Risk Identification of Wind Energy Development in Iraq

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***Abstract*— The relevance of this paper is related to the energy crisis in Iraq and the need for a partial transition to affordable and environmentally friendly sources of electricity supply. One of such sources is wind energy. The purpose of the work is to determine the wind energy potential of Iraq and the identification and risk assessment of projects for the construction of wind energy facilities. For this purpose, the relief of the ground surface was analyzed, average wind speeds and average wind power density at heights of 10 m, 50 m and 100 m were determined for Iraq as a whole and separately for its regions using Global Wind Atlas. Based on the obtained indicators and the minimum wind speed required for launching powerful wind turbines, two areas - Basra and Al-Amara - were selected for further study. For them, the average monthly speeds per year were determined and wind roses were plotted using the RETScreen program (NASA). To determine the wind power plant output in Basra and El-Amara districts, several plants with rated power of 1000 kW with tower height of 70 m were selected: Bonus -1MW/54 (rotor diameter d=54.2 m), A-1000/S (d=54.2 m), Nordex N54-70 m (d=54 m), Gev HP 62/70-70 m (d=62 m). The results of wind power capacity calculation at different speeds are presented graphically. Considering the results of the study on the potential for realization of different level of wind turbine power generation projects, a SWOT-analysis was conducted. Identification and risk assessment was carried out with determination of the degree of damage and probability.**

Keywords— wind potential, wind power, wind speed, average wind power density, wind turbine capacity, average energy density, SWOT-analysis

I. INTRODUCTION

Wind power is becoming increasingly relevant in today's world because of several key reasons. First, wind farms are an environmentally friendly source of energy that does not emit harmful substances into the atmosphere and does not contribute to the greenhouse effect. This is especially important in the face of the growing global problem of climate change.

In addition, wind energy contributes to the diversification of a country's energy portfolio, which increases its energy security and independence. Wind turbines can be located both onshore and offshore, which increases flexibility in the location and development of this type of energy [1]-[4].

Additionally, with the development of technologies in the field of wind energy, the efficiency of installations improves, production and operation costs are reduced, making such projects increasingly competitive with conventional energy sources. Thus, wind energy remains an important sector for sustainable development and the transition to a low-carbon economy.

Recently, Iraq has faced serious electricity supply problems and power outages over a long period of time. This is due to various factors including infrastructure complexity, poor management of the country's power sector, etc. Periodic power outages have a negative impact on people's lives, businesses and the economic development of the country. The energy crisis is aggravated by the fact that electricity consumption in Iraq is growing annually by 6...7% on average. This is due to population growth and rising temperature extremes above 50 °C on hot summer days. Insufficient electricity makes daily life difficult for citizens, leads to instability and creates social and economic problems. The Iraqi authorities are taking steps to improve the electricity situation, including modernizing existing infrastructure, expanding production capacity and introducing new technologies. However, solving electricity problems requires time, effort and financial investment [5]-[8].

Iraq has a significant potential for wind energy development due to its climate and geographical features. The country has long plains and coastline that provide excellent conditions for the construction of wind farms.

In addition, wind energy development in Iraq can help create new jobs, stimulate investment and promote local production of components for wind farms. It also contributes to improve the energy security of the country and promotes sustainable development in general [9]-[11].

The aim of the paper is to determine the wind energy potential of Iraq and to identify and assess the risks of wind energy projects.

Planning and development of a wind farm is a long and complex process that can take up to several years depending on the requirements of a particular country. Usually, when designing a wind farm, a large number of studies are required to estimate wind parameters, predict power generation, and the environmental impact of the future wind farm. In wind resource assessment (WRA), which aims to estimate the future energy yield used to determine the bankability of a wind project. A modern wind resource assessment first involves measurements at turbine hub height using a wind measurement system (mast, lidar) over a period of one or two years. Then sophisticated data processing is carried out to derive a long-term wind resource.

The installation of a wind measuring complex already implies financial investments in research. Especially in the context of the energy crisis and in the constrained financial conditions of Iraq, this becomes a problem.

Consequently, before the financial investment phase, it can be very useful to get a first idea of the future energy output at the beginning of the process to consider the risks and to make sure that the project has a reasonable chance of becoming bankable [12].

Wind atlases can be used for this purpose. A wind atlas is a dataset that provides an estimate of the wind resource at a particular location in the form of statistics or time series at different altitudes. In recent years, the use of wind atlases has accelerated with the creation of open access datasets such as the Global Wind Atlas (GWA) [13].

The estimation of wind resource generation for a particular area by Global Wind Atlas is suitable for preliminary studies because they take into account default values for many factors that are important for wind farm site design.

II. Materials and Methods of Research

The work uses general scientific methods of comparative analysis, collection and study of information sources, statistical analysis of data, and synthesis.

The source materials for the analysis are data obtained from the Global Wind Atlas [13], as well as the RETScreen program (NASA) based on ground station and satellite data. In this work, wind speeds at 10 m, 50 m and 100 m heights are determined, as well as average wind power density at these heights for Iraq as a whole and its districts separately. Wind roses for the selected locations were plotted to determine the prevailing wind directions. The average monthly velocities during the year were determined. The dependence of the capacity of some wind power plants on wind speed was calculated and plotted.

Risk identification of wind power construction projects was carried out based on the results of SWOT analysis. SWOT-analysis is effective in the initial assessment of the current situation. The list of the most significant risk factors was determined using the Delphi method. The essence of this method is to maximize consensus in determining the right decision through a series of sequential actions - surveys, interviews, brainstorming sessions.

III. Research Results

First of all, the topography was studied to determine the wind energy potential of Iraq. Terrain, specifically the roughness of the underlying surface, affects wind direction and speed. For example, mountains can cause changes in wind flow, causing turbulence or creating sheltered areas where there may be little or no wind. Hills and valleys can also affect winds by creating areas of increased or decreased wind flow. Wind parameters such as speed, direction and turbulence can be altered by topography [14], [15].

It is known that wind speed changes with increasing altitude. At the ground surface, friction acts as a drag and near the surface, wind speed is almost zero. In the lowest atmospheric layer, around 50-100 m, the effect of surface friction is most noticeable and is important for wind energy production. Prandtl showed that the variation of wind speed directly above the ground follows the logarithmic law of wind speed from a given direction. Modern powerful wind turbines are installed at heights of more than 100-150 m above ground level. At the roughness level, the mean wind speed goes to zero; below this level, only turbulent pulsations occur. Knowledge of the vertical profile of wind speed characteristics is extremely important for wind farm project developers not only to determine the energy capture they can expect at that altitude, but also for design purposes and to understand the dynamics, structural loads on the wind turbine design [16-20].

Iraq is characterized by a desert landscape. Most of Iraq is located within the Mesopotamian lowland, the northern part of which is a plain with a height of 200-500 m with some massifs up to 1460 m, and the southern part is a waterlogged alluvial lowland. In the north of Iraq stretches low ridges that reduce wind characteristics, and in the southeast there is an exit to the Persian Gulf with a coastline of 58 km, which indicates the high potential of the area. The roughness of Iraq's land surface is shown in Fig. 1.

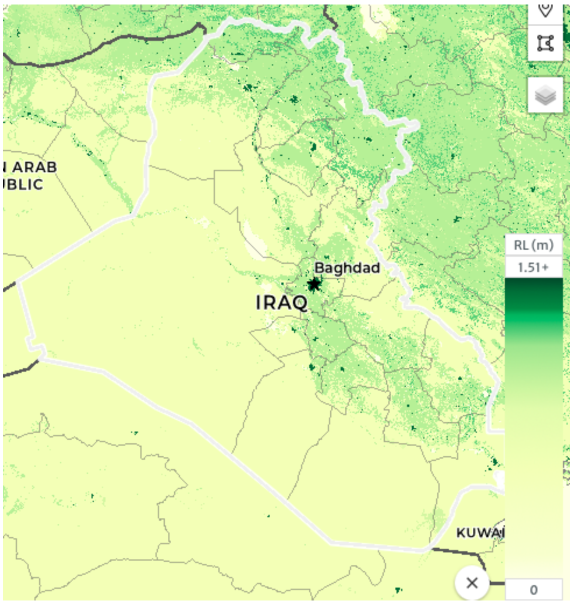
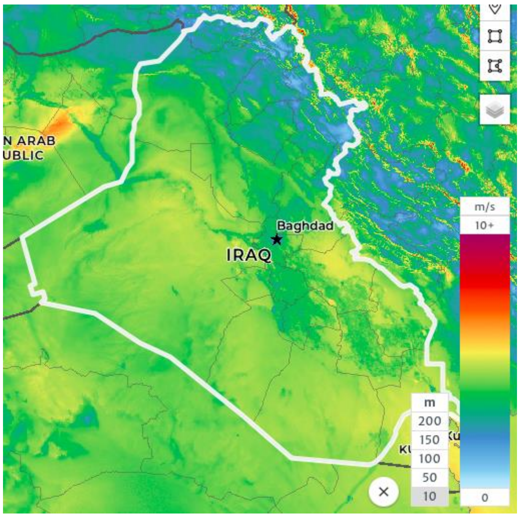


Fig. 1. Surface roughness of the Iraqi surface [16]

In terms of topography, most of Iraq has excellent prospects for wind energy.

In the next step, it was of interest to investigate the wind speed at different altitudes in the country, including neighborhoods. The altitudes of 10 m and 50 m are of interest for commercial and residential wind turbines. Obtaining wind characteristics at heights from 100 m above the ground is necessary for the construction of wind farms.

A map of wind speeds in Iraq at 10 m, 50 m and 100 m altitudes is shown in Fig. 2.



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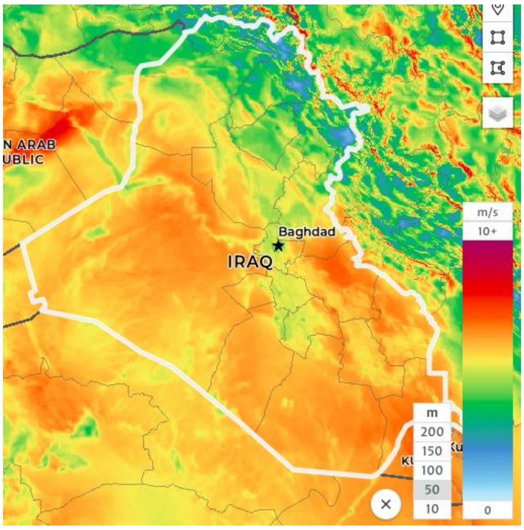

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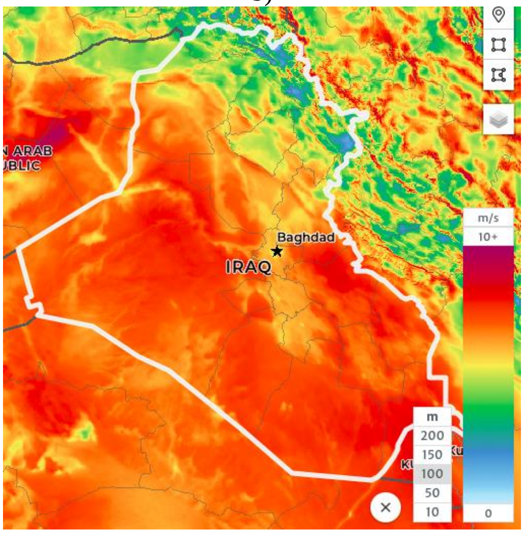


c)

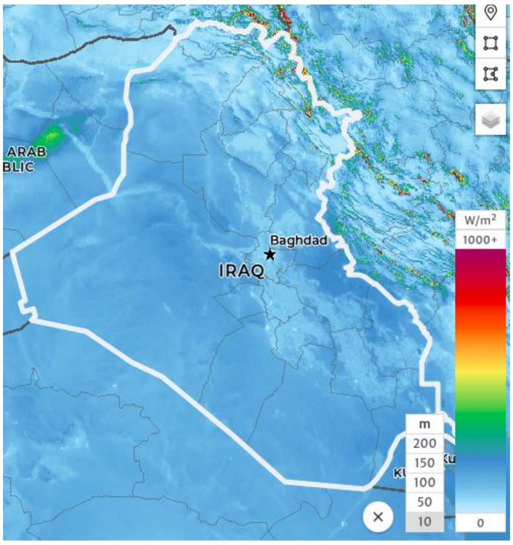
Fig. 2. Map of wind speed in Iraq: a - at a height of 10 m from the ground surface; b - at a height of 50 m, c - at a height of 100 m [16].

The next parameter of interest is average wind power density, which is a quantitative measure of wind energy, the average annual power available per square meter of turbine operating area for a particular height above the ground. The calculation of average wind power density includes the effect of wind speed and air density:

$$P_{un} = 0.5\rho v^3, \qquad (1)$$

where, ρ – air density, *v* – wind speed.

The map of Iraq in terms of average wind power density at 10 m, 50 m and 100 m heights is shown in Fig. 3.



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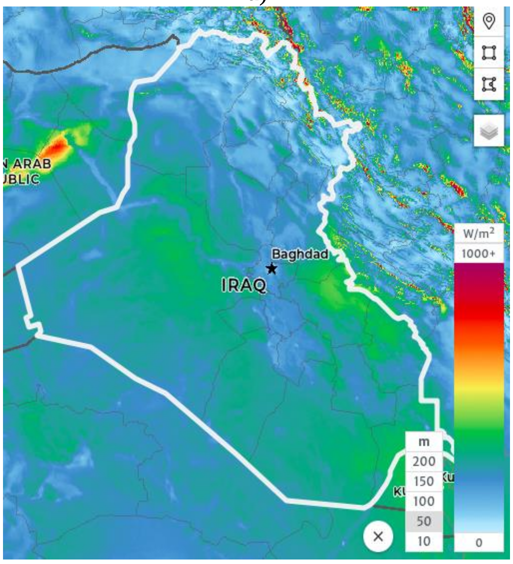

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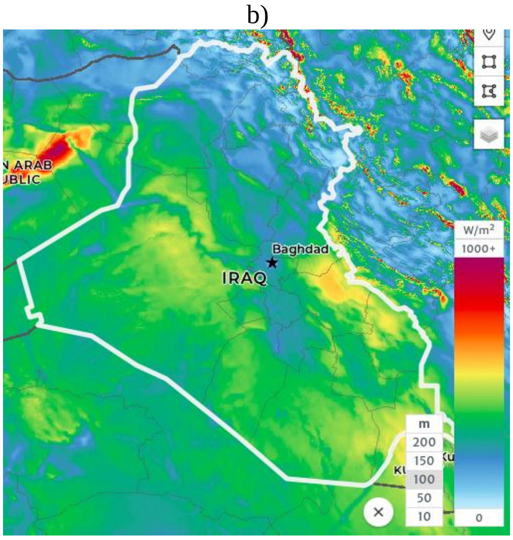

c)

Fig. 3. Map of average wind power density for Iraq: a - at a height of 10 m from the ground surface; b - at a height of 50 m, c - at a height of 100 m [16]

Average wind power density varies at a height of 10 m - from 70 to 170 kW/m^2, at a height of 50 m - from 150 to 320 kW/m^2, at a height of 100 m - from 240 to 450 kW/m^2. The obtained data allow us to make a preliminary conclusion that most of the country, especially the southern part has sufficient wind potential for the construction of wind farms.

The values of the parameters of average wind speed (v, m/s) and average wind energy density (N, W/m²) for all regions of Iraq are given in Table 1.

TABLE I. AVERAGE SPEED AND AVERAGE WIND POWER DENSITY

Measuring height	**10 m**		**50 m**		**100 m**	
Governorates	v, m/s	N, W/m²	v, m/s	N, W/m²	v, m/s	N, W/m²
Baghdad	3,81	95	5,26	192	6,23	259
Salah al-Din	4,65	163	6,12	285	7,34	409
Diyala	4,93	191	6,65	363	7,91	513
Wasit	5,14	215	6,91	403	8,22	569
Maysan	4,89	192	6,6	364	7,88	518
Basra	5	176	6,8	344	8,15	509
Dhi Qar	4,72	153	6,4	297	7,64	429
Muthanna	4,85	166	6,59	320	7,9	465
Qadisiyah	4,63	149	6,3	292	7,49	414
Babil	4,29	132	5,84	253	6,95	352
Kerbela	4,62	154	6,29	290	7,54	418
Najaf	4,63	152	6,31	287	7,57	412
Anbar	4,79	169	6,5	322	7,79	468
Ninewa	4,42	157	6	274	7,19	383
Dahuk	3,64	239	4,75	252	5,49	270
Erbil	4,96	469	6,28	513	7,15	551
Kirkuk	4,03	147	5,44	266	6,44	347
Sulaymaniyah	4,67	476	5,91	511	6,75	552

The best values of wind characteristics are observed in the following areas: Diyala, Wasit, Maysan, Basra.

In Erbil and Sulaymaniyah districts, only the northeast and the southern part have good wind characteristics. In these areas, installation of industrial wind turbines can be assumed at some sites, residential and commercial turbines (at 10 m and 50 m heights) are possible at limited locations.

There are currently a large number of wind turbine manufacturers in the renewable energy market. Modern technologies have significantly improved their performance characteristics, including the minimum starting wind speed required to start and start the wind turbine [22]. For different types of wind turbines, the starting speeds may differ depending on their design and purpose. For domestic wind turbines, the starting speed is usually between 2 and 3 m/s. This means that the turbine will start generating electricity in wind speeds of 2 m/s or higher. Higher wind speeds promote more efficient operation of wind turbines. For commercial wind installations, the starting speed can be higher, around 3 to 4 m/s. These installations are usually larger and more powerful, requiring higher wind speeds to start and generate electricity. Industrial wind turbines have even higher starting speeds, which can start at 4 m/s or higher. These turbines are installed in large wind farms and are high capacity, so they require higher winds to operate efficiently.

In areas of Iraq with lower average wind speeds, it is advisable to install small capacity wind turbines (600-1500-2000 W). The advantage of such installations, as a rule, is low starting wind speed (2 m/s).

The main problem with wind farms is that their efficiency is low at low wind speeds. The starting speed of most modern wind power plants is within 3 - 4 m/s. But it is necessary to keep the wind flow at this level for at least 10 minutes, only then the automation will give permission to start the wind turbine. In this case, more or less tangible, energy production will begin only at 7 meters per second, and the plant operating at an average speed of 6 m / s, generates a capacity of 44% higher than at a speed of 5 m / s. Thus, when the wind speed increases by only 1 m/s, the magnitude of wind flow capacity increases significantly [22], [23].

It is important to remember that the optimal wind speeds for wind turbine operation may vary depending on the specific plant configuration, manufacturer and location. It should also be kept in mind that in addition to the starting speed, optimal wind speeds and protective systems against excessive speeds and wind gusts are necessary for efficient operation of wind turbines.

In the southern part of Diyala district, the minimum wind speed is about 3 m/s during the day at an altitude of 100 m. In Wasit district at the same altitude, the average minimum wind speed during the day is 6.14 m/s; in Maysan district 6.22 m/s, and in Basra district 6.20 m/s.

To further assess the wind energy potential, wind data for Basrah (Basrah city) and Maysan (Al-Amara city) districts were analyzed. Using the RETScreen program (NASA), the average wind speed data were obtained by month throughout the year. The results are shown in Fig. 4.

This histogram shows that both Basra and El Amar have insignificant differences in average wind speeds. Throughout the year, the best wind speeds are in the summer months. This is a good performance for the wind power industry in Iraq, since it is during the summer months that a large amount of electricity consumption is for refrigeration and air conditioning equipment, namely air conditioners.

To identify the prevailing wind direction when selecting a site for a wind farm, a wind rose should also be plotted for the location (Fig. 5 and Fig. 6).

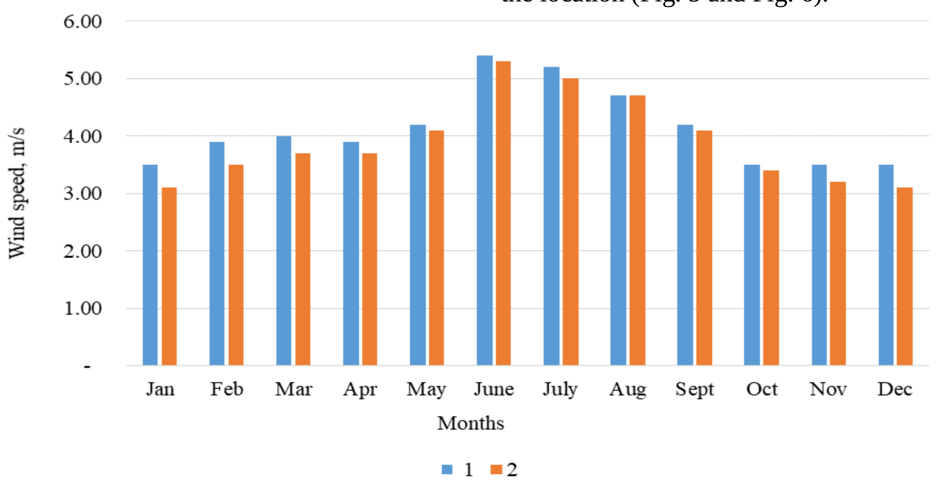

Fig. 4. Average wind speed by month: 1 - in Basra (Basra), 2 - in El-Amara (Maysan) [17]

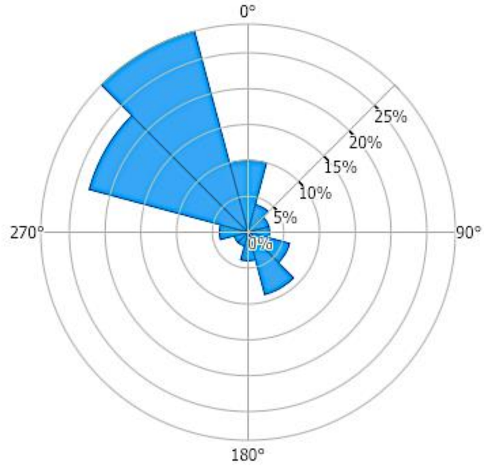

Fig. 5. Wind pattern in Basra [16]

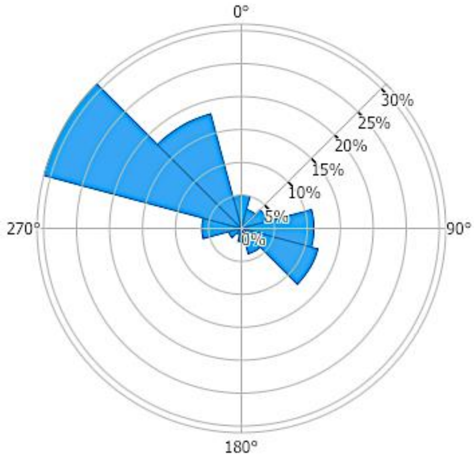

Fig. 6. Wind pattern in El Amara [16]

The prevailing direction in both cases in the north-western sector.

To determine the wind power plant output in these locations, several installations with a rated power of 1000 kW with a tower height of 70 m were selected: Bonus - 1MW/54 (rotor diameter d=54.2 m), A-1000/S (d=54.2 m), Nordex N54-70 m (d=54 m), Gev HP 62/70-70 m (d=62 m).

The capacity of a wind power plant (WPP) can be found by the formula:

$$P_{wt} = 0{,}5 \cdot \rho \cdot A_0 \cdot C_p \cdot \vartheta_d^3, \quad (2)$$

ρ – Air density, A_0 – wind wheel area, C_p – wind energy utilization factor (0,32), ϑ_d^3, – design wind speed.

The results of wind turbine capacity calculation at different wind speeds are presented graphically in Fig. 7.

Taking into account the results of the study, the Delphi method was used to identify and assess the risks of wind power construction projects [24].

SWOT-analysis is shown in Fig. 8. Risk factors, degree of damage and probability obtained as a result of expert assessment are summarized in Table 2.

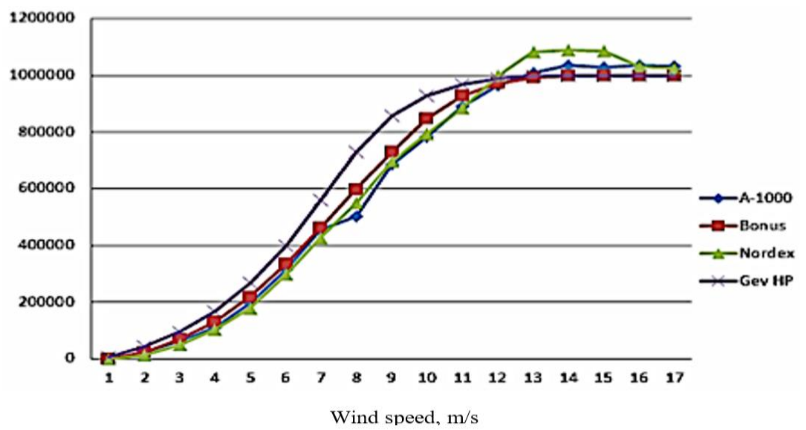

Fig. 7. Dependence of wind power plant capacity on wind speed

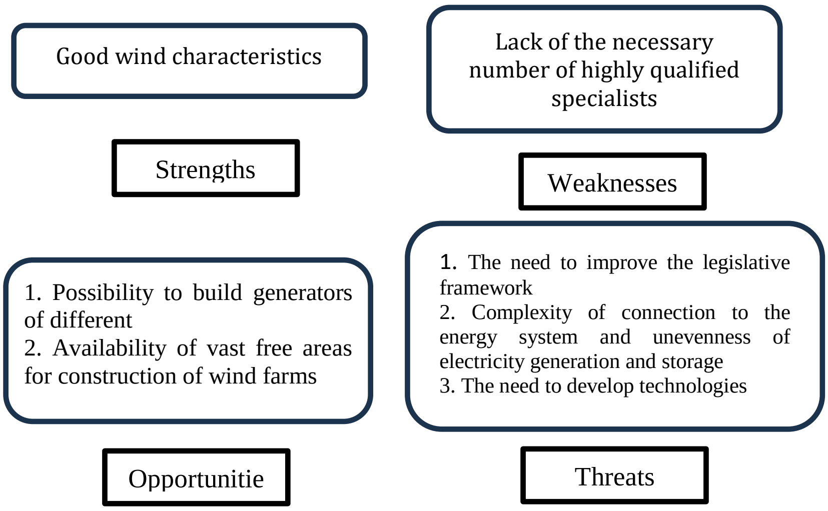

Fig. 8. SWOT analysis

TABLE II. RISK FACTORS

Risk factors	Probability/damage
The need to improve the legislative framework	60 %, middle
Complexity of connection to the energy system and unevenness of electricity generation and storage	60 %, middle
The need to develop technologies	85 %, middle
Lack of the necessary number of highly qualified specialists	65 %, high

Risk management opportunities derived from the SWOT-analysis include:

Training of specialists abroad, the need for and opportunities to develop autonomous stations, and long warranties from manufacturers of equipment components. Investors and legislative documents are somewhat more complicated. Here a clear concrete strategy for wind energy development at the state level is needed.

IV. CONCLUSION

The Global Wind Atlas and RETScreen (NASA) surveys of Iraq's topography, wind characteristics at 10 m, 50 m and 100 m altitudes showed generally good potential for wind energy development in the country, and identified areas with excellent opportunities for wind farms. For some wind farms, the dependence of power output on wind speed was calculated in order to predict the possible power generation in the selected areas.

A SWOT-analysis was used to assess the risks in planning the construction of wind power generation considering various factors, which showed the degree of damage and the probability of these risks. Based on this assessment, risk management opportunities are given.

The findings show sufficient potential for the implementation of different levels of wind turbine power generation projects for wind power generation in some areas, especially in the southern part of the country.

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