

WAVE POWERED WATER DESALINATION IN EGYPT

A.S. Bayoumi¹, A. Incecik², H. El Gamal³ and K. Shalash⁴

¹ Mechanical Engineering Department, Arab Academy for Science, Technology, & Maritime Transport, Egypt, E-mail: seif_bayoumi@aast.edu

² Naval Architecture and Marine Engineering Department, University of Strathclyde, UK, E-mail: atilla.incecik@strath.ac.uk

³ Mechanical Engineering Department, Alexandria University, Egypt, E-mail: haelgamal@yahoo.com

⁴ Mechanical Engineering Department, Arab Academy for Science, Technology, & Maritime Transport, Egypt, E-mail: karim_shalash@hotmail.com

ABSTRACT

Egypt energy consumption is estimated to increase extensively over the next decades and almost all available conventional water resources have been exhausted. The traditional methods of electricity production are leading to serious environmental and economical complications, while the vast urban expansion, mainly along the coastal areas to relieve the population pressure from the old valley and delta, requires the abundance of energy and potable water resources.

Egypt comprises around 3000 kilometers of sea coasts with different environmental conditions. In order to establish wave energy program in Egypt, the wave energy along the Egyptian coasts should be estimated.

This paper aims to estimate the wave energy potential at specific site. For this purpose MATLAB was used to obtain Pierson-Moskowitz spectrum to estimate the proper wave energy density distribution at this site, and to define moments to describe the intensity of the wave-field. From these spectral moments many of the time series characteristics have been calculated. Consequently the wave power per unit width of wave crest has been estimated.

Keywords: Egypt, Water Desalination, Wave Energy

1. INTRODUCTION

Egypt has already exhausted its fixed Nile water share, and the groundwater requires expensive energy to abstract more and costs to transport. The allocation of the total water resources among agriculture, industry and domestic uses are within the ratio of 85%, 9% and 6% respectively. The criteria proposed by [1] for the selection of areas for water desalination are the presence of a source of saline water, the abundance of renewable energy, the suitability of soil for agricultural activities, the accessibility to marketing locations, and the potential for several development fields (industrial,

economic, touristic, agricultural, etc.). The most prominent areas to be selected for research and development are along the Red Sea coast, along the northwest Mediterranean Sea coast where several touristic, agricultural and new community potentials exist (see Fig. 1).

Wave energy may provide Egypt with an alternative energy source for electricity production and water desalination, due to vast urban expansion, mainly along the coastal areas, and the on-going developments in remote areas to relieve the population pressure from the old valley and delta, and to create new community opportunities in new regions.

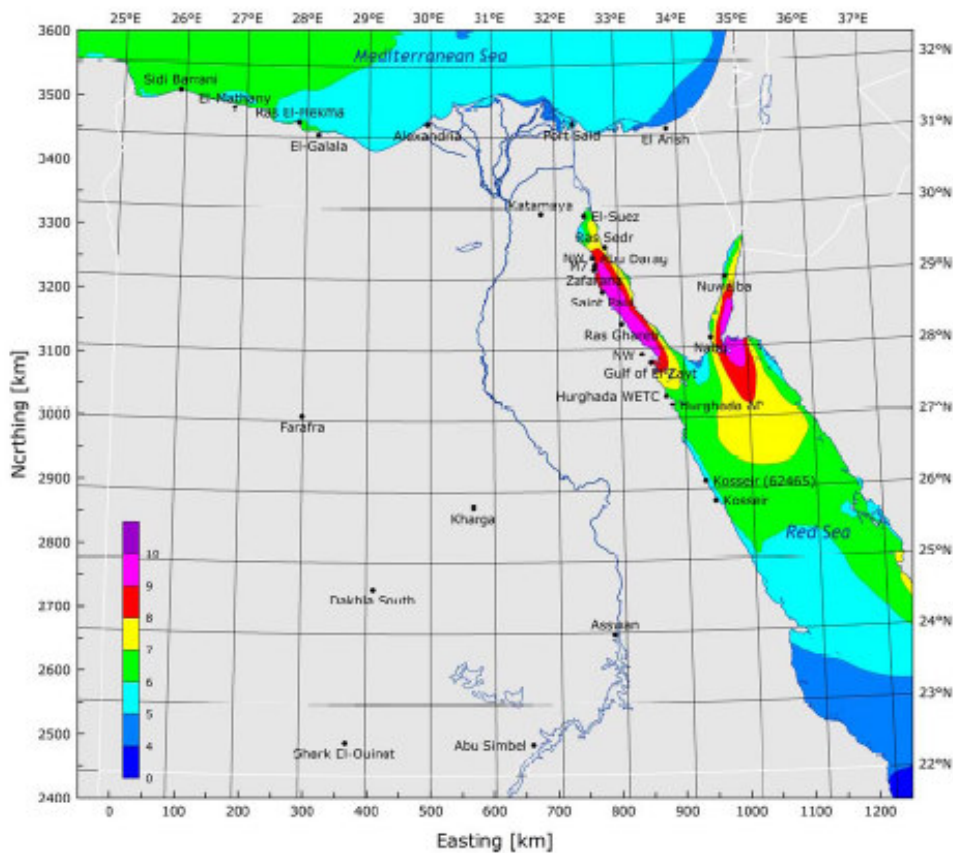


Fig. 1 Offshore wind resource map of Egypt: mean wind speed at 50 m a.g.l. determined by mesoscale modeling (*Wind Atlas for Egypt, 2006*).

An important feature of sea waves is their high energy density, which is the highest among the renewable energy sources [2] with low to medium environmental impact. In the Mediterranean Sea, the average annual wave energy may reach 275 MWh/m [3]. For this purpose, several research programs with government and private support started mainly in Portugal, Spain, France, Greece ...etc. aiming to harness the wave energy in medium and long term.

2. WAVE-POWERED WATER DESALINATION

2.1 Categorization of Wave Powered Desalination Plants (WPDP)

The categorization of the wave powered desalination plant (WPDP) depends strongly on the type of the wave energy converter used. A literature survey revealed six concepts previously or currently under investigation. Five of these have been developed to the point of an experimental model and only one has been fully implemented. The concepts of WPDP can be categorized according to six types of WEC and two types of desalination technology: reverse osmosis (RO) and vapor compression (VC) [4].

2.2 Wave Powered Desalination Technologies

The first reported technology was the DELBUOY, which used oscillating buoys (Fig. 2) to drive pistons pumps anchored to the seabed [5,6]. These pumps fed seawater to submerged RO modules.

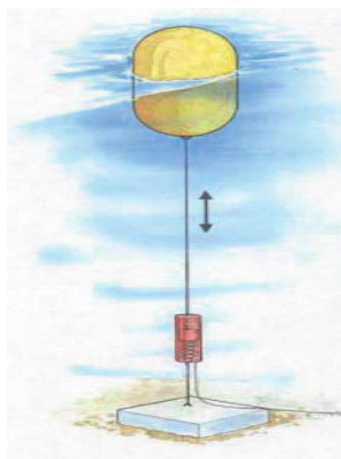


Fig. 2 Point absorber

The second technology reviewed is based on the Salter duck shown in Fig. 3. Salter later proposed a version of the duck for desalination, in which vapor compression equipment is actually housed inside the floating duck [7,8]. Rocking motion will give rise to changes in water level inside the hull of the duck, generating pressures sufficient to drive evaporation and condensation across a falling-film heat exchanger.

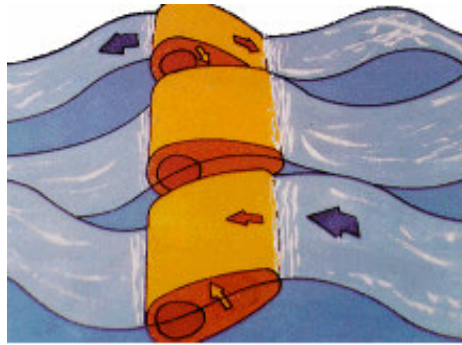


Fig. 3 Slater Duck

The third technology reviewed is the McCabe Wave Pump presented in Fig. 4, consisting of a three-section hinged barge [9,10]. The two oscillating arms of the floating barge are attached symmetrically to a central section, which is inhibited from pitching by an under slung inertial damping plate. Large forces are therefore developed between the arms and the centre section. These forces are harnessed by means of pistons, pumping seawater for feeding RO units.

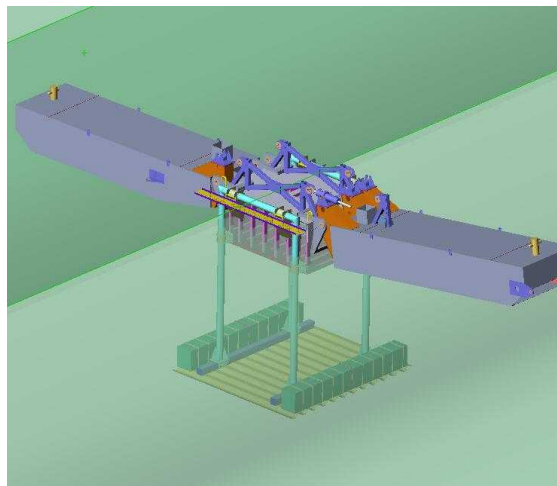


Fig. 4 McCabe Wave Pump

The fourth technology is the OWC device (Fig. 5) installed at Vizhinjam in India. The wave power captured is converted to single-phase electricity and used to drive a RO unit.

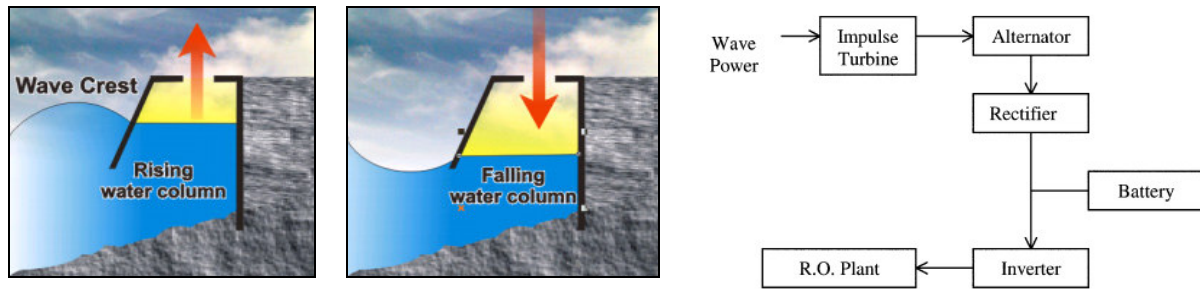


Fig. 5 Scheme for OWC wave powered desalination plant

The fifth concept reviewed is the proposal of Sawyer and Maratos [11] to use a tapered channel similar to the TAPCHAN device shown in Fig. 6, or parabolic focusing device to induce flow of seawater within a pipe. They propose to use the water hammer effect to generate large intermittent pressures, by means of a valve that opens and shuts at the end of the pipe. Theoretically it is feasible to use the water hammer effect to develop pressures sufficient to drive RO. The technology is very similar to the hydro-ram widely used to lift irrigation water from rivers.

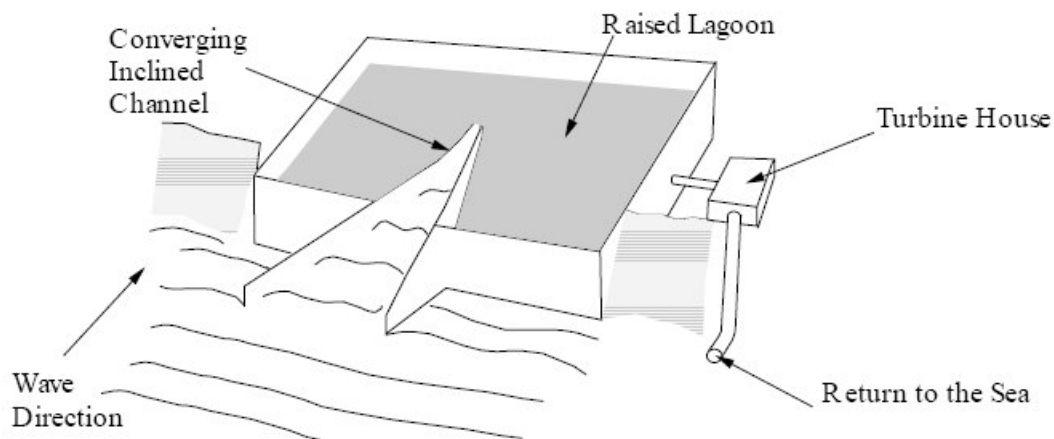


Fig. 6 TAPCHAN device

Finally, a relatively new concept that could be applied to desalination is the Wave-jet, a device resembling the prow of ship [12]. It concentrates waves and it can tolerate a certain tidal range. Wave action causes water to be ejected from the prow and the intention is to collect this water in a high-level reservoir. The Wavejet can therefore raise substantial quantities of seawater to a head of a few meters. For the purpose of desalination, it is intended to supply this seawater to a pressure intensifier device, supplying a smaller quantity of seawater at sufficient pressure to run a reverse osmosis unit [13].

3. QUANTIFYING THE WAVE ENERGY AT SIDI BARRANI

3.1 Methodology and Availability of Data

In order to quantify the wave energy at Sidi Barrani region within 32-31° N latitudes and 25-27° W longitudes (Fig. 1), weather data at this region have been collected. By the use of MATLAB code Pierson-Moskowitz spectrum has been performed to estimate the proper wave energy density distribution at these sites. To describe the intensity of the wave-field, it is useful to define moments. Since moments are defined slightly differently in wave analysis than for turbulent flows. From these spectral moments many of the time series characteristics have been calculated. Consequently the wave power per unit width of wave crest has been estimated.

The seasonal weather data (seasonal mean wind speed) used are referred to Meteorology, Synoptic Charts & Weather Routing course provided by The Arab Academy for Science, Technology, and Maritime Transport (AASTMT).

3.2 Data Reduction

Pierson-Moskowitz spectra:

$$S(\omega) = \frac{\alpha g^2}{\omega^5} \exp\left[-\beta \left(\frac{g}{U\omega}\right)^4\right] \quad (1)$$

where $\omega = 2\pi f$, f is the wave frequency in Hertz, $\alpha = 8.1 \cdot 10^{-3}$, $\beta = 0.74$, g is the gravitational acceleration and U is the wind speed in m/s.

n^{th} spectral moment:

$$m_n = \int_0^{\infty} \omega^n s(\omega) d\omega \quad (2)$$

Significant Wave Height:

$$H_{1/3} = 4\sqrt{m_0} \quad (3)$$

Average Wave Height:

$$H_{av} = \sqrt{2m_0} \quad (4)$$

Observed average period in an irregular sea state:

$$T = 2\pi \frac{m_0}{m_1} \quad (5)$$

Average period between successive crests:

$$T_p = 2\pi \sqrt{\frac{m_2}{m_4}} \quad (6)$$

Average period between successive zero up-crossing:

$$T_z = 2\pi \sqrt{\frac{m_0}{m_2}} \quad (7)$$

Energy period:

$$T_e = 1.12 T_z \quad (8)$$

Power per unit width of wavefront:

$$P' = 0.5 H_{1/3}^2 T_e \quad (9)$$

4. RESULTS AND DISCUSSIONS

Graphical representation of Pierson-Moskowitz spectrum which represents the distribution of wave energy as a function of frequency is illustrated in Fig. 7.

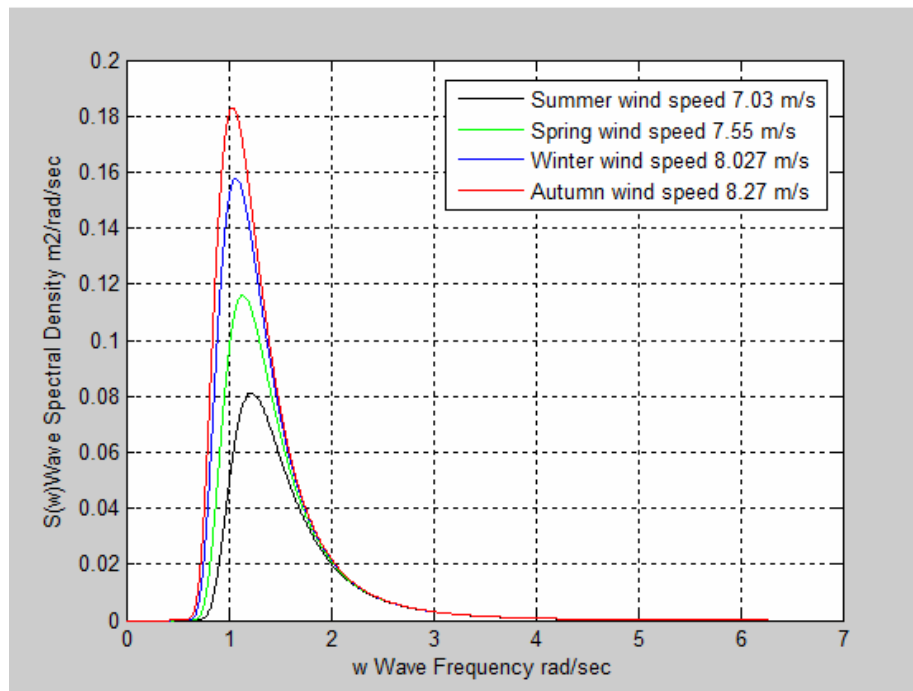


Fig. 7 Wave spectra of a fully developed sea for seasonal wind speeds according to Pierson-Moskowitz

Table 1 represents time series characteristic results such as significant wave height H_s , peak period T_p , zero up-crossing period T_z , energy period and the power per unit width of wavefront P' according to different wind speeds U during each season.

Table 1 Values of U , H_s , T_p , T_z , T_e and P' for the 4 seasons at Sidi-Barrani

Season	U (m/s)	H_s (m)	T_p (s)	T_z (s)	T_e (s)	P' (kW/m)
Spring	8.27	1.4587	1.48315	4.2924	4.8075	5.1147
Summer	7.55	1.2158	1.3555	3.9193	4.3896	3.2443
Autumn	7.03	1.0541	1.2687	3.6488	4.0867	2.2704
Winter	8.0275	1.3744	1.4354	4.1667	4.6667	4.4076

5. CONCLUSIONS

The increase in the Egyptian population and the shortage of the conventional fossil energy resources directed the Egyptian researchers to study the feasibility of extraction useful energy from renewable energy resources such as the sun and the wind.

The wave power per meter width in the Mediterranean Sea at Sidi-Barrani varies from 2-5 kW/m throughout the year. This amount of power maybe converted into useful amount of energy that can be used in the desalination of seawater. This process will help in the provision of electricity and/or fresh water from renewable energies.

In order to create a technological and industrial foundation for making use of wave energy in Egypt, a detailed assessment of wave energy resources along the Egyptian coasts should be performed. Many complications may appear during the preliminary phase, but considering the long term benefits, this should be acceptable.

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