Study of Ocean Thermal Energy Conversion Power Plant

S. Balakumar, C. Sathivel

[1]Associate Professor, Department of Industrial Engineering and Management, GCT,

Coimbatore, India

ABSTRACT- *The usage of organic isobutane will be explored for a closed-cycle Ocean Thermal Energy conversion (OTEC) on-shore plant that delivers 110 MW electric powers. This paper will shieldthe concept, process, energy calculations, cost factoids and conservational aspects. In isobutane cycle, hot ocean surface water is used to evaporate and to superheat isobutane in a heat exchanger. Isobutane vapor then expands through a turbine to produce useful power. The exhaust vapor is summarized afterwards, using the cold deeper ocean water, and impelled to a heat exchanger to complete a cycle. Results show the major design characteristics and equipment's of the OTEC plant along with cycle effectiveness and cycle improvement techniques.*

Keywords: *Ocean Thermal Engineering Conversion (OTEC); isobutene; thermal plant; energy convergence.*

I. INTRODUCTION

Due to the sky-rocketing prices of the conservative energy sources that is oil, coal and natural gas along with its enlargedconservational impacts caused by combustion gases and polluting products; those conservative types are losing interest in the field of energy exploration and development. On the other hand, the renewable energy sources are acquisition more and more interest to improve its exploitation methods while minimizing costs and risks. The continuous unpredictability of petroleum price, the gradual decrease in the reserves of conventional energy resources, and the environmental problems formed by the combustion of carbon based fuels, have placed great heaviness on energy supplies to discovery solutions that cuts the energy bill, reduce the environmental impact of burning fossil fuel and improve the scorching efficiency of the current combustion systems. Sustainable energy systems for power generation and new alternate cooling systems for fossil and nuclear power plants are desirable to reduce water consumption and CO2 emissions. A large amount of energy is also used and high CO2 emissions are twisted to extract, supply, treat and use fresh water and for desalination plants.

Oceans cover 70% of the earth surface, founding the world's largest solar energy collector and energy storage system. On aregular day, 60 million km2 of tropical seas absorb an amount of solar radiation equal in heat content to about 250 billion barrels of oil. The oceans are a vast renewable energy resource, with the probable to help produce billions of watts of electric power. The saltwater used is also rich in nutrients and it can be used to culture both marine organisms and plant life near the shore or on land. Casing over 70% of the planet's area, the Earth's oceans could hypothetically be exploited as a source of practically inexhaustible renewable energy. Ocean Thermal Energy Conversion (OTEC) is a method that services naturally happening temperature differences between warm surface water and colder deep ocean water. This technology was initially proposed by the French Engineer Jacques Arsene d'Arsonval in 1881. As solar energy strikes the surface of the ocean, it warms the highest layers of water. Depending on latitude, weather and time of year, surface temperatures may approach 80°F (26°C). Beneath the surface, at depths greater than about 1500 ft. The water temperature methods 40°F (4°C), since, at that temperature, water has its maximum density. This temperature is also moderatelycontinuous all around the year.This temperature ramp of about 20°C amongst warm surface water and deep cold water could be benefitual using an Ocean Thermal Energy Conversion (OTEC) system to crop a significant amount of electrical power. Concerns with effectiveness losses due to biofouling, system power desires and heat replacing systems have led to consideration through case studies and analysis.

II. LITERATURE REVIEW OF OTEC TECHNOLOGY

There are three main types of OTEC cycle designs: open cycle, closed cycle, and hybrid cycle. In an Open Cycle, seawater is the working fluid. Warm saltwater is pumped into a flash evaporator where pressure as low as 0.03 bar cause the water to boil at temperatures of 22°C. This steam magnifies through a low-pressure turbine connected to a maker to create power. The steam then passes through a condenser using cold seawater from the depths of the ocean to condense the steam into desalinized water. In a Closed Cycle, a low sweltering point liquid such as ammonia, propane, isobutane or another type of refrigerant is used as the working fluid in a Rankin cycle. The heat from warm seawater curving through an evaporator vaporizes the working fluid. The vapor enlarges through a turbine, and then flows into a condenser where cold seawater condenses it into a liquid. The closed OTEC cycle will be of interest in this study, and the isobutane working fluid will be investigated to be used as working fluid. Actual designs of CC (Closed Cycle) OTEC use Ammonia as its working fluid while Isobutane is usually being used along with pentane in geothermal power plants.

A Hybrid Cycle association the structures of both the closed-cycle and open-cycle systems. In a hybrid OTEC system, warm seawater enters a vacuum chamber somewhere it is flash-evaporated into steam, which is similar to the open-cycle evaporation process. The steam vanishes the working fluid of a closed-cycle loop on the other side of an ammonia vaporizer. The vaporized fluid then drives a turbine that produces electricity. The steam condenses within the heat exchanger and provides desalinated water. OTEC system routine is related to the working fluid properties using good working fluid could generate a more efficient and cheaper plant.Cycle efficiency was considered by and it was found that higher cycle efficiency could be achieved using isobutane as working fluid. On the other side using isobutene is not suggested in closed-cycle OTEC system because the inlet stable operating turbine pressure is in a very narrow range.

2.1. Other Uses for OTEC Technology

OTEC systems not only produce electricity, it can also tackle many other uses in dissimilar fields, some of which can be listed as:

2.2.1 Fresh water production - The rapid manufacturing growth and the population explosion all over the world have resulted in the problem of pollution of rivers and lakes by industrialized wastes and the large amounts of sewage satisfied. On a global scale, man-made pollution of natural sources of water is becoming the single largest cause for fresh water shortage. The only nearly unlimited sources of water are the oceans and seas. Their main drawback, conversely, is their high salinity. Consequently, it would be striking to tackle the water-shortage problem with purification of this water. Desalination is just one of the effective potential products that could be produced via OTEC technology. Fresh water can be fashioned in open-cycle OTEC plants when the warm water is vaporized to turn the low pressure turbine. Once the energy is produced the water vapor is summarized to make fresh water. This water has been found to be purer than water offered by most populations as well it is estimated that 1 MW plant could produce 45 m3 of water per second.

2.2.2 Air conditioning and Refrigeration - Once cold water pipes are connected for an OTEC power plant, the cold water being pushed to the surface can be used for other than being the working fluid for the condenser. One of these uses is air habituation and refrigeration. Cold water can be used to circulate finished space heat exchangers or can be used to cool the occupied fluid within heat exchangers. This technology can be applied for hotel and home air conditioning as well as for refrigeration schemes.

2.2.3 Aquaculture and Mari-culture - Additionalopportunity for taking advantage of OTEC plants is the use of the water pipes to harvest marine plants and animals for the purpose of food. This proposition is still under exploration.

2.2.4 Coldwater Agriculture - As seaside areas appropriate for OTEC are in tropic regions, there is a potential to increase the overall food multiplicity within an area using the cold water instigating from the deep ocean. It has been proposed that burying a network of cold-water pipes underground the temperature of the ground would be ideal for spring type crops like strawberries and other plants delimited to cooler climates.

2.2. Main Characteristics of Isobutane

Isobutane C_4H_{10} also known as methyl propane is an alkane with four carbons initially called Butane. Alkanes are chains of carbon atoms where each carbon atom has as several hydrogen atoms attached as conceivable. This means that all of the bonds among carbon atoms are single bonds. Such a molecule is said to be inundated. Butane has also four carbons, and the form with one carbon in the middle is called isobutane. The iso is short for isomer, which means a molecule with the similar atoms, but arranged in a dissimilar way. Isobutane is a Colorless, odorless gas used generally in lighters and camp stoves as a fuel. It is simply liquefied under pressure, and the liquid becomes a gas instantaneously when the pressure is released.

Isobutane is also used as a propellant in some hair posies and in spray breath fresheners. When used as a refrigerant, dry isobutane has negligible ozone depletion potential and very low Global Warming Potential. It can assist as a good auxiliaryfor R-12, R-22, R-134a and other chloro-fluoro-carbon or hydro-fluoro-carbon refrigerants in most conventional-stationary preservation and air conditioning systems.

III. GENERAL PLANT LAYOUT DESIGN

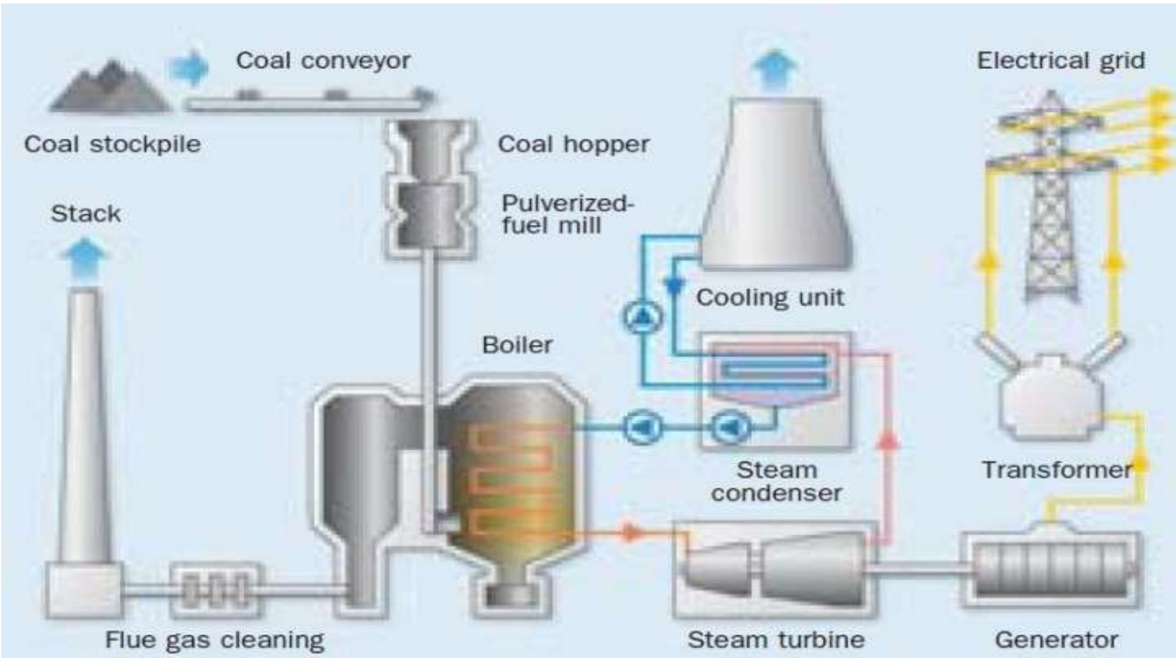

Fig 1.General Plant Layout

After going through numerous OTEC systems and isobutane-operated cycles from dissimilar references in the literature review, the subsequent assumptions were made to insure maximum power output with lowest heat input. Those conventions, which were proficient after intensive isobutane-property reviewing at dissimilar pressures and temperatures, started from the turbine-side where the turbine inlet and outlet temperatures and pressures had to be resolute, and then remaining circumstances were extended by calculations to the condenser, evaporator and pump. The following Fig.1 shows the major cycle components with compulsory data about cycle states and equipment specifications.Subsequent are briefed calculations for the design of OTEC plant cycle, those calculations were made for a single sub-plant, and it can be applied for every single sub-plants.

3.1 Efficiency Improving Methods

Following are some suggested measures to improve the cycle efficiency,

3.3.1 To Use better heat transfer material with higher U-value:

By cumulative the U-value would result in decreasing the heat transfer area with cultivating the heat transfer characteristics through easier and more effective heat transfer. On the other hand, selection of such material would necessitate additional cost, and the selected material would have less antifouling characteristics, both of which should be carefully studied during selection analysis. Submissions for such heat transfer material would be Copper (401 W/m.K) and Aluminum (250 W/m.K).

3.3.2 The Use of Reheat-Regenerative Ranking Cycle:

Thecommon improvement in real power plants on Ranking Cycle is the Reheat-Regenerative Ranking Cycle. For the Reheat process, two turbines work in series. The first receives isobutane vapor from the evaporator at high pressure. Subsequently the vapor has passed through the first turbine, it re-enters the evaporator and is heated before passing through a second, lower pressure turbine. Among other advantages, this prevents the vapor from summarizing during its expansion which can seriously damage the turbine blades, and improves the effectiveness of the cycle, as more of the heat flow into the cycle occurs at higher temperature.The reformative features here effectively raise the nominal cycle heat input temperature, by reducing the accumulation of heat from the evaporator at the relatively low feed-water temperatures that would exist without reformative feed-water heating. This improves the efficiency of the cycle, as more of the heat flow into the cycle occurs at higher temperature.

3.3.3 Decrease Tout of warm water:

Diminishing the warm water liberation temperature or increasing the cold water expulsion temperature results in a lower warm water flow per unit working fluid flow, and hence in lower water pumping necessities. On the other hand, this would decrease the log mean temperature difference (LMTD) in the evaporator or condenser and hence increases the heat exchanger size which will be costly. Consequently, a compromise among water pumping provisions and heat transfer equipment should be completed.

IV. ENVIRONMENTAL IMPACTS OF OTEC PLANTS

OTEC technologies have many probable benefits to the atmosphere as it is a source of clean, renewable energy and attaches the ocean water for electricity generation which is aplentiful and is almost unrestricted. The use of OTEC also confirms reliable constant power output that is not dependent on certain climate situations. OTEC does not discharge any CO_2, and mixing the deep water with the upper layers of the ocean essentially helps to grow phytoplankton, algae and coal which may lead to an increase on CO_2 fixation.Environmental anxieties associated with OTEC systems have been brought up. One main concern is with the closed-loop and hybrid systems that depend on a low boiling point working fluid in heat exchangers. These theoretically harmful substances could leak into the ocean if the pipes were ever damaged. Additional problem would be the habitat disruption in the ocean due to the installation of the pipes.Though OTEC does present potential issues that may be undesirable to the environment, with proper designing, research and care the negative impacts can be reduced or avoided.

V. CONCLUSIONS

The basic design contemplations were conversed for an OTEC power plant to produce 110 MW of electrical power using isobutane as a working fluid. In depthcontrols for heat flow and material flow rates were performed and actual equipment was suggested for real implementation. Overall it consisting of the combined 24 sub-plants each with separate evaporator, turbine, condenser and circulating pump.

REFERENCES

[1] Ghenai, G., Energy-Water-Carbon Interconnection: Challenges and Sustainable Solutions Methods and Strategies. Int. J. of Thermal & Environmental Engineering Volume 7, No 2 (2014) 57-64. DOI: 10.5383/ijtee.04.02.001

[2] Aswathanarayana, U., Harikrishnan T., Sahini K., Green Energy Technology: Economics and Policy. Int. J. Taylor & Francis Group, London, UK 2010.

[3] Gritton, E., Pei R., Aroesty J., Balaban M., Gazley C., Hess R. and Krase W., A Quantitative Evaluation of Closed-Cycle Ocean Thermal Energy Conversion (OTEC) in Central Station Applications: Prepared for US Department of Energy, Government of USA, 1980.

[4] Tchanche B. F., Papadakis G., Lambrinos G., and Frangoudakis A., Criteria for Working Fluids Selection in Low-Temperature Solar Organic Rankin Cycles: Proceedings of Eurosun Conference, Lisbon, Portugal, Oct. 7–10., 2008.

[5] Gong, J., Gao, T., Li, G., Performance Analysis of 15kW Closed Cycle Ocean Thermal Energy Conversion System With Different Working Fluids: Journal of Solar Energy Engineering, (135), pp. 024501, 2012.

[6] Balabel, A. and Kotb, H., Analysis of a Hybrid Renewable Energy Stand-Alone Unit for Simultaneously Producing Hydrogen and Fresh Water from Sea Water: Int. J. of Thermal & Environmental Engineering Volume 6, No. 2 (2013) 55-60. DOI: 10.5383/ijtee.06.02.002

[7] Goodbody, E., and Thomas-Hope, E., Natural Resource Management for Sustainable Development in the Caribbean: Canoe Press, 2002.

[8] Seymour, R., Ocean Energy Recovery: The State of the Art. ASCE Publications, 1992.

[9] Bucker D. and Wagner W., Reference Equations of State for the Thermodynamic Properties of Fluid Phase n-Butane and Isobutane: J. Phys. Chem. Ref. Data, Vol. 35, No. 2, 2006.

[10] TRW Energy Development Group, GEOTEC Engineering Concept Study Prepared for Naval Weapons Centre: Government of USA, 1984.

[11] Wikipedia. Material properties and characteristics and equipment specifications: www.wikipedia.com, 2013.

[12] Vega L., First Generation 50 MW OTEC Plant-ship for the Production of Electricity and Desalinated Water: Offshore Technology Conference OTC 20957, USA., 2010.

[13] Wu C. Thermodynamics and Heat Powered Cycles: A Cognitive Engineering Approach, Nova Science Publishers, Inc. New York, USA. 2007.

[14] Finney, Ocean Thermal Energy Conversion: Guelph Guelph Engineering Journal, (1), pp.17 - 23, 2008.