Stream tidal energy assessment near the coast of Saboga Island, Panama: Data analysis.

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I. INTRODUCTION

It is believed that Panama's foremost renewable energy asset is the abundance of tidal energy resources along the Panamanian coasts. However, there is a lack of field measurements and scientific research on the variables necessary to characterize tidal energy resources in Panama. Only one previous study was conducted with a timeframe limit of one week for the years 2020 and 2022 using a Lagrangian buoy or drifter in Saboga Island [1].

This research aims to develop an understanding of energy potential that can be obtained from the tidal currents near Saboga Island using a metoceanic buoy for four months. Therefore, this study makes a major contribution to research on the assessment of stream tidal energy by estimating the amount of power that can be harvested from a single 4-meter-diameter horizontal tidal turbine.

The recent development of tidal stream technologies worldwide and the trends in design consolidation to floating horizontal stream tidal turbines are critical factors in selecting this technology where the calculations are based. The estimations are based on the geometry and properties of the commercial stream tidal turbine SIT-250 from SCHOTTEL GmbH and the actuator disk theory [2], [3].

The tides in the Gulf of Panama are semidiurnal, with ranges that vary between 4 to 6 meters. The tidal coefficient ranges from 50 to 93, with spring and neap currents around 0.8 m/s. The studied area has a depth ranging from 10 meters to 25 meters. The above information is essential for site characterization [4], [5]. The characterization of tidal flow, wave, and wind conditions near Saboga Island using a metoceanic buoy provides data on the maritime conditions in the Gulf of Panama, which are highly valuable for assessing locations with wave energy potential.

II. METHODOLOGY:

The on-site measurements were collected on Saboga Island, part of the Pearl Islands archipelago. Saboga has a population of 508 inhabitants. This archipelago is situated in the Gulf of Panama, approximately 75 km from Panama City, at the exact coordinates (8.63104, -79.0566). The study area is located between the channel of Isla Contadora and Saboga Island. This location was selected based on a prior study conducted by the Polytechnic University of Catalonia and the International Maritime University of Panama. Additionally, the choice of this site considered the safety of navigation routes and the surveillance area of the permanent station of Panama's National Aeronaval Service (SENAN) on Saboga Island.

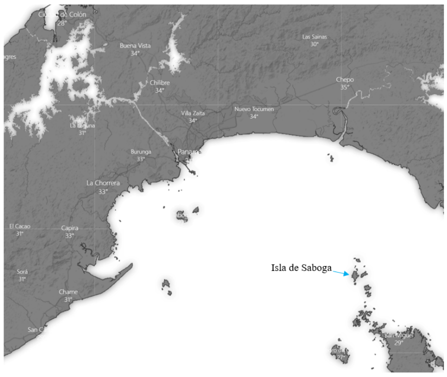

Fig. 1 General location of Saboga Island in the Pearl Islands archipelago, Gulf of Panama. Source: ArcGis – mapviewer - Panama

The methodology to collect data for this study was using a metoceanic buoy for four months. International standards, such as IEC 62600-201 [6] and guidelines from the European Marine Energy Centre (EMEC) for marine renewable energies, indicate that a project in stage 1 refers to the pre-feasibility and feasibility development phase and requires a minimum of 35 days of temporary measurements [7]. In this initial stage, the energy potential can be estimated from direct resource measurements using static current profile measurements. The methodology of this study is based on a single measurement point using a metoceanic buoy. A metoceanic buoy was chosen for this study as an economic means to carry on with the research compared to the suggested use of an acoustic Doppler current profiler (ADCP) according to IEC 62600-201. Further data collection is required to determine the accuracy of the measurements and the relationship between the methodology using a metoceanic buoy and an

ADCP.

Data management and analysis were performed using the data collection system of the buoy and satellite transmitted to a server. The information was analyzed directly on the web platform from the server and downloaded in Excel and MATLAB for data filtering and further analysis. Data filtering is an important aspect when collecting oceanic variable information. Data collection generated extensive datasets filtered to clean data from maintenance periods and extraordinary events, such as anchor failures. Outliers and errors were eliminated through basic statistical techniques. Other common disturbances are related to boat traffic near the measurement buoy, maintenance rounds (involving manual buoy repositioning), and extreme weather and oceanographic conditions, such as storms. The main parameters of the metoceanic buoy collected were sea surface temperature, indirect tidal current, location, wind direction, wave direction, and significant wave height.

Fig. 2 Metoceanic buoy in the vicinity of Saboga Island. In the background, support, and signaling buoys can be observed. November 2022.

III. Data Collection and Analysis:

In this section, we analyze the data of our research, examining the environmental dynamics observed in the Gulf of Panama from January to March 2023. Figures 3 and 4 provide key insights into wave patterns and wind speeds. Additionally, Figure 5 illustrates the potential for energy production through detailed analyses of tidal current velocities, setting the stage for understanding the feasibility of tidal current technologies. These findings collectively inform the path toward sustainable energy prospects and electrical energy generation in this region of Panama.

Figure 3 shows the "wave rose" of the maximum significant wave height values based on the data collected during the selected period from January to March 2023. The intensity and frequency of the measurements indicate a predominance in the northeast direction.

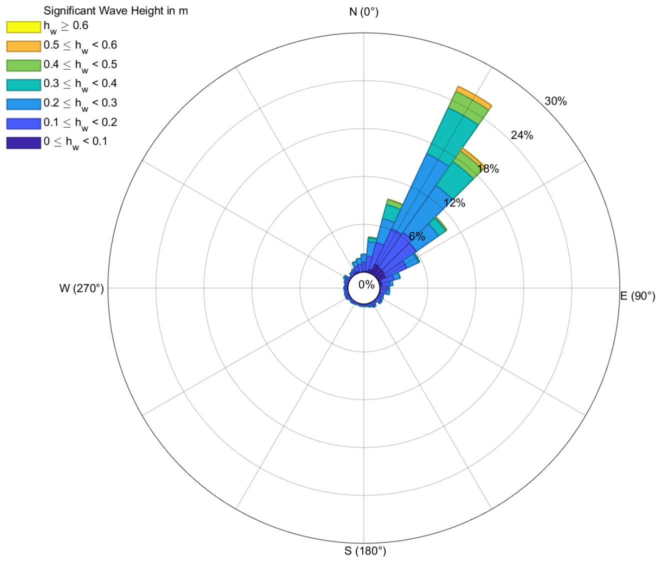

Fig. 3 Wave rose – Significant wave height in (m).

Figure 4 shows the "wind rose" based on the data collected during the selected period from January to March 2023. The average period measured during the same period was around 4 to 6 seconds. Generally, wave periods in this area of the Gulf of Panama are short, with relatively low significant wave heights. These characteristics are favorable for developing tidal current technologies that use floating platforms due to the low interaction of waves with a floating structure.

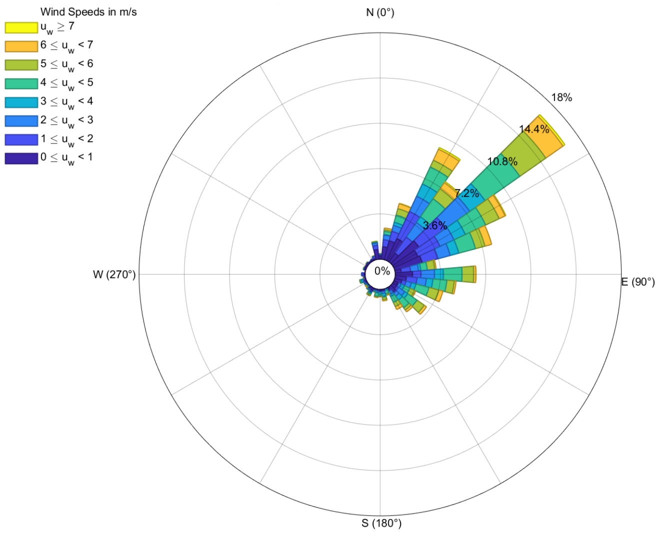

Fig. 4 Wind rose – Wind speed near the surface of water.

In Figure 5, the average absolute tidal current speed is plotted day by day from a chosen interval of the total collected data. Tides in Panama are semidiurnal, so it can be observed that within the same day, four values of speed close to zero are recorded when the tide is at its lowest or highest, and four values correspond to the maximum speeds during the filling or emptying periods of the tides.

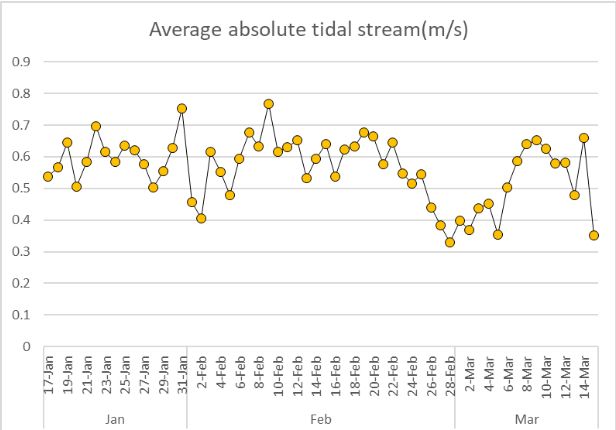

Fig. 5 Average absolute tidal current speed (m/s) - indirectly measured via GPS. As indicated in previous site studies, the average tidal current is relatively lower than measurements using a drifting buoy.

IV. Discussion

Average absolute tidal current velocity (m/s) is indirectly measured using the GPS mounted in our SOFAR buoy [6]. The average tidal current is relatively lower than measurements obtained using a drifting buoy, as indicated in previous site studies [8], [9]. The power in an axial turbine is related to the flow velocity in a cubic relationship, so small increases in velocity represent substantial power increases. The actuator disk model simplifies the amount of power that can be extracted under normal conditions and depends on the intrinsic power coefficient of the turbine. The studied turbine has a high-power coefficient ranging from 0.37 to 0.45 [10], [11].

The recorded current values are relatively low; however, they fall within the viable range for energy production. It is possible to generate between 3 kW and 8 kW of power at the measurement point using the STI 250 turbine as indicated in figure 6. With this substantial energy output, a single turbine could power approximately 2 to 4 households.

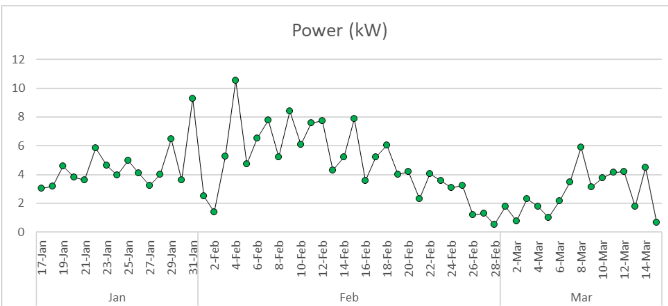

Fig. 6 Average power – Estimated from measurements using the actuator disk model.

Addressing the uncertainties inherent in data analysis is essential to the research project. These uncertainties encountered in this project stage will be examined in the upcoming third phase of our study. A Computational Fluid Dynamics (CFD) simulation will be carried out, employing a simplified representation of the SIT 250 turbine in a 3D model. Through the simulations, we aim to gain a deeper understanding of the complex interactions within the tidal currents, enabling us to refine our energy production estimations and further enhance the accuracy and reliability of our findings.

V. Conclusion

The manufacturer's characteristic curve of the Schottel SIT 250 Class 2 turbine indicates the upper and lower limits within which it operates. The power output is nearly zero at low speeds, and at speeds exceeding 3 m/s, the turbine's power output remains constant until reaching 6 m/s. After 6 m/s, the turbine ceases operation to protect it from high tidal current mechanical stresses [10]. Speed values exceeding 3 m/s are unlikely in the Gulf of Panama. A suitable turbine for the site characteristics of the tidal current around Saboga Island should allow the best performance at low speed. A specific design or control operational model should be implemented to take complete advantage of the tidal energy resource of this area of Panama.

Our findings in the Gulf of Panama suggest that the region holds potential for tidal energy production despite relatively low recorded current values. The STI 250 turbine could generate substantial power, ranging from 3 kW to 8 kW, which could effectively supply energy to 2 to 4 households per turbine. The Schottel SIT 250 Class 2 turbine's characteristic curve provides valuable operational insights. While higher-speed currents remain unlikely in the Gulf of Panama, optimizing turbines for lower speeds and implementing specialized control models can unlock the full tidal energy potential in this tropical area. This research bears broader relevance for sustainable energy applications. It also serves as a foundation for future investigations, focusing on the specific design and performance of tidal energy systems in this unique Panamanian context and extending the calculation for a tidal stream turbine farm to completely power the entire Saboga Island.

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References

[1] Marcel·la CASTELLS, “Estudio del potencial energético de las energías renovables y su impacto ambiental en el archipiélago de Las Perlas (Panamá). Primeras aproximaciones.,” Panama, 2017.
[2] L. Cacciali, L. Battisti, and S. Dell'Anna, "Free Surface Double Actuator Disc Theory and Double Multiple Streamtube model for in-stream Darrieus hydrokinetic turbines," Ocean Engineering, vol. 260, p. 112017, Sep. 2022, doi: 10.1016/J.OCEANENG.2022.112017.
[3] W. M. J. Batten, M. E. Harrison, and A. S. Bahaj, "Accuracy of the actuator disc-RANS approach for predicting the performance and wake of tidal turbines," Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, vol. 371, no. 1985, Feb. 2013, doi: 10.1098/RSTA.2012.0293.
[4] M. López Millán, “Análisis de la variación de nivel del mar y corrientes superficiales en el archipiélago de las Perlas (Panamá),” Universitat Politècnica de Catalunya, 2022.
[5] T. El Tawil, J. F. Charpentier, and M. Benbouzid, "Tidal energy site characterization for marine turbine optimal installation: Case of the Ouessant Island in France," International Journal of Marine Energy, vol. 18, pp. 57–64, 2017, doi: https://doi.org/10.1016/j.ijome.2017.03.004.
[6] International Electrotechnical Commission, IEC TS 62600-201 - Marine energy - Wave, tidal and other water current converters - Part 201: Tidal energy resource assessment and characterization. International Electrotechnical Commission, 2015.
[7] European Marine Energy Centre, “Pathway to commercialisation An EMEC guide to research, development and testing of marine energy technology,” 2022. Accessed: Mar. 16, 2023. [Online]. Available: www.emec.org.uk
[8] Sofar Ocean, "Spotter Technical Reference Manual Sofar," 2022. [Online]. Available: https://www.sofarocean.com/
[9] A. Martinez, A. Mujal, and M. Grifoll, “Estudio hidrodinámico de la mar en la isla de Saboga,” 2020.
[10] J. Hayman and R. Starzmann, "Floating Tidal Instream Energy," 2018.
[11] C. Glennon et al., "Tidal stream to mainstream: mechanical testing of composite tidal stream blades to de-risk operational design life," J Ocean Eng Mar Energy, vol. 8, no. 2, pp. 163–182, May 2022, doi: 10.1007/s40722-022-00223-4.