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Sensitivity Analysis of OTEC-CC-MX-1 kWe Plant Prototype

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Abstract: The Mexican Caribbean Sea has potential zones for Ocean Thermal Energy Conversion (OTEC) implementation. Universidad del Caribe and Instituto de Ciencias del Mar y Limnologia, with the support of the Mexican Centre of Innovation in Ocean Energy, designed and constructed a prototype OTEC plant (OTEC-CC-MX-1 kWe), which is the first initiative in Mexico for exploitation of this type of renewable energy. This paper presents a sensitivity analysis whose objective was to know, before carrying out the experimental tests, the behavior of OTEC-CC-MX-1 kWe regarding temperature differences, as well as the non-possible operating conditions, which allows us to assess possible modifications in the prototype installation. An algorithm was developed to obtain the inlet and outlet temperatures of the water and working fluid in the heat exchangers using the monthly surface and deep-water temperature data from the Hybrid Coordinate Ocean Model and Geographically Weighted Regression Temperature Model for the Mexican Caribbean Sea. With these temperatures, the following were analyzed: fluctuation of thermal efficiency, mass flows of R-152a and water and power production. By analyzing the results, we verified maximum and minimum mass flows of water and R-152a to produce 1 kWe during a typical year in the Mexican Caribbean Sea and the conditions when the production of electricity is not possible for OTEC-CC-MX-1 kWe.

Keywords: sensitivity analysis; power generation; close cycle OTEC; ocean renewable energy; Mexican Caribbean Sea; OTEC plant prototype

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1. Introduction

Due to the increment of energy demands to satisfy the population's needs, scientists and researchers have been looking for new ways to produce energy or making them more efficient. In past centuries, converting large-scale thermal energy into power using water as working fluid in a Rankine Cycle has been widespread, but recently, converting low-grade heat into mechanical and electrical energy has shown increased interest [1].

Examples of converting low-grade thermal energy into electricity are semiconductor thermocouples, thermionic, and thermoelectric devices that can directly convert thermal energy into electrical energy based on the Seebeck effect [2]. Although these devices have been applied in different areas such as photovoltaic (PV) solar cells [3], air–ground heat transfer systems [4], the transport sector, and industrial and human waste heat [2], their performance is based on conversion materials. Furthermore, its power density remains significantly lower compared to other low-grade thermal energy conversion techniques [5].

Organic Rankine Cycle (ORC) is used to produce mechanical energy. ORC uses an organic fluid with a low critical temperature instead of water in a conventional Rankine cycle to convert heat from several sources, such as solar energy, geothermal heat, biomass, or industrial heat waste to produce mechanical energy [1]. The main advantage of this principle is that it offers co-generation on a small scale with better efficiency and with little maintenance [6].