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Site feasibility for offshore wind farm development: A preliminary case study at Jakhau, Gujarat (India)

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ABSTRACT

Renewable and sustainable energy technologies have been adopted globally to meet increasing energy demands. Offshore wind farms are crucial for reducing greenhouse gas emissions and enhancing the availability of power supply. Planning offshore wind energy farm development, involves carefully considered multiple variables to identify the ideal project sites. This study assesses the feasibility of offshore wind farm development along the northern coast of Gujarat, India, which has been identified as an optimal zone for wind energy generation. This assessment was based on a long-term analysis of critical parameters, including wind speed, bathymetry and met-ocean conditions. The annual average wind speed in the study area is about 7m/s, making it feasible for offshore wind energy production. Bathymetric data show depth values ranging from 10 m to 23 m, suitable for monopile foundation structures, recommended for offshore turbines in shallow waters. The site experienced a maximum tidal fluctuation of 3 m, which affected the turbine design and placement. Wave patterns were analyzed to understand the local wave climate. This study incorporates these parameters into the site selection process, considering environmental sustainability, technical feasibility and cost-effectiveness. The results suggest that the identified location of the northern Gujarat coast provides a suitable environment for developing an offshore wind farm. This study gives valuable insights into the criteria required for the early planning stages of offshore wind projects. The findings show that the Jakhau, Gujarat has a good potential for offshore wind farm development.

Keywords: Offshore wind farm, Feasibility study, Bathymetry, Met-ocean parameters, GIS, Jakhau (Gujarat)

INTRODUCTION

Globally, fossil fuels are the most extensively utilized energy source. Historically, fossil fuels have been the primary component of energy systems in both industrialized as well as developing nations (Caetano et al., 2017). People are now forced to choose renewable energy owing to rising energy demands and the depletion of fossil fuel supplies. By the end of the 20th century, wind energy had become increasingly popular for producing electricity (Rashid and Sarkar, 2022). One of the first and most important contributions to the generation of wind energy dates back to 1941 (Kaynia, 2019). Offshore wind farms perform better than onshore wind farms because of their higher and more consistent wind speeds at the sea. India's more than 7000 km long coastline (Dimri et al., 2023), presents a significant opportunity for offshore wind energy harvesting (Rashid and Sarkar, 2022). An overview of India's offshore wind resources was provided through satellite data analysis (Nagababu et al., 2016). Subsequently, satellite data were used to assess the offshore wind potential off the western coast of India (Nagababu et al., 2017).

The feasibility of establishing offshore wind farms in the northeastern Arabian Sea was thus investigated, considering factors such as harbors, wind speed, proximity to the coast, and marine protected zones (Mani Murali et al., 2014). Soil-structure interaction (SSI) is crucial for designing wind turbines under seismic loads, influencing dynamic performance on clay with monopile foundations using p-y curves (Prowell, 2011; Bisoi and Haldar, 2014; Zuo et al., 2018). Owing to their ease of fabrication, design, and installation, monopiles are the most commonly used foundation type worldwide. Approximately 80% of the wind turbine foundations currently in use are monopiles. Other standard foundation types for offshore wind turbines include, gravity foundations, jacket foundations and floating turbine systems (IRENA, 2012). The Indian government approved Rs. 7,453 crore VGF scheme to support 1 GW offshore wind projects in Gujarat and Tamil Nadu, aiming for 37 GW capacity and long-term CO_2 reductions under the 2015 Offshore Wind Energy Policy (Press Information Bureau, 2024). Onshore wind turbines installed near the Jakhau coast in Gujarat are part of India's extensive wind-energy initiatives. This coastal region, known for its solid, steady, and consistent wind patterns, provides an ideal environment for wind energy generation. The turbines in this area contribute significantly to the state's renewable energy output, tapping into the vast wind potential of Gujarat.

The wind farms near the Jakhau coast enhances energy security and support to local economies through job creation and infrastructure development (Murthy and Atmanand, 2013), Gujarat has installed on-shore wind turbines along its coast about 5 km from the shore. As India achieves its ambitious renewable energy targets, exploring the feasibility of offshore wind farms along the Gujarat coast, becomes essential in diversifying the nation’s energy portfolio and reducing its dependence on fossil fuels.

Such feasibility study encompasses various techno-economic assessments, wind resource analysis, bathymetry studies, environmental impact evaluations, and technological feasibility. This coast offers promising wind conditions, particularly in areas such as the Gulf of Khambhat and along the southern coastlines, where strong and steady winds create optimal conditions for energy generation. While the broader