1.11 TIDAL POWER PLANTS

Tidal power is generated by capturing the energy of tides caused by the gravitational pull of the moon and sun on the world's oceans. The effect of the moon is about twice that of the sun due to its much closer position to the earth. As a result, the tide closely follows the moon during its rotation around the earth, causing the movement of a huge amount of water twice daily. Tidal energy is one of the most abundant clean forms of renewable energy with no greenhouse gas or other pollutions. There are basically two methods of extracting energy from tidal flows:

- Extracting the potential energy of tides moving in vertical direction, known as *tidal energy systems*.

- Extracting the kinetic energy of tidal motion in the horizontal direction, known as *tidal stream systems* or *tidal wave systems*.

1.11.1 TIDAL ENERGY SYSTEMS

In this system a barrage (a type of dam) is built across a river estuary in order to make use of the relative differences in the height of water between high tides and low tides, as shown in Figure 1.18.

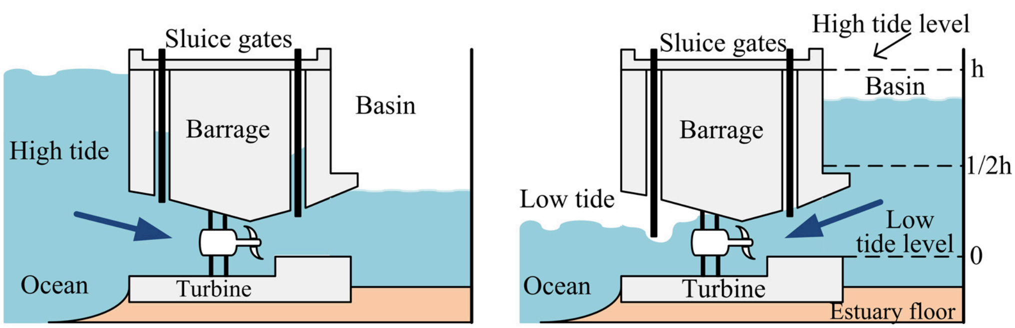

FIGURE 1.18
Simplified diagram of a tidal barrage.

Sluice gates on the barrage are opened to allow the reservoir behind the dam to be filled during the high tide. During the low tide, the gates are closed and the water behind the dam is released through the turbine, just as in a regular hydroelectric power plant. The turbine turns the generator to produce electricity. An alternative method is a two-way generation scheme which generates power during both incoming and outgoing tides. The amount of energy generated from a tidal barrage is determined by the difference in height between a high tide and a low tide, namely the tidal range. The mass of water moving through the tidal range is the volume times the water density ρ, that is,

$$m = \rho A h \tag{1.12}$$

where A is the area of the tidal basin in m^2, and h is the range in m.

As water exits the bay, the level of the reservoir decreases; therefore, the height of the center of gravity is $\frac{1}{2}h$, so the released energy is $mg(\frac{1}{2}h) = \frac{1}{2}\rho g A h^2$. Hence the average tidal power in Watts is

$$P = \frac{\rho g A h^2}{2T} \tag{1.13}$$

where
T = time interval between tides or tidal period, which is approximately 12 hours, 25 minutes
g = 9.81 m/s^2
ρ = density of seawater $\approx$ 1025 kg/m^3

Taking into account the blade capacity factor or power coefficient C_p, turbine efficiency η_t, and the generator efficiency η_g, the net power output is

$$P_o = \eta_g \eta_t C_p \frac{\rho g A h^2}{2T} \quad \text{W} \tag{1.14}$$

For systems designed to generate power during both incoming and outgoing tides, the potential energy of (1.14) is doubled. The total average tidal power for a plant using both tidal directions is

$$P_{o(2)} = \eta_g \eta_t C_p \frac{\rho g A h^2}{T} \quad \text{W} \tag{1.15}$$

The blade capacity factor or power coefficient is in the range of 20 - 35 percent.

The first large-scale tidal barrage power plant in the world was built in 1966 at La Rance in France. It generates 240 MW, using 24 low-head Kaplan turbines, with an annual production of 600 GWh, powering approximately 240,000 homes. Only two other tidal barrage plants operate worldwide, a 24MW plant on the Bay of Fundy in Nova Scotia, Canada, and a 0.5 MW plant in Kislaya Guba, Russia. A tidal power plant under construction in Ansan, South Korea, utilizes the seawater at high tide when it comes to Sihwa artificial lake, made by a tide embankment. The plant will be equipped with 10 turbine generators for a total capacity of 254 MW. Also, South Korea plans to build the world's largest tidal power station, 812 MW, on Ganghwa Island by the year 2014. As of 2009, a plan to build a large-scale tidal barrage across the river from Brean Down in England to Cardiff in Wales is under consideration.

Example 1.4

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1.11.2 TIDAL WAVE SYSTEMS

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Example 1.5

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