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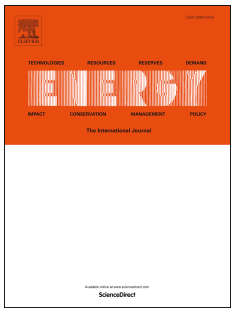

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SIMULATION AND TESTING OF A SOLAR RECIPROCATING STEAM ENGINE

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Abstract: A solar thermal system for steam generation was built in the city of San Carlos, Salta province, Argentina. This system is a Linear Fresnel Collector (LFC) used for producing steam for many applications, such as vegetable drying, water desalination, and power generation. A steam engine was coupled to this LFC for power generation. This paper shows the steam engine simulation, where thermal and dynamic equations were developed and written on the Simusol program. Mechanical power output and other parameters of the engine were also simulated as well as steam consumption, in order to establish laws in relation with mechanical load on axis and regulate the rpm regime and inlet pressure for optimal steam engine operation. The results of the simulation of power output are compared with experimental measurements. The steam engine was tested, and the obtained experimental results demonstrate the feasibility of generating power (i.e. 2 kW ± 5% (288 rpm) or 8 kW ± 2% (400 rpm)). Furthermore, it is found that the experimental measurements are in an acceptable agreement with the simulation outcomes of the analytical model. Finally, knowing the steam engine behavior allows to optimize the solar energy resource use for power generation.

Keywords: solar heating, steam engine, numerical simulation, Simusol, power output.

1. Introduction

According to the British Petroleum Company [1], renewable energy sources used in power generation grew by 15.2% in 2016, slightly below the 10-year average growth of 15.9%. Globally, solar power generation grew by 32.6%. At the same time, solar steam generation projects have been growing significantly, with currently more than 300 solar plants around the world at different stages of development [2]. All of them include turbines in their power block. In 1981, a steam engine had been used to convert steam into energy at Australia's first ever solar farm in the remote town of White Cliffs in New South Wales [3], supplying the local hospital, school, post office and twelve homes [4,5]. Steam engine technology is mainly used in small thermal and electrical applications [6] because of their lower initial cost and better efficiency than that of certain turbines [7] For this reason, the Institute of Non-Conventional Energy (INENCO) built a small-scale Linear Fresnel Reflector (LFR) in Argentina producing steam at pressures above 15 bars in which a double effect reciprocating steam engine with 7 HP output was installed to produce electricity [8]. The Fresnel generator produces both steam to heat a drier and electricity to drive the fan in the drier [9]. San Carlos, Salta province, where the prototype was installed, receives high amounts of solar radiation, and direct normal irradiance (DNI) can reach maximum around 1000 W/m^2.