Hydrodynamic and CFD modeling of a tidal barrage power plant in Buenaventura Colombia

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I. Introduction

Renewable energy sources is an alternative to decarbonize the economies and reduce the GHG worldwide emission [1], and the marine energies like the tidal power technology is one of them [2]. Recent research revealed the potential of tidal energy in the central coastal area of the Colombian Pacific, [3], [4]. Here in, the Buenaventura city located in Valle del Cauca department in Colombia has an important opportunity for develop the tidal power technologies nearby its marine coastal regions.

II. Methods

This research implemented a 3D hydrodynamic model (Delft3D) [5] for simulating the circulation of the Buenaventura Bay. It was utilized current profiles measured with an ADCP current. The water level data was retrieved from a tidal station within the bay. Temperature and salinity were obtained from in situ data measured and stored in REDCAM database. Meteorological data, such as winds, temperature and others comes directly from a nearby local station. The bathymetry data was provided by the Maritime General Directorate of Colombia, DIMAR, collected in 2021 along the navigable access channel as well as other areas within the bay. To simulate the hydrodynamics of the tidal power plant, a CFD model was configured in the CFD Autodesk software.

The setup model parameters were taken from the research of Rueda-Bayona et al. [3]. We test the hydraulic modeling options of the flow module of Delft3D model , to simulate the effect of hydraulics structures as gates and dams. Several runs were performed, and the results did not evidence significant changes in the energy balance in the operational area of the tidal barrage. According to this, it was observed that the hydraulic simulation must be performed using a different numeral approach differently to the Finite Difference method of Delft3D. Firstly, we test the hydrodynamic modeling of HECRAS (www.hec.usace.army.mil/software/hec-ras), which is a 2D model. Also, we test another numerical approach such as the CFD modeling to analyze the fluid dynamics across the tidal power barrage, then, the CFD Autodesk model was configured.

III. Results

We test the hydraulic modeling options of the flow module of Delft3D, to simulate the effect of hydraulics structures as gates and dams. Several runs were performed, and the results did not evidence significant changes in the energy balance in the operational area of the tidal barrage. In this sense, the hydraulic option of gates in Delft3D did generate the expected hydrodynamic results.

Later, we set the HEC-RAS model in 2D mode, and the results did not reflect the expected behaviour of the fluid dynamic in structure hydraulics (gates), mainly, because the 2D model integrates along vertical and cannot capture the proper vertical 3D current profiles under the gates. The modeling results of HECRAS indicate that the flow patterns and velocity magnitudes across the gates of the tidal barrage did not represent properly the energy balance nor the intensification of the flow across the gates due to the reduction of the surface control area because of the barrage.

As a result, we decided to implement the CFD Autodesk model and results depicted the expected values of flow velocities across reduced areas by control structures as gates and dams. The CFD results depicted expected values of flow velocities across reduced areas by control structures as gates and dams. Here in, we configured 3 modeling cases according to tidal regime of the area: Syzygy, Quadrature and Stoa, tidal events previously identified by the research of Rueda-Bayona et al. [3].

The CDF model reported expected values of currents flowing under gates (Table I, Fig. 1, Fig. 2), according to hydraulic calculations of hydraulic parameters of gates. During ebbtides in Syzygy occurred the maximum velocities in the 21 gates of the tidal plant. The highest velocity was 11 m/s registered in the gate 6, and the gates 2 and 7 reported magnitudes about 9 m/s. The minimum velocities were observed in the gate 23 with 2.8 m/s.

Table I

Fluid velocities across the gates of the tidal power plant during the most important tidal events of 2021.

Gate number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
		Velocities (m/s)																							
December	Flood	3.2	3.5	4	4	4.6	5	5.5	5.6	6	6	6	5.8	5.7	5.4	4	4	3.5	3.5	3.5	3.2	3.2	3.2	3.2	3.2
	Ebb	4.4	4.1	4	4	3.6	3.8	2.6	2.7	2.7	2.6	2.6	2.7	3.2	3	3.4	3.5	3.6	3.8	3.6	3.8	3.8	3.8	3.9	3.9
	Stoa	1.3	1.3	1.4	1.6	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.5	1.5	1.4	1.3	1.3	1.3	1.3	1.3
April	Flood	1.5	2.5	2.5	3	3	3	3	3	4.5	4.5	6.5	6.5	6.5	4.5	4.5	5.5	5	5	5	5.5	5.5	5.5	5.5	5
	Ebb	5.5	9.5	5.5	5.6	5.5	11	9.5	3.5	4.5	7.5	6.5	6.5	3	3	3.5	5.5	5.5	4.5	3.5	3.5	3.5	3.5	2.8	7.5

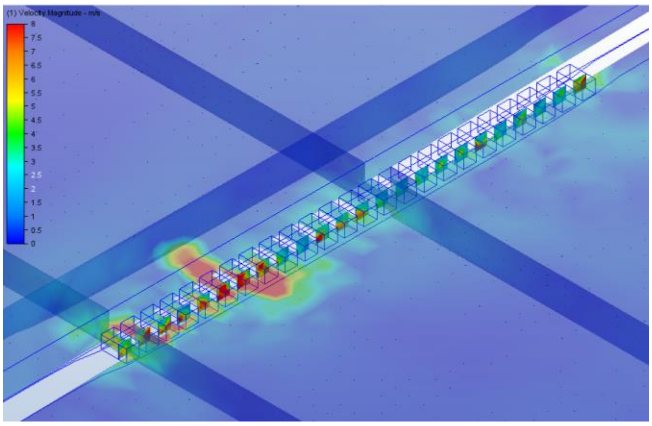

Fig. 1. Top view of the CFD results of flow in the tidal barrage during a ebb tide event of 2021

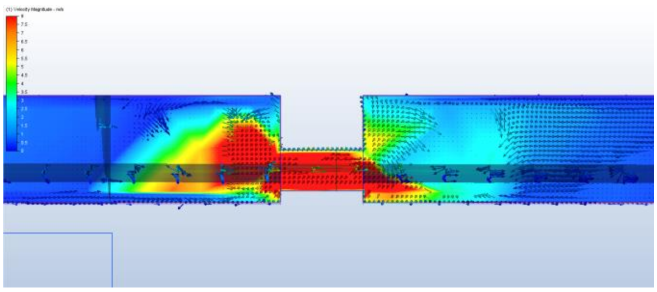

Fig. 2. Cross-sectional view of the CFD results of flow in the tidal barrage during a ebb tide event of 2021

IV. DISCUSSION & CONCLUSION

According to the preliminary results, the velocities of Sicigy (April 2021), showed impressive velocities over between 9 and 11 m/s, what suggest a high possibility of producing electricity through tidal turbines. The mean behavior of velocities in the gates pointed values of 3 and 5 m/s in most of the cases. The results of stoa were very interesting because it was not expected having flow velocities upper the 1 m/s, what is a very good result because the plant might produce electricity even during the stoa condition.

At the moment, the results suggest that exist a high possibility of implementing tidal barrage plants in Buenaventura city (Colombia).

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