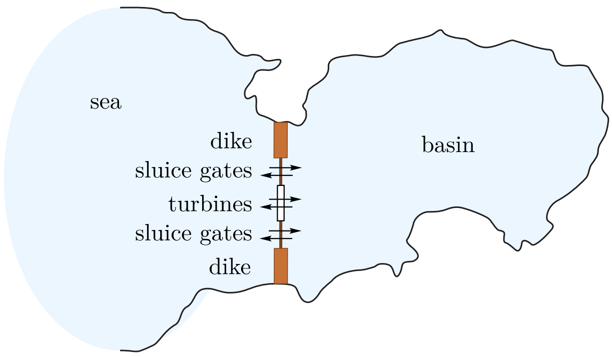
Assignment of MCTE – 2022/2023
Preliminary design of a tidal barrage



1 Definition of the problem

The objective of the assignment is the preliminary design of a tidal power plant through the definition of the basic configuration parameters. For the purposes of this analysis, we need to make some simplifying assumptions, namely

- Sea level and basin level are horizontal.
- The mean sea level $\bar{z}$ is a constant and is defined in Table 1.
- The tidal range is modelled by considering only two components

  $$\zeta\left(t\right) = A_1 \cos\left(2\pi t/T_1 + \phi_1\right) + A_2 \cos\left(2\pi t/T_2 + \phi_2\right),$$

  as described in Table 1.

- The basin area (in m^2) is a function of the water depth with respect to the mean sea level.

  $$A(z) = az^2 + bz + c.$$

  where the constants are given in Table 2.

- The turbines should operate at maximum power as a function of dimensionless speed. The turbine operating curves are described by

  $$Q_{11} = \begin{cases} 0.1693 n_{11} + 0.08989, & \text{if } 4.38 \leq n_{11} \leq 7.92, \\ -0.0003639 n_{11}^3 + 0.009377 n_{11}^2 - 0.09259 n_{11} + 1.757 & \text{if } 7.92 < n_{11} \leq 17.17, \end{cases}$$

and

$$\eta_{\mathrm{turb}} = \begin{cases} -0.02076456 n_{11}^2 0.20238444 n_{11} + 0.48984553, & \text{if } 4.38 \le n_{11} \le 7.92, \\ -0.0002757 n_{11}^3 + 0.002048 n_{11}^2 + 0.0006861 n_{11} + 0.7931, & \text{if } 7.92 < n_{11} \le 17.17. \end{cases}$$

- The turbines can operate in "sluice mode" when filling the reservoir.
- The discharge coefficient C_{d} for the turbine and sluice gates is assumed to be 1.
- The generator is synchronous and the grid operates at 50 Hz.
- The generator efficiency is given by the function

$$\eta_{\mathrm{gen}} = \begin{cases} -6714\Lambda^4 + 2592\Lambda^3 - 380.8\Lambda^2 + 27.04\Lambda + 0.003294, & \text{if } 0 \le \Lambda \le 0.125, \\ -1.169\Lambda^4 + 3.312\Lambda^3 - 3.443\Lambda^2 + 1.542\Lambda + 0.7104, & \text{if } 0.125 < \Lambda \le 1.0, \end{cases}$$

where the load Λ is defined as the ratio of the turbine shaft power divided by the generator rated power $\Lambda = P_{\mathrm{turb}}/P_{\mathrm{gen}}^{\mathrm{rated}}$.

2 Numerical Simulation

Students can develop their own software or use a provided Jupyter notebook code written in Python to simulate the power plant operation. This notebook is available at https://github.com/joaochenriques/IST_MCTE/blob/main/Barrages/SimulEbbGeneration_WithConfigClass_OPT.ipynb. For more information on modelling tidal power, see the lecture notes and code documentation.

3 Preliminary Design

In the first analysis, the tidal power plant is assumed to operate only in ebb generation. The preliminary design of the power plant aims to determine the following configuration parameters:

- The number of n_{turbs} turbines.
- The turbine rotor diameter D.
- The generator rated power $P_{\mathrm{gen}}^{\mathrm{rated}}$ and the number of pole pairs of the generator.
- The area, A_{gate}, and number of gates, n_{gates}, used to fill the basin.

The choice of the number of pole pairs of the generator is limited by the need to avoid cavitation conditions on the turbine rotor blades.

For the modelling of the power plant, it is also necessary to define the turbine starting head h_{start} required to start the turbine operation in ebb mode. The turbine starting head can be assumed to be constant or a function of time, as the tidal resource is predictable.

The choice of parameters should take into account an appropriate capacity factor for the power plant. The time interval chosen for the simulations should consider periodic operation.

Although not compulsory, students may wish to explore other modes of operation, such as bi-directional or flood generation.

Table 1: Data to be used in the assignment. The first column corresponds to the number assigned to the group at the time of registration on the course website.

Gr.	**MSL**	**1st tidal component**			**2nd tidal component**			**Basin area**		
No.	$\bar{z}$	A_1	T_1	ϕ_1	A_2	T_2	ϕ_2	a	b	c
[−]	[m]	[m]	[hour]	[rad]	[m]	[hour]	[rad]	[-]	[m]	[m^2]
1	12	3.00	12.4206	-1.4	1.40	12.6584	-3.0	-7.93×10^4	1.45×10^6	2.54×10^7
2	13	3.50	12.4206	-1.2	1.50	12.0000	-2.2	-1.94×10^5	3.56×10^6	5.36×10^7
3	14	3.31	12.4206	-1.4	1.21	12.6584	-2.5	-7.93×10^4	1.26×10^6	2.49×10^7
4	11	2.87	12.4206	-1.5	1.27	12.0000	-1.0	-1.47×10^5	1.97×10^6	4.13×10^7
5	14	4.21	12.4206	-0.5	1.80	12.6584	-1.5	-9.27×10^4	1.27×10^6	2.33×10^7
6	13	3.70	12.4206	-0.9	1.11	12.6584	1.5	-1.31×10^5	2.64×10^6	4.66×10^7
7	12	4.30	12.4206	-1.9	1.98	12.0000	1.0	-9.37×10^4	1.54×10^6	3.05×10^7
8	13	2.88	12.4206	-0.2	0.90	12.6584	2.0	-1.81×10^5	3.26×10^6	4.90×10^7

4 Deliverable

The work should preferably be done in groups of 2 students. The project report must be submitted in PDF format to the *Fenix* website.