

## Thermal simulation and experimental identification of electro-thermal model parameters for a point-focus concentrating photovoltaic module

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### Abstract

The main objective of this work has been to perform an accurate thermal model for a point-focus concentrating photovoltaic module, adopting Fresnel lenses with a concentration factor of 748 X. For 3D thermal behaviour simulations, software based on FEM (finite element method), are generally used. For the accurate simulation, the software needs to define correctly the thermal conductivities and the thermal capacities for all materials constituting the module, which, in some cases, cannot be get from the literature, therefore it is necessary their experimental determination. For this scope we made an identification procedure that allowed to identify the unknown parameters and to validate the simulations performed by software. The FEM software used for the 3D thermal behaviour simulations was based on the Comsol Multiphysics Platform.

The procedure allowed estimating the convective thermal exchange coefficients for the gas inside the module and between the module and the outside air. Further it permitted to determine with good accuracy the following parameters:

- a) cell junction temperature coefficient,
- b) cell junction temperature,
- c) cell thermal resistance,
- d) thermal capacities of gas, cell and backside of the module.

The experimental apparatus (showed in fig.1) allowed to perform two parallel tests: *peak test* and *transient test*. The experiments started from a thermal equilibrium initial condition switching on the current generator, which polarized the module in dark condition causing, for Joule effect, its heating.

The *peak test* consisted in the rapid acquisition of the voltage on the module during the first 2 seconds after beginning by an oscilloscope with a fit of ten thousand samples. It began sampling the voltage when the Hall Effect ammeter (connected through an I-V converter to the CH2 of the oscilloscope) measured a current value greater than a trigger level fixed in the setup of the oscilloscope. The voltage peak occurred at less of 1 millisecond from the beginning, due to the electric frequency response of the module. The oscilloscope allowed capturing the voltage peak on the module due to the fast increasing of the junction temperature that caused the fast decreasing of the voltage as showed in fig.2.

The *transient test* permitted to acquire the temperature transients in some important points of the module by using some thermocouples and a data-logger till the stationary condition was reached. It took more than one hundred minutes as showed in fig.3 to reach full stationary condition. We acquired also the whole transient of the voltage on the module. We carried out the test on a special module, made on purpose by Solartec, adopting five thermocouples which measured the temperatures under and upper the cell, on the lens, on the backside and of the internal gas volume.

For the identification of the desired parameters, we defined a concentrate parameters thermal model, where its unknown parameters were the thermal resistances between the points on which were located the thermocouples. In order to simplify the identification procedure we designed in Proteus environment the electric circuit equivalent to the thermal model (fig.4) and we divided the identification procedure in two main parts: *stationary identification* and *dynamic identification*. The stationary one identified the unknown convective thermal coefficients, the cell thermal resistance, the cell junction temperature and cell junction temperature coefficient, while the transient one identified the thermal capacities. For the *stationary identification* we determined the equations that solved the circuit in stationary conditions (when the *transient test* was completed) along with the equations related to voltage peak measured by the *peak test*. We introduced these nonlinear equations system in Mathcad environment and, solving them, we determined all the incognitos thermal resistances.

For the *dynamic identification* we calculated some symbolic transfer functions (in Laplace field) between some points of the circuits. We included the data measured during the transient test in the identification toolbox of Matlab which permitted to identify poles of the transfer functions. Since poles of the transfer function depend on thermal capacities and thermal resistances, we were able to calculate the thermal capacities from the poles and the thermal resistance identified in the stationary identification. Then we introduced the identified values of capacities and resistances in Proteus and simulated the circuit verifying that the simulated temperatures were equal to the measured ones.

Finally, from the values of the identified thermal resistances we got the desired thermal conductivities and we put them with the identified thermal capacities in the COMSOL model. We made the simulation in COMSOL verifying that the simulation in indoor conditions gave the same results of the experimental ones.

We have also made a thermal simulation in outdoor conditions and, in the future, we think to validate it setting up an apposite apparatus for the outdoor thermal identification.

Keywords: III-V Semiconductors, Gallium Arsenide Based cells, Multijunction Solar Cells, Concentrator modules, Characterisation, Thermal model, Testing

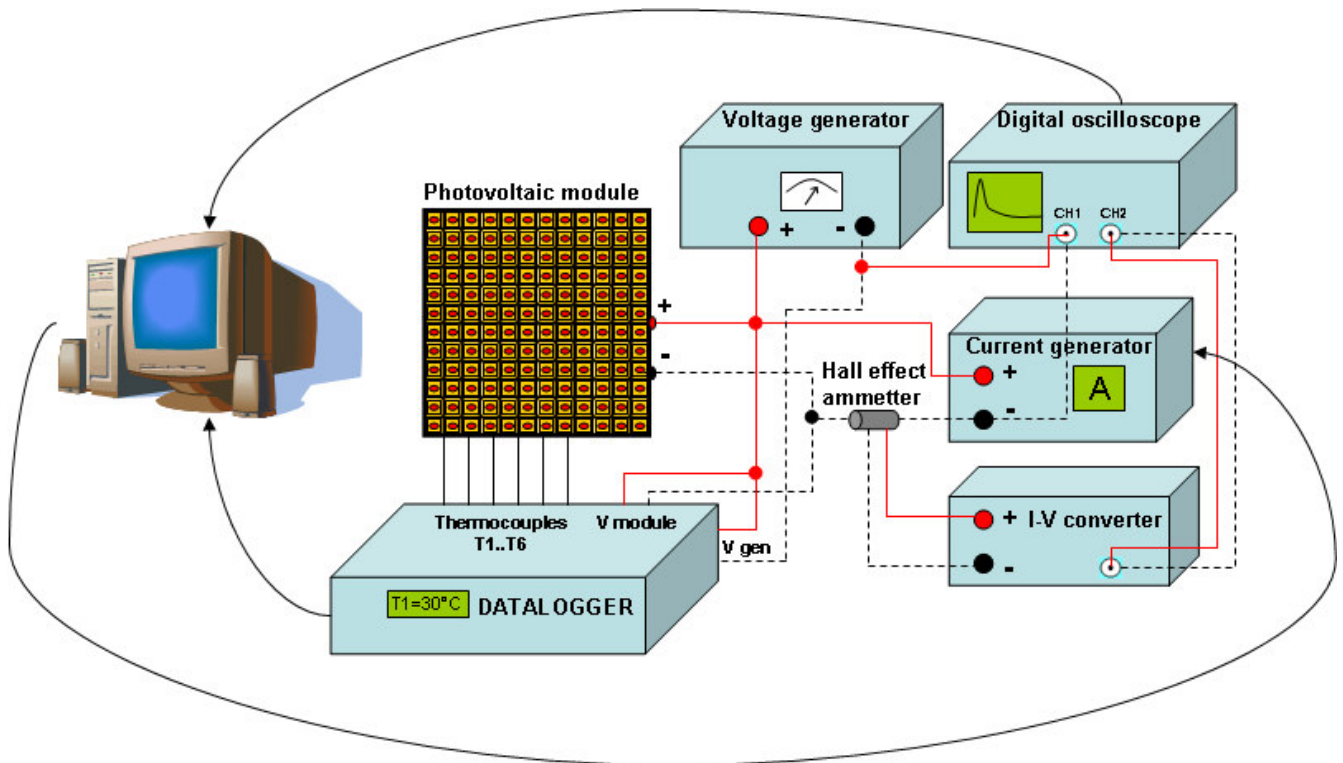


Fig. 1 Experimental apparatus for the thermal identification procedure

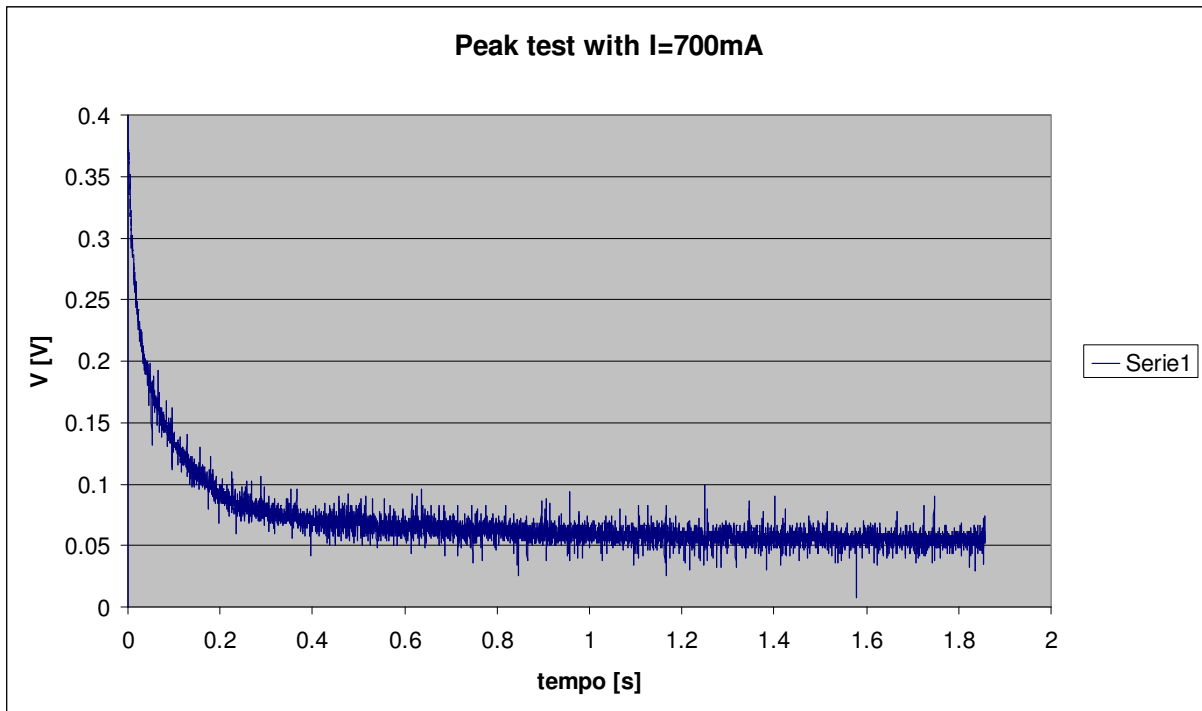


Fig. 2 Peak test with  $I=700\text{mA}$

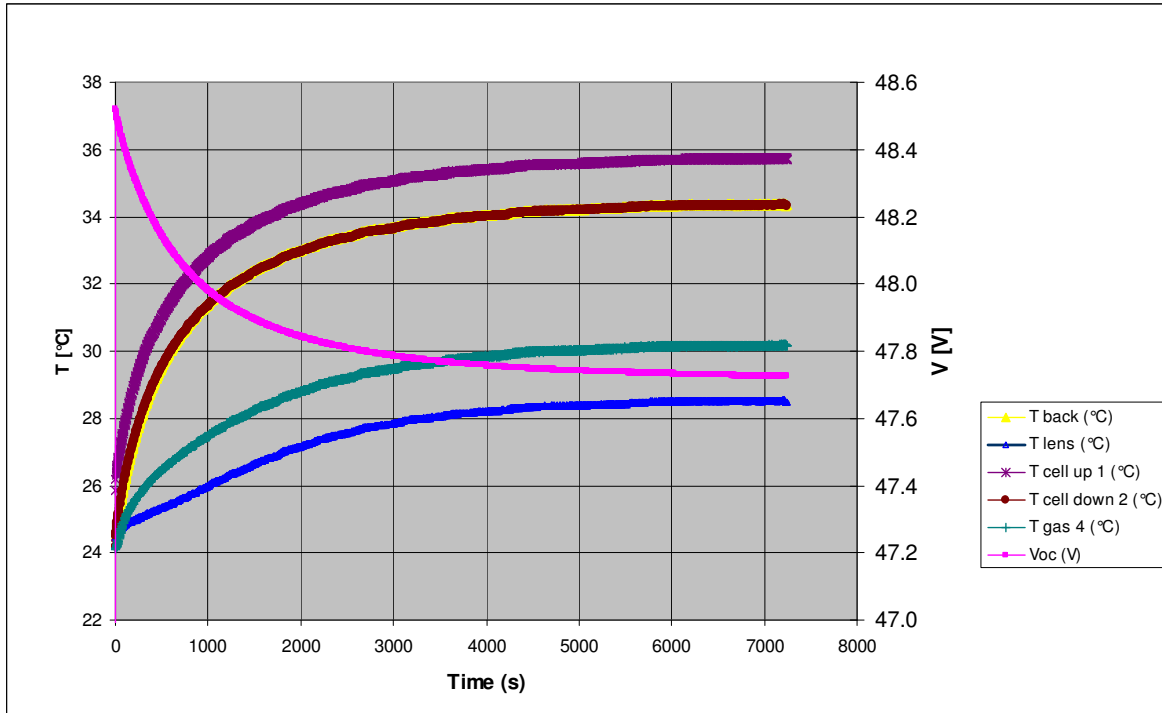


Fig. 3 Transient test with I=500mA

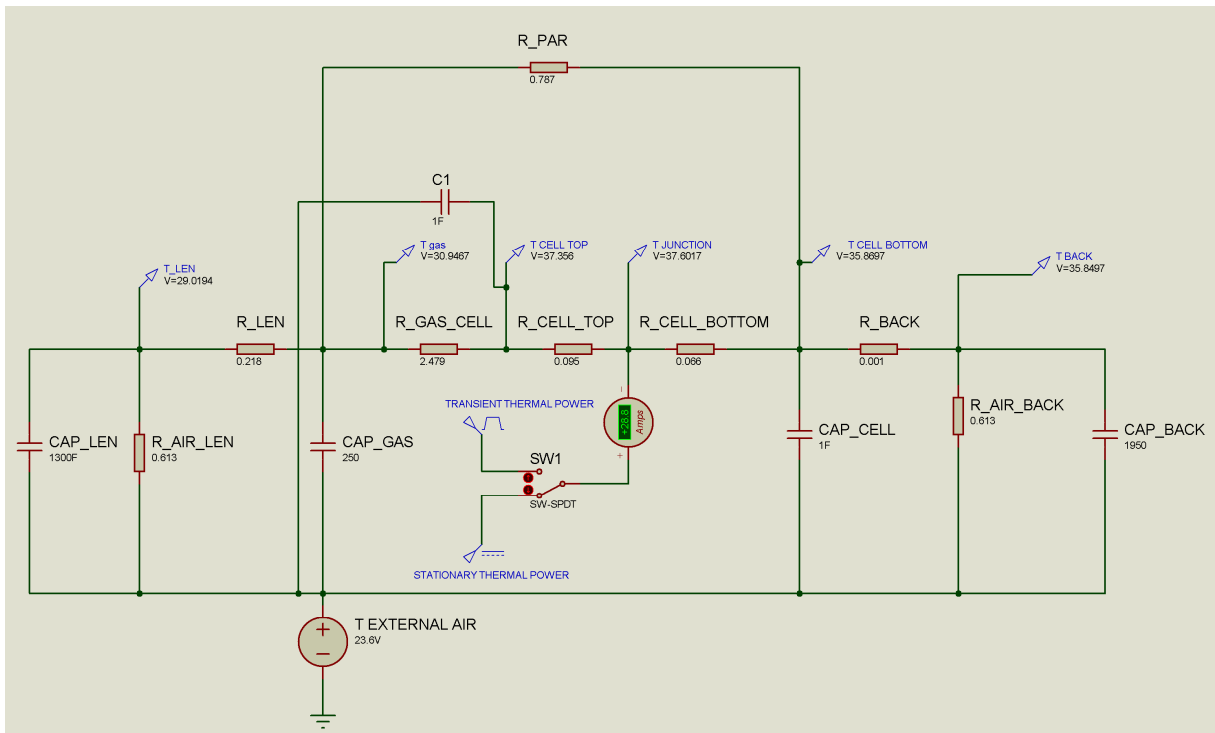


Fig. 4 Electric circuit equivalent to the thermal model