Conceptual Design of an Open-Cycle OTEC Power Plant using the thermal waters at La Jolla beach, Ensenada, B. C.

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I. Keywords

OTEC (Ocean Thermal Energy Conversion); Open-Cycle OTEC; Renewable energy; Thermal Gradient; Coastal geothermal resource.

II. Introduction

Ensenada, Baja California, has a population over 443,807 people [1] occupies a territory of 19,538 km² and is located 110 km south of the border with the United States. The city depends on the exploitation of aquifers, through water wells and runoff, due to inadequate management, aquifers have suffered overexploitation in recent years. In order to meet the water needs it has been necessary to use the seawater as a source of a cool water to supply fresh water to the population. It is estimated that water consumption is 140.2 L/hab/day [2].

The Baja California Peninsula hosts many thermal anomalies along its coasts particularly in the intertidal zone, which is the area between low tide and high ocean tide. La Jolla beach is located 20 km south of the Ensenada city and 8 km to the west of the agricultural town of Maneadero. The beach hosts a thermal anomaly with temperatures of up to 52 °C at the surface and up to 93 °C at 20 cm depth [4].

The design of open-cycle OTEC (Ocean Thermal Energy Conversion) technology can take advantage of the thermal gradient between the temperature of the thermal anomaly water in La Jolla Beach and the surface waters of the sea, it represents an opportunity to generate electricity and locally desalinated water from renewable resources. The total net demand in the Baja California Electric System is 3175 MW [3].

III. Open-Cycle Otec Power Plan

In the Open-Cycle OTEC (OC-OTEC), water is used as the working fluid, it is pumped to a flash evaporator, where a fraction of the water evaporates; the mixture is led to a separator that removes the liquid water from the dry vapor to send the latter to a low-pressure turbine to generate electricity, once the steam leaves the turbine it is condensed in a heat exchanger using cold sea water, obtaining desalinated liquid water as a product. The main systems are the pump, the flash evaporator, the turbine, and the condenser [5]. In this work the OTEC power plant uses thermal water as working fluid and is condensed with surface water from the sea (Fig. 1).

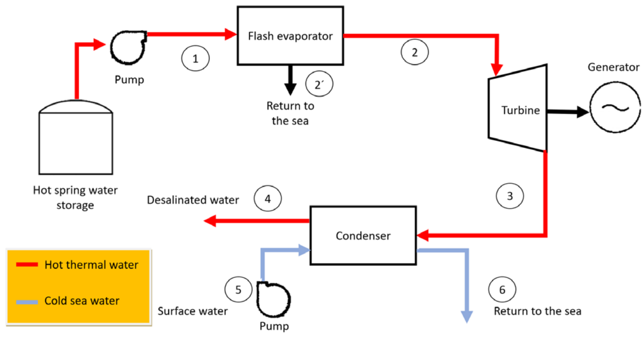

Fig. 1 Schematic diagram of the OTEC plant.

It´s calculated the mixture of the thermal source water, to determine the mass flow and a final temperature in a storage tank, this is 54.94 °C and 325±43.5 kg/s, the average temperature of sea water is 16 °C. The thermodynamic Rankine cycle is evaluated as show in table 1.

Table 1. Data used for balance.

		HOT WATER		Steam		Cold water		
PARAMETERS	UNI.	1	2´	2	3	4	5	6
Temperature	°C	54.94	50.65	54.94	29.8	29.8	16	29.5
Pressure	kPa	101.3	101.3	15.71	4.197	101.3	4.197	101.3
Enthalpy	kJ/kg	230.1	212.1	2600	2469.8	124.9	67.1	123.7
Entropy	kJ/kg K	0.7671	0.7121	7.991	7.991	0.434	0.239	0.43

The results of mass and energy balance are shown in Table 2, and temperature-entropy diagram in figure 2.

Table 2. Results of mass and energy balance.

Result	Description	Value	Units
η_{carnot}	Carnot efficiency	0.119	
η_{th}	Cycle efficiency	0.0105	
(x_r)	Steam quality at the turbine outlet	0.9474	
$\dot{m}_{water\ H,i}$	Thermal water inlet to the evaporator	325	$\frac{kg}{s}$
$\dot{m}_{water\ H,e}$	Return outlet of thermal water in brine	322.56	$\frac{kg}{s}$
$\dot{m}_{steam}$	Water vapor input to the cycle	2.44	$\frac{kg}{s}$
$\dot{m}_{water\ C,i-e}$	Sea water inlet and outlet in the condenser	101.35	$\frac{kg}{s}$
$\dot{m}_{d-water}$	Desalinated water	2.42	$\frac{kg}{s}$
Q_e	Energy input in the evaporator	5782.6	kW
Q_C	Energy output in the condenser	5721.8	kW
W_t	Turbine power	0.318	MW
W_G	Generator power	0.286	MW
W_{bH}	Hot water pump power	29.4	kW
$W_b c$	Cold water pump power	10.3	kW

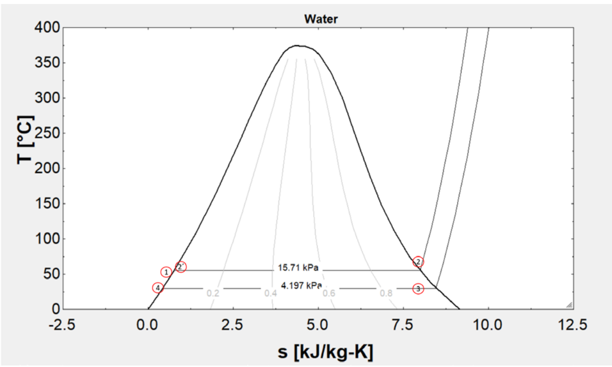

Fig. 2 Temperature-entropy diagram, and process of figure 1 in red circle.

IV. Conclusions

Mass and energy balance of La Jolla OC-OTEC plant resulted in a desalinated water flow of 2.42 L/s and a net power of 245.83 kW the plant would be self-sustaining for its operation since it would provide energy for the operation of the pump and other accessories, producing 2.5 GWh/year of electricity an 76,317 m³/year of desalinated water.

To continue with this project, the detailed engineering, and costs of the subsystems of the OC-OTEC plant will be carried out. It is also considered an environmental impact study to prevent, mitigate and control the negative effects due to the use of the thermal waters of the area.

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