Ocean Thermal Energy Conversion: A Review

[1]Vijay Mane, [2]Saloni SalunkhePatil

[1]Assistant Professor, [2]Bachelor of Engineering Student,
[1]Department of Chemical Engineering,
[1]Bharati Vidyapeeth College of Engineering, Navi Mumbai, India.

Abstract : *Due to Increasing problems regarding global climate change, limited fossil fuels resources, local air-pollution with necessity of huge energy supply leads to research and develop Renewable Energy Technologies (RET's). This study has been undertaken to highlight the ultimate alternative for global warming. Ocean Thermal Energy Conversion (OTEC) is a renewable energy technology that uses small temperature difference between the surface of the ocean and deep ocean water to run the heat engine. As ocean is the most rich and expanded source which covers about 70% of the Earth which will help to prevent ill effects of global warming. The aim of this paper is to highlight comparison between OTEC and other RET's, types of OTEC system, byproduct utilization and future of the OTEC system.*

Index Terms - *OTEC, Renewable Energy Technology, Global Warming, Ocean.*

I. INTRODUCTION

The most popular renewable energy sources are wind, solar and biomass which gives technical and economical limitations such as design, operation and maintenance. Due to global warming, air pollution and limited sources of fossil fuel, there is need to develop renewable energy technologies (RET's). The rapidly depleting fossil fuel reserves and increasing energy demand, the energy from renewable sources especially from ocean is an attractive alternative. The technology which is used for power generation by using small temperature difference between the surface and deep ocean water is known as ocean thermal energy conversion (OTEC). Over 70% of area is covered by oceans on the earth and the ocean stores an amount of energy equal to 10,000 times all world energy demand Thus, ocean is considered to be the only renewable source which is able to replace fossil fuels. This system is less efficient because of the temperature difference between the surface and the ocean water is very small, this gives an advantage for the yield of different by-products which further makes OTEC economically stable than any other RET's. OTEC plant generates electricity indirectly from solar energy by using temperature difference between surface of the ocean and deep ocean water. It has been estimated that 60 million square kilometers of tropical seas absorb solar radiant heat energy equivalent to 250 billion barrels of oil. Even though the power conversion efficiency of OTEC is very low, it has an added advantage of yieldi2ng by-products beside production of electricity. There are various forms of ocean energy such as Ocean Thermal Energy Conversion, Wave Energy, Tidal Energy, Salinity Gradient Energy etc. Among these types of energies first three are widely used. The world's population is expected to double by the middle of 21st century and the conventional power generations cause problems like ozone layer damage, ecological imbalance, emission of pollutants etc.

II. COMPARISION OF OTEC WITH OTHER RET's

OTEC is considered to be most important type of renewable energy because it not only generates power but it also utilizes cold deep water for air conditioning purpose, culture of sea weeds, production of temperate crops in tropical area and production of mineral water. Even though massive investment is required for OTEC, still the generation cost of electricity is low as compared to other sources of energy because of the capacity factor of OTEC is 95% this leads to OTEC to become more dominant than tidal energy which accounts capacity factor of 20%. The figure below shows capacity of renewable energy generated by capital investment and capital factor. [1]

III. HISTORY AND CURRENT DEVELOPMENTS

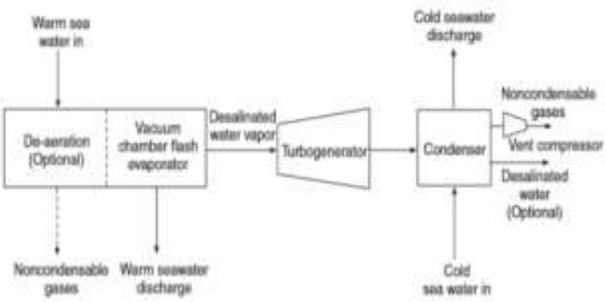
This technology is not new, it firstly came into picture in 1881 by a French scientist Jacques Arsene, Later Georges Claude, a student of Jacques Arsene, built an experimental open-cycle OTEC system which produces 22KW of electricity at Matanzas Bay, Cuba, in 1930. In 1956, another French scientist gave an idea for an open cycle design which had a capacity of 3 MW but the plant remained incomplete because of competition from inexpensive hydroelectric power. Many development projects and research papers were done between 1950 and 1960 by few research organizations, since then many modifications have been made to develop this technology. In 1980 Saga University, Japan constructed and tested 50KW offshore OTEC plant. In 1997, Saga University and the Nation Institute of Ocean Technology (NIOT), India signed a technical agreement for a 1MW floating OTEC plant which further constructed in 2001. The closed cycle was used to maximize the efficiency. Further, the experimental success of 1MW plant, a 25-30MW system is planned.

Ocean Energy and Solar PV	Input					Capacity Factor	Output
	Generation Capacity (MW)	(MWh) year	Capacity Investment Million USD	MW/Million USD	MWh/Million USD		Cost of ocean energy USD/KWh
Wave Energy	10	24,000	63	0.16	380	30%	0.56
Tidal Energy	254	406,400	298	0.85	1363	20%	0.28
Offshore Wind	10	33,600	40	0.25	840	42%	0.17
OTEC	53	402,800	451	0.12	893	95%	0.13
Salinity Gradient	200	1,280,000	600	0.33	2133	80%	0.09
Solar PV	10	16,000	38	0.26	421	20%	0.25

IV. TYPES OF OTEC CYCLES

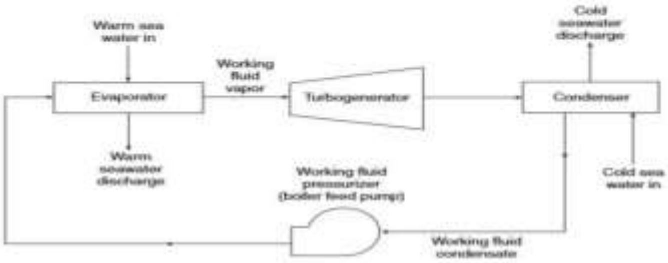
1) Open Cycle

The steam generated by ocean water as working fluid. Further warm sea water is flash evaporated in a partial vacuum in the evaporator. The vapor expands through the turbine and is condensed with cold sea water. Open cycle eliminates costing of expensive heat exchangers. The entire system i.e. from evaporator to condenser uses 1-3% pressure of that atmosphere. The condensed water is released from the plant can be used for commercial potable water. The major drawback of open-cycle is the low operating pressures in systems, which are needed large components to accommodate the high volumetric flow rates of steam. As sea water is used as working fluid this system reduces additional cost for heat exchangers.



2) Closed Cycle

In this system, heat transfer from warm surface sea water takes place in the evaporator, producing a saturated vapor from the working fluid. Electricity is generated when this saturated vapor expands to lower pressure through the turbine. Latent heat is transferred from the vapor to the cold sea water in the condenser and the resulting liquid is pressurized with a pump to repeat the cycle. This forms closed loops hence it is called as closed cycle system. The selection of working fluid depends on cost and availability, compatibility with system materials, toxicity, and environmental hazard. The widely used working fluids are ammonia and various fluorocarbon refrigerants.



V. BY-PRODUCTS PRODUCED FROM OTEC PLANT

From stimulation studies of OTEC plant, it is clear that a 1.2 MW Open Cycle-OTEC plant could give desalinated water nearly about 2200 m3 /day. Between the periods of 1993 to 1998 an actual Open Cycle – OTEC plant trial was made which produced desalinated potable water as by-product at the rate of 0.4 L/sec and net electricity production of 103 kW. According to agricultural growth, the nutrient-rich cold-water feed increases the yield of different agricultural products, mainly in the pharmaceutical products and natural pigments. This cold-water field can also be used for agricultural. Studies shows that by using cold water feed yield of banana plantation have been increased by 10 times and that of sugarcane plantation is 30 times.

VI. CURRENT PROBLEMS WITH OTEC SYSTEM

Due to the moderate temperature differences measurable also in tropical areas, OTEC systems have typically low energy efficiency and massive investment. Constructing an offshore OTEC power plant at a high commercial scale is quite challenging. The OTEC system is not that effective as compared to other RET's which leads to stop the widespread commercialization of OTEC plant. Researchers have been leading lots of theoretical and experimental studies in order to decrease investment costs and maximize the economic profitability of OTEC systems and this can only achieve by increasing energy productivity such as by increasing surface seawater temperature or combining different technologies or producing other goods together with electricity.

VII. ADVANTAGES OF OTEC SYSTEM

a) **Fresh water production:**

Desalination is just one of the effective potential products that could be produced via OTEC open cycle technology when the warm water is vaporized to turn low pressure turbine. Once the electricity is produced water vapor is condensed to make fresh water. This water is found to be purer than water offered by most of the communities also it has been estimated that 1MW plant could produce 55kg of water per second and this water can also be used for irrigation to improve the quality and quantity of crops in tropical regions.

b) **Air Conditioning and Refrigeration:**

As cold-water pipes are installed for an OTEC plant, the cold water is being pumped to surface and it can be used for air conditioning and refrigeration. Cold water can be used to circulate through space heat exchangers and this technology can be applied for hotel and home air conditioning as well as for refrigeration.

c) **Aquaculture and Mari culture:**

The water pipes from OTEC plant can be used to harvest marine plants and animals for the purpose of the food. It is proposed that seawater life including salmon, American lobster, flat fish and sea urchin could be harvested for ingestion using cold water pipes which is available from OTEC plants. Also, this water contains phytoplankton and other biological nutrients that serve as a catalyst for fish and other aquatic populations.

d) **Coldwater Agriculture:**

Because the coastal areas for OTEC are in tropic regions there is potential to increase the overall food diversity within an area using cold water pipes for spring type crops like strawberries and other plants restricted to cooler climates.

VIII. FUTURE OF THE OTEC SYSTEM

The world is focusing more on the commercialization of the OTEC plant on large scale. Makai Ocean Engineering is one of the largest companies focusing on this technology. The company has already planned to build large scale OTEC plant with US Navy and Lockheed Martin for Hawaii region with the investment of 15 million dollars. They are focusing to build 10MW OTEC plant which will be further become base to 100MW OTEC plant. China is also planning to acquire commercialization of 10MW offshore OTEC plant with Lockheed Martin and Reign wood group. The main challenge to construct the plant is its capital cost but the profit generated from the by-products of this system can cover up the cost. In short OTEC has potential not only to produce energy but also to produce potable water and other by-products which are essential for daily needs.

IX. CONCLUSION

According to installed capacity of other RET plants; OTEC plant has a central role. In future, OTEC will be the sustainable alternative to the tropical regions for energy supply. If we consider the diminishing fossil fuel supply, increasing population which increases the rate of demand and the lack of actual private investments in ocean technologies, government funding is highly necessary for the development of OTEC system. As this system is eco-friendly there are many small-scale plants have been constructed and large-scale commercialized plants are still in progress.

X. ACKNOWLEDGMENT

I would like to express my special thanks of gratitude to my mentor PROF. VIJAY MANE who gave me the wonderful opportunity to highlight the topic "OCEAN THERMAL ENERGY CONVERSION."

REFERENCES

[1] Dr A. Bakar Jaafar, 2019, the Ignieuir - Magazine of the Board of Engineers, Malaysia, Vol. 77.
[2] Etemadi, A., Emdadi, A., Asef Afshar, O. & Emami, Y., 2011. Electricity Generation by the Ocean Thermal Energy. Energy Procardia, 27-30 September, Vol. 12, pp. 936-943.
[3] Vega, L., 2003. Ocean Thermal Energy Conversion Primer. Marine Technology Society, Volume 6, pp. 25-35.
[4] Fujita, R. et al., 2011. Revisiting ocean thermal energy conversion. Marine Policy, Vol. 36, pp. 463-465.
[5] Subhashish Banerjee, Les Duckers, Richard Blanchard, Binoy K. Choudhury, 2012, "Ocean Thermal Energy Conversion (OTEC): By-product Availability," Encyclopedia of Energy Engineering and Technology.
[6] Strickland, E., 2013. Lockheed Martin Pioneers Ocean Energy in China.

[7] Martì, J., Laboy, M. & Ruiz, O., 2010. Commercial Implementation of Ocean Thermal Energy Conversion. Sea Technology Magazine, April, pp. 10-14.
[8] Yamada, N., Hoshi, A. & Ikegami, Y., 2009. Performance of solar-boosted ocean thermal energy conversion plant. Renewable Energy, January, Volume 34, pp. 1752-1758.
[9] Straatman, P. & Van Sark, W., 2008. A new hybrid ocean thermal energy conversion-Offshore solar pond (OTEC-OSP) design: A cost optimization approach. Solar Energy, January, Volume 82, pp. 520-527.
[10] Bombarda, P., Invernizzi, C. & Gaia, M., 2013. Performance Analysis of OTEC Plants with multilevel organic Rankin cycle and solar hybridization. Engineering for Gas Turbines and Power, April, Volume 135, pp.
[11] Ocean Thermal Energy Conversion: Technology Brief by IRENA, June 2014.