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Hydrogen Production and Power Generation from Ocean Waves

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***Abstract** - Oceans get heated repetitive by the solar radiation from sun. Ocean covers almost 85% of the globe surface; ocean power has high potential for both electricity production and other byproducts. Solar energy contributes to a reduction of greenhouse gases when compared to energy generated from fossil fuels. Ocean energy source will be an apt solution for meeting global demands of electricity. The nonrenewable energy resources of petroleum and other co_2 sources are increasing the pollution level and causing the environmental affects. in future decades fossil sources like oil and coal might be shortage and huge hike in capital cost of coal. This research paper focuses a method of generating power by utilizing the temperature variation between the ocean surface and colder deep waters. This paper further discusses the electrolysis process for converting the power produced in an ocean thermal energy conversion system into hydrogen, environmental effect and special conditions of these processes.*

Keywords: Hydrogen; Energy from Ocean; Renewable.

I. INTRODUCTION

The abundant resources of energy which can be derived from oceans using the incident solar radiations have not been utilized significantly. Appropriate incident of radiation on ocean surface can be taken by sea in hot regions, which results an annual average temperature of 283ºC [1]. Countries closure to sea has enormous potential to generate ocean-based renewable energy. Literature reviews indicates that the temperature of the water in Deep Sea Ocean is approximately 20°C. This is an ample heat source to convert the low boiling point fluids like propylene and ammonia to a gas or vapor. This temperature difference is sufficient to drive vapor turbines coupled to electrical generators. The rating capacity also reported to be varied with respect to temperature of surface water. Electricity can be transmitted from ocean side to shore using an underwater cable. Arsonval et al. (1881) proposed a method for tapping the ocean energy. Claude et al. (1930) built a 22 kw plant with a turbine of low pressure. In 1956, a French scientist designed a 3 MW plant for Abidjan, West Africa. In 1964, J. H. Anderson developed a closed cycle plant, which overcomes the deficiency of Claude. An experimental set up of 50 kW OTEC system was built at Keahole Point, Hawaii in May 1983.

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In 1984, Dr. H. Uehara, a Japanese physicist invented more advanced cycle for OTEC system. In 1985, Dr. Alex Kalina an American physicist invented Kalina cycle. A 1 MW closed OTEC demonstration system with a 4-stage axial flow reaction turbine was built in the year 2001 and pioneered by National Institute of Ocean technology (NIOT), Chennai. Compact plate heat exchangers were employed for condenser and evaporator. The working fluid in the system is Ammonia [2]. OTEC is getting importance right from the Fukushima nuclear accident in Japan. Faming Sun et al. (2011) reported that the potential of ocean power of 1 million kwhr in 365 days[3]. Nihous [4] suggested OTEC as simple principle and it engages mechanical work extraction in a Rankine cycle. Soerensen et al. [5] reported that global potential of ocean is about 92,000 TWh/year, in contrast to global electricity demand of 16,000 TWh/year which is sufficient to meet present energy crisis. Jacob et al. [6] and Cornett et al. [7] investigated the potential for generating 280 TWh per year of ocean energy across Europe. Jacob et al. [6] also had reported a potential of 255 TWh per year in the United States which had been calculated during the year 2003 by the US EPRI. In 1974 the establishment of NEL by Hawaii Authority in US becomes one of the world's largest facilities for OTEC research [6]. Power output of 255 kW was achieved successfully by using a land-based OTEC experimental facility built at Hawaii which had been in operation during 1993-1998. It was also envisaged that that certain proportion of steam was utilized for surface condenser to produce desalinated water at 0.4l/s.[8, 9].

II. CYCLE OF OPERATION

The general OTEC system constitutes the following (i) Evaporator, (ii) Condenser, (iii) Turbine, (iv) Water pump, (v) Ammonia, (vi) storage tank, (vii) pre desecrator and some others liquefaction unit. The sketch of OTEC is shown in Figure. 1. The principle of operation is similar to heat engine. In a steady-state control volume power developed in must be same to the variation between the rate of heat transfer between the warm water and cold water [10]. In closed-cycle OTEC, a low boiling point fluid like ammonia gets vaporized due to rate of heat transfer from the warm water. Then vapor gets expand in a turbine. The ammonia vapor later gets condensed by the cold water pumped through a cold pipe. Pump transfers water from a lower level in sea for condensing ammonia vapors. The condensate is again recycled back into the boiler (Evaporator) to complete the cycle process. Closed-cycle OTEC gets operated at high pressures, so it requires tiny turbines than open-cycle systems.

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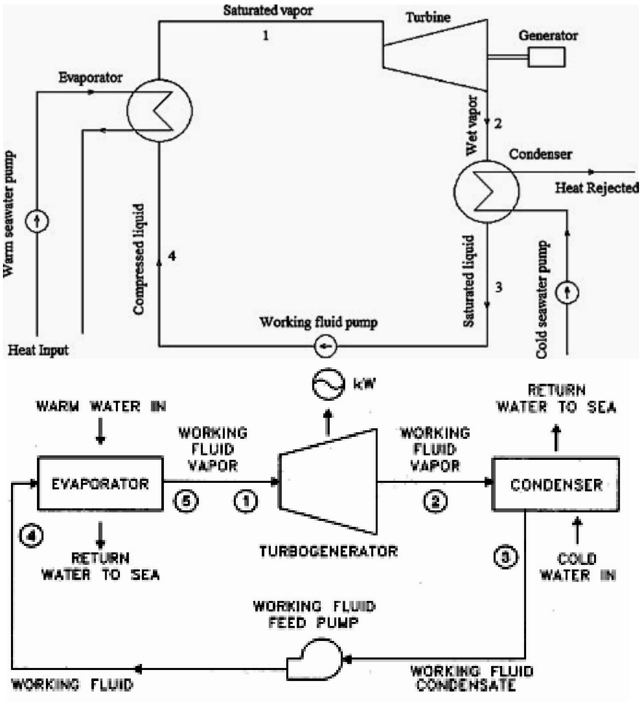

Figure 1.Schematic view of a closed-cycle system.

III. HYDROGEN RECOVERY

In an electrolysis process, hydrogen and oxygen can be spitted under certain operating condition [11]. Kazim et al. (2003) investigated the feasibility of extracting hydrogen in OTEC using polymer electrolyte membrane electrolyser (PEM) [11]. Hydrogen generation rate was reported in range of 2.5 Nm^3/h to 60 Nm^3/h as ΔT raised from 5°C to 25°C. The actual power output was reported to be varied from as low as 11 kW at temperature difference of 5ºC to as high as 258 kW at temperature difference of 25ºC.

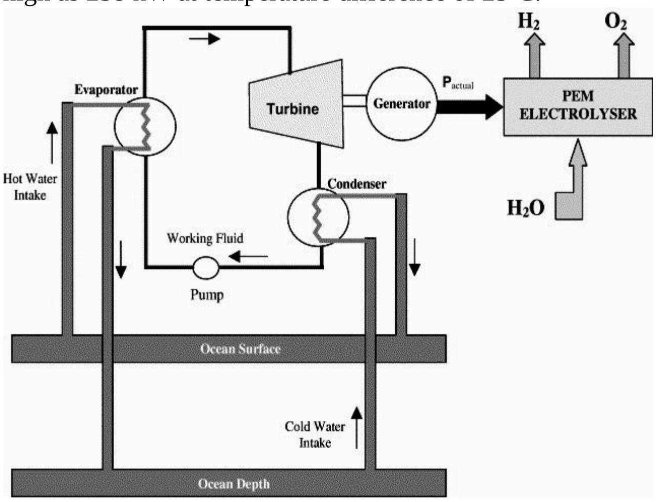

Figure.2. OTEC system with a PEM Electrolyser.

Penner et al. (2002) and W.H. Avery et al. (1999) also had suggested the conversion of hydrogen through electrolysis process [12, 13]. It was reported by COLANO Energy [14] that their proposed 100 MW OTEC project site at Mamuju is potential to pump 0.8 million gallon/MW of water for transforming it into Hydrogen. Hydrogen is a clean, transport, store and inexhaustible fuel which can satisfy the global energy demand. It had been drawn attention to utilize hydrogen to run fuel cells rapidly [14].

Ikegami et al. investigated the production of Hydrogen in an OTEC power plant with a seawater desalination plant**.** Power source for hydrogen production is taken directly from the OTEC unit [15].

IV. SOLAR BOOSTED OTEC AND RECOVERING VALUE ADDED PRODUCTS

A solar-boosted OTEC system first-order performance model was carried out in a 100 kw OTEC system at Kumejima Island. Noboru Yamada et al. [16] envisaged that installation of a a solar based collector with an OTEC system (Figure.3) enhanced the efficiency. The thermal efficiency of SOTEC with solar booster is reported thrice higher than an OTEC.

Hiroki Kobayashi (2002) also had demonstrated the feasibility of extracting mineral water. In his report he described the process of extracting desalinated water with ion-exchanger and mineralizer which comes more valuable industrial product [17]. The Concept of recovering value added fuels along with power generation is shown in Figure.4 and Figure.5[18].

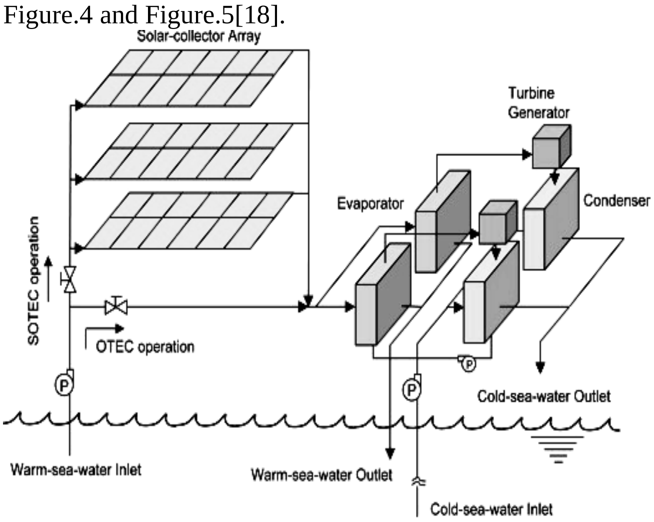

Figure.3.Solar boosted Ocean Thermal Energy Conversion

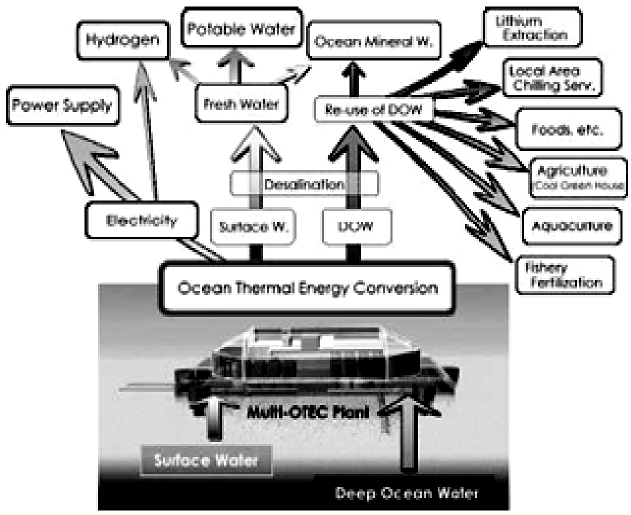

Figure.4. Extracting value added products.

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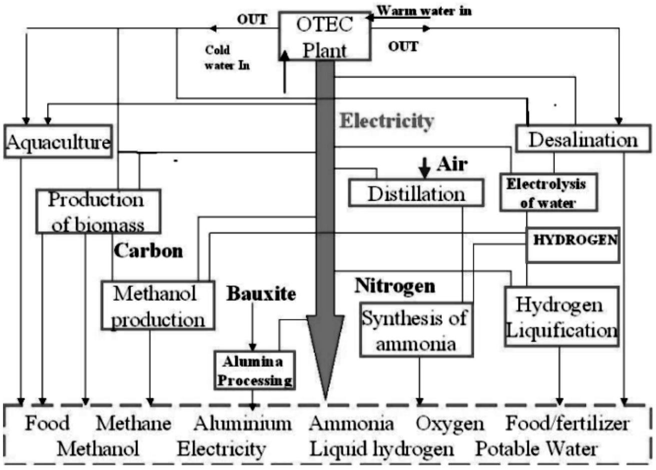

Figure.5. Extracting By-Products in OTEC.

V. RESULTS AND DISCUSSIONS

The feasibility of extracting energy from the Earth's oceans is envisaged. Maria Bechtel et al. reported that energy extracted from an OTEC plant is equivalent to energy output of a hydro power plant of fifty six meters [19]. It has also been suggested to select corrosion resist materials like Titanium, copper-nickel alloys to protect heat exchangers, platforms and cold-water pipes. (Thomas et al., 1989) reported the problem of biofouling of OTEC heat exchangers due to explosion to surface seawater. So the effective heat transfer is to be ensured to protect the heat exchangers from biofouling. Research experts suggests that OTEC plants can be ranged in various capacities from 0.5 MW to 12 MW, and with a minimum desalinated water of 1700 m^3 to 40000 m^3 per day.

Etemadi et al. [20] reported that the vaporized warm water in an OTEC plants can be diverted for giving a source of desalinated water for municipal and agricultural. For cultivating marine organisms the cold-water effluent can be utilized [20].

VI. CONCLUSIONS

OTEC technology makes it possible to extract the energy from the suns radiation. OTEC can be sited anywhere across tropical oceans. Further research is required on the environmental effects as well as financial feasibility of renewable ocean energy projects. OTEC researchers report the unwillingness of private power sectors to make the enormous initial investment. So power sector initiation and financial incentives will attract and draws attention towards the technology. It was also suggested that careful site selection will not cause much impact to environment.

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