University of Sallahadin
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Distributed Generation

Chapter Eight

Tidal Energy

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Definition

- Tidal energy is a form of renewable energy 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 movement of the seas.

Tidal Energy

- Tidal energy utilizes the twice-daily variation in sea level (between low and high) caused primarily by the gravitational effect of the Moon and, to a lesser extent the Sun on the world's oceans.
- The Earth's rotation is also a factor in the production of tides.

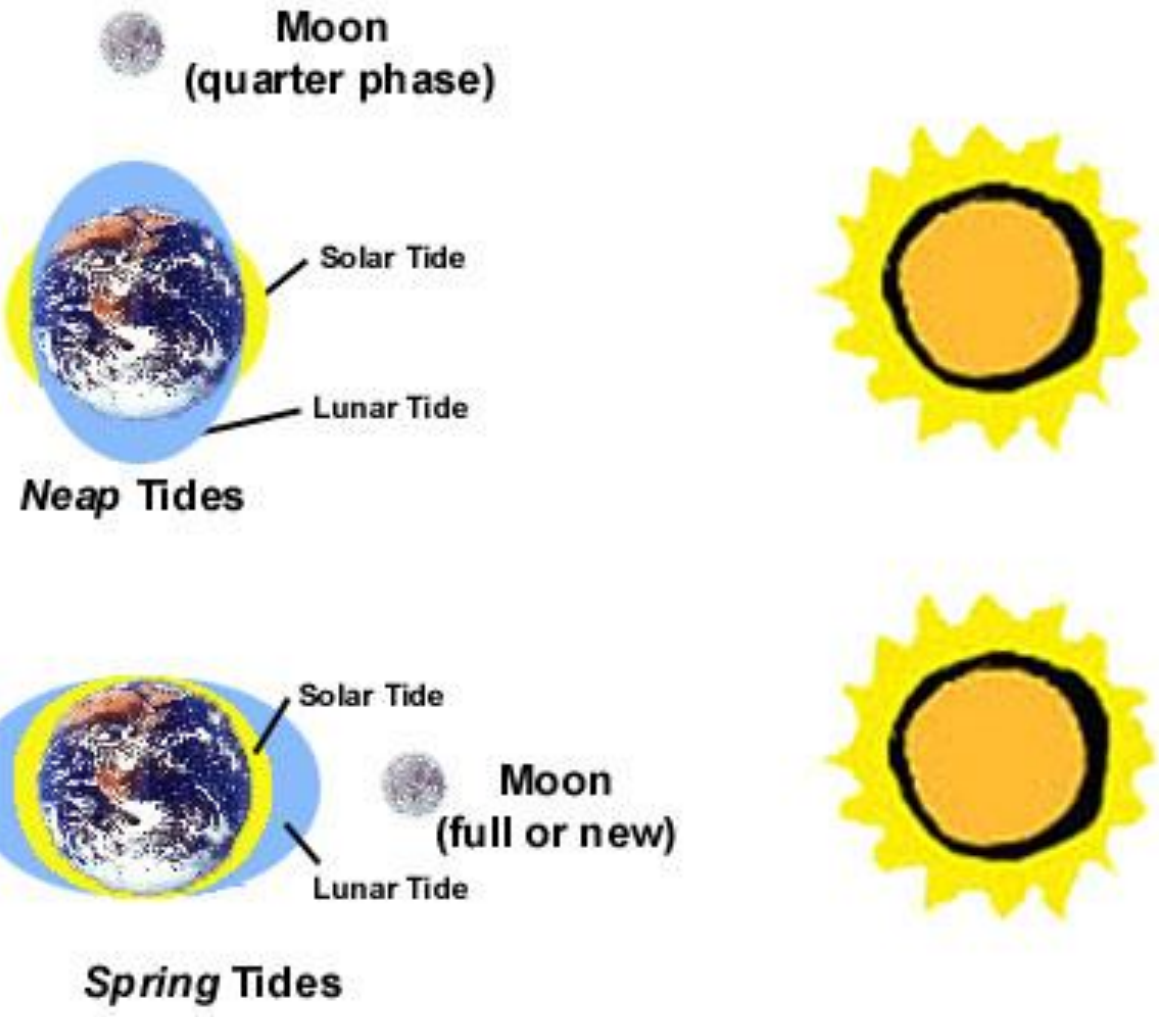
Tidal Energy

- The interaction of the Moon and the Earth results in the oceans bulging out towards the Moon (**Lunar Tide**).
- The sun's gravitational field pulls as well (**Solar Tide**).
- As the Sun and Moon are not in fixed positions in the celestial sphere, but change position with respect to each other, their influence on the tidal range (between low and high tide).

Tidal Energy

- If the Moon and the Sun are in the same plane as the Earth, the tidal range is the superposition of the range due to the lunar and solar tides. This results in the maximum tidal range and called **Spring Tides**.
- If they are at right angles to each other, lower tidal differences are experienced resulting in **Neap Tides**.

Spring and Neap Tides



High and Low Tides

High tide

Low tide

History of Tidal

- Tidal energy is one of the oldest forms of energy used.
- Dating back to 787 A.D., tide mills were constructed, consisting of a storage pond and a sluice (gate that controls water flow).
- In the early 1960's, the first commercial scale tidal power plant was built in France, consisting of twenty four 10MW turbines.

Producing Electricity from Tides

- The generation of electricity from tides is very similar to hydroelectric generation, except that water is able to flow in both directions and this must be taken into account in the development of the generators.

- Two types of tidal energy can be extracted:

1. Kinetic energy of currents between ebb and flood tides.
2. Potential energy from the difference in height (or head) between high and low tides.

Producing Electricity from Tides

- The potential energy contained in a volume of water is:

$$E = \frac{1}{2} A \rho g h^2$$

h is the vertical tidal range in meter (High tide – Low tide).

A is the horizontal area of the barrage basin.

ρ is the density of water = 1025 kg/m^3

(Seawater varies between 1021 and 1030 kg/m^3)

g is the acceleration due to the Earth's gravity = 9.81 m/s^2 .

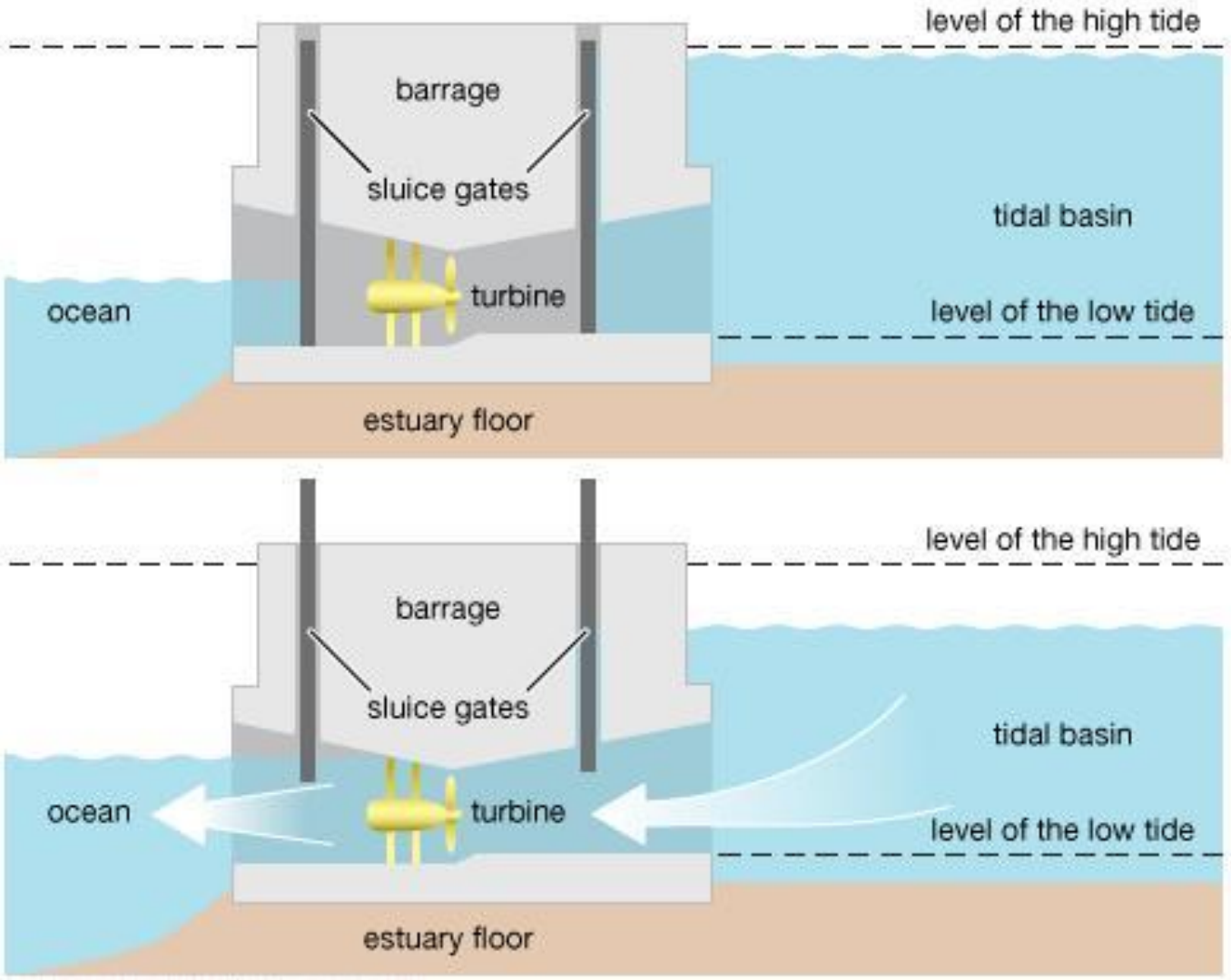
Producing Electricity from Tides

- The simplest generating system for tidal plants, known as an ebb generating system, involves a dam, known as a barrage across an estuary.
- Sluice gates on the barrage allow the tidal basin to fill on the incoming high tides (**known as the flood tide**) and to exit through the turbine system on the outgoing tide (**known as the ebb tide**).
- Alternatively, flood-generating systems, which generate power from the incoming tide are possible, but are less favored than ebb generating systems.

Ebb Generation

- The basin is filled through the sluices & freewheeling turbines until high tide. Then the sluice gates & turbine gates are closed.
- They are kept closed until the sea level falls to create sufficient head across the barrage and the turbines generate until the head is again low.
- Then the sluices are opened, turbines disconnected and the basin is filled again. The cycle repeats itself.
- Ebb generation (also known as outflow generation) takes its name because generation occurs as the tide ebbs.

Ebb Generation



Tidal Turbine Types

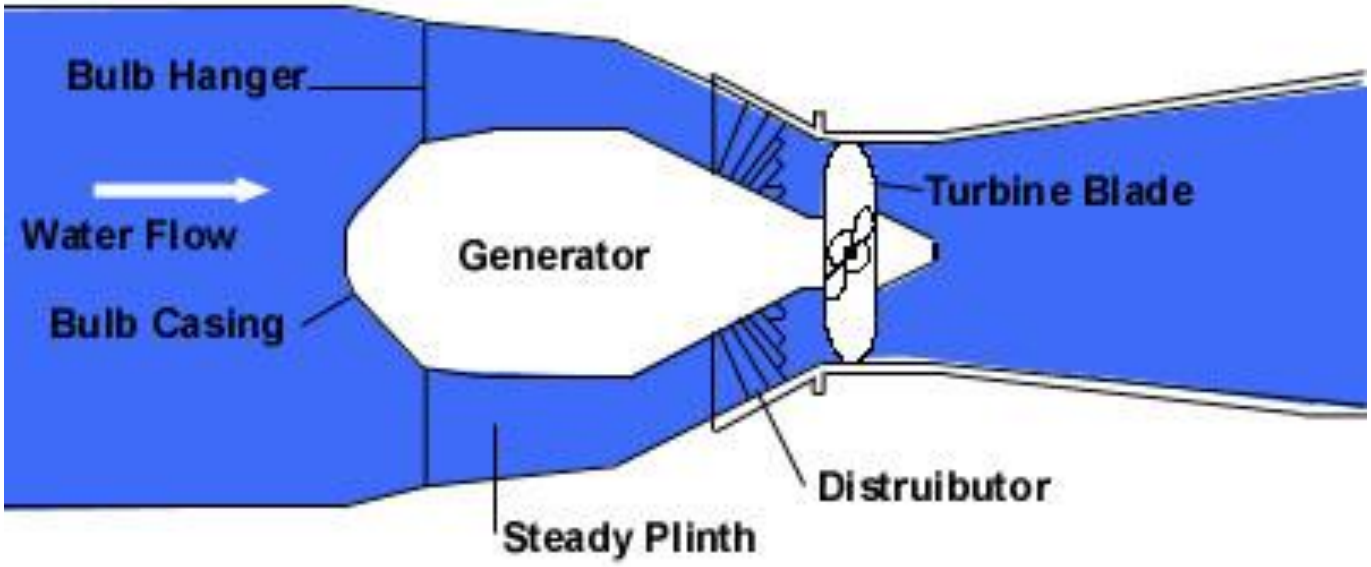
- Main types of Tidal Turbines are:

1. Bulb turbine
2. Rim turbine
3. Tubular turbine

Tidal Turbine Types

Bulb turbine

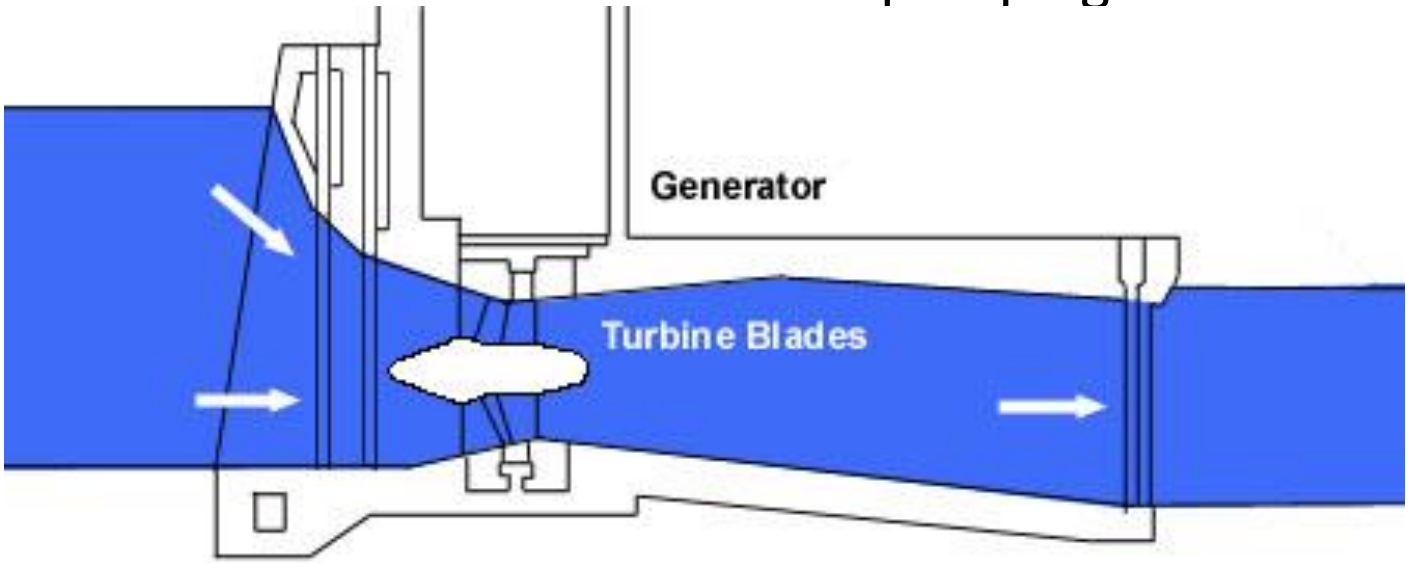
- In systems with a bulb turbine, water flows around the turbine, making access for maintenance difficult, as the water must be prevented from flowing past the turbine.



Tidal Turbine Types

Rim turbine

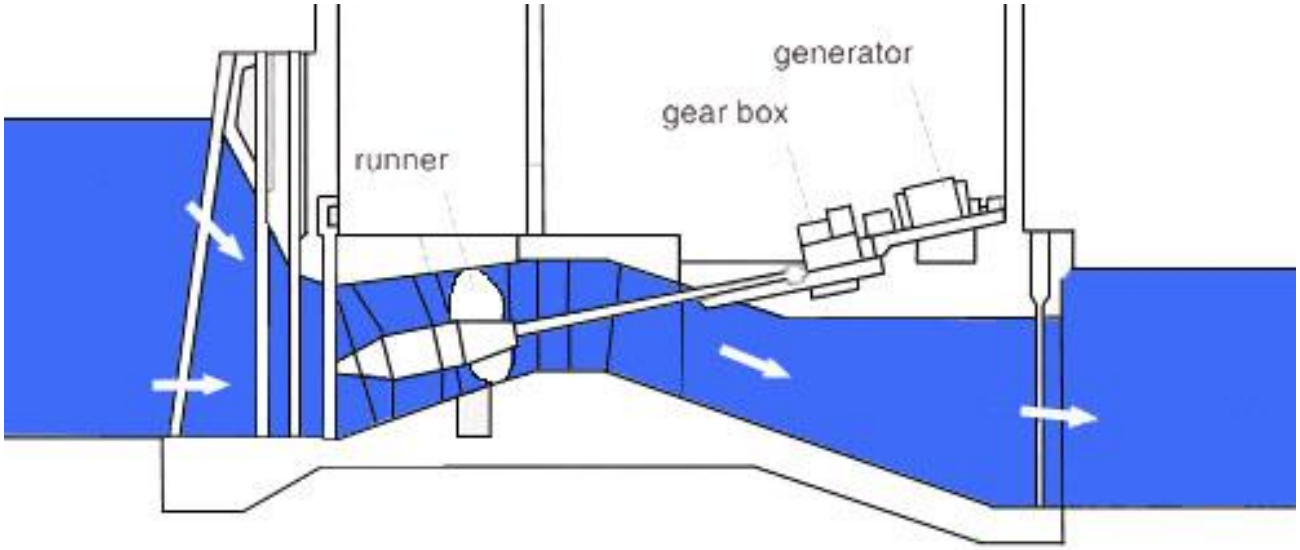
- Rim turbines reduce these problems as the generator is mounted in the barrage, at right angles to the turbine blades. Unfortunately, it is difficult to regulate the performance of these turbines and it is unsuitable for use in pumping.



Tidal Turbine Types

Tubular turbine

- In tubular turbines the blades are connected to a long shaft and orientated at an angle so that the generator is sitting on top of the barrage.



Different Generation Technologies

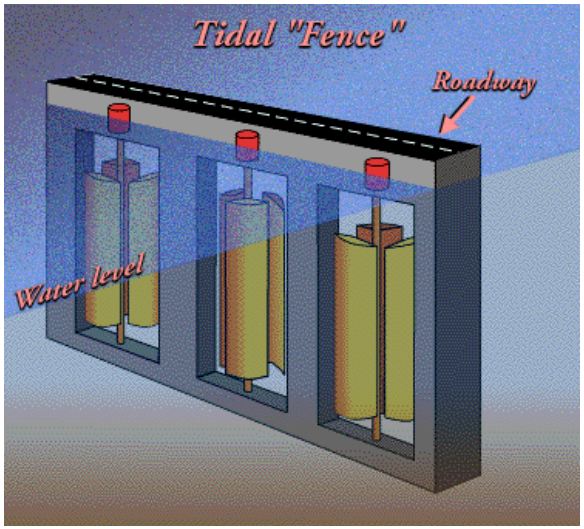
- Main technologies of tidal power generations are:

1. Tidal Fences.
2. Tidal Lagoons.
3. Tidal Turbines.

Different Generation Technologies

Tidal Fences

- Tidal fences are composed of individual, vertical axis turbines which are mounted within the fence structure, known as a caisson.
- Kind of like giant turn styles which completely block a channel, forcing all of the water through them.



Different Generation Technologies

Tidal Fences

- Unlike barrage tidal power stations, tidal fences can also be used in unconfined basins, such as in the channel between the mainland and a nearby off shore island, or between two islands.
- Since they do not require flooding of the basin, tidal fences have much less impact on the environment, and are significantly cheaper to install.

Different Generation Technologies

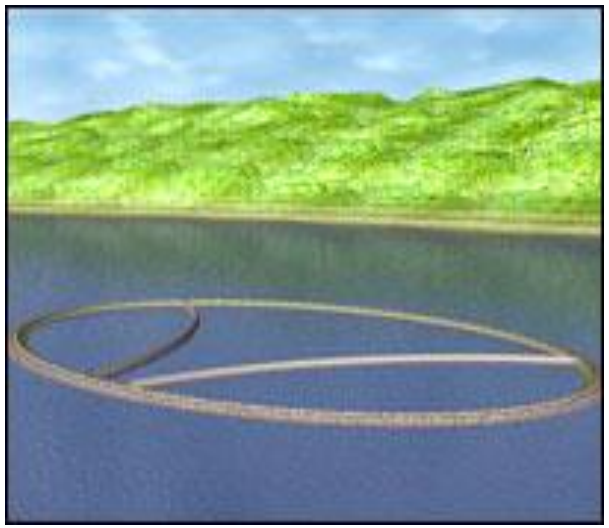
Tidal Fences

- Unlike barrage generators, tidal fences have the advantage of being able to generate electricity once the initial modules are installed.
- Since a caisson structure is still required, which can disrupt the movement of large marine animals and shipping, there are still ecological concerns.

Different Generation Technologies

Tidal Lagoons

- Tidal lagoons are an adaptation of the barrage system. Similar to standard barrage models, tidal lagoons retain a head pond and generate power via conventional hydro-turbines.
- The difference is that the conventional barrage designs exploit the natural coast line to minimize barrage length.



Different Generation Technologies

Tidal Lagoons

- However, this entails blocking the estuary regardless of how deep it is. This raise the costs considerably.
- However, a lagoon, for a low cost can pretty much be built anywhere that there is a high tidal range.
- The lagoon has relatively little visual impact, as it is below the high water tide mark and appears like a normal sea wall at low tide.

Different Generation Technologies

Tidal Lagoons

- The lagoon can be built using loose aggregates found in quarries or demolished structures. This rubble would be 'dumped' until an impound wall was complete. As any aggregate can be used, it is possible to restrict construction costs by implementing the cheapest materials available.
- This construction technique also has the added benefit of creating an artificial reef. As well, a calm water lake would be created in the middle where smaller fish and birds could grow.

Different Generation Technologies

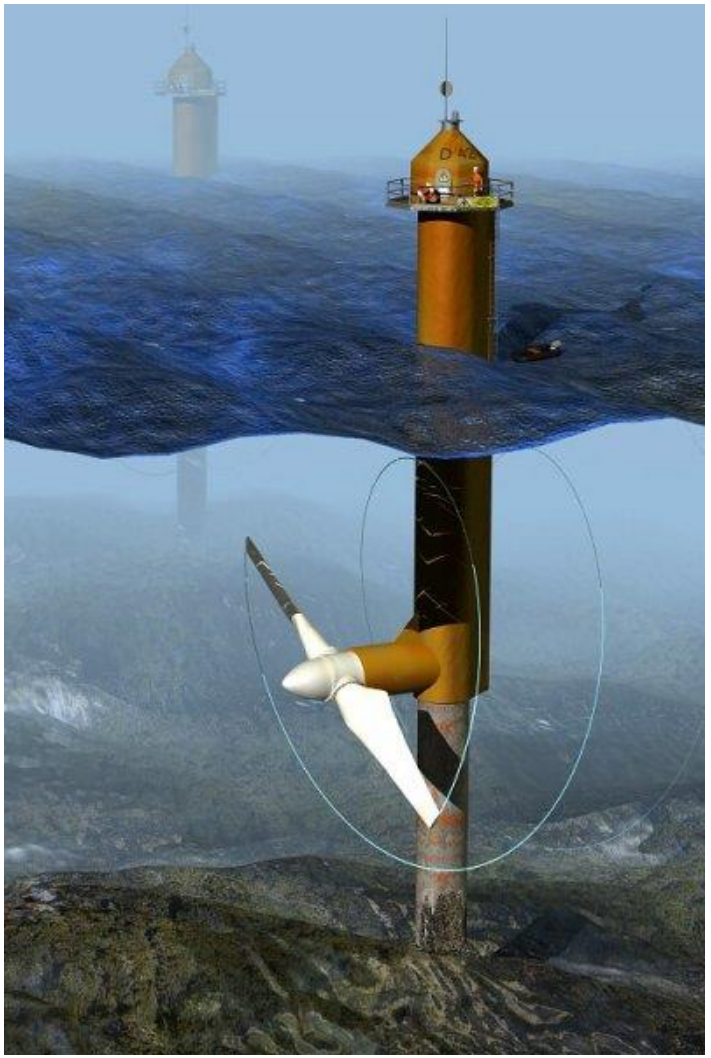
Tidal Lagoons

- Tidal Electric is planning to test the concept in Swansea Bay with a relatively small 30MW output plant.
- French tidal power plant is the largest tidal power project in the world with a capacity of the 240 MW.

Different Generation Technologies

Tidal Turbines

- Proposed shortly after the oil crisis of the 1970s, tidal turbines have only become reality in the last decade.
- Resembling a wind turbine, tidal turbines offer significant advantages over barrage and fence tidal systems, including reduced environmental effects.



Different Generation Technologies

Tidal Turbines

- Tidal turbines utilize tidal currents that are moving with velocities of between 2 and 3 m/s to generate between 4 and 13 kW/m^2.
- Fast moving current (>3 m/s) can cause undue stress on the blades in a similar way that very strong gale force winds can damage traditional wind turbine generators, whilst lower velocities are uneconomic.

Different Generation Technologies

Tidal Turbines

- Tidal turbines offer significant advantages over barrage and fence tidal systems:

1. High energy intensity.
2. Minimal environmental impact.
3. High energy return on energy invested.

Different Generation Technologies

Tidal Turbines

1. High energy intensity:

A 1MW tidal turbine can access five to ten times as much energy per square meter of rotor than a 1MW wind turbine, resulting in a smaller and potentially lower cost machine.

Different Generation Technologies

Tidal Turbines

2. Minimal environmental impact:

tidal turbines are visible enough to be avoided by mariners but they have a low visual impact on the seascape, they produce no pollution or noise and their slow moving rotors which turn at less than one revolution in four seconds (15 rpm) are considered unlikely to harm marine life.

Different Generation Technologies

Tidal Turbines

3. High energy return on energy invested.

Tidal turbines should offer faster energy payback than most other renewables.

Different Generation Technologies

Future Expansion of Tidal Turbines

- Tidal Farms. Sets of up to hundreds of tidal turbines working in conjunction.
- Potential for giga-watts of power
- Marine Current Turbine created SeaGen (1MW), which expanded to a 5 turbine tidal farm that will provide 5MW.

Advantages

1. No pollution.
2. Renewable resource.
3. More efficient than wind because of the density of water.
4. Predictable source of energy vs. wind and solar.
5. Does not affect wildlife

Disadvantages

1. Expensive to build and maintain
2. Not easy to connect to the grid.
3. Technology is not fully developed.
4. Barrage style only produces energy for about 10 hours a day.
5. Barrage style has environmental effects such as fish and plant migration.

Tidal Energy Calculations

The tidal range of tide at a particular place is 10 m and the surface of the tidal energy harnessing plant is 9 km^2. Knowing the density of sea water is 1025.18 kg/m^3 and the power conversion efficiency is 30%. Find:

1. Mass of the sea water
2. Potential energy content of the water in the basin at high tide.
3. The total energy potential per day
4. The mean power generation potential per day
5. The daily-average power generated

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- Twidell John & Weir Tony, " **Renewable Energy Resources**", 2nd edition, 2006.
- REN 21, "**Renewables 2015 Global Status Report**", 2015

Next Lecture

- Wave Energy

Questions and Thank you