DESALINATION USING TIDAL ENERGY

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Contents

Summary

Tidal energy, when available, can supply energy for fresh water production. The present analysis includes the possible desalination techniques that can be implemented in association with tidal power. Expressions for the tidal power developed basically in terms of the tide basin area and tide range are shown. Typical tidal power plant components are illustrated as required to operate in conjunction with desalination equipment especially with an expected tidal plant. Economic life is about two- to three-fold of that of other known power plants.

Reverse osmosis, vapor compression, electrodialysis and freezing-melting are the most suitable desalination candidates that are investigated to be associated with tidal energy. For each of these systems, energy transfer studies through the combined system enable the prediction of the tidal power-distilled water production at the expected operating conditions and illustrated through different nomograms. An economic comparison is also shown with respect to wind and solar energy sources. It is shown that tidal power is expected to be competitive only for huge fresh water production rates.

1. Introduction

Tidal energy has potential usage in many desalination technologies. An overview of tides, as natural phenomena, is undertaken. Possible power generation capabilities of tides are shown. Implementation of desalination technologies, such as Vapor Compression (VC), Reverse Osmosis (RO), Electrodialysis (ED), and Freezing-Melting (FM) are possible in association with tidal energy. Brief performance characteristic governing equations for such tidal-desalination system are shown.

2. Tides

The tidal phenomenon can be simply shown as the periodic motion of the waters of the sea, caused by celestial bodies, principally the moon and the sun, upon different parts of the rotating earth.

In its rise and fall, a periodic horizontal movement of the water called tidal current accompanies the tide. Because of the greater proximity of the moon, tides on earth follow the lunar cycle, and their amplitude varies according to the relative position of the earth, the moon and the sun. Amplitude or tidal range is the difference between the level of high and low tides.

The periodic rise and fall of the sea surface is referred to as the astronomical tide, because winds, earthquakes, and other forces coming from the land can produce long waves similar to tides resulting in periodic changes in the sea level. However, they are not due to the same causes as the astronomical tide. In the Mediterranean, tides were first studied as far back as the fourth century.

Three main forces are responsible for high and low tides. They are the gravitational pull from the sun and the moon and the rotational force of the earth. The rate of rise and fall of the tides is not uniform. This is because the size and shape of the ocean basin and the interference of land masses prevent the tides of the ocean from assuming a simple regular pattern. The range or amplitude of tide is the difference in level between consecutive high and low tides. The range of tides is affected by many factors such as the intensity of forces producing tides and basin configuration. Each ocean is made up of a number of oscillating basins.

Accordingly, their response to daily, diurnal or semi-diurnal forces varies. Along the ocean coasts, tides can assume significant amounts, however, they are quite weak in the middle. The tidal crest height varies considerably from one place to another. Fall and rise of tides are due mainly to the moon's gravitational attraction. A tidal day can be defined as the interval between two upper transits of the moon over the meridian of a geographical site. It takes 24 h and 50 min or 24.84 solar hours.

2.1. Spring and Neap Tides

Spring tide occurs when the sun, the moon, and the earth are aligned resulting in the maximum effect. However, minimum effect occurs when the angle between the three bodies is near 90.

The Coriolis and other geostrophic forces, and the basin morphology influence the tidal wave. Open ocean tides have amplitude of about 50 cm, but coastal tides can often exceed several meters. In general, tidal currents are appreciable in relatively shallow water near continents, however, they are rather weak elsewhere. The total estimated earth's potential waterpower is about 3×10^9 kW.

Tidal amplifications in some basins result in increase of head usable for power generation.

It is speculated that much of the 13 000 MW of the world's tidal energy resources can be exploited where estuaries and embayments have a sufficient tidal range. Moreover it is shown that the world tidal energy could produce a total of 350 TWh (Charlier 1982).

The maximum tidal energy that can be utilized can be expressed as:

$$E = n\rho gAR \qquad (1)$$

where, n number of effects, $n = 1/2$ for single effect and 1 for double effect, ρ is water density, A is the basin area, and R is the tide range. However, the total annual energy in kWh that can be generated in a single basin with double effect unit can be expressed as [1]:

$$E = 0.017\, R^2\, A, \text{kWh y}^{-1} \qquad (2)$$

With a tidal cycle of semi-diurnal tide being 12.4 h, the average power generated (P) can be expressed as:

$$P = 6\times \rho \times g \times A \times R^2 \qquad (3)$$

However, only about 30 per cent of this power can be retrieved.

For preliminary performance analysis of tidal desalination, the following relation for tidal power generation can be used as:

$$P_{tide} = 0.67 \times A \times R^2$$

where P_{tide} is the generation power in MW, A is the basin area in km and R is the tidal range in m.

3. Tidal Power Plants

Figure 1 shows typical tidal power plant works of the following main components:

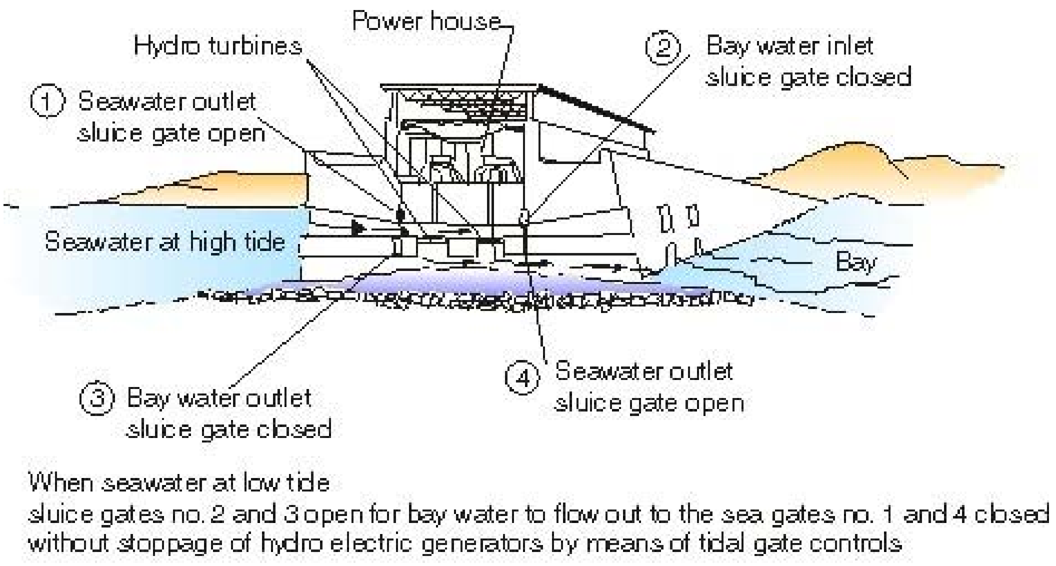

Figure 1. Typical tidal power plant components.

3.1. Barrage

The main function is to resist waves of severe shocks and where pressure changes sides continuously. The barrage needs to provide channels for the turbines in reinforced concrete. Construction of the barrage will have an impact on the tidal amplitude and resonance of the bay.

3.2. Locks and Gates

Tidal power basins must be filled and emptied. Accordingly, gates are opened regularly and frequently, but heads vary in height and on the side where they occur. Gates structures can be floated as modular units into place.

3.3. Power House

Large size turbines are needed since only small heads are available. Accordingly, power house is also a large structure. Bulb type turbines, as axial flow turbines, are used in French and Soviet operating plants. Other types are, inclined shaft turbines, rim type turbines, or straight flow turbines are also considered as promising power generating units.

3.4. Basins

In basins the water is retained. Basins may be coastal indentations, embayments, bodies of water between islands and continents, or estuaries. The tidal power scheme can be a single or a multiple basin project. Single basin plants are currently the most economical, typically shown in Figure 2. However, most projects envision the use of two basins. Generation can take place in one direction only, or in both, and pumped storage may be included in the operation.

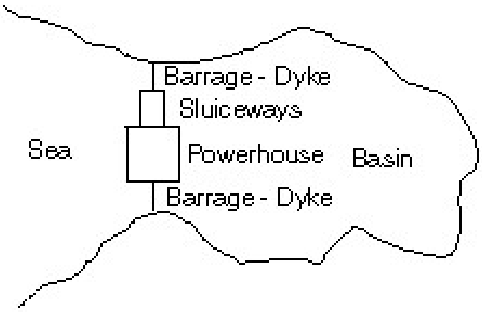

Figure 2. A single tidal basin scheme.

3.5. Storage

In tidal power generation plants, many of the components required are of a pumped storage scheme. For tidal power being produced in "mechanical form", only batteries, compressed air, and a hydraulic storage can be considered. A flywheel could be used when its technology is advanced.

3.6. Economical Considerations

The tidal economic life of the scheme is in the range, 75-100 years compared to 35 years for conventional thermal plants, 25 years for nuclear power plants, and 50 years for hydroelectric scheme. Though initial capital and early years of operation are relatively high for tidal plants, a break even plateau is reached at the time a nuclear plant of the same age has already had to be replaced and a fossil fuel plant is due for total replacement.

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