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CASE STUDY: COST ANALYSIS AND EMISSION AND ANALYSIS OF A 100MW GRID-CONNECTED WIND ENERGY SYSTEM USING RETScreen EXPERT SIMULATION SOFTWARE

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Abstract:

This research demonstrates the feasibility of using wind energy as a clean source for electricity generation. The study was conducted at a wind farm in the eastern city of Misrata, using the RETScreen program for performance and cost evaluation. Wind is considered a renewable and non-polluting source, and the research aims to compare the efficiency of the wind farm with gas-fired power plants.

The RETScreen program was used to determine the suitable location for establishing a wind farm based on the appropriate wind speed and selecting the appropriate turbine from the program's library. Multiple results were obtained, including speed, power, and energy curves. The research also investigated the connection of the wind farm to the public electricity grid and analyzed the costs and carbon emissions associated with the farm.

الملخص:

توضح هذه الدراسة جدوى استخدام طاقة الرياح كمصدر نظيف لتوليد الكهرباء. أجريت الدراسة في مزرعة رياح في مدينة مصراتة شرق البلاد، باستخدام برنامج RETScreen لتقييم الأداء والتكلفة. تعتبرالرياح مصدراً متجدداً وغير ملوث. وتهدف الدراسة إلى مقارنة كفاءة مزرعة الرياح مع محطات توليد الطاقة التي تعمل بالغاز.

تم استخدام برنامج RETScreen لتحديد الموقع المناسب لإنشاء مزرعة الرياح بناء على سرعة الرياح المناسبة واختيار التربين المناسب من مكتبة البرنامج. تم الحصول على نتائج متعددة. بما في ذلك منحنيات السرعة والقوة والطاقة. كما بحثت في ربط مزرعة الرياح بالشبكة العامة للكهرباء وتحليل التكاليف والانبعاثات الكربونية المرتبطة بالمزرعة.

Kewords – Retscreen, Wind Power, Grid on

1. Introduction:

The increasing global energy demand, driven by rapid population and economic growth, has led to a significant reliance on fossil fuels for energy production. However, the use of these fossil fuels, including coal, natural gas, and diesel, poses a grave threat to the environment and human health. This urgent concern calls for alternative energy sources that can mitigate pollution and reduce the exploitation of our surroundings. As a result, there is a growing interest in harnessing the potential of various renewable energy sources available in nature to meet our ever-increasing energy demands.

This paper presents a comprehensive analysis of the cost and emission aspects of a grid-connected wind energy system. The study utilizes the RETScreen EXPERT simulation software to evaluate the financial feasibility and environmental impact of the wind energy system. With the increasing demand for clean and sustainable energy sources, wind power has emerged as a promising solution for meeting electricity needs while minimizing carbon emissions. Grid-connected wind energy systems have gained significant attention due to their potential to provide renewable energy on a large scale. However, it is crucial to assess the economic viability and environmental impact of such systems to ensure their successful implementation.

In this case study, we focus on analyzing the cost factors associated with setting up and operating a grid-connected wind energy system. This includes the initial capital investment, operation and maintenance expenses, and the overall cost of electricity generation. By employing the RETScreen EXPERT simulation software, we can accurately estimate the financial parameters and conduct a thorough cost analysis of the wind energy system.

Furthermore, the paper also addresses the environmental impact of the grid-connected wind energy system. By evaluating the emission levels associated with electricity generation from wind power, we can assess its contribution to reducing greenhouse gas emissions and mitigating climate change. This analysis provides valuable insights into the environmental benefits of wind energy systems and their role in achieving sustainable development goals.

The findings of this study contribute to the existing knowledge on the economic viability and environmental performance of grid-connected wind energy systems. The cost analysis outcomes can assist policymakers, investors, and energy planners in making informed decisions regarding the implementation of wind power projects. Additionally, the emission analysis results highlight the potential of wind energy as a clean and sustainable source of electricity.

Samuel Sarpong Asamoah et [1]. presents the technical, financial, and environmental impact assessment of a 50-MW utility-scale wind farm in

Ghana at four locations (Anloga, Atiteti, Sege, and Denu). The monthly average wind speeds were 6.01 m/s, 5.98 m/s, 5.46 m/s, and 5.17 m/s, respectively, at 60 m above ground level. The capacity factors were 24.9%, 24.4%, 20.6%, and 18.0% at the respective locations. The Net Present Value (NPV) was the main financial metric used to determine project viability. The results showed that the wind project is viable in all locations. The Electricity Exported to the Grid and the Electricity Export Rate (EER) had the highest impact on the NPV, with values of 0.63 and 0.62, respectively.

El Khchine et al. [2] evaluated the wind potential and trends in select regions of Morocco using various approaches. They estimated Weibull parameters based on mean hourly wind speed data, incorporating methods like standard deviation, wind variability, power density, Moroccan, and WAsP methods. The annual shape parameter varied from 1.65 to 4.85, while the annual scale parameter ranged from 4.05 m/s to 10.03 m/s. These findings indicate that the studied locations are suitable for utility-scale power generation.

El Sattar et al. [3] economically evaluated wind energy in Egypt considering the Levelized Cost of Energy in some regions in Egypt. They established that a potential wind farm implementation in two regions were economically feasible. The LCOE ranged from 0.052 to 0.326 $/kWh for three regions that were under study with an average capacity factor range of 23.5–58%.

Rafique et al. [4] conducted a feasibility of a 100 MW wind farm at different locations in Saudi Arabia. They concluded that the proposed wind power farm was viable both technically and economically with all sites estimated to be profitable.

Pradhan et al. [5] discussed the feasibility of on the basis of technical complexity and economic feasibility along with controllability of unwanted flue gas emission, which is analyzed using **RETSCREEN** simulation software

This study showed excellent results in terms of carbon emissions, which were reduced by 68,118 tons of carbon dioxide.

Himiri et al. [6] estimated the wind power potential at three (3) locations in Algeria. The estimated capacity factors of the wind farm were in the range of 21%–38% with positive NPVs at all.

2. Location and Wind Resource:

For the study site, which was selected north-east of the city of Misurata "Al Arar" at longitude 15.1 and latitude 32.4, wind speed data was taken from the official website of the Atlas of Wind, where the wind speed ranged from 7.0 - 7.86 m/s measuring at 100m, and the site is suitable for the establishing a wind farm, as the study site is characterized by being in the open and not surrounded by high obstacles. The site is also characterized by its proximity to electrical grid lines.

Tabels (1) (2) show the location data obtained from the RetScreen simulation program, including the location’s elevation above sea level, longitude and latitude, temperatures and relative humidity, in addition to wind speed and other additional data, which are displayed on a monthly average All year round.

Power capacity per turbine (kW)	2,000
Manufacturer	AAER
Model	A-2000-100
Number of turbines	57
Power capacity (kW)	114,000
Hub height (m)	100
Rotor diameter per turbine (m)	84
Swept area per turbine (m^2)	5,542

Table 3: Specifications of the selected turbine

In order to obtain a production of 100MW from the entire farm, the efficiency of the turbines must be taken

	unit	Climate data location	Facility location
Latitude		32.4	32.2
Longitude		15.1	15.3
Climate zone		3A – Warm – Humid	
Elevation	m	32	0
Heating design temperature	^{0}C	9.0	
Cooling design temperature	^{0}C	34.2	
Earth temperature amplitude	^{0}C	10.2	

Table 1: Climatic data for the chosen location compared to a point with measured data.

Month	Air temperature (^{0}C)	Relative Humidity %	Atmospheric pressure (kPa)	Wind Speed (m/s)	Earth temperature (^{0}C)
January	13.8	66.8	101.8	5.0	15.1
February	14.1	67.3	101.7	5.4	15.0
March	15.8	67.3	101.5	5.8	16.3
April	17.9	66.4	101.7	5.7	18.5
May	20.8	69.9	101.7	5.3	21.5
June	24	70.9	101.7	4.9	25.3
July	26.2	72.9	101.7	4.4	28.3
August	27.2	72.7	101.7	4.4	29.3
September	26.5	70	101.4	4.6	27.9
October	23.8	67.5	101.5	4.7	24.8
November	19.3	66.2	101.6	4.8	20.6
December	15.1	66.9	101.8	5.0	17.0

Table 2: Climatic data for the project site.

3. Selection of study turbines:

As for the turbine that will be worked on in this research, it is produced by AAER and has the name (A-2000-100). After reviewing the program library, this type was selected because it is the most suitable for the site in terms of its specifications, which are shown in Table (3).

into account, as the efficiency of this type of turbine reaches 88%, and Table (4) shows these losses, represented by both the turbine arrangement with a value of 4%, and the blade losses of 2%. In addition to other losses of 6%.

To reach this actual capacity of 100MW, the number of 57 turbines must be chosen, which were calculated from the following equation.

$$P_T = N \times P_{out} \times \eta$$

Array losses %	4
Airfoil losses %	2
Miscellaneous losses %	6
Availability %	88

Table 4: Losses in the turbine.

Therefore, the geographical area of the study site must be 5400 meters long and 3150 meters wide. Considering several references, the distance between the row and the next row must be 7 times the diameter, meaning (7 * 84 = 588 meters) = approximately 600 meters, and the distance Between the turbine and the turbine next to it, there is 4 times the diameter (7 * 84 = 336 metres) = approximately 350 metres.[1]

Figure (1) shows an approximate diagram of a wind farm containing 57 turbines.

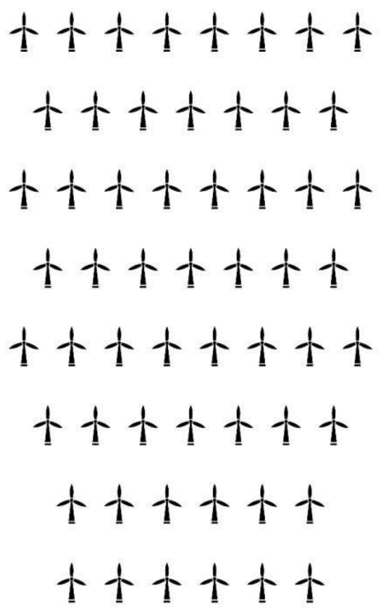

Figure 1: Illustration of the distribution of 57 turbines.

4. Wind Speed VS Energy and power curve data:

The power and energy output for the turbine model named (A-2000-100) chosen is depicted by the tabular format shown below here we can observe the minimum wind speed for the power generation (cut-in speed) is 4m/s. Also the increase in quantity of electrical power produced with speed is also shown over here in Table (5).

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh)
0	0	
1	0	
2	0	
3	0	445
4	43	1,359
5	146	2,775
6	292	4,456
7	494	6,145
8	774	7,690
9	1,136	9,034
10	1,567	10,167
11	1,926	11,097
12	2,001	11,834
13	2,001	12,387
14	2,001	12,766
15	2,001	12,987
16	2,001	
17	2,001	
18	2,001	
19	2,001	
20	2,001	
21	2,001	
22	2,001	
23	2,001	
24	2,001	
25	2,001	
26	2,001	
27	2,001	
28	2,001	
29	2,001	
30	2,001	

Table 5: Wind Speed VS Energy and power curve data

This data can also be shown in the curve shown in Figure (2).

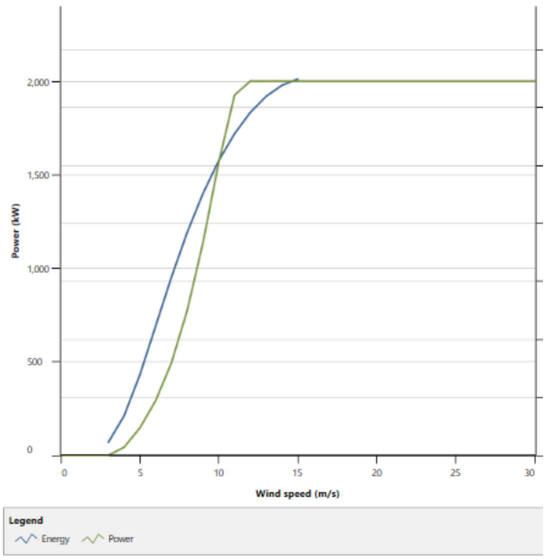

Figure 2: The relationship between wind speed, Energy and Power.

5. Cost Analysis:

The cost analysis in this study includes all financial aspects and comparisons of the project being implemented, that is, all costs such as installations, maintenance, geographical area, and periodic needs mentioned for the purpose of analysis, as this tool of the program includes all information and full details about the cost, in addition to details of annual savings. And costs. The option is also given to enter all types of costs included in the construction of the project. The total cost is calculated from the following equation: [5]

$$\textbf{Total initial costs} = \textbf{FS} + \textbf{PD} + \textbf{E} + \textbf{PS} + \textbf{BM}$$

whereas:

(**Feasibility Studies** FS) The cost of the project site feasibility study.
(**Project Development** PD) The cost of developing the project.
(**Engineering** E) Costs related to engineering matters.
(**Power System** PS) Costs of power systems.
(**Balance of system and Miscellaneous** BM) Miscellaneous other costs.

Figure (3) shows the value of these costs, which are distributed at $4,500,000 as initial studies and a feasibility study. As for the costs related to developing the project, they are approximately 3% of the total cost, amounting to $10 million, As for engineering and infrastructure costs, they represent 14% of the total cost of the project as a whole, equivalent to $50 million, As for the energy system costs, they are represented in the total price of 57 turbines, as shown in Figure (3), while the other miscellaneous costs amount to about 18% of the total project, whose entire cost is $357 million.

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost	1	$ 4,500,000	$ 4,500,000	
Subtotal:				$ 4,500,000	1.3%
Development					
2Development	cost	1	$ 10,000,000	$ 10,000,000	
Subtotal:				$ 10,000,000	2.8%
Engineering					
Engineering	cost	1	$ 50,000,000	$ 50,000,000	
Subtotal:				$ 50,000,000	14.0%
Power system					
Wind turbine - 100000 kW (8m/s @10m)	kW	114,000		$ -	
Road construction	km			$ -	
Transmission line	km			$ -	
Substation	project			$ -	
Energy efficiency measures				$ -	
Totally for 57 Turbines	cost	1	$ 228,000,000	$ 228,000,000	
Subtotal:				$ 228,000,000	63.9%
Balance of system & miscellaneous					
Spare parts	%	100.0%	$ 12,000,000	$ 12,000,000	
Transportation	project	1	$ 50,000,000	$ 50,000,000	
Training & commissioning	p-d	1	$ 2,500,000	$ 2,500,000	
	cost			$ -	
Contingencies	%		$ 357,000,000	$ -	
Interest during construction			$ 357,000,000	$ -	
Subtotal:				$ 64,500,000	18.1%
Total initial costs				$ 357,000,000	100.0%

Figure 3: Total project cost

As Table (6) shows, as a result of simulating this case, 436,230 MWh will be exported to the public electricity network over the project's estimated lifetime of twenty years. The cost of producing electricity can be calculated through the following equation:

Electricity cost (kWh) = total project cost / electricity production over the life of the project

Therefore, the cost per kilowatt hour is $0.081, which is a very excellent value compared to traditional sources of energy production.

Capacity factor	%	43.7
Initial costs	$	228,000,000
O&M costs (savings)	$	4,104,000
Electricity export rate		Electricity export rate – annual
	$/kWh	0.10
Electricity exported to grid	MWh	436,230,2

Table 6: Total Electricity export.

6. Emission Analysis:

In this section, the advantage of using a wind energy conversion system as an alternative to traditional energy sources is explained by noting the amount of reduction of one of the most important major pollutants of carbon dioxide. It is shown here that by using a 100MW wind power plant instead of power stations based on traditional sources, a reduction was observed. Net annual carbon dioxide emissions amounted to 280,539 tons, and Figure (4) shows a comparison between carbon dioxide emissions in tons for the basic case "gas station" and the study case "wind farm."

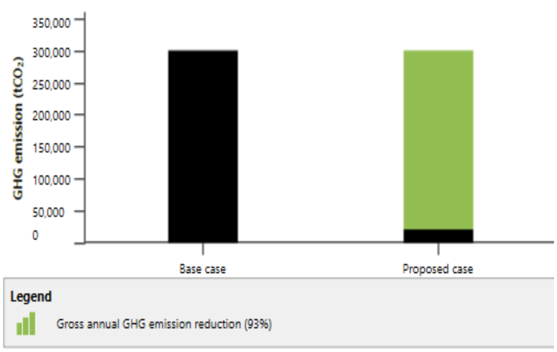

Figure 4: A comparison between carbon dioxide emissions in tons for the base case "gas station" and the study case "wind farm."

7. Conclusion

- **Environmental Efficiency:** The study demonstrates that using a grid-connected wind energy system can significantly reduce carbon dioxide emissions compared to traditional power plants.
- **Economic Feasibility:** The 100 MW wind power project in Misurata is shown to be economically viable, with electricity costs being lower than traditional sources.
- **Technical Performance:** The RETScreen program was used to evaluate the technical performance of the wind farm, helping to optimize productivity and efficiency by selecting the appropriate location and turbines.
- **Social Benefits:** The project contributes to sustainable development and reduces reliance on fossil fuels, enhancing local environmental quality.
- **Recommendations:** The findings encourage the adoption of wind energy projects in areas with suitable resources and call for support from policymakers and investors.

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