Design of a prototype of a 1kWe open-cycle OTEC power plant for the Mexican Caribbean Sea

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INTRODUCTION

Currently, the production of clean energy is one of the most outstanding and necessary for reducing greenhouse gas factors, these have led to growing problems related to climate change and global warming, this is where renewables play a role essential to provide a solution [1].

Ocean water retains approximately 15% of total solar energy as thermal energy. The technology that enables the ocean to generate energy through temperature differences is called Ocean Thermal Energy Conversion (OTEC). This type of energy is concentrated in the superficial part of the seawater and decreases exponentially with increasing depth [5].

The implementation of an OTEC plant can occur in tropical regions because the optimum temperature differences between warm surface seawaters and deep cold seawaters sea are satisfied, and have attracted the attention of many researchers [2].

Mexico has ideal thermal gradient conditions for the installation of OTEC plants [6] specifically; the Mexican Caribbean Sea has a thermal gradient of 20 °C throughout the year. Potential locations in the State of Quintana Roo suitable to build an OTEC plant at distances less than 10 km from the coast are Isla Cozumel, Punta Allen, Tulum, Sian Ka´an, Xcalac, Mahahual and Banco Chinchorro [3].

Currently, the Universidad del Caribe and the Instituto de Ciencias del Mar y Limnología with the support of the Centro Mexicano de Innovación en Energía – Oceano (CEMIE-O), are implementing a prototype of a closed cycle OTEC plant (OTEC-CC-MX-1kWe) in Cancun, Quintana Roo. This prototype uses the difference of temperatures between the warm surface seawaters (27 °C) and the cold deep seawaters (7 °C) of the Mexican Caribbean Sea to generate 1 kW of electrical energy [4].

This article presents the advances made for the design of the open cycle OTEC plant prototype (OTECA-MX-1kWe) and its energy comparison with OTECC-MX-1kWe.

OTEC-OC PLANT PROTOTYPE

The open cycle or Claude cycle is the precursor to several OTEC cycles and refers to the use of seawater as a working fluid. Basic Rankine cycle convert the thermal energy of the hot surface water into electrical energy. Figure 1 shows the diagram with the basic components of the prototype: flash evaporator, turbine connected to an electric generator, steam condenser, and a deaerator.

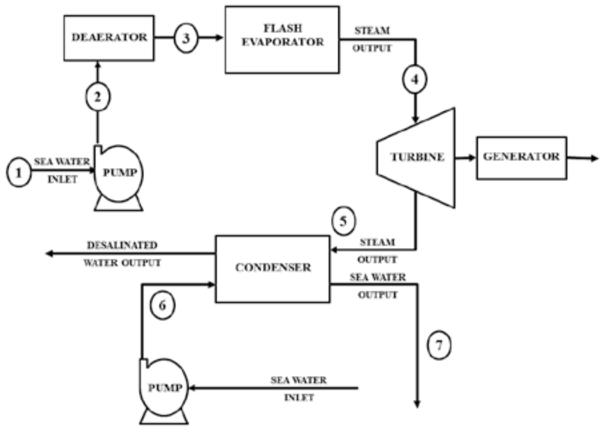

Figure 1. Open cycle OTEC plant diagram (OTECA-MX-1kWe)

In the open cycle, hot seawater is de-aerated and then passed to a flash evaporation chamber, where a fraction of the seawater turns to low pressure steam. Steam passes through a turbine, which draws energy from it, and then exits into a condenser. This cycle gets the name “open” from the fact that the condensed fluid does not return to the evaporator as in the “closed” cycle. Instead, the condensed fluid can be used as desalinated water, or it is mixed with the cooling water and it is discharged back into the ocean.

The mass and energy balances were evaluated with the following equations:

The heat transferred in the evaporator in kJ/s (qe) is:

$$q_e = \dot{m}_{\omega\omega}(h_2 - h_1)$$

where $\dot{m}_{\omega\omega}$ is the mass flow and h is the enthalpy.

Steam generation rate (kg/s):

$$\dot{m}_s = \frac{q_\omega}{hfg}$$

hfg is the water vaporization heat.

Turbine work in J/s (W_T) is:

$$W_T = \dot{m}_s(h_2 - h_4)$$

The rejected heat in J/s (q_c) is:

$$q_c = \dot{m}_{c\omega}(h_5 - h_4)$$

Thermal efficiency is:

$$n_{th} = \left(1 - \frac{q_c}{q_\epsilon}\right)$$

The monthly thermal efficiency of the OTECA-MX-1kWe prototype will be compared with the monthly efficiency of OTECC-MX-1kWe with the aim of contributing to decision making for the selection of the optimal OTEC plant for the Mexican Caribbean. It is the first step to design a prototype of an open-cycle 1MWe OTEC plant that will serve as the basis for future research on the life cycle, environmental and social impacts of this type of OTEC plants.

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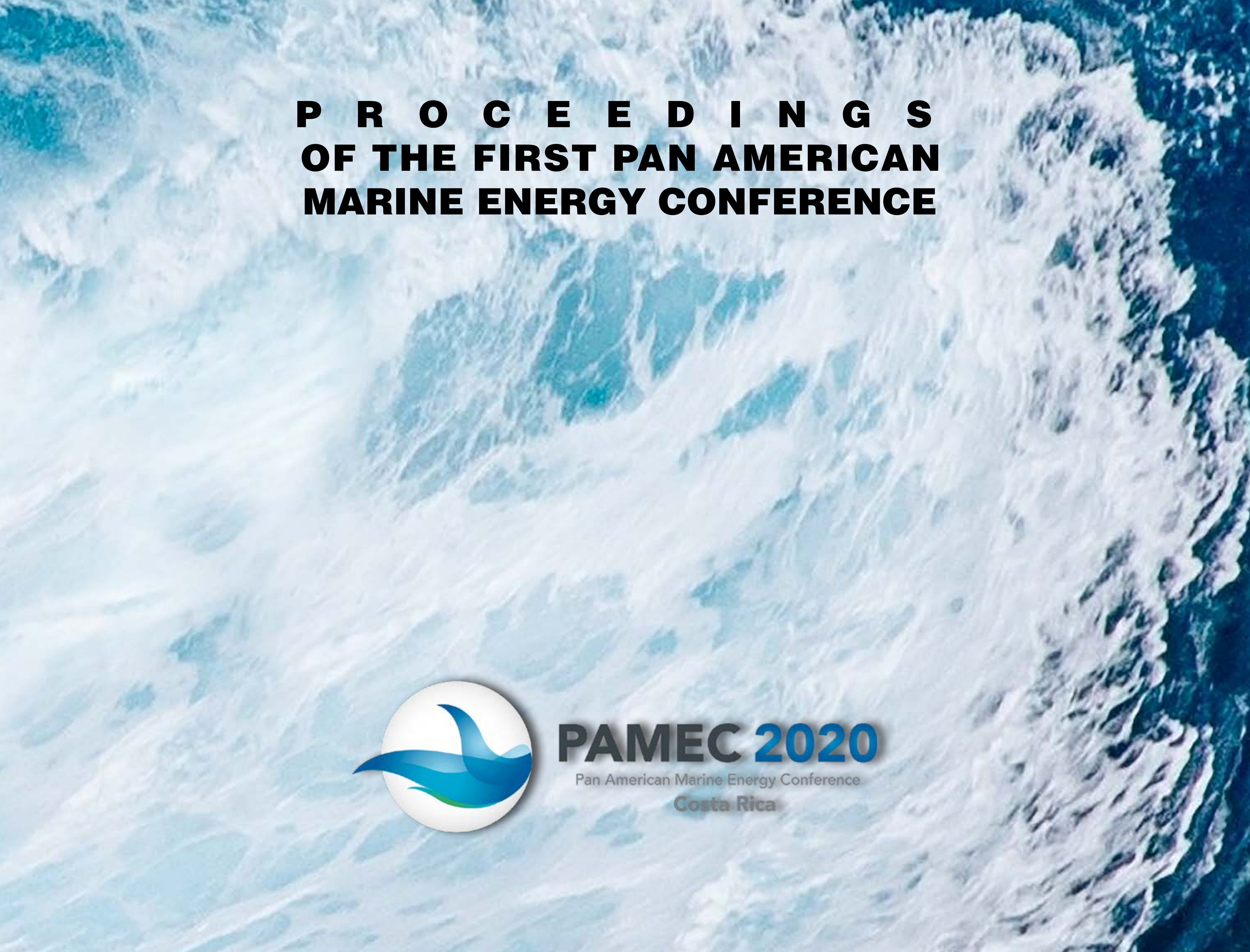

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