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Ocean Thermal Energy Conversion (OTEC)

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ABSTRACT: *Ocean thermal energy conversion (OTEC) is considered as a promising resource of energy in the future. It is one of the renewable energy resources that do not arise any indeed harmful impact on our environment. Since it is an eco-friendly resource, this does not mean that it is a purely clean resource. It may cause a negligible environmental influence that will be mentioned in this paper. The essential ingredient that is used in this technology is ocean water instead of fossil fuel that has a potent contribution to inevitable global warming. It is known that there are many layers in ocean water and each of them has a certain temperature. These differences in temperature are exploited not only to generate power but also to produce potable water. The OTEC system has three scenarios that can be harnessed in terms of ocean water temperature differentials which are a closed-cycle, an open-cycle, and a hybrid-cycle. Although OTEC relies on an enduring source, it is undoubted there are economic challenges.*

Keywords: *environment, OTEC, ocean, power planet, renewable energy, thermal energy*

I. INTRODUTION

Our planet has become more and more in need for energy since the demand is growing sharply. With this increase, focus should be placed on the energy resources that are eco-friendly instead of the resources that cause crucial ecological issues, i.e. environmental pollution and the global warming. Ocean thermal energy conversion (OTEC) is one of the significant energy resources that could play a prominent role in the future. This technology started as a conceptual idea in 1881 by the French physicist Jacques Arsene[1]. Then, Dr. Georges Claude implemented it as a practical system in 1930 in Cuba (Matanzas Bay)[1]. Many development projects and research papers were done between 1950 and 1960 by few research organizations. However, it appears that OTEC was not desirable by governments by the end of the 20th century because the nuclear energy was not only more interesting than other energy resources at that time but also the oil price dropped in 1990s. To be more specific, in the latter period of that time, renewable energy had been a neglected resource without taking into account the environmental future. At the beginning of the 21st century, the oil price increased by more than 1400% per barrel and global warming became a more crucial issue, posing threats to the planet. Consequently, renewable energy has resurfaced and become a strongly desirable resource.

Since the ocean water has the most percentage on the earth surface (70%), it is logical to take advantage of this natural source to satisfy the energy demand. OTEC is considered a renewable energy technology since it derives the hot energy from the sun which means it is a huge solar energy. It exploits the differential temperature between the warmer water of the ocean surface that is heated by the sun and the deep ocean point that is a depth of about 800-1000m that has the lower temperature to generate energy[2]. The differential temperature that is desired to run the OTEC system is 20^{o}C[2].

OTEC power plant construction has two types depending on whether it is built in a land which is land-based power plant or floating inside an ocean which floats a power plant[3]. They have similar functions and materials. However, the land based power plant is costly, more than the floating power plant because the cold-water pipe must be sloped to achieve the cold water. Thus, it needs to be longer than in the floating power plant since it has vertical cold water pipe. On the other hand, the land based power plant is more beneficial to harness the cold water as an air condition fluid without extra cost transport. In addition, its maintenance is easier since it does not need to sail into the ocean.

II. HOW OTEC PLANT WORKS:

The basic concept of OTEC working is pumping warm water from the ocean surface through a boiler. The steam expands and spins a turbine coupled to a generator to produce electric power. In other words, the generator converts the mechanical energy that is produced by the turbine into electrical energy. The cold water is pumped from the ocean depth through a condenser, so that condenses the working fluid back into a liquid to complete the cycle. There are three cycles of the OTEC plant that can be designed to generate power[4].

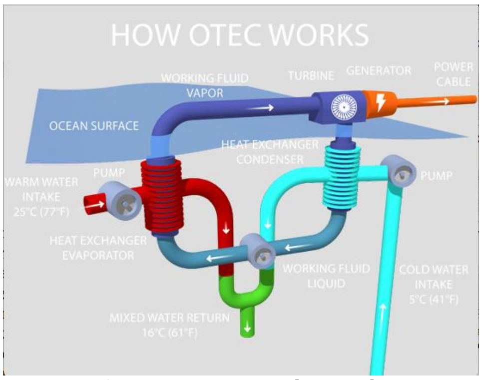

Figure1: How OTEC Plant Works

2.1 Open-cycle:

Pumping warm water as a working fluid to a low-pressure room through a valve and the flash vaporization, in turn, rotates the generator to produce electricity. The cold water that is pumped from the depth condenses the vapor whether through a direct contact condenser or indirect contact surface condenser. Then, this condensed water is released from the plant to either the ocean or it can be used for commercial potable water.

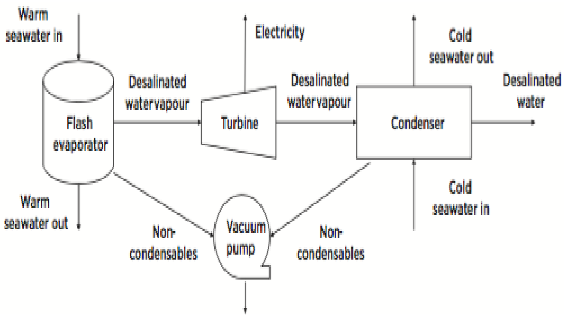

Figure2: Open-Cycle

2.2 Closed-cycle:

The closed-cycle system uses a working fluid such as ammonia that has a low boiling temperature. It is heated by warm water that is pumped from an ocean surface to a heat exchanger where it boils the working fluid. The vapor of the working fluid passes through a turbine attached to a generator. The vapor is condensed by cold ocean water to complete the cycle. The tube size and turbine diameter are much smaller than in the open cycle. Although the surface area of the heat exchanger is smaller, it has more efficiency of the thermal source than the open cycle. However, fresh water cannot be extracted.

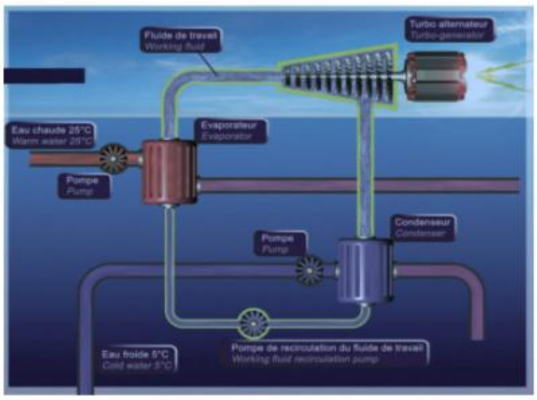

Figure3: Closed-Cycle

2.3 Hybrid-cycle:

As its name suggests, it combines both the open and closed cycles which can produce power and potable water. The warm water is steamed by flash evaporation which is similar to the open cycle process. The steam then heats the working fluid as in the closed cycle. Vaporization of the working fluid rotates the turbine to generate electricity. The cold water condenses the steam to be desalinated water.

III. ADVANAGES OF OTEC:

OTEC is clean renewable energy that uses natural resources to generate electricity. Consequently, it is no doubt that it does not play an essential role in environmental pollution such as producing carbon dioxide even on the long term. At this time, there is no detrimental effect on ocean water when it is utilized and then discharged into the ocean again at a depth of more than 70 m, according to the US Department of Energy (DOE)[5]. In addition, it can produce power continuously throughout the whole year without stopping because it relies on not only inexhaustible recourses but also on abundant resource that never depletes, unlike other energy resources that depend on fossil fuels that may disappear at any time as well as their price has been fluctuating through the past several decades. It also surpasses the other renewable energy such as the wind and solar energy that produce the power by sources that may not be available every time. In addition to generating electricity, it could produce desalinated water for those who live in islands which suffer from water shortage. It can produce about 2.28 million liters of drinkable water per megawatt electricity, according to R. Magesh study[6]. In addition, cold ocean water can also be harnessed to be utilized in the cooling system of buildings without consuming electricity[3].

IV. DISADVANAGES OF OTEC:

One of the important factors that should be paid attention to is the differential temperature which should be at least 20^{o}C in order to make the OTEC system profitable. It is usually hard to find an adequate location close enough to a shore to achieve this temperature. Moreover, OTEC plant efficiency is relatively small, which means that it should be constructed on a comparatively large scale to produce the desirable amount of electricity production. Consequently, the large scale OTEC plant system needs massive investment to be built especially when it is far away from the land because its construction needs more materials like pipes along with the maintenance on the long term, as well. It is obvious that to obtain the cold water from ocean depths, length of pipes should be around 1 km; also, to produce 10 MW, for instant, they should be wide enough (up to 7m) to convey huge volumes of cold water. So, they may influence not only the structure of a coast and it is hard to install them inside oceanic environments and then do the maintenance but also marine life since there is no deep study that has been done on this issue because the large scale OTEC plant has not been built yet.

V. ENVIRONMENTAL IMPACT:

Since OTEC does not use fossil fuel, it will not produce environmental pollution such as carbon dioxide. However, the area where the OTEC is built will be impacted temporarily when the construction is in the process. So, the OTEC plant areas should be carefully selected to avoid damaging the marine environment. OTEC plant emissions especially in the open or hybrid cycle cannot be compared with fossil fuel emissions when producing an equal amount of electricity. Moreover, its emissions do not impact the human directly, but it may affect the ozone layer, especially when chlorofluorocarbons are used instead of ammonia[1].

VI. OTEC PLANT CONSTRUCTION SO FAR:

Research organizations and OTEC companies in the world have been competing to construct OTEC plant as large as possible to be at the forefront of this technology. At this moment, there are many experimental plants that have been built on a small scale. Hawaii has the oldest floating closed cycle OTEC plant which was built by Natural Energy Laboratory of Hawaii Authority (NELHA) in 1979 and produced 103 kW[2]. In 1982, Japan Institute for Ocean Energy Research built the closed cycle OTEC plant that produced 120 kW for research purposes[2]. Japan also developed the offshore OTEC plant that could produce 100 kW in March 2013. It was developed by three companies, namely: Yokogawa Solution Services Company, IHI Plant Construction Company, and Xenesys Inc. This project may be the first step for them to build an ambitious offshore OTEC plant that could produce 10 MW in the future[7]. India had an unsuccessful experiment of developing a floating closed cycle OTEC plant that was in the beginning of 21st century because of the pipe problem[2]. It was developed by the Indian government in collaboration with Indian Institute of Technology to produce 1MW. The first closed-cycle OTEC plant was connected to a real electrical grid is at Hawaii. It was developed by Makai Ocean Engineering from 2011 to the end of summer 2015. It can generate roughly 105 kW that is enough to serve more than a hundred Hawaiian houses, and it is considered the largest operational OTEC plant at this moment[8].

VII. OTEC PLANT FUTURE:

The world has been attempting to develop large scale OTEC plants to exploit this technology commercially. However, it is no doubt that OTEC plant construction faces a difficulty to obtain subsidies due to the world economy depression. Consequently, there are a few prototype large scale plant projects that are planned to appear in the near future. Makai Ocean Engineering is one of the leading companies in this technology. It has an ambitious plan to build a large scale OTEC plant cooperatively with Lockheed Martin and the US navy to feed, for example, Hawaii and Guam. They have invested $15 million in developing the first stage of a 10 MW OTEC plant that will be the base of a commercial 100 MW OTEC plant[9]. China has also a courageous plan to acquire commercial OTEC plant by Reignwood Group through collaborating with Lockheed Martin to construct an offshore 10 MW OTEC plant[2]. Another OTEC project will be done by both DCNS France and Akuo Energy called NEMO at the Sea of Martinique Island. It will be producing 16 MW by 2018. DCNS France has also a research project with the University of Technology Malaysia to provide its dedicated expertise that determines the feasibility of establishing a new OTEC plant at Layang Layang Island in Malaysia[10].

VIII. OTEC PLANT COST:

The construction cost varies based on several pillars. Scale size has an essential role to affect the budget of OTEC plant project. The cost goes down as much as how huge the plant is[2]. The large-scale construction needs less money investment than small scale. The plant design also changes the cost which means open cycle design is partly more expensive than closed cycle design[2]. However, open cycle design has a feature that cannot be negligible which is that it can make drinkable water. Another factor is the suitability of the place where the plant is built. There are conditions that should be met to determine whether the place is profitable or will cost more money to obtain cold water[2].

Electricity production cost per kWh of OTEC plant depends on the amount of power that the plant can produce. In other words, when the OTEC plant produces more power, the cost will considerably reduce. For example, the cost of electricity is about $0.75-0.9/kWh of a 1.35 MW plant and around $0.15/kWh of a 100 MW plant[11]. Since the large-scale plant has not been operated so far, it is obvious that the kWh cost is not competitive with conventional energy or even other renewable energy recourses.

IX. CONCLUSION:

Although OTEC is an old technology, and not only an unexhausted resource but also an excellent alternative energy resource for being environmentally friendly, it has not evolved to be a reliable source of energy yet due to the world fluctuating economy and the scarcity of the places that are suitable for OTEC plants to be built. Wherefore, there are many small-scale plants that have been constructed at the present where large scale ones are being under the process. Consequently, the effectiveness of this technology remains hypothetical until proven practically when the large scale is done and connected to a power grid as it has been done in Hawaii on a small scale.

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