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

1 Definition of the problem

The present assignment is to perform a preliminary tidal range power plant design by defining the basic configuration parameters. For the present analysis, we will introduce the following assumptions and simplifications:

- The tide level is modelled considering only two components

$$\zeta\,(t) = A_1 \cos\left(\omega_1 t + \phi_1\right) + A_2 \cos\left(\omega_2 t + \phi_2\right),$$

  as described in Table 1.

- The water level within the basin is horizontal.

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

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

- The turbines should operate at the maximum power output as a function of the dimensionless rotational speed. The operating curves of the turbine 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

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

- The turbines may operate in "sluice mode" when filling the barrage.

- Turbines are not reversible, so pumping water is not an option.

- The discharge coefficient C_d for the sluice gates is assumed to be 1.

- The generator is synchronous and the grid operates at 50 Hz.

- The generator efficiency is only a function of the load

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

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

2 Numerical simulation

The students can develop their software or use a supplied 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. Additional information about modelling the tidal range power plant is given in the code documentation.

3 Preliminary design

In the first analysis, the tidal power plant is assumed to operate in ebb generation only. 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 $P_{\text{gen}}^{\text{rated}}$ and the number of pairs poles.
- The area, A_{gate}, and the number of sluice gates, n_{gates}, used to fill the basin.

For modelling 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 as constant or a function of the time since the tidal resource is predictable.

The selection of the parameters should consider an appropriate capacity factor for the power plant. The time interval selected for the simulations should consider a periodical operation.

Although not mandatory, students may explore other operating modes such as two-way or flood generation.

Table 1: The two principal components of the tide level at the power plant location.

1st component	2nd component
$A_1 = ?\,\mathrm{m}$	$A_2 = ?\,\mathrm{m}$
$\omega_1 = ?\,\mathrm{rad/s}$	$\omega_2 = ?\,\mathrm{rad/s}$
$\phi_1 = ?\,\mathrm{rad}$	$\phi_2 = ?\,\mathrm{rad}$

4 Deliverable

The work is to be done preferably in groups of 2 students. The report should be submitted in PDF format to the following email: joaochenriques@tecnico.ulisboa.pt.