Stream tidal energy assessment near the coast of Saboga Island, Panama. Part 1: Data collection.

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Abstract*– The project aims to assess the stream tidal energy potential near the coast of Saboga Island in Panama. The document presents the initial phase of the research, focused on data collection essential for conducting an energy assessment in the subsequent stage. This paper specifies the methods used to collect the data, which include the deployment of a metoceanic buoy loaded with sensors that measure oceanographic data. The survey produces basic data regarding waves, tidal current, location, surface temperature, wind direction and general conditions near the coast of Saboga that is important for future work.

***Keywords--** Tidal current energy; Tidal energy converter; Horizontal-axis turbine; data collection.*

I. INTRODUCTION

The energy stored in our oceans is a vast renewable resource that could potentially decrease fossil fuel consumption in coastal cities and communities [1]. Sea levels naturally increase and decrease because of the gravitational interactions of the earth, moon, and sun. These tide-related movements can be measured using a metoceanic buoy to create a comprehensive data base that can be analyzed for future energy assessment in a tropical region as Panama [2].

The energy assessment on the island of Saboga is a project divided into the data collection and simulation phase. Stage one focused on data collection and for this, a monitoring station for sea variables was installed using a metoceanic buoy. The metoceanic buoy internally contains different sensors that were configured for data transmission via satellite, which are accessible through an internet platform [3]. There is a database of approximately four months which will be the starting point for the next stage. This document shows the main data sets that were collected to this date.

This work is divided into four sections. Section I serves as the introduction and background, providing a comprehensive overview of tidal energy converters classification, with a specific focus on tidal stream energy converters. This section presents a clear understanding of the different types of converters utilized in harnessing tidal energy. Section II is dedicated to the methodology of the buoy installation and the type of data that was collected during January to March 2022. Section III presents the main results of the survey. Finally, section IV is the discussion and conclusion of this first stage of the project.

Digital Object Identifier: (only for full papers, inserted by LACCEI).
ISSN, ISBN: (to be inserted by LACCEI).
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A. Background

The project is on Saboga Island in the the Pearl Island archipelago. This Archipelago is in the Gulf of Panama located around 75 km from Panama City with exact coordinates (8.63104, -79.0566). The area studied is near the coast of Saboga Island and the canal between Contadora and Saboga Island. The location was chosen according to a previous study developed by the Polytechnic University of Catalonia and the International Maritime University of Panama [4][5]. Also, the place was chosen considering boat routes safety and the surveillance range area of the Panamanian National Aeronaval Service.

Fig. 1 General location of the data collection point (Yellow circle).

One of the potential energy technologies that is presented in this document is tidal stream energy converters which are a type of energy conversion that is gaining traction in the international ocean energy industry and in academics[6] because tidal stream energy could be moving towards a design consolidation into horizontal-axis turbines [7] and the development of turbine arrays [8], [9]. However, the deployment and research of the tidal energy industry is still at an early stage [10] with challenges on feasibility implementation cost [11], turbine operation under unsteady and turbulent flows [12], structural loads requirements [13], blade design [14], environmental impacts [15], site locations [16] and others [17]. Despite the challenges that this technology is facing, there is special interest from researchers and organizations to overcome the current limitations to scale TECs to massive commercial use in coastal communities [18]–[21] as Saboga Island. The successful implementation of an ocean energy project in Panama will require conducting thorough energy assessments to identify a suitable area along the extensive 3,000-kilometer coastline of the Panamanian territory. These assessments are crucial in determining the optimal location that offers favorable conditions for harnessing ocean energy resources.

The following table shows statistics of the total combined capacity of ocean energy [22] by the first quarter of 2023.

TABLE I
TOTAL OCEAN ENERGY DEPLOYMENT

Rank	Total ocean energy deployment worldwide		
	Ocean energy type	***Installed capacity (MW)***	***Percentage (%)***
1	Tidal barrage	521.5	96.86
2	Tidal stream (TEC)[a,b]	14.34	2.66
3	Wave (WEC)	2.31	0.43
4	OTEC: Ocean thermal energy conversion	0.23	0.04
5	Salinity gradient	0.05	0.01
	Total installed capacity (world)	538.43	

[a] Some sources indicate a total of 14 tidal stream operational projects with a t total combined capacity of 14.32 MW [11] and other sources indicate the start-up of new turbines[7] increasing the total capacity.

[b] Orbital Marine is added to the total combined capacity.

Table II provides a comprehensive list exclusively focused on horizontal axis tidal stream turbines. This emphasis is particularly relevant to the area surrounding Saboga Island, as its shallow waters could possess ideal characteristics for the installation and operation of tidal stream turbines.

TABLE II
OPERATIONAL PROJECTS AS Q1-2023: HORIZONTAL-AXIS TIDAL STREAM TURBINES ONLY.

TEC name	Total ocean energy deployment worldwide		
	Power (kW)	***Type***	***Percentage (%)***
Sabella D-15	2300	Fixed	16.04
Seagen S2 MW twin rotor	2000	Fixed	13.95
Atlantis AR2000	2000	Fixed	13.95
O2 orbital Marine	2000	Floating	13.95
Alstrom	1000	Fixed	6.97
Sabella D-10	1000	Fixed	6.97
Atlantis AR1000	1000	Fixed	6.97
Voith	1000	Fixed	6.97
MCT	600	Fixed	4.18
AR500	500	Fixed	3.49
PLAT-I	420	Floating	2.93
Openhydro	200	Fixed	1.39
Nova	100	Fixed	0.70
Schottel hydron D3	70	Fixed	0.49
Schottel hydron D4	62	Fixed	0.43
Schottel hydron D5	54	Fixed	0.38
O2 orbital Marine	2000	Fixed	0.24
Total installed capacity (kW)	14341		

B. Classification of tidal stream energy converters based on the supporting platform

Tidal stream energy converters are generally classified as horizontal-axis turbines, vertical-axis turbines and cros-flow turbines. Nevertheless, a classification that considers the platform where the turbine is mounted is helpful from the operational and maintenance point of view [23]. Similarly, the floating and fixed supports can have a variety of design types.

TABLE III
OPERATIONAL PROJECTS AS Q1-2023: HORIZONTAL-AXIS TIDAL STREAM TURBINES ONLY CLASSIFIED BY ITS SUPPORTING PLATFORM.

Rank	Classification of tidal stream energy converters		
	Ocean energy type	***Installed capacity (kW)***	***Percentage (%)***
1	Floating turbines Horizontal-axis turbine	2,420	16.9
2	Fixed turbines Vertical-axis turbine	11,921	83.1

II. METHODS AND TECHNIQUES

A. Metoceanic buoy

The equipment chosen to collect the data was a metoceanic buoy manufactured by Sofar Ocean. The specifications of the buoy are indicated in the following chart.

TABLE IV
METOCEANIC BUOY TECHNICAL SPECIFICATIONS.

Classification of tidal stream energy converters	
Ocean energy type	***Installed capacity (MW)***
Wave frequency range	0.03-1 Hz (30s to 1s)
Wave direction resolution	0 - 360 degrees (full circle)
Sampling rate	2.5 Hz (Nyquist @ 1.25Hz)
Wave displacement accurancy	Approximately +/- 2cm
Sea surface temperature	±0.1°C absolute accuracy ±0.02°C resolution
Cloud storage	Real-time and historical data outputs.

The buoy is equipped with solar panels, sufficient battery autonomy and satellite communication.

The buoy can monitor and collect information of the following parameters. The definition of each parameter can be found in reference[24], [25], [26].

TABLE V
METOCEANIC BUOY DATA PARAMETERS

Metoceanic buoy parameters	
Variable	***Units***
wave height	m
Peak period, Mean period	s
Peak direction, Mean direction	deg
Peak directional spread	deg
Mean directional spread	deg
Variance density spectrum	deg
Directional moments (a1, b1, a2, b2)	
Sea surface temperature	°C
Wind speed, Wind direction	m/s, deg
Drift speed	m/s
Geographical coordinates (lat, lon)	deg
Humidity	%rel
Mean Barometric Pressure	hPa

B. Buoy mooring installation and location

The mooring installation consists of weather resistant components such as ½-inch twisted nylon lines, surface floats, stainless-steel thimbles, shackles, swivels, and a concrete anchor. The primary objective of the mooring system is to ensure stability to keep the buoy in place. Furthermore, the mooring design allows for optimal freedom of movement, minimizing interference with wave measurements. The interference of the mooring is present, and it should be considered as a noise factor. The buoy was installed using a mooring system according to fig. 2.

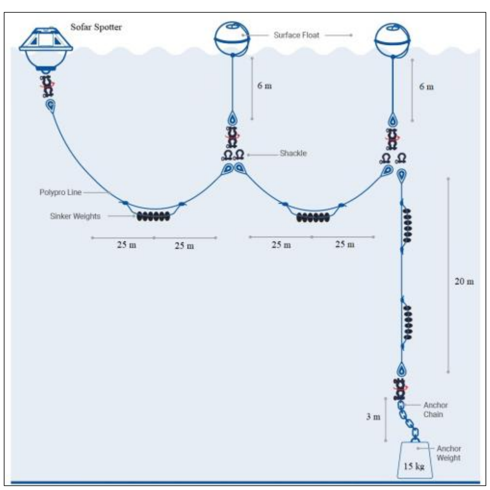

Fig. 2 General arrangement of the mooring system.

The dimensions of the surface floats were 15 and 18 inches and their main function is to allow free movement and support of the buoy. The calculation for the mooring system is as shown in table VI. The calculations were carried out using SeaMoor from Sealite.

TABLE VI
DESIGN OF THE MOORING ARRANGEMENT

Data for mooring calculation		
Parameter	***Value***	***Units***
Low tide	14	m
High tide	20	m
Max. wind speed	10	m/s
Max. water speed	1	m/s
Min. Sinker mass	14.4	kg

The precise location of the buoy corresponds to the indicated position in fig 3. Note that the location of the buoy does not represent a risk for the local ferry and boat routes.

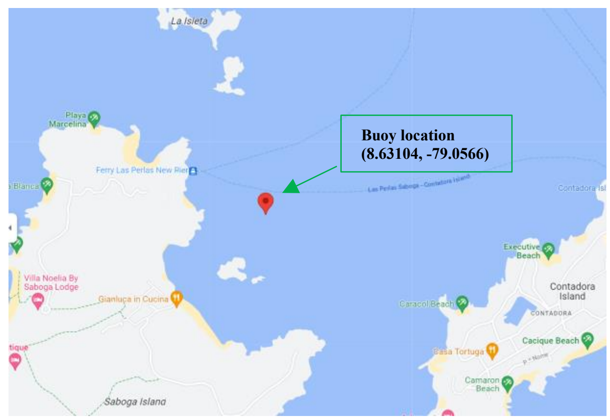

Fig. 3 Location of the buoy. Note that is between Saboga and Contadora island.

III. RESULTS

A. Data collected

The filtration of data is an important aspect when collecting information from ocean variables. The survey generated extensive datasets that require careful filtration to extract relevant and accurate insights. The first step involves removing outliers and errors through rigorous quality control measures and basic statistical techniques. The common events that produce outliners are boats passing close to the buoy arrangement, maintenance rounds and extreme climate and oceanographic conditions.
The information is presented as raw data without classification between spring and neap tides or flood and ebb tides.

The following tables indicate the raw data collected during the data collection period. Measurement started in November 2022 until Abril 2023.

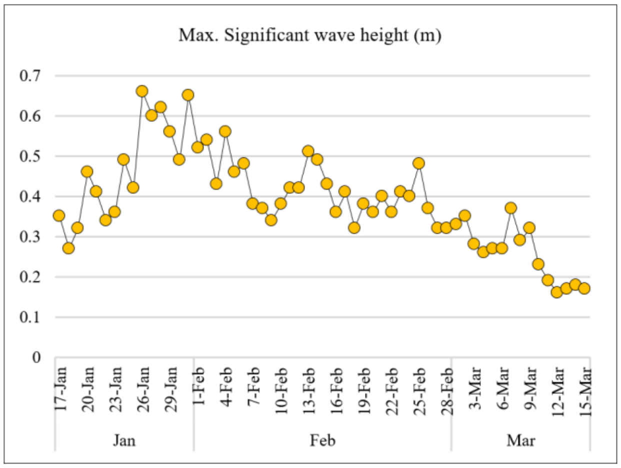

Fig. 4 Max. Significant wave heigh.

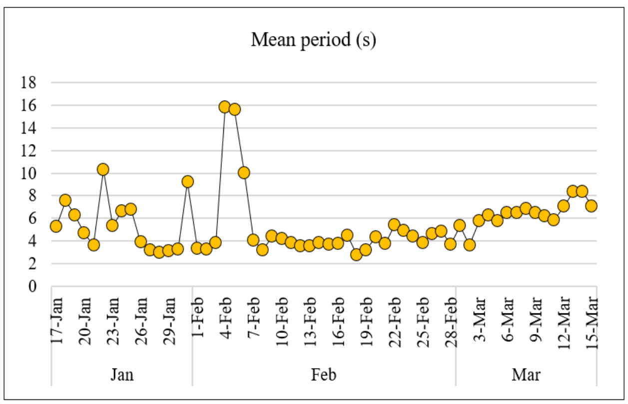

Fig. 5 Mean wave period (s). Note spikes during spring tide periods.

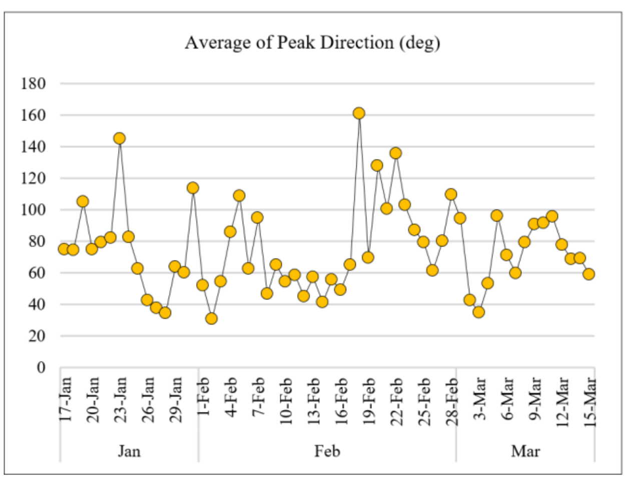

Fig. 6 Average of Wave Peak Direction (deg). Note that the direction is predominantly North-east and east. The angle is measured clockwise in degrees starting from North as 0 degrees.

Ocean surface wind speed and an average tidal speed are presented in fig 7 and 8.

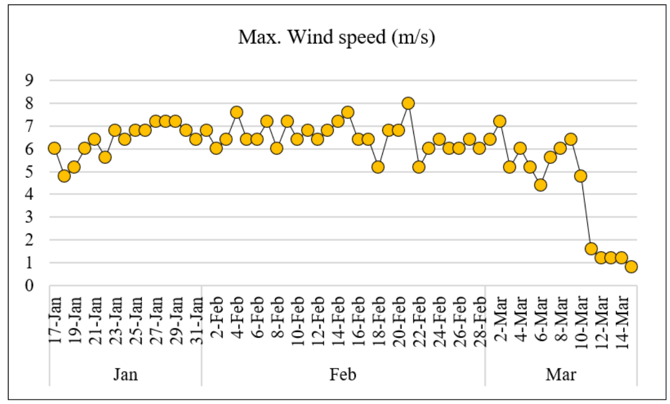

Fig. 7 Max. Wind speed (m/s)

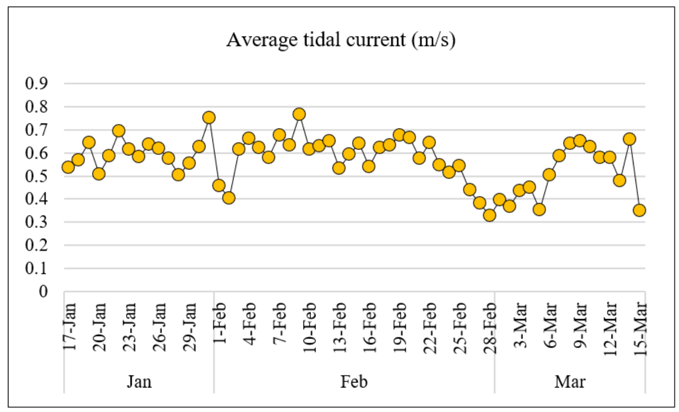

Fig. 9 Average tidal current (m/s) - indirect measurement from GPS. The average tidal current is relatively lower than the measurements using a drift buoy as indicated in site previous studies. [5]

B. Basic site characteristics

Tides in the Gulf of Panama are semidiurnal with ranges that varies between 4 to 6 m. The tidal coefficient goes from 50 to 93 with spring and neap currents around 0.8 m/s. The surveyed area has a depth ranging from 10 meters to 25 meters. The information above is important for site characterization [27] and it will be presented as completed in a separate document.

IV. Discussion and Conclusions

The monitoring station was successfully installed using a state-of-the-art metoceanic buoy equipped with temperature sensors, an atmospheric pressure sensor, GPS capabilities, wave direction and intensity measurement, drift mode, and real-time data visualization through a web platform transmitted via satellite. [4]

Based on our initial findings, these are the preliminary conclusions and recommendations:

1) Saboga Island could be a place where tidal stream energy can be harvested due to its basic site characteristics presented in this document.
2) Allocate approximately 2 months for conducting pre-installation tests of the metoceanic buoys.
3) Collaborate with local organizations such as civil protection and coastal guards to ensure the proper installation and continuous monitoring of the offshore monitoring equipment.
4) Utilize stainless steel 316 or superior for all hardware exclusively for securing the metoceanic buoy to the seabed.
5) Plan dedicated maintenance days to ensure the integrity of the anchors and hooks of the metoceanic buoy, as well as any other measuring equipment operating under adverse weather conditions at sea. This also will help in the process of filtering data.
6) Emphasize the importance of eliminating data related to extraordinary events from the database generated by the metoceanic buoy. Extraordinary events are the cases where the buoy comes loose or is hit by a boat. The buoy currently has two support and signaling buoys with lights; however, it can be hit by boats.

ACKNOWLEDGMENT

This project is financially supported by The National Secretariat of Science, Technology and Innovation of the Republic of Panama (SENACYT) and the Technological University of Panama as part of the Master in science in mechanical engineering program, under grant agreement: MCIM-2021-32. Additionally, this review is part of a fund granted through public call for new researchers 2021 (SENACYT) as project APY-NI-2021-18: Numerical modeling of a tidal energy converter near the coast of Saboga Island. Finally, special thanks to the administrative and faculty staff of the mechanical engineering department at UTP. SENACYT and UTP are not liable for any use that may be made of the information contained in this article; it merely expresses the author's viewpoint.

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