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ORIGINAL ARTICLE

Ecological and environmental effects of wave energy developing (South coast of Caspian Sea, Iran)

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The Caspian Sea has some potential alternative energy source including the wave energy, caused by the temperature difference between the water surface and the sea floor. The greatest potential as a renewable energy that can be developed in the south coast of Caspian Sea (Iran), derived from wave energy as a power plant. The piping installation, turbine system design, the gear systems, and the generator systems are essential instruments to maximize the conversion of wave energy into electrical energy in the wave power plant. Renewable energy can be efficiently converted into electrical energy is expected to be a solution to energy needs in Iran.
Key words: the south coast of Caspian Sea; renewable energy; wave power plant; conversion

Introduction

The energy crisis predicted hit the world due to oil scarcity and the increasing demand for energy. It is required a break through to harness energy, other than non-renewable energy. Non-renewable energy dependence resulted in some constrains to harness this energy because the energy limitations of the population in the future. Despite being discussed in patents since the late 18th century (Ross, 1995) modern research of harnessing energy from ocean waves was stimulated by the emerging oil crisis in the world (Salter, 1974). Considering climate change and the rising level of CO, the focus on generating electricity from renewable sources is now an important area of research. Information regarding wave power already used by many countries, including Iran (Pebrianto, 2008). There are three kinds of energy in the sea, i.e. wave energy, tidal energy and ocean thermal energy. One of the energy in the ocean that can be utilized is the wave energy. Waves on the surface of the ocean with periods of 3 to 25 sec are primarily generated by winds and is the fundamental feature of coastal regions of the world.

Scientists have been trying to extract useful heat energy from the oceans for over a century, but the effectiveness is still low. So far, only a few small-scale experimental units are operating. One is producing about 100kW of electricity (about 5-10 percent as much as a single wind turbine) in Japan, another is generating about half as much in Hawaii, and a third is now producing about 1000kW in India; these are tiny amounts of energy that don't prove the long-term commercial viability of OTEC in a world where there are many other sources of power and the economics of energy have to be rewritten from one day to the next.

After years of planning and construction, the Lockheed Martin company finally finished work on a 100kW prototype OTEC plant in Hawaii in August 2015. Depending on possible effectiveness, some bigger plants could follow. Lockheed has already announced plans for a 10000kW (with 100 times more generating capacity) in China. Under current economic conditions, OTEC plants are most likely to be constructed in or near small tropical islands that have little or no energy resources of their own, a high-dependence on expensive, imported oil, and perhaps a pressing shortage of freshwater as well; a combined OTEC power and desalination plant could be very attractive in that situation. Early customers are likely to include power-hungry US naval bases in tropical American territories—and that's one of the reasons why the US Navy is currently investing in the technology.

Wong et al. (2001) indicated that in closed environments, flows due to plumes that move in the bottom of the closed basin have caused internal waves that their phase velocity is towards down and their group velocity is towards up directions (Wong et al., 2001). Also this structure has caused creation of shear strata which are effective in creation of stratified structure of physical quantities such as salinity and temperature (Bidokhti, Shekarbaghani, 2011).

Vertical structure of physical properties such as salinity and temperature in lakes also indicate these strata. For instance, Boehrer (2000) by investigating vertical structure of salinity and temperature in Constance Lake indicated that regular strata are observed in them so that internal waves can be analyzed into modes that each can transfer independently, considering this fact that independent waves in lakes can be observed with higher probability (Boehrer, 2000). Therefore, the hypothesis that in lakes, all water motions end in internal waves is a reasonable hypothesis. Hence, he attributed the profile of flow velocity in Constance Lake to the velocity obtained from solving equations of internal waves and by proposing an analytic model of normal modes of internal waves, justified them. Several studies have been conducted on coastal areas and waves caused by winds in the however, few studies have been conducted on marine physics of various parts of Caspian Sea. Therefore, it seems that the present study is a new approach in terms of issues of marine physics related to internal parts of the Caspian Sea especially in The Apsheron region, which is a shallow region (Fig.1) (Shekarbaghani, 2016).

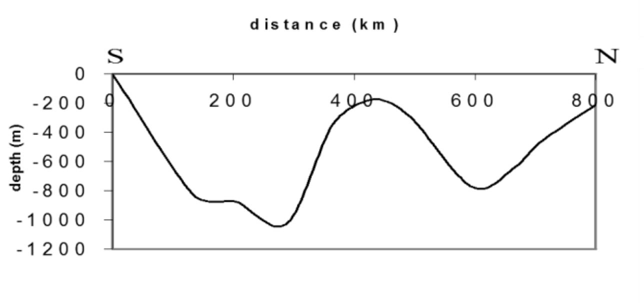

Figure 1. Bottom topography of the Caspian Sea is indicated by distance from southern shore in southern –northern direction.

Methods

Ocean thermal energy conversion (OTEC) is a process or technology for producing energy by harnessing the temperature differences (thermal gradients) between ocean surface waters and that of ocean depths. Energy from the sun heats the surface water of the ocean. In tropical regions, surface water can be much warmer than deep water. This temperature difference can be used to produce electricity and to desalinate ocean water. Ocean Thermal Energy Conversion (OTEC) systems use a temperature difference (of at least 25° C) to power a turbine to produce electricity. Warm surface water is pumped through an evaporator containing a working fluid. The vaporized fluid drives a turbine/generator. The vaporized fluid is turned back to a liquid in a condenser cooled with cold ocean water pumped from deeper in the ocean. OTEC systems using seawater as the working fluid can use the condensed water to produce desalinated water Ocean thermal energy conversion (OTEC) generates electricity indirectly from solar energy by harnessing the temperature deference between the sun-warmed surface of tropical oceans and the colder deep waters. A significant fraction of solar radiation incident on the ocean is retained by seawater in tropical regions, resulting in average year-round surface temperature of about 28°C. Deep, cold water forms at higher latitudes and descends to flow along the seafloor toward the equator. The warm surface layer, which extends to depths of about 100–200m, is separated from the deep cold water by a thermo-cline. The temperature difference ΔT, between the surface and thousand – meter depth range from 10 to 25°C , with large differences occurring in equatorial and tropical waters, as depicted. ΔT establishes the limits of the performance of OTEC power cycles; the rule of thumb is that a differential of about 20°C is necessary to sustain viable operation of an OTEC facility.Since OTEC exploits renewable solar energy; recurring costs to generate electrical power are minimal. However, the fixed or capital costs of OTEC system per kilowatt of generating capacity are very high because large pipelines and heat exchangers are needed to produce relatively modest amounts of electricity. These high fixed costs dominate the economics of OTEC to the extent that it currently cannot compete with conventional power systems, except in limited niche markets. Considerable effort has been expended over the past two decades to develop OTEC by products, such as fresh water, air conditioning, and mariculture that could offset the cost penalty of electricity generation.

The Khazar or Caspian Sea is a huge lake in North of Iran. This lake is situated between Iran, Turkmenistan, Kazakhstan, Russia, and Azerbaijan. The Caspian sea with an area about 3.5 million square kilometer is situated between 35 till 60 altitude in north and 40 to 60 in east and its estimated length is about 1205 kilometer and its width about 554 kilometer. In water physics of Caspian Sea it could be divided to three sections which is north Caspian middle Caspian and south Caspian these sections in area point of view are a little different. But in depth are very different and thus its physical characteristics are different. the south part of this sea which is laid in Iran border are in fact the most deepest and point of the sea and full of water the deepest point is 1100 meter and the mean depth is estimated to be about 350 meter .the temperature is the same as other physical characteristics in the length of the sea is very different. The temperature in north part of the sea is very low which in the winter it freeze and this temperature is gradually increase by getting to the south and in result the south coast is the warmest point of this sea.

Caspian Sea

The Caspian Sea is the largest inland body of water in the world and accounts for 40 to 44% of the total lacustrine waters of the world (Fig.2). The coastlines of the Caspian are shared by Azerbaijan, Iran, Kazakhstan, Russia, and Turkmenistan. The Caspian is divided into three distinct physical regions: the Northern, Middle, and Southern Caspian (Shekarbaghani, 2016).

The Northern–Middle boundary is the Mangyshlak Threshold, which runs through Chechen Island and Cape Tiub-Karagan. The Middle–Southern boundary is the Apsheron Threshold, a sill of tectonic origin between the Eurasian continent and an oceanic remnant. That runs through Zhiloi Island and Cape Kuuli. The Garabogazköl Bay is the saline eastern inlet of the Caspian, which is part of Turkmenistan and at times has been a lake in its own right due to the isthmus that cuts it off from the Caspian sea (Figs 2, 3).

Figure 2. Map of the Caspian Sea, yellow shading indicates Caspian drainage basin

Figure 3. Caspian Sea image (from above)

Ocean Thermal Energy Conversion

OTEC is an efficient, clean process, which utilizes the difference in temperatures between the ocean surface and its depths to produce energy. The ocean thermal energy conversion process works something like a refrigerator in reverse. The warm surface waters vaporize a refrigerant and the vapour is then used to drive a turbine. There frigerant vapour is then condensed back into a liquid after being cooled by coldwater brought up from the ocean depths.

This technology is best applied in the tropics like India, because the sun heats the ocean surface to comparably high temperatures, creating the highest temperature differentials between surface and depths, which translates into the largest potentials of energy production. This paper describes the status of the various ocean thermal energy technologies, with emphasis placed on those with a near-term potential and applicability in largen umbers. Ocean Thermal Energy Conversion (OTEC) power plants exploit the difference in temperature between warm surface waters heated by the sun and colder waters found at ocean depths to generate electricity. A temperature difference of 20°C or more between surface waters and water at depths of up to 1000 m is required. This situation can be found in tropical and sub-tropical oceans between the latitudes of 25ºS to 32ºN. Those hot ocean waters have a more useful purpose than just generatin ghurricanes. A reverse refrigeration process generates electricity from, the difference in temperature between surface and deep water**.** OTEC power plants can be located either on-shore or at sea, with the generated electricity transmitted to shore by electrical cables, or used on site for the manufacture of electricity intensive products or fuels. For OTEC plants situated on shore to be economical, the floor of the ocean must drop off to great depths very quickly. This is because a large portion of the electricity generated by an OTEC system is used to pump the cold water up from the depths of the ocean. The longer the cold water pipe, the lower the net electrical output of the power plant. OTEC uses the ocean's warm surface water with a temperature of around 25°C (77°F) to vaporize a working fluid, which has a low-boiling point, such as ammonia. The vapor expands and spins a turbine coupled to a generator to produce electricity. The vapor is then cooled by seawater that has been pumped from the deeper ocean layer, where the temperature is about 5°C (41°F). That condenses the working fluid back into a liquid, so it can be reused. This is a continuous electricity generating cycle. The efficiency of the cycle is strongly determined by the temperature differential. The bigger the temperature difference, the higher the efficiency. The technology is therefore viable primarily in equatorial areas where the year-round temperature differential is at least 20 °C.

Here we presented the brief survey of some key moments in the history of ocean thermal energy development

1881: French physicist Jacques d'Arsonval suggests extracting heat energy from the oceans.

1926: Georges Claude, a student of d'Arsonval's, builds a prototype, on-shore energy-extracting machine on the coast of Cuba. In 1935, he tries and fails to construct an experimental off-shore OTEC plant on a cargo ship. With Paul Boucheret, Claude receives a US patent for an open-cycle OTEC system (number 2006985) on July 2, 1935.

1927: OTEC gains first widespread publicity when Albert G. Ingalls writes up the idea in an article "Inexhaustible Power from Sea Water—a Dream or a Prophecy?" in Scientific American (May 1927, pages 339–342).

1960s: American engineer J. Hilbert Anderson (a specialist in refrigeration and heat cycles) and his son James Anderson, Jr. begin studying ocean thermal energy. Having identified major shortcomings in Claude's OTEC plant, they propose using a closed loop of "working fluid" to remove heat from the upper ocean in a similar way to the mechanism of a refrigerator. They're granted US patent 3312054 for their "Sea Water Power Plant," based on closed-cycle OTEC using propane as the working fluid, on April 4, 1967.

1974: The United States opens the Natural Energy Laboratory of Hawaii (NELHA) on 130 hectares (322 acres) of land at Keahole Point on the Kona coast as its primary test laboratory for OTEC. Using closed-cycle technology, it successfully builds a prototype, offshore, "mini-OTEC" plant on a US Navy barge.

1980: India begins a long series of research studies into OTEC, currently led by its National Institute of Ocean Technology (NIOT).

1982: Tokyo Electric Power Company and Toshiba successfully construct a small (100kW) OTEC plant on the island of Nauru, though much of the electricity is used to operate the plant and only 30-40kW is successfully fed into the power grid.

1993: The Natural Energy Laboratory sets a new record for open-cycle OTEC of 50kW. Six years later, it successfully tests a 120kW closed-cycle plant.

2008: Tamil Nadu Electricity Board is operating an experimental 1MW plant at Kulasekarapattinam, near Tiruchendur in the Tuticorin district.

2009: US Navy contracts Lockheed Martin to develop a 5–10MW OTEC plant (currently budgeted at $12.5million).

2015: Lockheed Martin opens its OTEC plant in Hawaii, connects it to the US power grid, and announces plans for a much more ambitious 10MW plant in China.

Results

The temperature difference in column of water in the Caspian Sea is obvious, also the thermo-cline phenomena in south Caspian, especially in summer, was distinguished. The higher difference in temperature takes place at low depth and in summer (in about 200 meter) this difference in temperature is rare one in this depth in all over the world. Ocean thermal energy conversion relies on the fact that water near the surface is heated by sunlight while seawater deep in the dark is much colder. OTEC plants use warm surface water to heat ammonia or some other fluid that boils at a low temperature. The resulting gas is used to drive turbines that produce electricity. The gas is then cooled by cold water pumped up from the ocean depths and the resulting fluid is recycled to help generate power (Fig. 4).

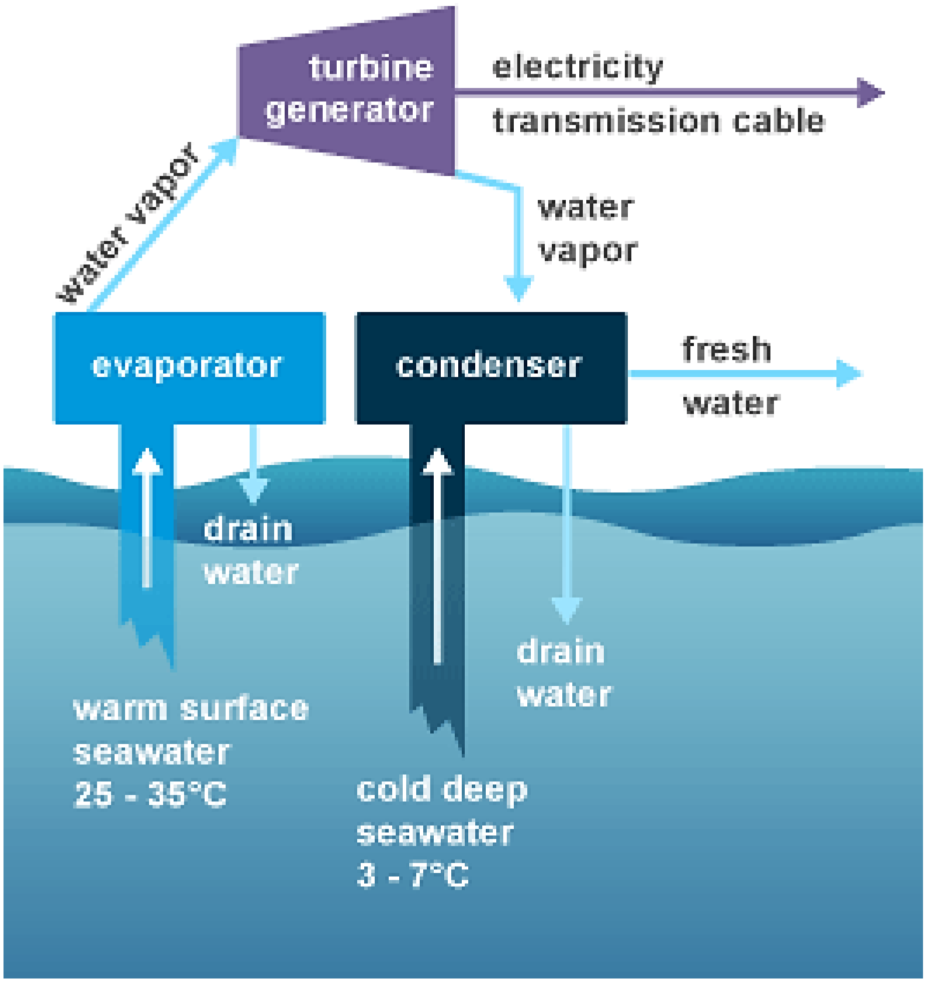

Figure 4. A model for converting thermal energy of water to electricity

Discussion

Most of the planet is covered by the oceans, and they absorb a staggering amount of energy from the sun each day. Ocean thermal energy conversion, or OTEC, taps into this energy to produce electricity (Charles, 2008). Unlike electrical generation from most other forms of renewable energy which varies with weather and time of day, such as solar and wind energy, OTEC power plants can produce electricity 24 hours per day, 365 days per year. This capability makes OTEC an attractive alternative to conventional base load power plants powered by fossil fuels or nuclear fission. Fresh water production is just one of the potential beneficial by-products of OTEC.

The cold deep ocean water can be used for aqua-culture (fish farming) as it is pathogen free and nutrient rich, or air-conditioning and refrigeration in nearby buildings. OTEC power plants have some negative impacts on the natural environment, but overall they are a relatively clean, non-polluting source of electricity when compared to conventional options such as fossil fuels or nuclear power. Cold water released at the ocean's surface will release trapped carbon dioxide, a greenhouse gas, but emissions are only about 4-7% of those from a fossil fuel power plant. Discharging the cold water at the oceans' surface could change local concentrations of nutrients and dissolved gases. However, this could be minimized by discharging the cold water at depths of greater than 50 m.

At the present time, despite the fact that OTEC systems have no fuel costs and can produce useful by-products, the high initial cost of building such power plants makes OTEC generated electricity more expensive than conventional alternatives. As such, OTEC systems at the present time are restricted to experimental and demonstration units. Island nations which currently rely on expensive, imported fossil fuels for electrical generation are the most promising market for OTEC. More experience in building OTEC power plants and standardized plant designs could bring OTEC costs down in the future. Heightened world concern over environmental issues such as global warming could also hasten the development of OTEC as a practical source of electricity.

Synergetic products are:

Fresh Water: The first by-product is fresh water. A small hybrid 1000 kW OTEC is capable of producing some 4,500 cubic meters of fresh water per day, enough to supply a population of 20,000 with fresh water. OTEC-produced fresh water compares very favorably with standard desalination plants, in terms of both quality and production costs.

Food: A further by-product is nutrient rich cold water from the deep ocean. The cold “waste” water from the OTEC is utilized in two ways. Primarily the cold water is discharged into large contained ponds, near shore, where the water can be used for

multi-species mariculture producing harvest yields which far surpass naturally occurring cold water upwelling zones, just like agriculture on land.
Cooling: The cold water is also available as chilled water for cooling greenhouses, such as the Seawater Greenhouse. The cold water can also be used for air conditioning systems, most likely linked with creating cold storage facilities for preserving food.

Conclusions

The wave energy is a potential renewable energy to be developed in Iran. One of the area that has potential to convert wave energy into electrical energy is the south coast of Caspian sea. In this area there has been established wave power plant models using an oscillating water pond technology. Furthermore, the design of the generator system is expected to develop wave energy in Iran will use design like a design that has use in the wave power plant in United Kingdom. Wave power plant in Iran has large kinetic energy intensity than the other renewable energy.
The warm seawater is flash-evaporated in a vacuum chamber in order to produce steam, which will drive the turbine. cycle OTEC, on the other hand, does not use seawater as its working fluid. Instead, a fluid with a low boiling point (such as ammonia) is used as the working fluid and heated by the warm surface water. The vaporized ammonia is then used to power the turbine and drive the generator.
The capturing of heat energy based on two parameters; depth and heat deference between surface water and deep water, so, the most suitable point in Caspian Sea for capturing the heat energy of water is its south part, which is in the neighborhood of Iran, because:
a) the most suitable points for capturing heat energy is depth waters, and the south part of Caspian Sea is the deepest part.
b) Measurement shows that in the south part of Caspian Sea the temperature difference between the surface and depth is relatively higher than the other sea parts.
Unlike wind and solar power, OTEC can provide constant power and does not depend on the time of day. The electricity it produces could also be used to drive chemical reactions that generate fuel such as hydrogen, ammonia or methanol.

Conflict of interest

The authors indicate no conflicts of interest.

References

Bidokhti, A.A., Shekarbaghani, A. (2011). The layered structure in exchange flows between two basins (Middle and Southern basins of the Caspian Sea). Int. J. Mar. Sci. Eng, 1(1), 13-22.
Alberdi, M., Amundarain, M., Garrido, A.J., Garrido, I., Casquero, O., de la Sen, M. (2011). Complementary control of oscillating water column-based wave energy conversion plants to improve the instantaneous power output. IEEE Trans Energy Convers, 26(4), 1021-1032. https://doi.org/10.1109/TEC.2011.2167332
Amundarain, M. Alberdi, M., Garrido, A.J., Garrido, I. (2011). Modeling and simulation of wave energy generation plants: output power control. IEEE Trans Ind Electron, 58(1), 105-117. https://doi.org/10.1109/TIE.2010.2047827
Babarit, A., Duclos, G., Clément, A.H. (2004). Comparison of latching control strategies for a heaving wave energy device in random sea. Appl Ocean Res, 26(5), 227-238. https://doi.org/10.1016/j.apor.2005.05.003
Boehrer, B. (2000). Modal response of a deep stratified Lake: Western lake Constance. J. Geophys. Res, 105, C12, 23837- 2384. https://doi.org/10.1029/2000JC900125
Charles, Q. Choi (2008).The Energy Debates: Ocean Thermal Energy Conversion. Live Science Contributor.
Drew, B., Plummer, A.R., Sahinkaya, M.N. (2016). A review of wave energy converter technology. Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy, 223(8), 887-902. https://doi.org/10.1243/09576509JPE782
Espindola, R.L., Araújo, A.M. (2017). Wave energy resource of Brazil: An analysis from 35 years of ERA-Interim reanalysis data. PLoS One, 12(8):e0183501. https://doi.org/10.1371/journal.pone.0183501
Falnes, J., Kurniawan, A. (2015). Fundamental formulae for wave-energy conversion. R Soc Open Sci, 2(3), 140305. https://doi.org/10.1098/rsos.140305
Falnes, J., Lillebekken, P.M. (2003). Budal's latching-controlled-buoy type wave-power plant. Proceed. Fifth European Wave Energy Conference, Cork, Ireland.
Kazmierkowski, M.P., Jasinski, M. (2010). Power electronics for renewable sea wave energy. Proceed. 12th International Conference on Optimization of Electrical and Electronic Equipment (OPTIM), 4–9. https://doi.org/10.1109/OPTIM.2010.5510476
Kim, C.K., Toft, J.E., Papenfus, M., Verutes, G., Guerry, A.D. et al. (2012). Catching the right wave: evaluating wave energy resources and potential compatibility with existing marine and coastal uses. PLoS One, 7(11):e47598. https://doi.org/10.1371/journal.pone.0047598
Manabu Takao, Toshiaki Setoguchi (2018). Air Turbines for Wave Energy Conversion. International Journal of Rotating Machinery, 12, Article ID 717398, https://doi.org/10.1155/2012/717398

Mishra, S.K., Purwar, S., Kishor, N. (2016). Design of non-linear controller for ocean wave energy plant. Control Eng Pract, 56, 111-122. https://doi.org/10.1016/j.conengprac.2016.08.012
Ross, D. (1995). Power from the wave. Oxford: Oxford University Press.
Rusu, E. (2014). Evaluation of the Wave Energy Conversion Efficiency in Various Coastal Environments. Energies, 2014, 7(6), 4002-4018; https://doi.org/10.3390/en7064002
Salter, S.H. (1974) . Wave power. Nature, 249, 720-724. https://doi.org/10.1038/249720a0
Shekarbaghani, A. (2016). Determine the best location for Ocean Thermal Energy Conversin (OTEC) in Iranian Seas. Modern applied sciences, 10(5), 32-40. https://doi.org/10.5539/mas.v10n5p32
Shekarbaghani, A. (2016). Study conversion of sea wave energy to electrical energy (case study: the waves of the Caspian Sea). Research Journal of Applied Sciences, 11(11), 1268-1274.
Tedeschi, E., Carraro, M., Molinas, M., Mattavelli, P. (2011). Effect of control strategies and power take-off efficiency on the power capture from sea waves. IEEE Trans Energy Convers, 26(4), 1088-1098. https://doi.org/10.1109/TEC.2011.2164798
Torre-Enciso, Y., Ortubia, I., De Aguileta, L., Marqués, J. (2009). Mutriku Wave Power Plant: From the Thinking out to the Reality. Proceed. 8th European Wave and Tidal Energy, Uppsala, Sweden.
Wang, L., Isberg, J., Tedeschi, E. (2018). Review of control strategies for wave energy conversion systems and their validation: the wave-to-wire approach. Renewable and Sustainable Energy Reviews, 81(1), 366-379. https://doi.org/10.1016/j.rser.2017.06.074
White, C., Halpern, B.S., Kappel, C.V. (2012). Proc Natl Acad Sci USA, 109(12), 4696-701. https://doi.org/10.1073/pnas.1114215109

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