Frontiers in Power and Energy Systems (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/fpes.2023.020102
ISSN 2516-2926 Vol. 2 Num. 1

# *Research Progress on Desalination Technology Based on Ocean Energy*

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***Keywords:*** Ocean energy, Desalination, Reverse Osmosi

***Abstract:*** The shortage of fresh water resources has become a hot topic of concern for mankind, and the demand for fresh water is not only reflected in residential drinking, but the demand for fresh water in other areas is also increasing. Desalination technology is currently an effective way of reducing the burden on fresh water, which accounts for only 3% of the total water system. And conventional energy sources are being depleted at an alarming rate, creating a need to encourage the use of non-conventional energy sources, which are inexhaustible, environmentally friendly and help to reduce carbon emissions, and which can address the energy shortage in developing countries and countries with abundant renewable energy sources but lacking clean water. This paper provides an overview of desalination technologies for various renewable marine energy sources, such as solar, wind, wave and tidal energy, analyses the dilemmas faced by desalination of various marine energy sources, and gives recommendations based on the current state of development.

## 1. Introduction

According to statistics, the total area of the earth's oceans is about 360 million square kilometres, accounting for about 71% of the earth's surface area, with an average water depth of about 3,795 metres. The oceans contain more than 1.35 billion cubic kilometres of water, accounting for about 97% of the Earth's total water volume, while only 3% of fresh water can be used for human consumption. Therefore, it has become a trend for humans to exploit resources in the ocean. Desalination as a supplement to water shortage has largely solved the problem of water shortage. Desalination requires energy, and marine energy, as a renewable energy source of concern and development in the 21st century, includes tidal energy, tidal current energy, wave energy, temperature difference energy, salt difference energy, wind energy over the ocean, solar energy on the surface of the ocean and marine biomass energy, etc. Ocean energy resources are widely distributed, highly exploitable and can be used locally. This not only reduces the use of non-renewable resources and alleviates the freshwater crisis, but also avoids pollution of the environment and follows the development trend of green energy.

## 2. Traditional Desalination Methods

The current methods of desalination mainly include physical and chemical methods. Among them, physical methods include thermal methods, solvent extraction methods, membrane methods, thermal methods include multi-stage flash distillation, multi-effect distillation, etc., membrane methods mainly include reverse osmosis, electrodialysis method; chemical methods include ion exchange methods, etc. The current desalination technologies applied on a large scale in industry are distillation, reverse osmosis and freezing methods.

### 2.1. Distillation

The distillation method is divided into multi-effect distillation technology and multi-stage flash technology. Seawater contains many kinds of solutes, itself for the desalination of seawater is the use of solvent and solute evaporation temperature difference, to achieve the separation of solutes and solvent purification. As the evaporation temperature of water is relatively low, fresh water can be separated from seawater by distillation and condensed to obtain fresh water for the purpose of desalination. As shown in Figure 1, the distillation method desalination device, distillation method desalination device output fresh water salt content in general in about 5mg / L water production, which means that the distillation method can not separate completely separate water and inorganic salts, that is to say, the distillation method to get the water is still salty; in addition, the distillation method will also appear a lot of scaling and corrosion of the container and other problems, so has not been widely used.

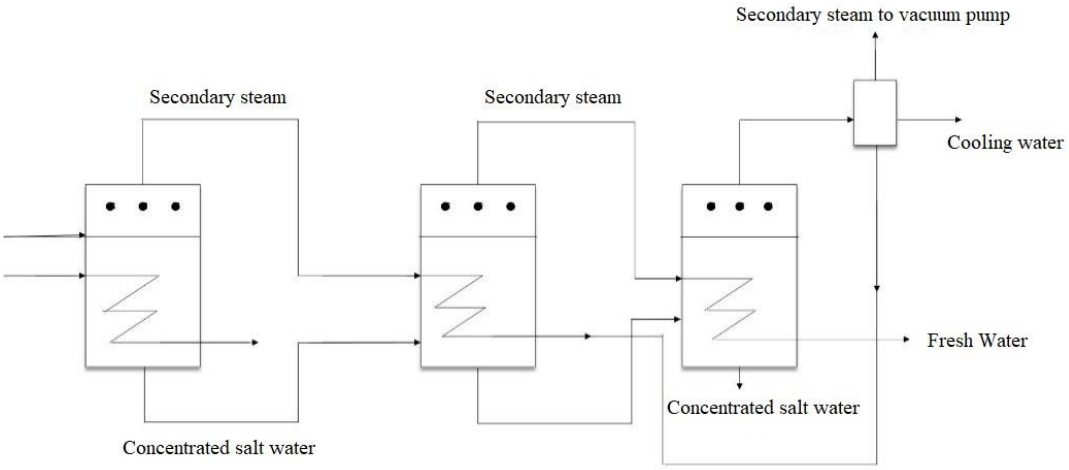


Figure 1: Flow Chart of Distillation Desalination.

### 2.2. Reverse Osmosis(RO)

The flow diagram of the reverse osmosis method is shown in Figure 2. The principle is that a semi-permeable membrane separates the fresh water from the seawater, allowing no solute to pass through, but only the solvent. In general, fresh water diffuses through the semi-permeable membrane from one side of the seawater and stops flowing when the water level on the other side of the seawater gradually rises to a certain height. Applying external pressure on the seawater side above the osmotic pressure of the seawater reduces the solvent in the seawater (pure water). The energy consumption of reverse osmosis is only 1/40th of that of distillation and 1/2 of that of electrodialysis. Energy saving is one of the main advantages of reverse osmosis.

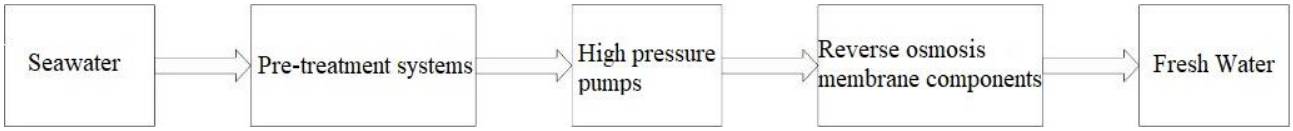


Figure 2: Flow chart of reverse osmosis method.

### 2.3. Freezing

The principle of the freezing method is to cool down a salt solution in a certain concentration range to the freezing point to precipitate water ice crystals, remove the ice crystals and then clean the surface and the seawater adhering to them in the interstices with fresh water, and then melt it to obtain fresh water. The freezing method is economically and technically advantageous for both large and medium desalination plants. However, the fresh water obtained by the freezing method contains impurities that cannot be used directly and can produce large amounts of heavy metal salts, causing environmental pollution.

At present, there are two main desalination technologies: reverse osmosis membrane method (membrane method) and low-temperature multi-effect distillation method (thermal method). Among them, the reverse osmosis method with reverse osmosis membrane is rapidly occupying the market with its advantages of simple equipment, easy maintenance and modular equipment, gradually replacing the distillation method as the most widely used method. In the installed capacity of desalination that has been built, the reverse osmosis method accounts for the highest proportion, 67%; distillation method accounts for 27%. Although the freezing method has a number of technical and economic advantages, its application is not very widespread.In summary, traditional desalination methods consume non-renewable resources on the one hand and pollute the environment on the other. Therefore, it is important to develop new energy sources and use them for desalination.

## 3. Marine Energy Desalination Methods

Ocean energy desalination is the coupling of ocean energy use with desalination methods, so that ocean energy is fully or partially responsible for the energy needed to desalinate seawater. The biggest advantage of ocean energy desalination over traditional desalination methods is that both energy and seawater come from the sea, which allows the efficiency of the whole system to be increased. The characteristics of the various types of ocean energy are shown in Table 1:

Table 1: Characteristics of ocean energy.

| Types of energy | Causes of formation | Energy level | Stability |
|---|---|---|---|
| Wind Energy | Air movement | Proportional to the cube of the wind speed and the area through which the wind flows | More stable |
| Solar | The energy produced by the continuous fusion of black sons inside or on the surface of the Sun. | Proportional to sunlight intensity and heated area | Very stable as long as there is sufficient sunlight |
| Wave Energy | Generated by the force of the wind on the sea surface | Proportional to the 2.5th power of the wave height and the | Periodic variation of randomness in the range 1 to 10s |

| | | | |
|---|---|---|---|
| | | area of the fluctuating water surface | |
| Tidal energy | Generated by the gravitational forces of the Sun and the Moon on the surface of the Earth | Proportional to the square of the tide and the flow | Tides and currents vary in semi-diurnal and semi-monthly cycles with a high degree of regularity |
| Temperature difference energy | Differential absorption of solar radiation by the surface and deeper layers of the ocean, and ocean circulation heat transport | Proportional to the amount of warm water and temperature difference in sea areas with sufficient temperature difference | Very stable |
| Tidal Energy | Changes in the Moon's gravity | Proportional to the cube of the flow rate | Very stable |

### 3.1. Desalination from Wind Energy

There are two methods of wind desalination, one is to convert it into electrical energy, which then drives the desalination unit, and the other is to convert it into mechanical energy, which then drives the desalination unit.

Using wind turbines to generate electricity and then drive high pressure pumps for reverse osmosis treatment, this approach is well established with the wind power seawater system on the island of Utsira in Norway and the reverse osmosis desalination unit at the Canary Institute of Technology; using wind power to generate electricity and MVC units are the 48 and 480 tonne per day MVC desalination units built on Rugen Island in Germany[1]; using the mechanical energy output from wind turbines to drive reverse osmosis desalination, the problem with this method is that reverse osmosis requires a stable power source and wind power is unstable.

### 3.2. Solar Desalination

There are two ways of solar desalination, one makes solar energy into thermal energy, which makes seawater desalination by phase change, and the other is solar energy into electrical energy, which drives a reverse osmosis unit.

Solar energy is converted into electrical energy, which is first stored in a battery and then driven by electrical energy in a reverse osmosis plant. This method is currently used in the reverse osmosis desalination plant in Mexico and the solar-powered reverse osmosis desalination plant in Kuwait. Distillation methods combined with solar energy include, in addition to the common method, MED (low temperature multi-effect distillation) and MSF (multi-stage flash distillation), and there are desalination plants of this type in many coastal areas[2].

### 3.3. Wave Energy Desalination

Wave energy is the kinetic and potential energy possessed by waves on the surface of the ocean[3]. Wave energy is currently used mainly for power generation, and there has been relatively little research into its application to desalination. Wave energy desalination systems have three main components: an energy absorption device, an energy conversion device and a desalination device. At present, wave energy conversion devices that can be applied to wave energy desalination are mainly oscillating float type, nodding duck type, oscillating water column type, water wave pump

type and water hammer pump type etc[4].Sharmila et al. designed a fully automated controlled wave energy generation reverse osmosis seawater system, coupling the oscillating water column type wave energy harvesting device with reverse osmosis technology. This system is able to save energy when the waves are large and release energy when the waves are small, and it can also maintain a stable water output from the system through a diesel engine, solving the problem of unstable water output[5].Folley et al. equipped the wave energy reverse osmosis seawater desalination equipment with a pressure conversion amplifier to achieve energy recycling[6]. Li Gang et al conducted design and performance experiments on sealed hydraulic cylinders applied with wave energy respectively[7].

Wave energy has the advantages of being renewable, non-polluting, large storage capacity and all-weather. In the research on wave energy desalination, there is also less research on the theoretical basis and numerical simulation of wave energy desalination. So far, there is still no wave energy desalination device with good operation effect and low water production cost, which is also a reason why wave energy desalination is slow to be commercialized. Whether considering from the total amount of wave energy or density distribution, wave energy desalination is worthy of research and promotion, and wave energy desalination is still a hot spot for future research.

### 3.4. Tidal Energy Desalination

Tidal energy is the difference in water potential energy formed by the constant cyclical changes in ocean water levels due to the gravitational force of the sun and moon, and the centrifugal force generated by the rotation of the earth-moon system consisting of the earth and moon, both acting together[8].The technology of tidal energy utilization has matured, but there are few studies on tidal energy desalination. Liu Yefeng et al. proposed tidal energy solar multi-effect distillation desalination, which can save a lot of energy by using tidal energy as the power source[9-10]. Ling Changming used tidal energy to concentrate and boost pressure, directly generating high-pressure seawater for RO membranes for desalination, the system's increased energy use efficiency by a quarter and reduced desalination costs by more than two yuan per ton compared to traditional methods[11]. Chen used tidal energy to drive a vacuum pump to achieve desalination of seawater in an evaporation tower[12].9

Many countries around the world have tidal energy power stations of different scales, but there is little research on desalination using tidal energy. Using tidal energy as a single energy source for desalination is difficult to convert the kinetic and potential energy of tidal energy into thermal energy, and if the proven tidal energy technology can be coupled with desalination, it is possible to achieve large-scale desalination.

### 3.5. Desalination from Ocean Temperature Difference Energy

Ocean thermal energy is harnessed by using warm seawater stored at the surface of the ocean to generate steam and drive a turbine, and by pumping cold seawater from the deep ocean to condense the finished steam. The US, Japan and China have all carried out more research into the use of ocean thermal energy for power generation[13]. Rey et al. designed a thermal energy conversion and distillation device using ocean temperature differential energy to desalinate seawater for the first time[14]. Al-Kharabsheh et al. used solar and temperature differential energy for desalination, reducing energy consumption by designing to maintain atmospheric and water pressure equilibrium[15].

Ocean temperature difference is independent of daytime and seasonal influences compared to other ocean energy. However, the cold seawater required for ocean thermal energy utilisation

systems often needs to be obtained from 500 to 1000 m deep[16]. This significantly increases the investment and maintenance costs, thus also limiting their commercial development.

### 3.6. Tidal Energy Desalination

Tidal energy is a relatively rapidly developing form of marine energy in recent years. Tidal energy is developed using the characteristics of fluid kinetic energy[17], so tidal energy capture systems use a structure similar to that of wind turbines. Current research in tidal energy includes the windmill tidal energy turbine from SMD in the UK, which can generate 1MW of electricity at an operating speed of 2.3m/s. A semi-submersible tidal energy generator for Evopod has been developed by Ocean Currents Energy in the UK[18] and is currently undergoing 1:4 model tests. Open Hydro in Ireland has developed a hollow turbine[19] with a simple construction and a direct-drive generator that does not require an additional variable speed mechanism. A pedestal-type three-blade tidal energy device developed by Hammerfest Storm in Norway , which has an automatic convection function and does not change the environment on the seabed when the turbine is moved. The "Wanxiang Ⅰ", "Wanxiang Ⅱ", "Hai Neng Ⅰ", "Hai Neng Ⅱ" developed by Harbin Engineering University "" Sea Energy II "" and other tidal energy devices, promoting the development of the field of tidal energy, is undoubtedly a new milestone in the history of tidal energy development.

Currently tidal energy is mostly developed for power generation, while research in desalination is limited to patented designs. Desalination from tidal energy is combined in a similar way to tidal energy and wave energy and can be divided into direct and indirect types. Of these, less research has been carried out on the direct use of tidal energy desalination. Compared to other ocean energy sources, tidal energy is smoother and more regular and has the greatest potential for large-scale commercialisation of tidal desalination if ocean energy development techniques are applied to desalination.

### 3.7. Coupling Methods for Ocean Energy Desalination Technologies

The common ways in which various types of ocean energy and desalination technologies are coupled are shown in Table 2.

Table 2: Common ways of coupling ocean energy with desalination.

| Types of energy | Multi-stage flash | Multi-effect distillation | Reverse Osmosis |
|---|---|---|---|
| Wave Energy | | | √ |
| Tidal energy | | √ | √ |
| Temperature difference energy | √ | | |
| Tidal Energy | | | √ |

## 4. Issues and Recommendations

Desalination from ocean energy has a very broad application prospect as it solves the water problem and is environmentally friendly. However, the development of ocean desalination is still at the stage of theoretical or small-scale experimental research. The main reasons for this are:

1) Ocean desalination has not received enough attention. Research on ocean energy is mainly focused on power generation, but there is very little research on the application of ocean energy to desalination.

2) Difficulties in the use of ocean energy. As the energy source of ocean energy desalination, the difficulty of utilizing ocean energy is one of the main factors restricting the commercialization of ocean energy desalination.

The commercialisation of ocean energy desalination is just around the corner, and the following suggestions are made on the improvement direction of ocean energy desalination and the idea of using a variety of ocean energy for desalination:

3) The improvement direction of ocean energy desalination: strive to achieve a desalination system that is directly driven by ocean energy, without secondary energy conversion, add an energy storage and distribution system to achieve smooth operation of the equipment and water discharge; enhance the performance of the energy recovery device to improve the energy utilisation rate; adopt new material processes and add a commutation system to the system interior to ensure the impact and corrosion resistance characteristics of the offshore underwater system and increase the service life of the equipment; develop different ocean energy desalination schemes according to different needs to achieve practical goals.
4) The idea of using a variety of marine energy for desalination in an integrated manner: the joint development and use of a variety of marine energy can help solve the defects of a single type of marine energy and realise the efficient transformation and use of marine energy.

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