Assignment – Tidal energy calculation

OE44170 –Offshore Renewable Technologies 2025

Description of the exercise

The goal of this exercise is to give a preliminary evaluation of the tidal energy potential of a particular site based upon limited information. It consists of two parts, the first covering tidal streams, and the second addressing tidal ranges. It is expected that you use a numerical software as Excel, Matlab or Python for the required calculations and the numerical answers. Justify and explain any choices and include a short discussion on the assumptions made and the numerical results.

Part 1a: Environmental data and tidal resource [20 pts]

In this first part you will use the harmonic method for a chosen site, where the constructive and destructive interference of a number of components of the tide are synthesized in order to generate a year-long time series, at hourly intervals, of the tidal currents.

The environmental data table (see Appendix 1), shows the peak spring and neap tidal velocities, the Formzahl number and the amplitudes for the three constituents of several locations of potentially high current speed. Based on this data you can make use of harmonic superposition of the three main components to create a time series of the tidal resource. Select the location according to your group number.

- Based on the environmental data generate the current velocity profile for one year at intervals of one hour. Make a plot of current velocity against time for 31 days, showing the neap and spring cycle. *[20 pts]*

Part 1b: Tidal stream energy production [30 pts]

After modelling the tidal stream resource you are going to evaluate the theoretical power that may be extracted given the main parameters of a specified hydrokinetic turbine. Assume a bi-directional hydrokinetic turbine is used with the following characteristics:

Cut-in speed [m/s]: 1.0
Cut-out speed [m/s]: 3.0
Rated power [MW]: 1.0
Total Efficiency (from water to electricity) [-]: 0.45
Capture area [m2]: 165

Using the previous information and the env. data from part 1 , make a plot of generated power against time for 31 days. Consider the water density of ρ_{water}=1025 [kg m^{-3}]. *[20 pts]*

- Obtain for one year period the following information:
  - Annual mean power, and max power produced. *[5 pts]*
  - Annual energy yield (AEY), and Capacity factor (CF). *[5 pts]*

Part 2: Operation of a tidal rage powerplant [50 pts]

In this second part you will simulate the operation of a tidal range powerplant and give an estimation of the power and energy production using a simplified 0-D model (see Appendix 2).

The given location has a tidal range that often exceeds 8 m, which makes it a suitable location for a tidal range scheme. The creation of a lagoon has been proposed using a wall of 9 km, and creating a basin area of about 10 km2. The scheme would have an energy-generating life of 120 years and would consist of 10 bulb turbines of 20 MW, for a total installed capacity of 200 MW. The lagoon was designed to be operated using a one-way ebb generation as shown in the schematic below.

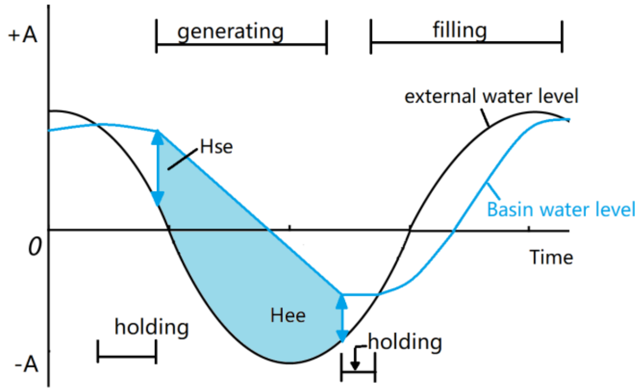

Figure 1. One way ebb generation operating scheme.

In a one-way ebb-generation scheme, water is first held in the basin at high tide while the sea level drops. When the difference in water levels is large enough (H>Hse), turbines are opened to generate power as water flows out. Once the head becomes too small for efficient generation (H<Hee), the turbines close and the basin is held again. As the tide rises, the basin is refilled without generating power by opening sluice gates and turbines, and the cycle repeats at the next high tide.

Considering only two constituents with tidal amplitudes of M2=3.5 m and S2=1.5 m, the tidal heights about mean sea level curves are provided for a representative spring-neap cycle of the site, (see file "Tidal_range_Dataset_2025.csv" available in Brightspace).

Using the previous information, use a 0-D model to simulate the water levels and power production of a one-way generation scheme with the following parameters. The starting and ending generating head during and ebb tide, can be considered as Hse=3.0 m and Hee=1.0 m respectively. For the exercise consider that each turbine has a diameter of 7.0 m, with a total fixed efficiency of 90% regardless of head, and a constant flow rate of 500 m3/s per turbine at all heads when generating power. The total area of the sluice gates would be approximately 500 m2. You can also assume that the initial water level inside the basin is at the same level as the tidal elevation.

- Obtain a plot of the water level inside the basin and the head difference against time for the 14 day period, i.e. the entire spring-neap cycle. *[15 pts]*
- Make a plot of the tidal elevation and the water level inside the basin for the first 50 hours. Show in the graph the different operating modes of the tidal power scheme. *[15 pts]*
- Provide an additional plot showing the total power produced and total flow rates for the same 50 hour period. *[10 pts]*
- Obtain for one year period the following information:
  - Annual mean power, and max power produced. *[5 pts]*
  - Annual energy yield (AEY), and Capacity factor (CF). *[5 pts]*

Note: You can assume that the given 14 day period is a representative tidal cycle for the entire year of operation. You can use a coefficient of 24.377, which is the proportional time of the year for one complete tidal cycle, to convert the predicted energy over one cycle to the annual energy generated.

Appendix 1: Constituents data for tidal stream resource

Group	Ref	Adm. Ref	Lat	Long	Pk Sp kt	Pk Np kt	F_{ZU}	M_2 ms^{-1}	S_2 ms^{-1}	K_2 ms^{-1}
1	7.12	SN167BV	47 33.7N	02 54.9W	5.2	3.5	0	2.2185	0.4335	0.4437
2	7.15	SN164BT	48 02.5N	04 46.7W	5.2	3.0	0	2.0910	0.5610	0.4182
3	7.22	SN161BI	49 44.6N	01 55.8W	6.3	4.3	0	2.7030	0.5100	0.5406
4	7.23	SN161BM	49 44.4N	01 52.1W	5.9	3.3	0	2.3460	0.6630	0.4692
5	7.45	SN0280	58 43.6N	03 14.2W	5.4	2.7	0	2.0655	0.6885	0.4131
6	7.50	SN027P	59 11.1N	02 52.4W	5.1	2.1	0	1.8360	0.7650	0.3672
7	7.51	SN027T	59 08.1N	02 48.4W	7.2	2.8	0	2.5500	1.1220	0.5100
8	7.63	SN048M	53 25.1N	04 34.9W	6.2	3.1	0	2.3715	0.7905	0.4743
9	7.72	SN005AM	50 30.4N	01 16.7W	4.6	2.3	0	1.7595	0.5865	0.3519
10	7.80	SN161AA	49 42.9N	01 58.9W	9.7	5.8	0	3.9525	0.9945	0.7905
11	8.56	SN864A	58 17 N	136 23 W	6.2	3.1	0	2.3715	0.7905	0.4743
12	8.57	SN866A	57 24 N	135 37 W	7.0	3.5	0	2.6775	0.8925	0.5355
13	8.58	SN886A	53 58 N	132 08 W	5.5	2.7	0	2.0910	0.7140	0.4182
14	8.60	SN910D	50 18 N	125 13 W	8.3	5.0	0	3.3915	0.8415	0.6783
15	8.61	SN857C	60 43 N	151 33 W	4.8	2.2	0	1.7850	0.6630	0.3570
16	8.81	S930	37 49 N	122 30 W	4.6	2.5	0	1.8105	0.5355	0.3621
17	9.11	SN593F	19 55 S	150 17 E	5.7	2.6	0.1	2.0460	0.7642	0.1023
18	9.20	SN650AS	46 36 S	168 21 E	4.3	3.0	0	1.8615	0.3315	0.0931
19	10.80	SN219B	25 29 S	48 16 W	4.4	0.8	0	1.3260	0.9180	0.0663
20	10.20	SN752C	34 45 N	126 18 E	8.3	4.5	0.1	3.1552	0.9367	0.1578
21	10.21	SN752B	34 34 N	126 19 E	9.3	4.1	0.1	3.3031	1.2818	0.1652

Adm Ref.- admiralty reference

Lat – latitude

Long - longitude

Pk sp kt - peak spring current in knots

Pk np kt - peak neap current in knots

Fzu - Formzahl number

M2 - principal lunar semi-diurnal constituent

S2 - principal solar semi-diurnal constituent

K2 - Lunisolar semi-diurnal constituent

Appendix 2: the 0-D model for tidal range power scheme

A 0-D (zero-dimensional) model of a tidal range power plant is a simplified tool that represents the entire basin as a single water volume with a uniform water level, ignoring spatial variations or detailed flow patterns. It simulates how water levels change over time and how water flows through turbines and sluice gates based on the head difference between the basin and the sea. This approach is computationally efficient and useful for estimating power output and operational performance during early design and feasibility studies. In this approach, the water elevation inside the basin *Z(t)* is considered from a simplified mass conservation expression:

$$A\frac{dZ(t)}{dt} = Q(t)$$

where, *A* is the constant area of the basin, and *Q(t)* is the total volumetric flow rate that enters or leaves the hydraulic structure.

The **water elevation inside the basin** is estimated based on a discrete backward difference scheme, such that new water elevation Z_{i+1} at any point of time, can be calculated according to the water level Z_i at the previous time step,

$$Z_{i+1} = Z_i + \frac{Q_i}{A}\Delta t$$

where Δt denotes the time step and Q_i the total flow rates at time t_i.

The **total water flow rate through sluices and turbines** during filling can be obtained from:

$$Q_s(t) = C_d A_s\sqrt{2gH(t)}$$

where *Cd* is the coefficient of discharge (assumed to be 1.0), and A_s is the total area opening of sluices and turbines, and *H(t)* is the head difference between the tide elevation and the basin.

The **power output from a single turbine** during generation is given by the following expression:

$$P(t) = \rho g H(t) Q_t(t)\eta$$

Where ρ is the water density, $Q_t(t)$ is the flow rate across the turbine and η is the total efficiency.

The **total power output** is then simply given by the product of a single turbine power and the numbers of turbines *N.* The total power can be multiplied by the time per interval, to give the energy produced This can be summed over all intervals to give an overall energy production for the time period, as desired.