Module-4a

Tidal Power

Syllabus

- Tidal Power: Tides and waves as energy suppliers and their mechanics;
- Fundamental characteristics of tidal power,
- Harnessing tidal energy, advantages and limitations.

About Tidal Energy

- Tides are periodic rises and falls of large bodies of water.
- Gravity is one major force that creates tides.
- In 1687, Sir Isaac Newton explained that ocean tides result from the gravitational attraction of the sun and moon on the oceans of the earth.
- Tidal energy is a form of hydropower that converts the energy of the tides into electricity or other useful forms of power.
- The tide is created by the gravitational effect of the sun and the moon on the earth causing cyclical movement of the seas.
- Therefore, tidal energy is an entirely predictable form of renewable energy.
- Tides are produced mainly by the gravitational attraction of the moon and the sun on the water of solid earth and the oceans.
- About 70% of the tide producing force is due to the moon and 30% to the sun. The moon is thus the major factor in the tide formation.
- Surface water is pulled away from the earth on the side facing the moon, and at the same time the solid earth is pulled away from the water on the opposite side. Thus high tides occur in these two areas with low tides at intermediate points.
- As the earth rotates, the position of a given area relative to the moon changes, and so also do the tides. There are thus a periodic succession of high and low tides.
- The difference between high and low water levels is called the range of the tide. The tidal range R is defined as : R = water elevation at high tide—water elevation at low tide.
- Because of the changing positions of the moon and sun relative to the earth, the range varies continuously.

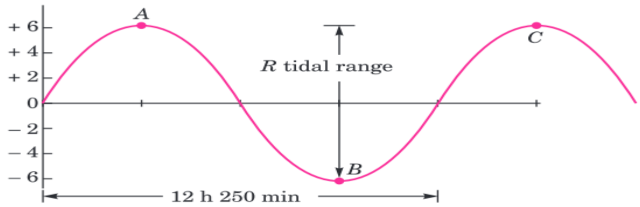
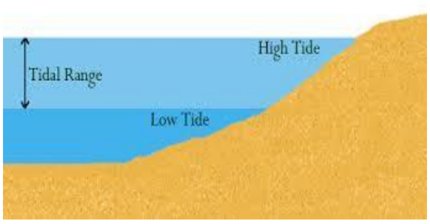


Fig. 9.7. The tides of sea.



General Information

Energy naturally present in ocean water bodies or in their movement can be used for the generation of electricity. This is achieved broadly in the following ways:

1. Tidal energy:

- During the rising period of tides, water is stored in a water reservoir constructed behind dams on shore.
- The potential energy of stored water body is used to generate electrical energy similar to that in a conventional hydropower plant.
- For the tidal energy method to work effectively, the tidal difference (difference in the height of the high and low tides) should be at least 4m.

2. Wave energy:

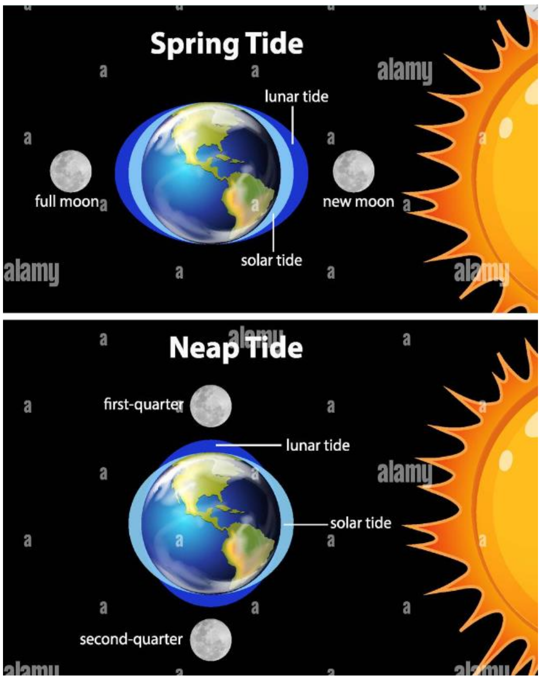
- Using the kinetic (dynamic) energy of the ocean, waves is utilized to rotate an underwater power turbine and generate electricity thereon as an underwater wind farm.

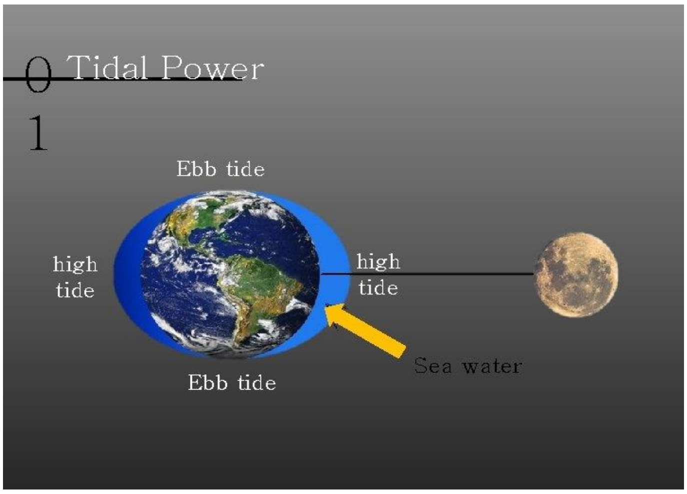
3. Ocean thermal energy:

- The temperature difference between warm ocean surface water and deep sea cold water is used to generate electricity.
- This is similar to geothermal power generation where heat trapped in the earth's surface is converted into electrical energy.

Tidal Energy Resource

- Tides are the waves caused due to the gravitational pull of the moon and also the sun (although its pull is very low).
- The rise of seawater is called high tide and fall in seawater is called low tide and this process of rising and receding of water waves happen twice a day and cause enormous movement of water.
- Thus, enormous rising and falling movement of water is called tidal energy, which is a large source of energy and can be harnessed in many coastal areas of the world.
- Tidal dams are built near shores for this purpose in which water flows during high tide and water flows out of dam during low tides.
- Thus, the head created results in turning the turbine coupled to electrical generator.
- Tidal energy has been developed on a commercial scale among the various forms of energy contained in the oceans.
- When the moon, the earth, and the sun are positioned close to a straight line, the highest tides called **spring tides occur**.
- When the earth, moon, and sun are at right angles to each other (moon quadrature), the lowest tides called **neap tides occur**.





- The water mass moved by the moon’s gravitational pull when moon is very close to ocean and results in dramatic rises of the water level -tide cycle.
- The tide starts receding as the moon continues its travel further over the land, away from the ocean, reducing its gravitational influence on the ocean waters -ebb cycle.

Tides and Waves as Energy Suppliers and their Mechanics

- Tidal power is taken from the Earth's oceanic tides. Tidal forces are periodic variations in gravitational attraction exerted by celestial bodies. These forces create corresponding motions or currents in the world's oceans.
- Due to the strong attraction to the oceans, a bulge in the water level is created, causing a temporary increase in sea level.
- As the Earth rotates, this bulge of ocean water meets the shallow water adjacent to the shoreline and creates a tide. This occurrence takes place in an unfailing manner, due to the consistent pattern of the moon's orbit around the earth.
- The magnitude and character of this motion reflects the changing positions of the Moon and Sun relative to the Earth, the effects of Earth's rotation, and local geography of the seafloor and coastlines.
- The rise of seawater is called high tide and fall in seawater is called low tide and this process of rising and receding of water waves happen twice a day and cause enormous movement of water.
- Thus, enormous rising and falling movement of water is called tidal energy, which is a large source of energy and can be harnessed in many coastal areas of the world.

Fundamental Characteristics of Tidal Power

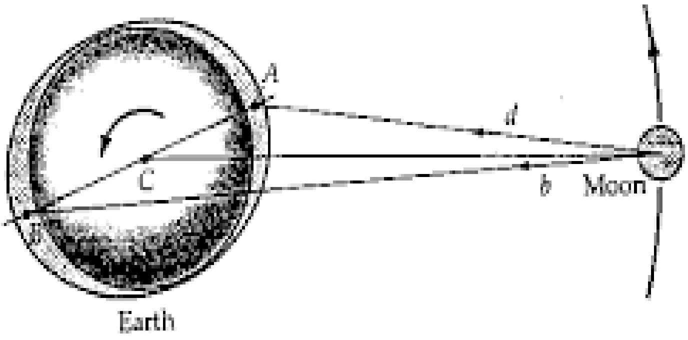
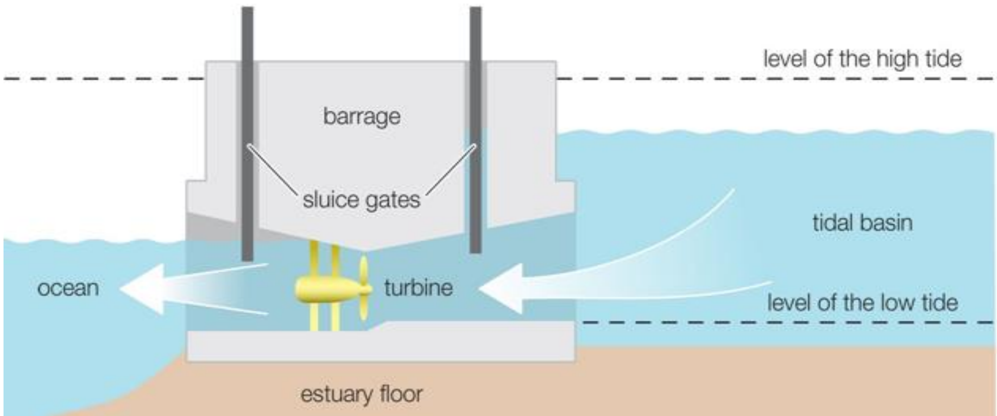


Figure 3–17

Tidal evolution. The Earth's tidal bulges (*A* and *B*) are driven by friction to be ahead of the Moon's orbital position. The friction slows the Earth's rotation, and the bulges accelerate the Moon in its orbit.

- Tidal power or tidal energy is a form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.
- Although not yet widely used, tidal energy has potential for future electricity generation.
- Tidal power is the only technology that draws on energy inherent in the orbital characteristics of the Earth–Moon system, and to a lesser extent in the Earth–Sun system.
- Greater tidal variation and higher tidal current velocities can dramatically increase the potential of a site for tidal electricity generation.
- Tidal power is also relatively prosperous at low speeds, in contrast to wind power.
- Water has one thousand times higher density than air and tidal turbines can generate electricity at speeds as low as 1m/s, or 2.2mph.

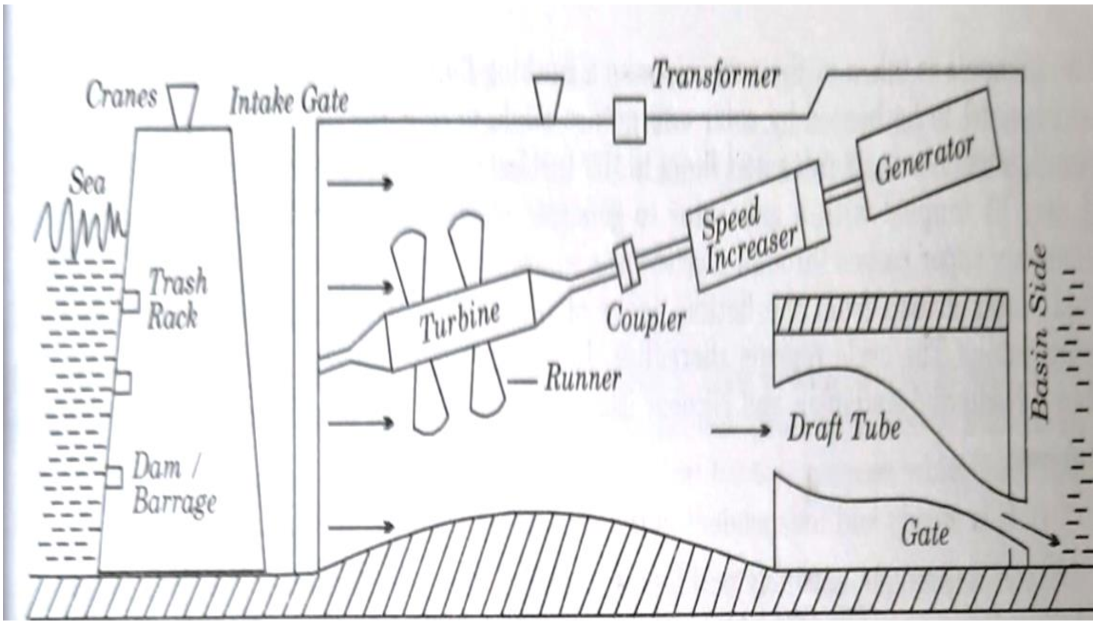
Components of a tidal power plant



1. Dam or barrage: A dam is used to form a barrier between the sea and a basin. It is designed to withstand the force of tidal waves and typically consists of reinforced concrete with channels for turbines. The dam is usually built near the mouth of a large bay.

2. Powerhouse: The powerhouse of a tidal power plant consists of several important components, including turbines, electric generators, and auxiliary components. The design of the power plant may also include provisions for pumping water between the basin and the sea in either direction.
3. Sluice ways: The sluice ways are used to fill the basin with water during high tide and empty it during low tide, as needed.

Harnessing Tidal Energy



- Tidal stream generator
- Tidal barrage
- Dynamic tidal power
- Tidal lagoon

Tidal stream generators:

- Make use of the kinetic energy of moving water to power turbines
- Can be built into the structures of existing bridges or are entirely submersed

Tidal barrage:

- Tidal barrages make use of the potential energy in the difference in height (or hydraulic head) between high and low tides

Dynamic tidal power:

- Dynamic tidal power (or DTP) is a theoretical technology that would exploit an interaction between potential and kinetic energies in tidal flows

Tidal lagoon:

- A new tidal energy design option is to construct circular retaining walls embedded with turbines that can capture the potential energy of tides.

Operation Methods of Utilization of Tidal Energy:

It is of 2 types:

1. Single-basin System
2. Double Basin

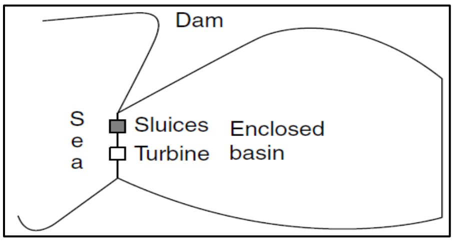
1. Single-basin System

- In a single basin arrangement there is only one basin interacting with the sea.
- The two are separated by a dam (or barrage) and the flow between them is through sluice ways located conveniently along the dam.
- Potential head is provided by rise and fall of tidal water levels, this is usually accomplished by blocking the mouth of a long narrow estuary with a dam across it, thereby creating a reservoir.
- The dam or barrage embodies a number of sluice gates and low head turbine sets.
- The generation of power can be achieved in a single basin arrangement either as a

(a) Single ebb cycle system, or

(b) Single tide cycle system, or

(c) Double cycle system.



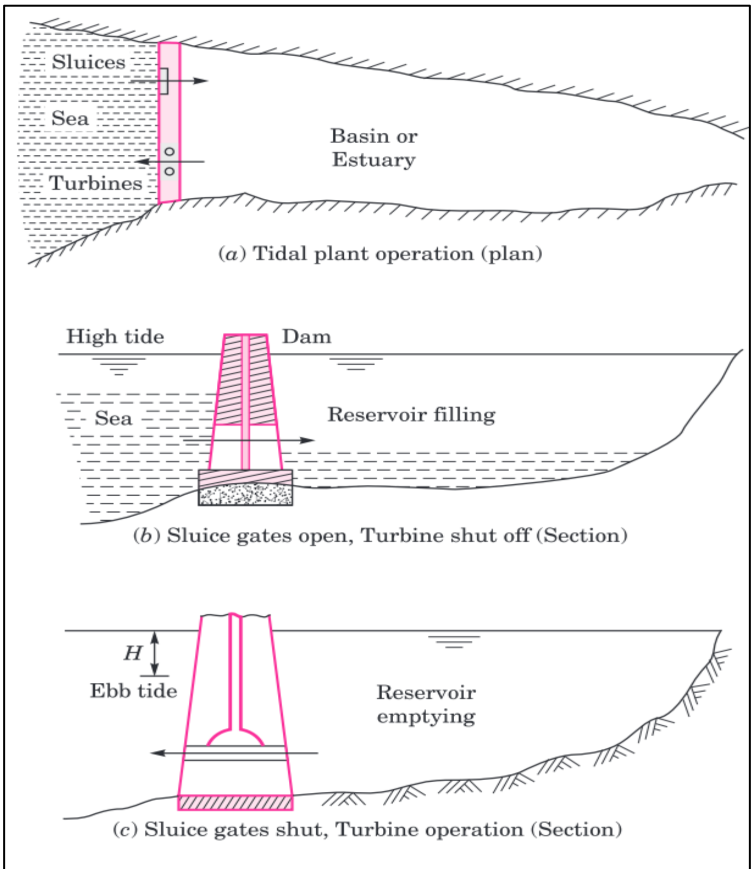


Fig. 9.10. Tidal power plant (single basin operation).

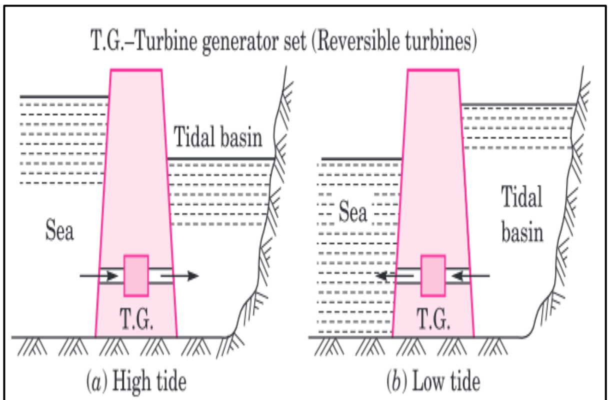


Fig. 9.11. Double cycle system.

i) Single ebb cycle system:

- In single ebb-cycle system, when the high tides (flood side) are falling, sluices are opened to permit the sea water to enter the basin, while the turbine sets are shut.
- The level of the basin begins increasing.
- The energy is stored in the form of tidal range.
- Tidal range provides water head during low tides.
- The generation of power takes place, when the water from the basin flows over the turbine into the low level sea water.
- The turbines are designed for single way operation. The power output from such system is intermittent in nature and highly variable.

ii) Single Tide-Cycle System:

- In single tide cycle system, the generation is affected when the sea is at flood tide. The sea water is admitted into the basin over the turbines. As the flood tide period is over and the sea level begins falling again, the generation is stopped. The basin is drained into the sea through the sluice ways. In this system also the power output is intermittent.

(iii) Double Cycle System:

- In double cycle system, the reversible turbines are installed and power is generated during filling and emptying of basin. Filling process occurs when the ocean is at high tide while the water in basin at low tide level, the emptying occurs when the ocean is at low tide and basin at high tide level.
- The flow of water in both directions is used to drive the reversible turbines. Each turbine drives the generator. In this system also continuous generation of power is not possible because of short duration. Electric power is generated during two short periods, during each tidal period of 12 hours 25 minutes or once every 6 hours and 12.5 minutes.

2. Double basin system

- There are two basins at different levels. A dam is provided between two basins. The turbines are located in the dam. The sluice gates are provided in the dam. One basin is called the upper basin; the water level is maintained above that in the other, the low basin. The high level basin gates are called the inlet gates and low level gates as outlet gates. The upper basin is filled with water.
- When the water level in upper basin A provides a sufficient difference of head between the two basins, the turbines are started. The water flows from basin A to basin B through the turbines and the power is generated. The power generation thus continues simultaneously along with filling up of water in basin A. When the tide attains its peak value, the water level in basin A is maximum; the inlet sluices are

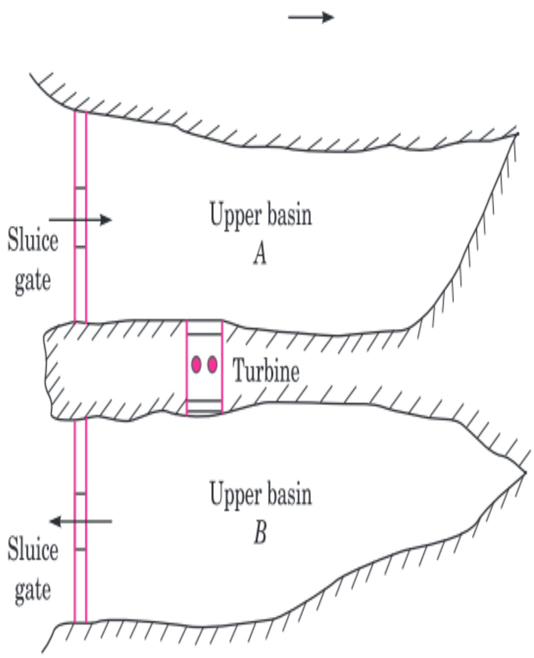


Fig. 9.13. Tidal power plant Double Basin Operation.

then closed. The water flows from the upper basin to the lower basin through the turbines.

- Thus, the water level in the upper basin falls and that in the lower basin rises. When the rising level in lower basin B becomes equal to the level of the falling tide, the outlet sluices are opened. When the tide reaches its lower most level, the outlet gates are closed. After some time the tide rises. When its level becomes equal to low level of the upper basin, the inlet gates are opened. Consequently the level of water in basin A starts rising. Thus, the cycle is repeated.

Advantages of Tidal Power

- About two-third of earth's surface is covered by water, there is scope to generate tidal energy on large scale.
- Techniques to predict the rise and fall of tides as they follow cyclic fashion and prediction of energy availability is well established.
- The energy density of tidal energy is relatively higher than other renewable energy sources.
- Tidal energy is a clean source of energy and does not require much land or other resources as in harnessing energy from other sources.
- It is an inexhaustible source of energy.
- It is an environment friendly energy and does not produce greenhouse effects.
- Efficiency of tidal power generation is far greater when compared to coal, solar, or wind energy. Its efficiency is around 80%.
- Despite the fact that capital investment of construction of tidal power is high, running and maintenance costs are relatively low.
- The life of tidal energy power plant is very long.

Disadvantages of tidal power:

- Capital investment for construction of tidal power plant is high.
- Only a very few ideal locations for construction of plant are available and they too are localized to coastal regions.
- Unpredictable intensity of sea waves can cause damage to power generating units.
- Aquatic life is influenced adversely and can disrupt the migration of fish.
- The energy generated is not much as high and low tides occur only twice a day and continuous energy production is not possible.
- The actual generation is for a short period of time. The tides only happen twice a day so electricity can be produced only for that time, approximately for 12 h and 25 min.
- This technology is still not cost effective and more technological advancements are required to make it commercially viable.

Problems Faced in Exploiting Tidal Energy

- Usually the places where tidal energy is produced are far away from the places where it is consumed. **This transmission is expensive and difficult.**
- **Intermittent supply:** Cost and environmental problems, particularly barrage systems are less attractive than some other forms of renewable energy.
- **Cost:** The disadvantages of using tidal and wave energy must be considered before jumping to conclusion that this renewable, clean resource is the answer to all our problems. The main detriment is the cost of those plants.
- **Altering the ecosystem at the bay:** Damages such as reduced flushing, winter icing, and erosion can change the vegetation of the area and disrupt the balance. Similar to other ocean energies, tidal energy has several prerequisites that make it only available in a small number of regions.

Estimate of Energy and Power in Simple Single Basin Tidal System

During the emptying process, the differential work done by the water is equal to its potential energy at the time. Considering a tidal range R, and inter-mediate head, at a given time, the amount of work is calculated, considering a small head dh, for a inter- mediate head h, as shown in fig.

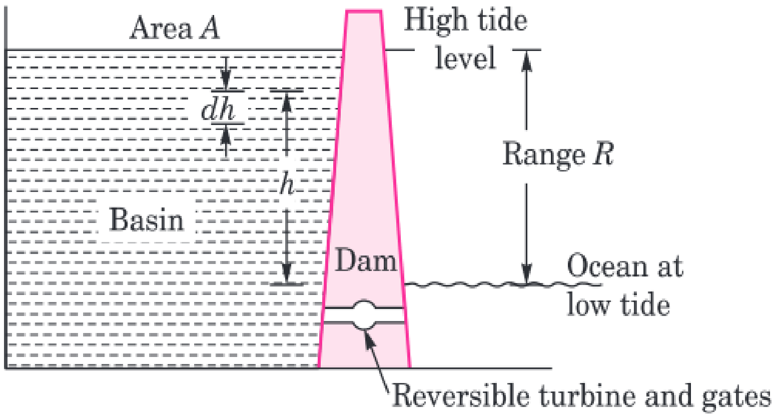


Fig. 9.14. Single Basin Tidal System.

We can write

$$dw = dm.g.h$$

but, $dm = -p.A.dh$

so that $dw = -p.A.dh\, g\, h$

where, W = workdone by water, kcal/kg or Joule.

g = gravitational constant

m = mass flowing through turbine, kg

h = head m

ρ = water density, kg/m^3

A = basin surface area, considered constant m^2

The total theoretical work during a full emptying (or filling) period is obtained by integrating the expression (9.4) *i.e.*

$$W = \int_R^0 dw = -g\,\rho\,A \int_R^0 h\,dh$$

$$= \frac{1}{2} g\,\rho\,A\,R^2 \qquad \text{...(9.5)}$$

The work is proportional to square of the tidal range.

The power is the rate of doing work.

The power is generated during emptying (or filling) and no power is generated during rest of the time. The *average theoretical power delivered* by the water is W divided by the total time it takes each period to repeat itself. Duration is 6*h*, 12.5 minutes as shown in Fig. 9.10. (6*h*, 12.5 minutes = 22,350 seconds).

Thus average theoretical power in watts:

$$\text{Pav.} = \frac{W}{\text{time}} = \frac{g\,\rho\,A\,R^2}{2 \times 22350} = \frac{1}{44{,}700} g\,\rho\,A\,R^2 \qquad \text{...(9.6)}$$

Assuming an average sea water density = 1025 kg/m^3, the average power per unit basin area is given by

$$\frac{\text{Pav.}}{A} = \frac{1}{44{,}700} \times 9.80 \times 1025\,R^2$$

Pav=0.255R^2 watts/m^2 (MW/km^2)