective wind turbines are positioned in the windiest areas. Wind speed is influenced by local terrain and raises with height above ground hence wind turbines are typically housed in tall towers. The output power increases constantly as the wind speed increases until it hits a saturation point, at which point the output power reaches its maximum value, which is designated as the rated output power [55].

The capacity factor (C_F) is the ratio of annual energy produced to wind turbine energy produced at rated power during a given time period (T). The capacity factor (%) is calculated as [56]:

$$C_F = \frac{AEP}{Rated\ output * T} \quad (20)$$

The capacity factor does not indicate efficiency. The power coefficient (c_p) is a measure of turbine efficiency; it represents the aerodynamic efficiency of wind turbines in converting wind energy into electricity, and it varies with wind speed. Power coefficient (c_p) is defined as the ratio of power extracted by the turbine (P_T) to the total contained in the wind resource (P_w) as shown [56]:

$$c_p = \frac{P_T}{P_w} \quad (21)$$

c_p= 0.59 (Betz limit for the maximum value), huge current megawatt turbines have peak of between 40% and 50%, whilst smaller turbines producing a few kilowatts have a peak of between 20% and 30%. The average output power of a turbine is a critical parameter of a wind energy system since it impacts overall power generation and the total income. The average output power of a wind turbine is the power produced at each wind speed multiplied by the fraction of time that wind speed is present, integrated by all conceivable wind speeds, so that [56]:

$$P_{e,ave} = \int_0^\infty P(v)\, f(v) dv \tag{22}$$

Where $P(v)$ the power curve value at wind speed is v, $f(v)$ is the Weibull pdf of wind speeds. After substitution and mathematical calculation we find that [37]:

$$P_{e,ave} = C_F . P_r \tag{23}$$

This means $P_{e,ave}$ that determines the performance of a wind turbine installed at a given site using the amount of capacity factor and P_r.

The cost per kWh of wind turbine that generated electricity is the essential financial calculation to invest in the wind energy. In the present work, the simple form of the cost estimation will present to find the total cost of the electrical powers per unit time. The details that needed to find the cost of the electrical power are: the installation, running cost of the turbine and the lifetime of the wind turbine. It can be used the following formula to obtain the total cost [57]:

$$Cost/kwh = \frac{Turbine\&other\ cost + (Annual\ recurent\ costs + lifetime\ )}{AEP * lifetime} \tag{24}$$

The size of the turbine and the length of its blades determine the quantity of power that can be harvested from wind. The output is proportional to the rotor's size and the wind speed's cube. Wind power potential increases by a factor of eight when wind speed doubles, according to theory. The capacity of wind turbines has grown over time [54]. In 1985, average turbines had a rotor diameter of 15 meters and a rated capacity of 0.05 megawatts (MW). Onshore turbine sizes of roughly 2 MW and offshore turbine capacities of 3–5 MW are available in today's new wind power projects. Commercial wind turbines with capacities of up to 8 MW and rotor diameters of up to 164 meters are currently available. The capacity of wind turbines increased from 1.6 MW in 2009 to 2 MW in 2014.The technical viability of installing this sort of technology is mostly determined by studies and research into the behavior of a power system when connected to wind turbines and subjected to transitory disturbances that may cause loss of generating stability [58].

Twenty-three stations were chosen for analysis. The daily model for wind velocity has maximum values in the middle of the day and the early morning hours. These maximum values varied between $5\ to 10\ m/s$. The wind velocity in summer is higher than in winter, which is fortunate because the demands on electrical energy increase in summer compared with winter because of increased cooling and ventilation loads [59].

Iraq is separated into three provinces. The first territory covers 48 percent of Iraq and has wind speeds ranging from 2 to 3 m/s. The second territory covers 35 percent of Iraq and has wind speeds ranging from 3.1 to 4.9 m/s. The third territory accounts for 8% of Iraq's land area and has wind speeds of more than 5 m/s. According to these studies, the approximate energy densities for wind areas are: Al-Emarra has 174 W/m2, Al-Nekhaib has 194 W/m2, AlKout has 337 W/m2, Ana has 353 W/m2, and Al-Naseria has 378 W/m2. Based on these findings, an average energy of 287.2 W/m2 can be calculated [60].

IV. Conclusion

This study sheds light on the issue of wind energy in Iraq and provides a look at the future of this type of energy in Iraq, which has suffered from geopolitical problems that have affected the country in recent decades and their impact on the country's infrastructure in the field of electricity generation, as wind energy in Iraq has very good future prospects. It is suitable for the production of electric energy with an analysis of. the cost of the wind machine in terms of kilowatt-hours and an economic feasibility study for it because it is a clean source of energy and the conversion process does not affect the environment in addition to solar energy. For small projects to produce, use and apply these types of renewable energy in government buildings, support postgraduate students from Masters and Ph.D. and encourage them to research in this field, and create a culture and community awareness of the benefits of using renewable energy and its contributions to reducing environmental pollution and its danger to public health and the future of future generations, focusing on areas with kilowatt production rates/ An hour as high as northern and southern Iraq to apply these studies in remote villages to save on the cost of a line The use of electricity and reliance on it in some simple uses as street lighting and irrigation systems, where the feasibility study of installing a wind energy system in the candidate areas as the best areas for generation and its difference with the seasons of the year to establish the so-called wind farms.

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