Evaluation of an Existing Solar Thermal System

Performance Check; Simulation's Performance Evaluation; Genetic Algorithm-Based Parameter Optimization

Graduate

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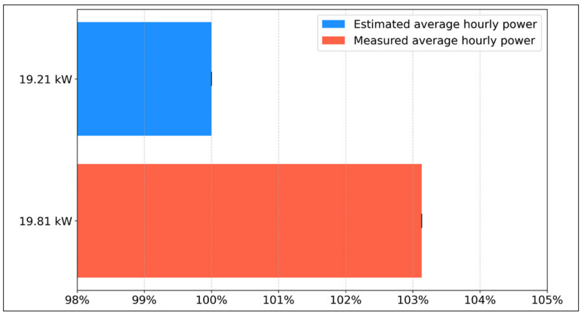
Problem: Various simulation tools available on the market can evaluate the energy yield of solar thermal collectors, but often disregard factors such as aging and soiling. This can lead to underestimating the impact of changing efficiency parameters on system performance over time. At the Pontificia Universidad Católica de Chile (PUC), Grupo Solar is developing an open-source library to improve accuracy by possibly taking these effects into account. As a basis for the library, a model of the 10-year-old solar thermal system (STS) at PUC was created. The STS consists of flat plate and evacuated tube collectors.

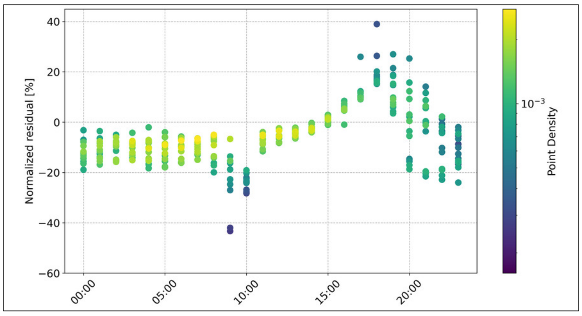
Definition of Task: The aim of this thesis is to evaluate the performance of the STS in operation at PUC, focusing on the model by Grupo Solar. The evaluation comprises three subtasks: Performance checks according to ISO standard 24194; simulation evaluation with different error metrics; and optimization of collector efficiency parameters through a genetic algorithm (GA). Python scripts were crafted for performance checks and error metric calculations in the first two subtasks. The third subtask involved literature review and modification of the STS model, incorporating a GA to optimize collector efficiency parameters.

Result: The results of the performance checks show that only the estimate of the FPC field is verified, but caution is advised due to uncertainties such as the lack of a solar keymark for the FPC. The python scripts are versatile and can also be used for other solar thermal collector fields. When using the scripts, efficiency parameters should be based on solar keymarks, and at least twenty valid data points need to be considered. Recommendations include the inclusion of wind speed limits and extending the script runtime beyond daily execution.
The python scripts developed to analyze the simulation prove to be versatile and can generally be used to compare simulated and measured data. They calculate R^2, Normalized Mean Bias Error (NMBE), Root Mean Squared Error (RMSE), Normalized Residuals and Dynamic Time Warping (DTW) for separate days. Additionally, these scripts introduce overlapping averages to account for simulation limitations such as the neglect of thermal inertia. The evaluation of the STS model shows significant errors, which was to be expected as the model was not yet calibrated. Recommendations include careful selection of sample sizes for smoothing the signals and consideration of specific error metrics based on the simulation objectives.
For the optimization of collector efficiency parameters, the GA effectively optimized parameters so that errors would get reduced, but variations arose based on optimization scenarios. A determination of the feasibility of these parameters based on literature research proved to be difficult, as factors such as dust accumulation and aging depend on factors like climate and location. The analysis revealed that the optimized parameters likely do not accurately reflect the efficiency parameters of the collectors. As an attempt was made to optimize the efficiency parameters for the FPC and the ETC simultaneously, future studies should consider individual parameter optimization for the FPC and ETC fields to avoid compensation effects.

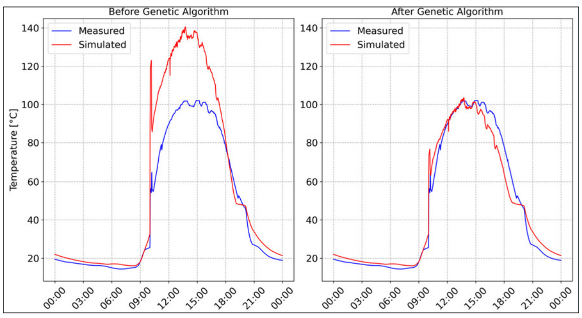
Average hourly estimated and measured power output of the flat plate solar thermal collector field
Own presentment



Normalized residuals distribution between the simulated and measured temperature of the water leaving the system
Own presentment



Simulated and measured temperature of the water before and after genetic algorithm-based parameter optimization
Own presentment



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Subject Area
Solar thermal technology