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POSTAL BOOK PACKAGE 2025

MECHANICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

RENEWABLE SOURCES OF ENERGY

6 CHAPTER Renewable Energy Sources Other Than Solar Energy

Practice Questions

Q.1 A simple single-basin type tidal power plant has a basin area of 22 km^2. The tide has a range of 10 m. The turbine stops operating when the head falls below 3 m. Calculate the average power generated during one filling/emptying process if the turbine-generator efficiency is 74%. Take specific gravity of sea water is 1.025.

Solution:

Given data:

Basin Area = 22 km^2 = 22 × 10^6 m^2

Upper Range = 10 m

Lower Range = 3 m

Generator Efficiency (η_g) = 0.74

Density (ρ) = 1.025 × 1000 = 1025 kg/m^3

To find: Average power output during one filling/emptying

Procedure:

$$\text{Energy } (E) = A\rho g\int_3^{10} h\,dh = \frac{1}{2}A\,\rho g\,h^2\Big|_3^{10}$$

$$= \frac{1}{2}\times 22\times 10^6\times 1025\times 9.81\left[10^2-3^2\right] = 10.065\times 10^{12}\text{ J}$$

$$\text{Average power } (P_{av.}) = \frac{E}{\text{time}} = \frac{10.065\times 10^{12}}{\left(\frac{44700}{2}\right)} \qquad [\because t \text{ for one filling/emptying}]$$

$$= 450.34\text{ MW}$$

$$\text{Average power output} = (P_{avg.})\times\eta_g = 450.34\times 0.74 = 333.25\text{ MW}$$

Q.2 For Rann of Kutch the basin area of a tidal project is 0.72 km^2 with a difference of 6 m between the high and low water levels. The average available head is 4.8 m and the system generates electric power for 5.5 hours in each cycle. If the overall efficiency of the plant is 80%, find out the power produced yearly. Take density of sea water 1025 kg/m^3.

Solution:

Power at any point of the time is given by

$$P = \frac{\rho Q H'}{75}\times\eta_p\times 0.736\text{ kW}$$

Now

$$\text{basin discharge } (Q) = \frac{AH}{t} = \frac{0.72\times 10^6\times 6}{5.5\times 3600} = 218.18\text{ m}^3/\text{s}$$

$\therefore$ Power at any point $(P) = \dfrac{1025 \times 218.18 \times 4.8}{75} \times 0.8 \times 0.736 = 8427.33$ kW

Energy generated per tidal cycle = $8427.33 \times 5.5 = 46.35$ MWh

Total number of Tidal cycle per year (N) = $2 \times \left(365 \times \dfrac{24}{24.833}\right) \simeq 705$ cycle

Yearly energy generation = $705 \times 46.35 = 32.676 \times 10^3$ MWh

Q.3 For a typical tidal power plant shown below, the basin area is 25×10^6 m^2. The tide has a range of 10 m. However, turbine stops working when the head on it falls below 2 m. Assume that density of seawater is 1025 kg/m^3, acceleration due to gravity is 9.81 m/s^2, combined efficiency of turbine and generator is 75% and period of energy generation is 6h and 12.5 min.

Determine:

1. Work done in filling or emptying the basin
2. Average power
3. The energy generated in one filling process (in kWh)

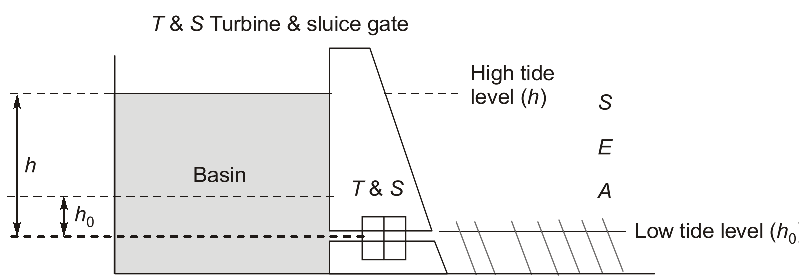

Figure: Single Basin tidal plant

Solution:

Potential tidal power can be reckoned based on a mathematical calculation. Let us assume that the surface area of the reservoir as stable between the full stored water level and the emptied floor, the energy produced by the ebbing water can be expressed as

$$d(W) = \rho g h d(V) = \rho g A h\, dh$$

Here $d(W)$ = energy unit; ρ = density of seawater; g = acceleration due to gravity; A = surface area of the reservoir assumed as a constant from high tide to low tide; h = instant water level height (m); V = volume of reservoir, R = tidal range, h_0 = minimum head below which turbine cannot work.

1. Total work done in filling or emptying the basin (h to h_0)

$$W = \int dw = \int \rho g A h\, dh = \frac{1}{2}\rho g A\left(h^2 - h_0^2\right)$$

$$= \frac{1}{2} \times 1025 \times 9.81 \times 25 \times 10^6 (10^2 - 2^2) = 12.066 \times 10^{12} \text{ Nm or J}$$

2. Average power,

$$P_{average} = \frac{W}{t} = \frac{12.066 \times 10^{12}}{22350} = 539.865 \times 10^6 \text{ W}$$

Also, average power of plant = $\eta_g \times P_{avg}$ = $0.75 \times 539.865 = 404.89$ MW

[t = 6 hour and 12.5 min = $6 \times 3600 + 60 \times 12.5 = 22350$ s]

3. Energy generated (in one filling)

$$E = \frac{0.75 \times 539.865 \times 10^6 \times 3600}{1000} = 1.457 \times 10^9 \text{ kWh}$$

Q.4 A hydrogen-oxygen fuel cell operates at 25°C. Given: ΔH°_{298K} = –296838 kJ/mole, ΔG°_{298K} = – 238291 kJ/mole, and molar mass of hydrogen molecule = 2.016 amu.
Determine:

1. Efficiency of the fuel cell.
2. Electrical work output per 20 gm/s of H_2 consumed.
3. Heat transfer to the surrounding.

Solution:

Given:
$$T = 25°C = 273 + 25 = 298 \text{ K}$$
$$\text{Enthalpy, } \Delta H^\circ_{298k} = -296838 \text{ kJ/kg mole}$$
$$\text{Free energy, } \Delta G^\circ_{298k} = -238291 \text{ kJ/kg mole}$$

Efficiency of fuel cell, η_{FC}:

$$\eta_{FC} = \frac{-\Delta G^\circ}{-\Delta H^\circ} = \frac{-238291}{-296838}$$
$$= 0.80276 \text{ or } 80.276\% \qquad \text{Ans. (i)}$$

Electrical work output per mole of H_2O produced is given as

$$P_{rev} = \frac{\Delta G_{max}}{\text{Molar mass of hydrogen}}$$
$$= \frac{238291}{2.016} \times 10^{-3} \text{ kW} = 118.2 \text{ kW} \qquad \text{Ans. (ii)}$$

Heat transfer to the surroundings, Q:

$$Q = T\Delta S = (\Delta H^\circ)_{298\,K} - (\Delta G^\circ)_{298\,K}$$
$$= -296838 + 238291$$
$$= -58547 \text{ kJ/kg mole} \qquad \text{Ans. (iii)}$$

The –ve sign indicates that heat is transferred from the system to surroundings.

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