Thermodynamic analysis of the viability of implementation of solar collectors in Rankine cycles

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Abstract
The present project aims at performing the comparative analysis of distinct configurations of Rankine cycles. Succeeding the analysis of a traditional and well established steam power generation cycle, solar power generation is evaluated by replacing extractions of steam from the turbine by solar preheaters and, moreover, the boiler by solar thermal collectors. Based on the literature analysis, three Rankine cycles configurations are proposed, in which the mass, energy and exergy balances are applied. From the thermodynamic analysis, the parameters of efficiency of the cycles are compared, such as destroyed exergy, exergy efficiency, pollutants emission, power production and reduction on the generation costs. Results are compared with the ones in literature in order to evaluate the feasibility of the implementation of the proposed cycle configurations.

Key words:
Renewable energy, Rankine cycle, Solar thermal collectors

Introduction
According to Cartlidge [1], the Sun delivers to Earth the same amount of energy in a single hour as that consumed by all of humanity in one year – about $5 \times 10^{20}$ J – and, in 36 hours, releases as much energy as exists in the Earth’s estimated oil reserves. Despite this, as reported by Solangi et al. [2], solar electricity currently provides only a fraction of a percent of the total global primary energy supply. The expressive insertion of solar energy into the global energy matrix has been arduously pursued by countries and researchers around the world and is of great importance in terms of national strategic energy planning. In this context, the present project aims to analyze, through different approaches, the feasibility of insertion of solar thermal collectors in Rankine cycles under the current technology conditions.

In order to evaluate different scenarios, a thermodynamic model for the base cycle is presented in Image 1. The carried out simulations contributed to the validation of the dynamics through the analysis of the cycle response to changes stipulated in variables of interest. It was possible, through the literature review, to select the most suitable type of solar collector for each of the project objectives of preheating water and of consisting the main energy source of a power cycle.

![Image 1. Base cycle representation.](image1.png)

Results and Discussion
The results obtained from the insertion of the CSP system to the base cycle in order to replace some of the steam extractions signaled the conclusion that the introduction of the Linear Fresnel CSP system is more adequately justified when applied at lower working temperatures. The insertion of the solar preheaters caused an improvement in the parameters of total efficiency and CO$_2$ emission of the power plant, decreasing the latter and increasing the first. It is observed a percentage improvement of approximately 7% in these parameters in the Altered Cycle 1 and 3% in the Altered Cycle 2.

It was possible to obtain the UA parameter of the heat exchangers responsible for transferring the heat of the working fluid used in the collectors to the working fluid of the power cycle under analysis. Moreover, the calculation of the auxiliary power required to the integral solar cycle was made from the fixation of the properties necessarily reached by the steam at the entrance of the power cycle.

Conclusions
The carried out analyzes pointed to the greater suitability of Linear Fresnel collectors to applications with lower working temperatures. In addition, the importance and relevance of the proposition of integrally solar cycles was evaluated and explored through the strategies of additional power supply and thermal storage.

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