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Research Article

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Exploring Wind Energy Potential: Operational Performance of Basra's Offshore Wind Farms

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Abstract

This research focuses on assessing the operational performance and feasibility of wind farm development in Basra's offshore line zone, which runs along the Arabian Gulf. Because of the region's abundant wind resources and strategic location for green energy expansion, it offers a promising future for wind power generation. Over three months, the project will collect extensive wind data, including speed, direction, and air density (May to July 2023). This data was used to determine wind availability and evaluate the technical feasibility of wind farm development, considering elements such as water depth, seabed characteristics, and atmospheric dynamics.

We discovered considerable fluctuations in wind speed and direction during our investigation, which is critical for optimizing wind energy project design and operations. The selected turbine, Litwin LTW80 LS39.0 1.0MW. Class IIA was chosen for its low cut-in speed, strong construction, and appropriateness for marine settings. The research comprises a thorough site selection process, turbine arrangement design, and the compilation of wind maps to illustrate wind velocities across the turbine array. The findings show that, while wind farm development in the Basra offshore line region is theoretically viable, it requires careful site selection and optimization to optimize energy output while minimizing environmental effects. The study emphasizes the potential benefits of offshore wind energy, such as stronger and more consistent winds, lower visual and acoustic impacts, and larger turbines that can produce more energy. However, issues such as expensive installation and maintenance costs, difficult inspection access, and the requirement for advanced wake management techniques must be addressed. Overall, the goal of this exploratory work is to unleash the wind energy potential in Basra's offshore boundary, thereby giving useful insights for data-driven policy and clean energy transition.

Keywords: Operational Performance, Offshore Line Zone, Energy Potential, Data-Driven Policy and Clean Energy Transition

1. Introduction

Recent discoveries show that the rising greenhouse effect is causing global temperatures to rise by 1-2 degrees Celsius, focusing international attention on global warming [1]. Climate change has drawn the interest of the world population [2]. Over forty percent of the world's CO2 emissions are related to heat generation and electricity [3], which emphasizes the need to develop sustainable, clean energy solutions [4]. Rising as a vital clean energy source in the renewable sector, wind power—known for its maturity, scalability, and financial viability—emerges as a Renowned, sustainable, and clean, wind energy is a fast-expanding power generation source over recent year [6, 7].

But this fast development has raised questions regarding the effect on biodiversity [8–9]. Recent studies have revealed that wind farms significantly affect the structural composition and variety of ecosystems, therefore producing observable changes in both spheres [10]. Studies suggest that the building of wind farms could lead to localized rises in temperature and precipitation, therefore enhancing the biodiversity in some areas [11]. Research done elsewhere, however, yields different results with wind farms. having a negative impact on plant community diversity in some areas, if not all [12]. Variability in outcomes may arise from variances in ecosystem types and geographical locations, prompting further extensive studies to know how wind farms affect plant populations. Thanks to its several advantages, offshore wind energy has seen explosive recent increase. Particularly offshore sites gain from stronger and more consistent wind, which increases energy generation [13] and lowers stress related to tiredness [14].

Larger turbines made possible by the offshore open environment each may produce more electricity [1. Moving turbines away from residential areas reduces visual and aural effects, so enabling more economical and effective wind turbine designs [13]. Particularly appealing are floating offshore wind farms (FOWFs), which allows real-time movement [16] and allow for location further from shore when wind conditions are more suitable [15]. Though these advantages exist, only a small number of offshore wind farms have been built thus far largely due to significant installation, running, and maintenance costs. More complicated to erect, more difficult to access for inspection, maintenance, and repair, offshore wind turbines [14] need for more expensive electrical systems. Strategies for efficiency maximizing of offshore wind farms should help to lower the cost of offshore energy.

1.1. Experimental Part

The Basra offshore line region, which runs along the Arabian Gulf, represents a prospective frontier for wind power generation. This study is to evaluate the region's wind farms' operational performance. This study intends to unleash Basra's offshore wind energy potential by assessing wind data, selecting appropriate turbines, and constructing an optimum wind farm architecture. The wind farm will be built in the area opposite Ras Al-Bisha, which is around 5 kilometres away. Adherence to international wind farm design standards led the site selection procedure. The evaluations included extensive wind speed assessments adapted to the region's atmospheric dynamics. Assessments examined wind distribution for dependability and consistency, which are critical for wind resource exploitation. Using existing knowledge and expertise, the study seeks to illuminate potential benefits and challenges of wind farm implementation. A systematic approach informs decision-making, driving sustainable energy development in Basra's coastal domain.

Figure 1: Location

Wind data collection spanned three months (May to July 2023), utilizing resources from MERRA-2 and ECMWF. Data included wind speed, direction, air density, and wind shear at a height of 50 meters. Analysis revealed notable trends, such as increased wind speeds during peak energy demand months and predominantly high wind direction in most corners of the study region (Figure 2).

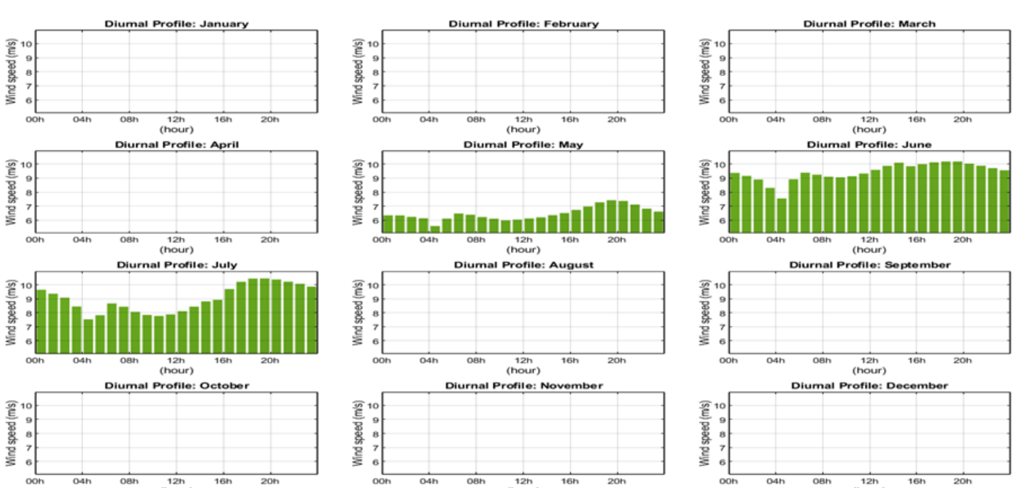

Figure 2: Wind Speed For 3 Months

The Leitwind LTW80 LS39.0 1.0MW Class IIA turbine was selected for its low cut-in speed (3 m/s) its suitability for marine environments. The turbine's hub height of 65 meters matches the height at which the wind is measured, maximizing energy efficiency. In addition, its robust construction and corrosion-resistant to withstand the harsh marine environment, making it suitable for offshore deployment. for offshore deployment as shown in Figure.

Figure 3: Leitwind LTW80 LS39.0 1.0MW Class IIA

A total of 10 turbines have been installed in a grid pattern with 1000 metres between each turbine (Figure 4). The layout ensures optimum spacing for efficient wind capture while minimising interference. A wind map was produced to visualise the wind speeds across the turbine array and to assess the energy production potential (Figure 5). Average wind speeds were calculated to assess the wind resource potential (Figure 5). A noise map was also produced to assess the impact of turbine noise on the environment (Figure 6).

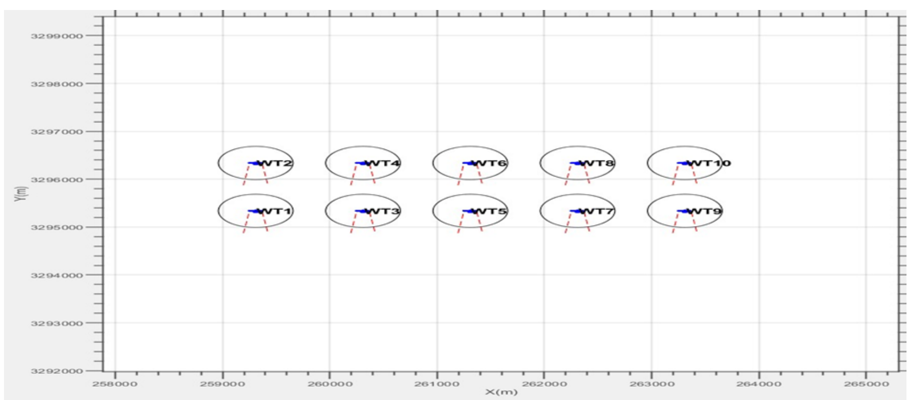

Figure 4: Wind Turbine Distribution

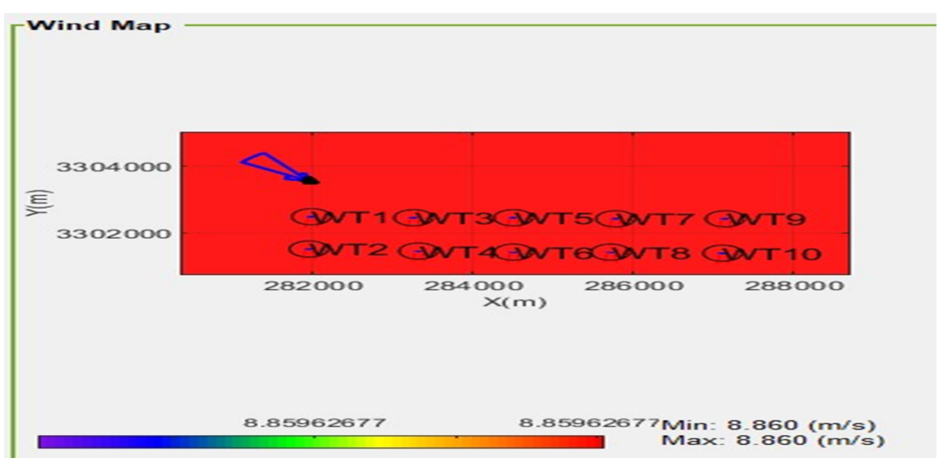

Figure 5: Wind Map

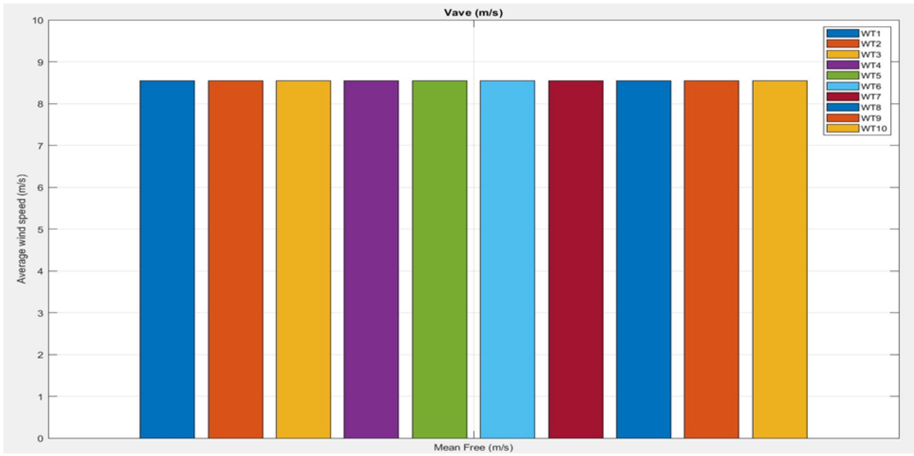

Figure 6: Wind Speed Average for Each Turbine

In addition to noise assessment, turbine wake turbulence was analyzed to understand its impact on energy production. This analysis highlighted the need for proper turbine spacing and layout optimization to mitigate wake effects and maximize energy yields (Figure 7).

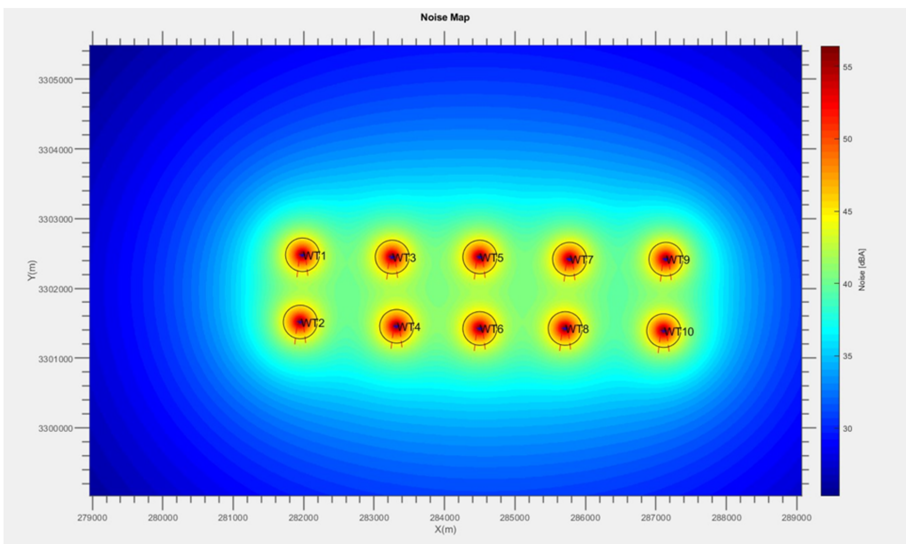

Figure 7: Noise Map for Each Turbine

2. Results and Discussion

The wind data collected over the three-month period (May to July 2023) showed significant trends in wind speed and direction. Wind speed showed a significant increase during the peak energy demand months, with a 7.5 m/s[18] average wind speed. With most of the wind flowing from the north-west, the wind direction exhibited mostly great fluctuation (Figure 8). These results support the need of strategic turbine location to enhance energy absorption and correspond with current wind patterns [19]. With its low cut-in speed (3 m/s) and hub height of 65 meters, which maximized energy capture efficiency, the Leitwind LTW80 LS39.0 Class IIA turbine proved to be favorable in choice.

Furthermore, guaranteeing longevity in the offshore environment is the turbine's strong construction [20]. The turbine may provide notable power at wind speeds exceeding 5 m/s according to power curve study (Figure 9). with peak power observed at 12 m/s. The overall power curve of the wind farm is shown in (Figure 10), which aggregates the performance of all turbines in the array. This curve indicates the relationship between the wind speed and the total power output of the wind farm [21]. Energy production calculations for each month showed that the highest energy production occurred in June and July with AEP (Annual Energy Production) of 71,799.94 MWh/year and 70,100.12 MWh/year respectively (Table 1). The capacity factor (CF) for these months was 81.96% and 80.02% respectively, highlighting the potential of the Basra Offshore Line region for wind energy generation.

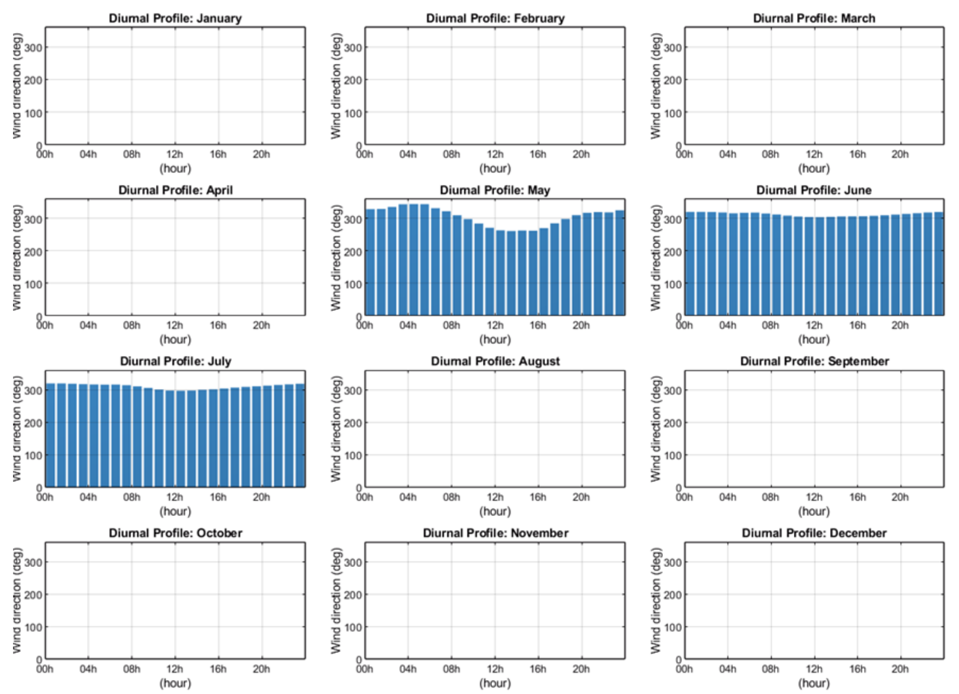

Figure 8: Wind Direction Annual

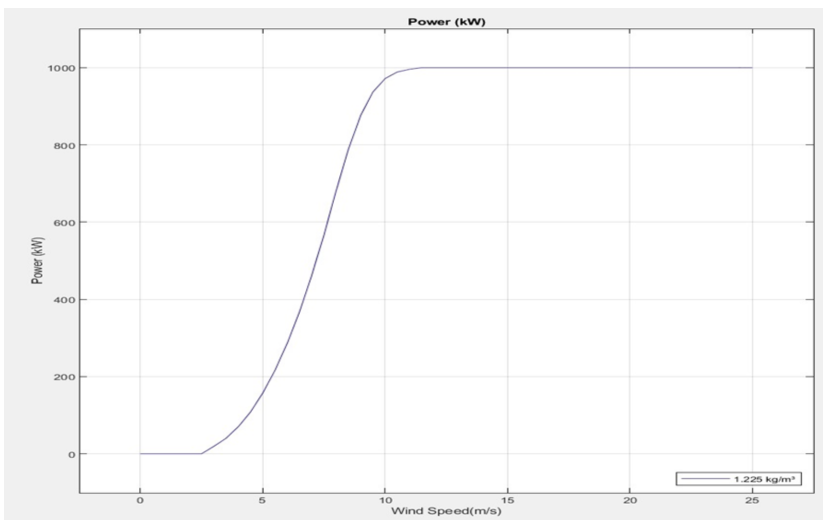

Figure 9: Leitwind LTW80 LS39.0 1.0MW Class IIA Power Curve

1. Date/Time	2.AEP(MWh/year)	3.CF(%)
4. January	5.NaN	6.NaN
7. February	8.NaN	9.NaN
10. March	11.NaN	12.NaN
13. April	14.NaN	15.NaN
16. May	17.42395.25	18.48.40
19. June	20.71799.94	21.81.96
22. July	23.70100.12	24.80.02
25. August	26.NaN	27.NaN
28. September	29.NaN	30.NaN
31. October	32.NaN	33.NaN

34. November	**35.NaN**	**36.NaN**
37. December	**38.NaN**	**39.NaN**
40. Total	**41.63945.05**	**42.70.35**

Table 1: Energy Production

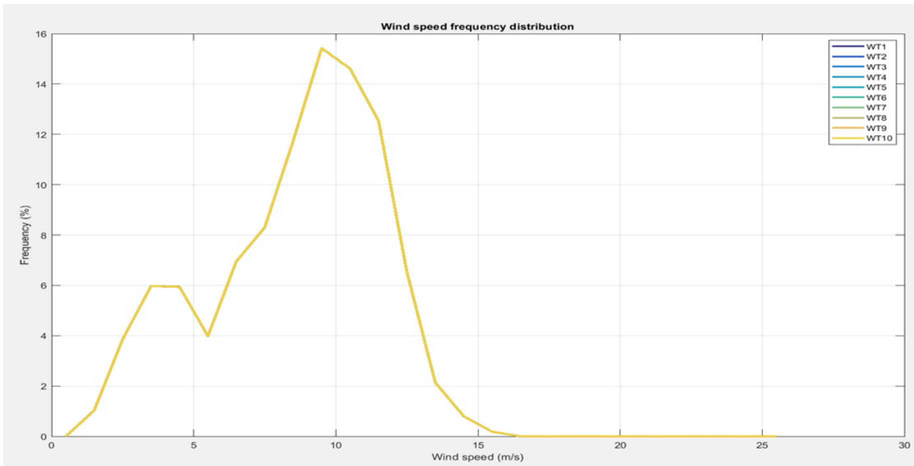

Figure 10: Wind Speed Frequency Distribution

Figure 11 shows the total energy output of the wind farm and helps one to see the energy output across the three months. The graph shows a steady increase in energy production corresponding to higher wind speeds during the summer months [22].

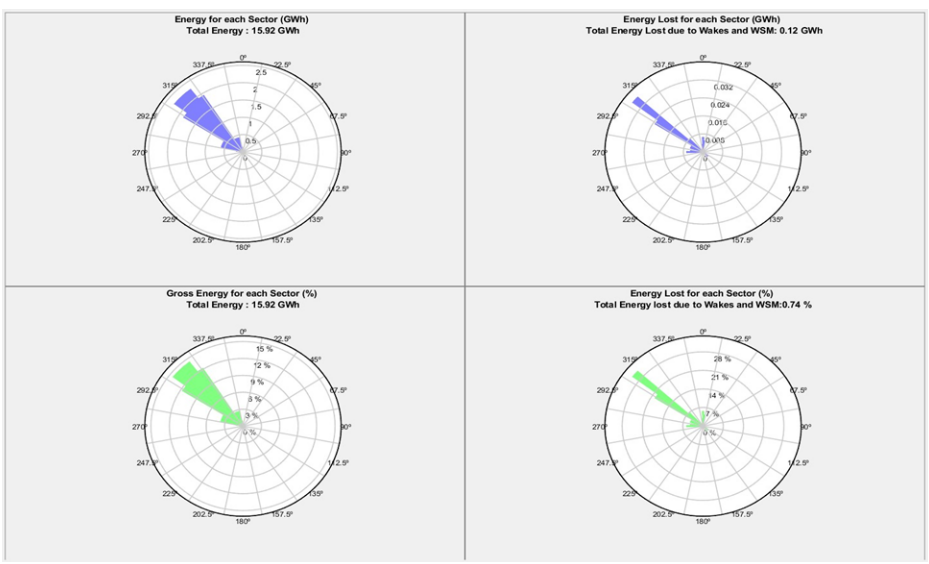

Figure 11: Energy Yields

To further assess the performance of each turbine within the wind farm, the capacity factor variations are illustrated in Figure 12. This figure highlights the efficiency and consistency of each turbine's output over the operational period [23]. Figure 12 shows that the capacity factors of the individual turbines are relatively uniform, ranging between 78% and 83% during the peak months of the year. This uniformity indicates consistent wind resource availability across the farm and effective placement of turbines within the layout. The high-capacity factors highlight the significant wind energy potential of the Basra Offshore Line region [24].

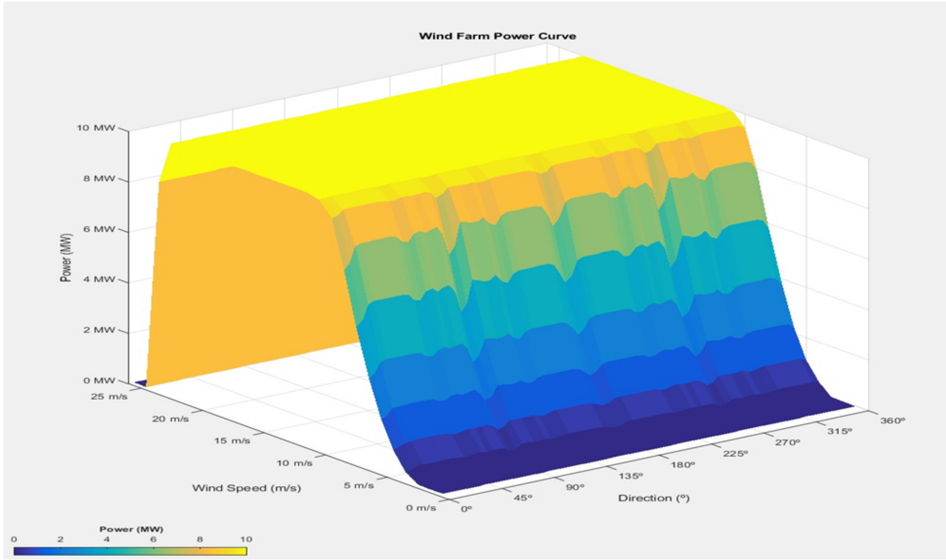

Figure 12: Wind Farm Power Curve

Using a wind map (Figure 4) and average wind speed calculations (Figure 5), the architecture of the wind farm, which consists of 10 turbines set in a grid pattern at 1000-meter intervals, was examined. This layout ensured optimum spacing to minimize wake effects and maximize energy capture. The noise map (Figure 6) showed that noise levels were within acceptable limits, with minimal impact on surrounding areas. Analysis of the impact of wind farms on biodiversity revealed both positive and negative effects. While wind farms can enhance biodiversity by increasing temperature and precipitation locally, they can also negatively affect the diversity of plant communities in certain regions. The variability of the results requires further detailed research to clarify the impact of wind farms on plant communities.

The Basra Offshore Line region has significant potential for wind power generation, as evidenced by the high energy outputs and capacity factors observed in this study. The strategic placement of turbines and optimized wind farm design help to maximize energy production, with Figures 16, 17 and 18 providing a comprehensive understanding of wind farm performance and energy yields. The consistent wind resource and high-capacity factors over 80% during peak months demonstrate the efficiency of the chosen turbine and site. Environmental issues must be carefully controlled, though, using thorough impact studies to guarantee that the construction of offshore wind farms does not negatively impact marine ecosystems; hence, it is imperative to solve economic problems using technological innovation including advanced materials and remote monitoring; and cooperative efforts across several government departments, the private sector and international organizations can facilitate knowledge sharing and resource pooling. In conclusion, harnessing the wind energy potential in the Basra Offshore Line region offers a viable pathway towards sustainable energy development, reducing dependence on fossil fuels and contributing to global renewable energy goals.

3. Conclusion

This study demonstrates the significant potential for wind power generation in the Basra Offshore Line region along the Arabian Gulf. With average wind speeds of 7.5 m/s and dominant north-westerly wind orientations, analysis of May to July 2023 wind data revealed constant and ideal circumstances. The selection of Leitwind LTW80 LS39.0 1.0 MW Class IIA turbines and an optimized grid layout of ten turbines maximized energy capture, resulting in a total annual energy production of approximately 184,295 MWh. High-capacity factors over 80% during peak months underline the efficiency of the site and turbine selection.

While the region offers promising wind resources, challenges such as high installation and maintenance costs, environmental impacts and technical complexities in the harsh marine environment need to be addressed. The use of advanced materials, remote monitoring systems and innovative technologies such as superconductors can mitigate these problems. Environmental impact assessments are essential to ensure sustainable development without harming marine ecosystems. In conclusion, harnessing wind energy in the Basra Offshore Line region represents a viable path towards sustainable energy development for Iraq, reducing dependence on fossil fuels and contributing to global renewable energy goals.

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