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SOLSTICE	Title of the PhD thesis: **Modelling and optimisation of linear Fresnel solar power plants with direct steam generation and energy storage**
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Context and objectives

This thesis is part of the ANRT's CIFRE programme and is being carried out at the PROMES-CNRS laboratory in collaboration with SUNCNIM, a French industrial company which is the manufacturer and operator of the solar power plant of Llo. The main idea of the research project is to develop a numerical model to evaluate the performance of the sub-assemblies of an innovative linear Fresnel solar power plant featuring both direct steam generation and energy storage. This model, validated experimentally with data from the solar power plant of Llo, will then be used to optimise the plant's operating strategies, including storage management.

Approach

The work has 3 main objectives:

i.   To build numerical models to define the performance of the sub-assemblies (solar field, turbine, storage) and then the overall performance of direct steam generation solar power plant with energy storage.
ii. To validate experimentally these models with data from the Llo solar power plant.
iii. To use the global model to optimise operating strategies and in particular storage management.

Main results

The global model to be developed can be divided into two main parts. The first part is the evaluation of the performance of the solar collectors consisting of an optical and thermohydraulic study and the second is the integration of the output of the first part into a global model considering the thermodynamic cycle and the storage system to determine the overall performance of the plant.

The first objective of the thesis is therefore naturally oriented towards the construction of an optical model. This model is built under Tonatiuh software based on ray-tracing method. This software allowed to model the 140 primary reflectors solar collector of Llo and its cavity receiver equipped with a secondary reflector. Several simulations for different solar positions enable to determine, as a first step, the maximum optical efficiency of the collectors obtained when the sun is at zenith. The maximum optical efficiency is defined as the power absorbed by the absorber over the solar power incident on the primary reflectors. Secondly, the Incidence Angle Modifiers - IAM representing the optical losses related to the incidence angle of solar radiation in the longitudinal and transversal planes of the collector is determined. Equation (1) expresses the overall optical efficiency:

$$\eta_{opt} = \eta_{max,opt} \, IAM_{\theta_\perp} \, IAM_{\theta_\parallel} \tag{1}$$

The IAMs obtained by the optical model are shown in Figure 1 : Transversal and longitudinal IAM of the solar collectors of Llo, NOVA-1 and LF-11Figure 1 and these results are compared with those obtained by the linear

Fresnel solar collector manufacturers NOVATEC (NOVA-1) and Industrial Solar (LF-11). The results of the optical model are close to the results of these manufacturers, thus validating the optical modelling approach.
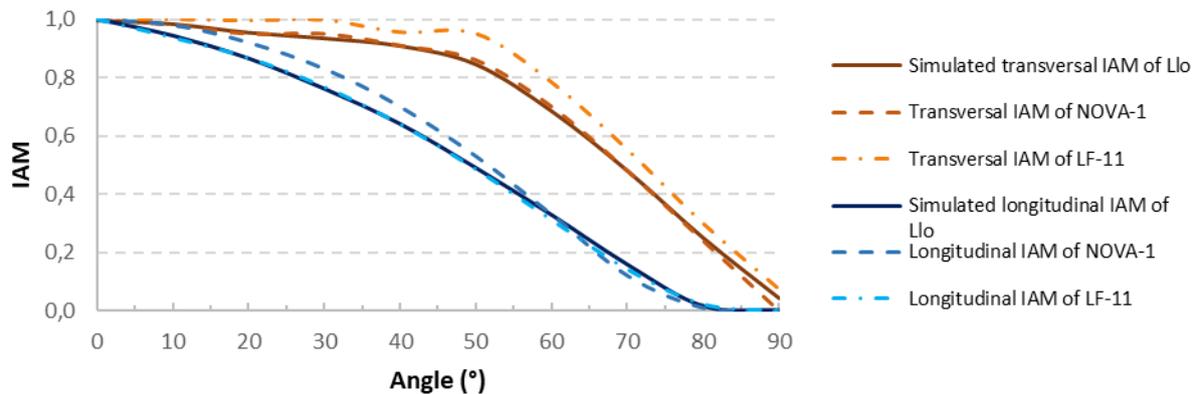

Figure 1 : Transversal and longitudinal IAM of the solar collectors of Llo, NOVA-1 and LF-11

Publications in national and international conferences

- Author for a communication (poster) in a national congress:

Edouard MONTANET, Sylvain RODAT, Quentin Falcoz, et al. Etudes des performances de la centrale solaire thermodynamique de Llo. *Journées Nationales de l'Energie Solaire*, Aug 2021, Font-Romeu, France. (hal-03369692)

- Author for a communication (presentation) in an international doctoral colloquium:

Edouard MONTANET, Sylvain RODAT, Quentin FALCOZ. Performance study of the solar power plant of Llo. Doctoral colloquium SFERA-III, Oct 2021, Almería, Spain. (hal-03369628)