

Thermal Modeling of a Solid Oxide Fuel Cell Stack (SOFC)

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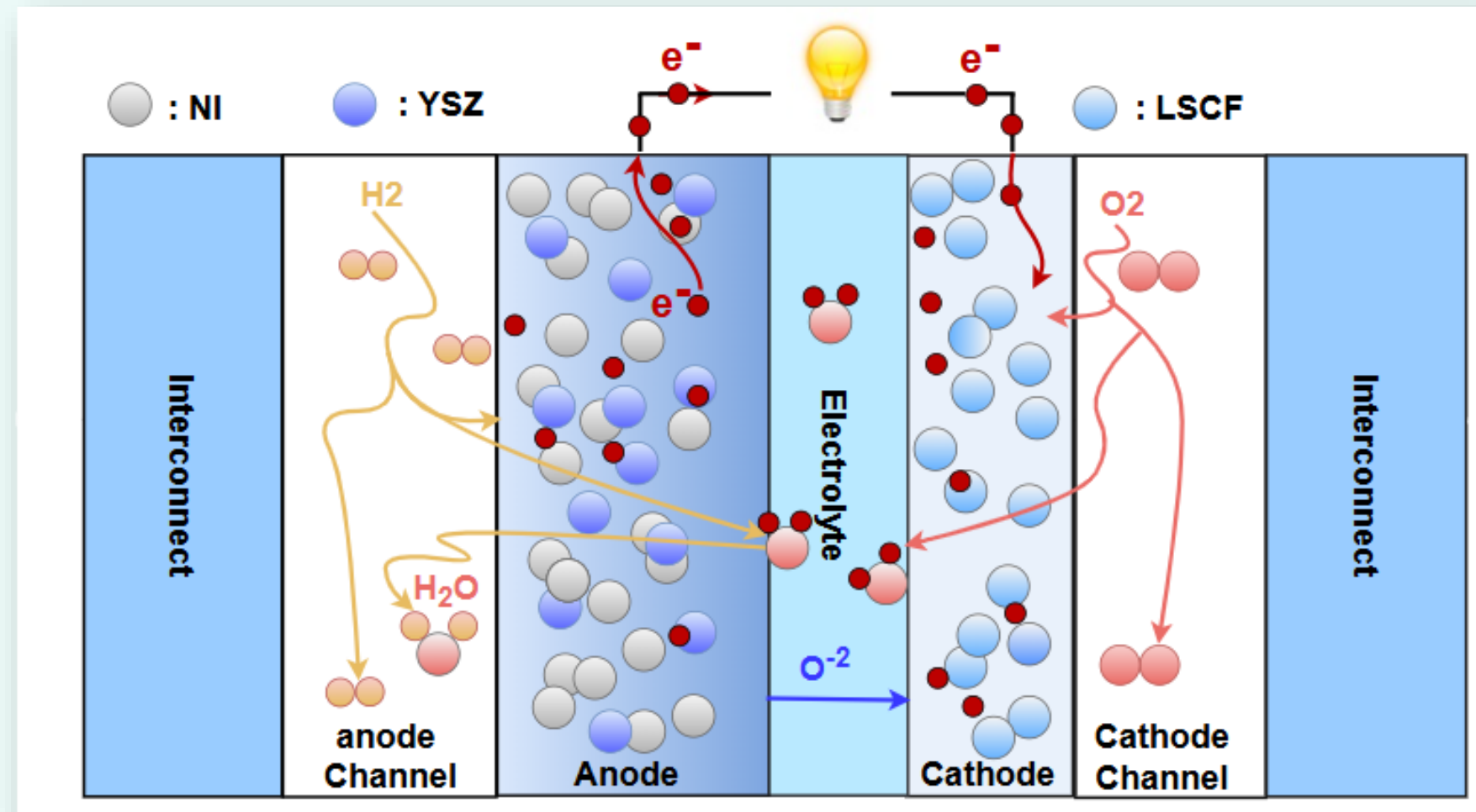
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Introduction

Solid Oxide Fuel Cells (SOFCs) :

- High electrical efficiency,
- Fuel flexibility,
- High operating temperature (600–1000°C),
- Internal reforming of hydrocarbons,
- effective heat recovery for cogeneration.

They are suited for stationary, maritime, and heavy-duty transport applications.

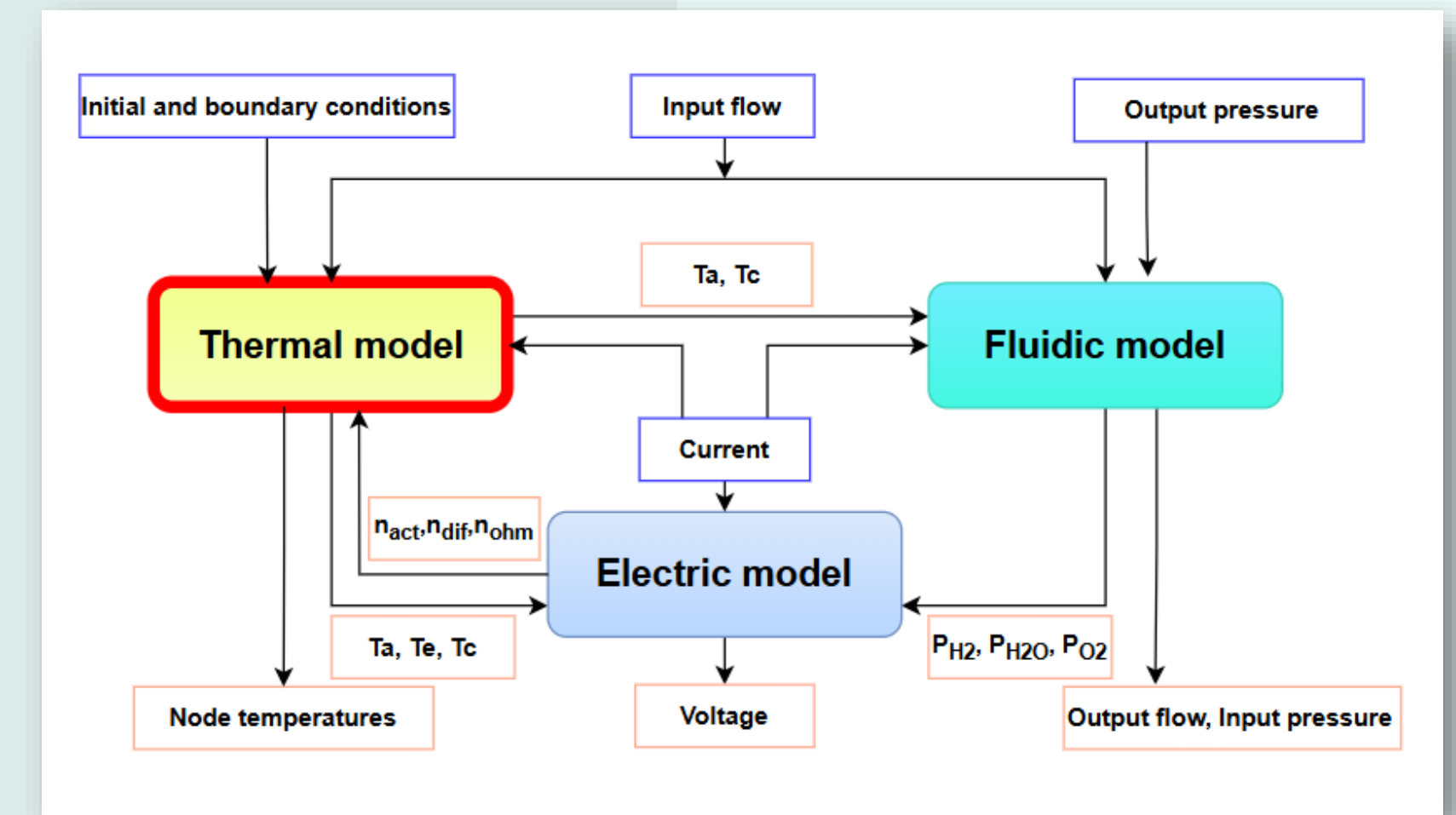


Equation globale : $H_2 + \frac{1}{2}O_2 \rightarrow H_2O + \text{électricité} + \text{chaleur}$

Objectives

Within the **FLEXISOC** project (PEPR H2), the objective is to develop a multiphysics macroscopic model of a SOFC stack, first for a reference H₂/air system then extended to multi-fuel operation.

In this work, a 2D transient thermal model is developed using a nodal approach.



Experimental setup



Test bench

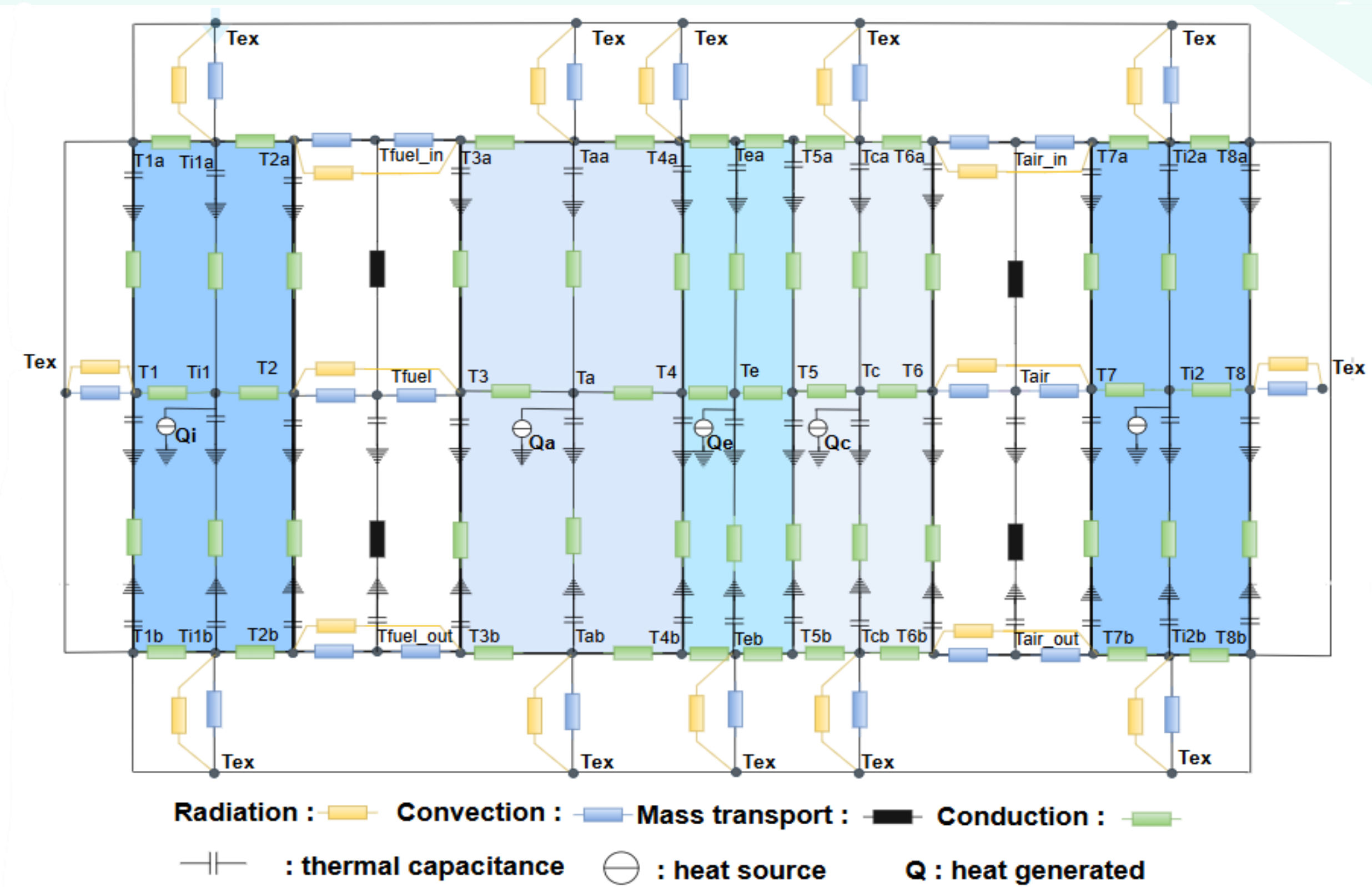
- Pmax : 2 kW
- Manufactured at: LAPLACE laboratory

Operation modes

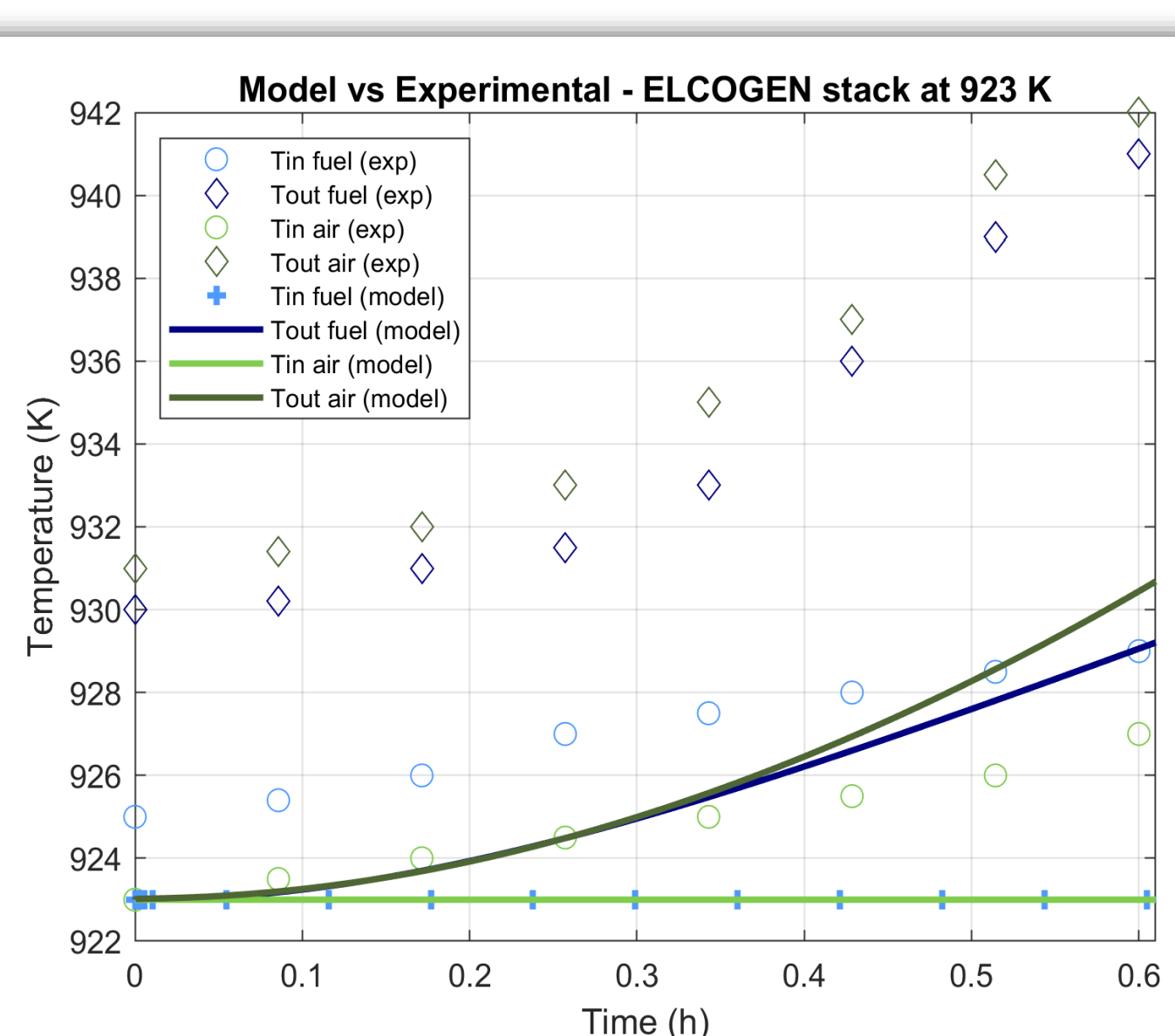
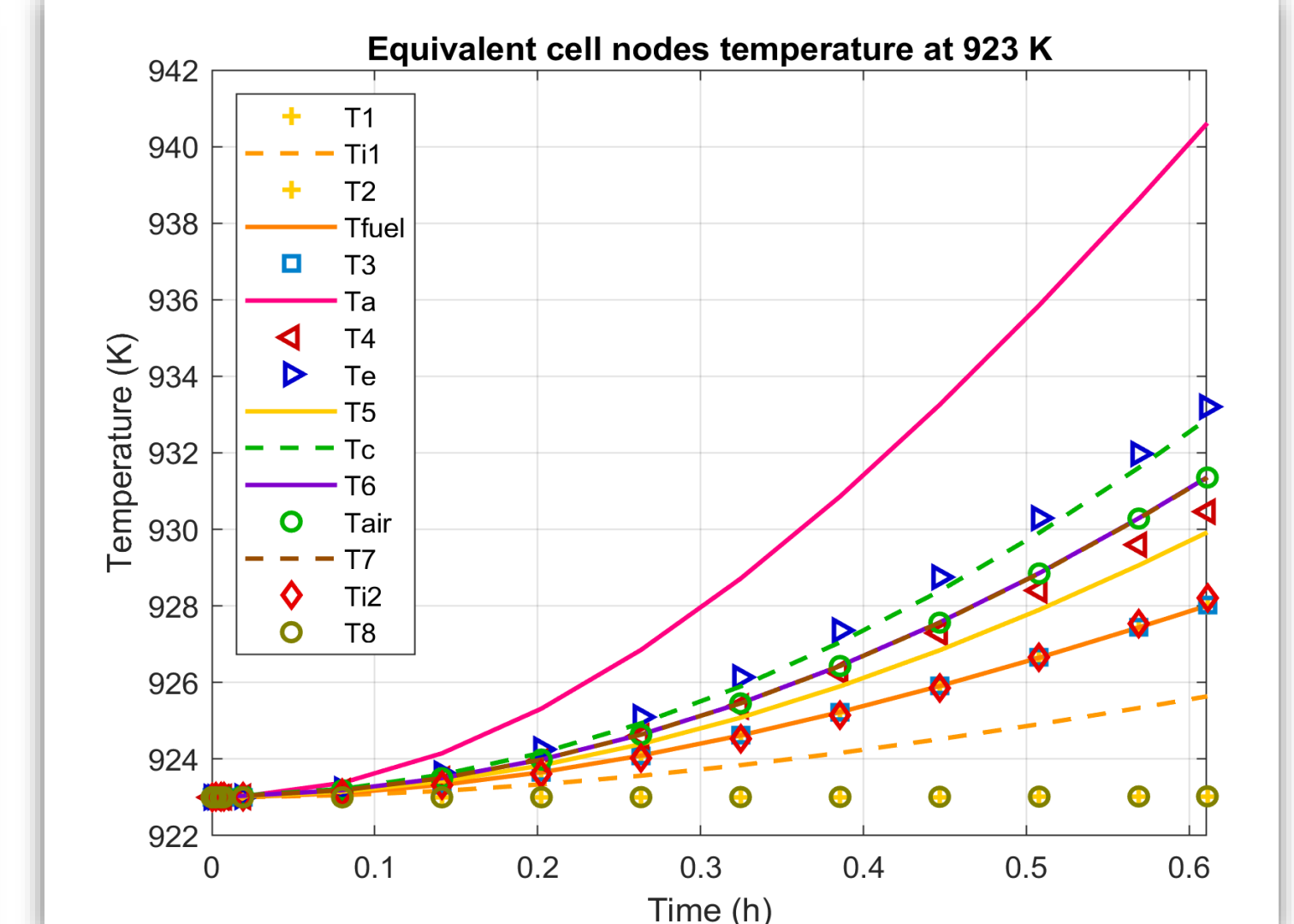
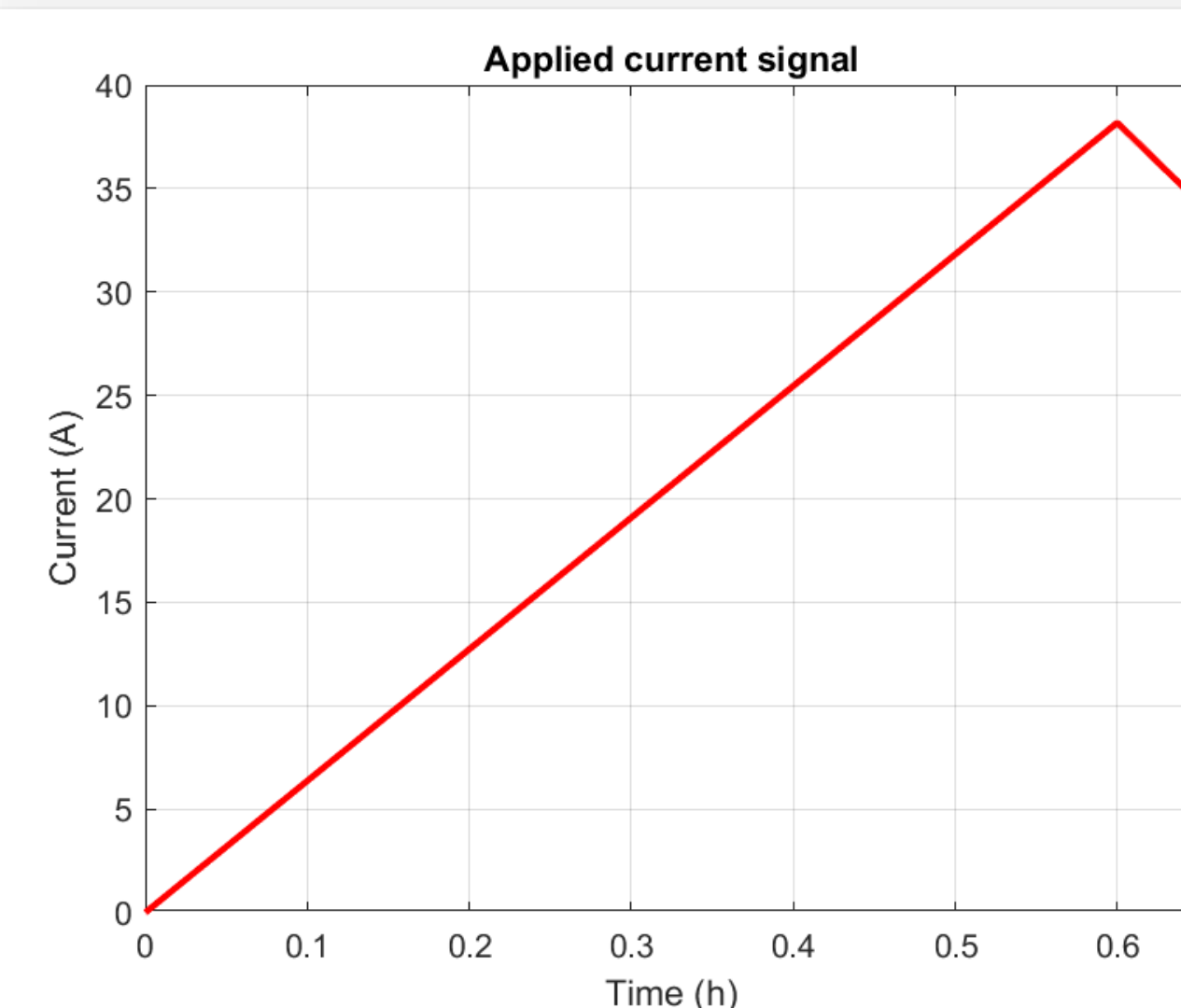
- Single cell or stack
- Fuel cell or electrolyzer

Stack E350

- Manufacturer : ELCOGEN
- Generation : 2nd generation
- Number of cells : 15
- Nominal power : 350 W
- Nominal temperature : 650°C
- Family : IT-SOFC



Results and discussion



- The model response follows the applied current signal consistently with the experimental data.
- The temperature variation (ΔT) is in good agreement with measurements.
- Final temperature values differ due to :
 - Initial condition set uniformly at 923 K for all nodes of the model.
 - Inlet temperatures (T_{in}) fixed as constant inputs at 923 K, whereas experimentally they are not constant and already above 923 K

Thermal model

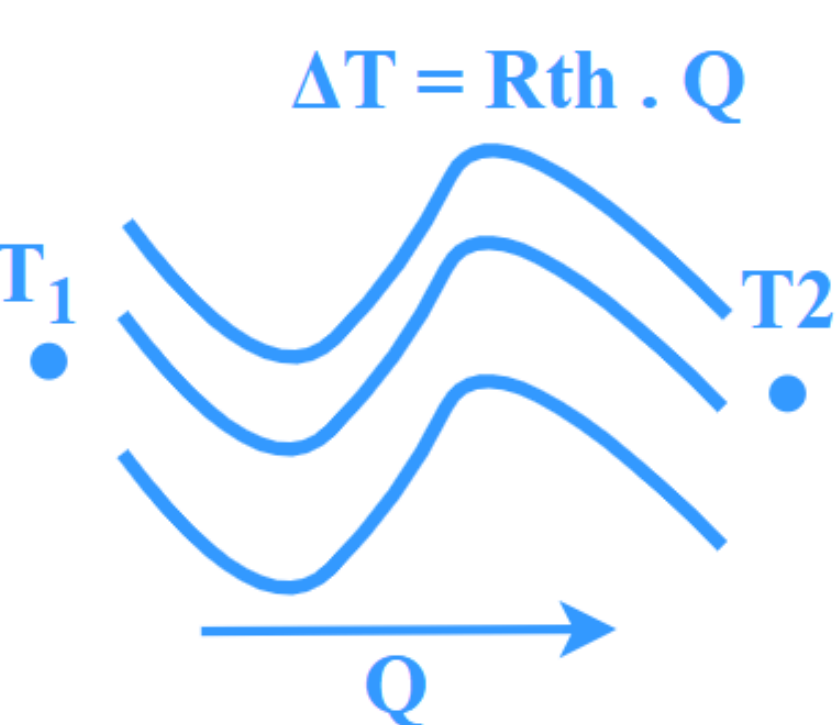
$$C_i \frac{dT_i}{dt} = \sum \frac{T_j - T_i}{R_{ij}} + Q_j$$

$$R_{ij-cond} = \frac{\lambda \cdot S}{e}$$

$$R_{ij-ray} = \frac{1}{\epsilon \cdot \sigma \cdot S \cdot (T_1^2 + T_2^2) \cdot (T_1 + T_2)}$$

$$Q = Q_a + Q_e + Q_c$$

$$Q_e = Q_{e_ohm}$$



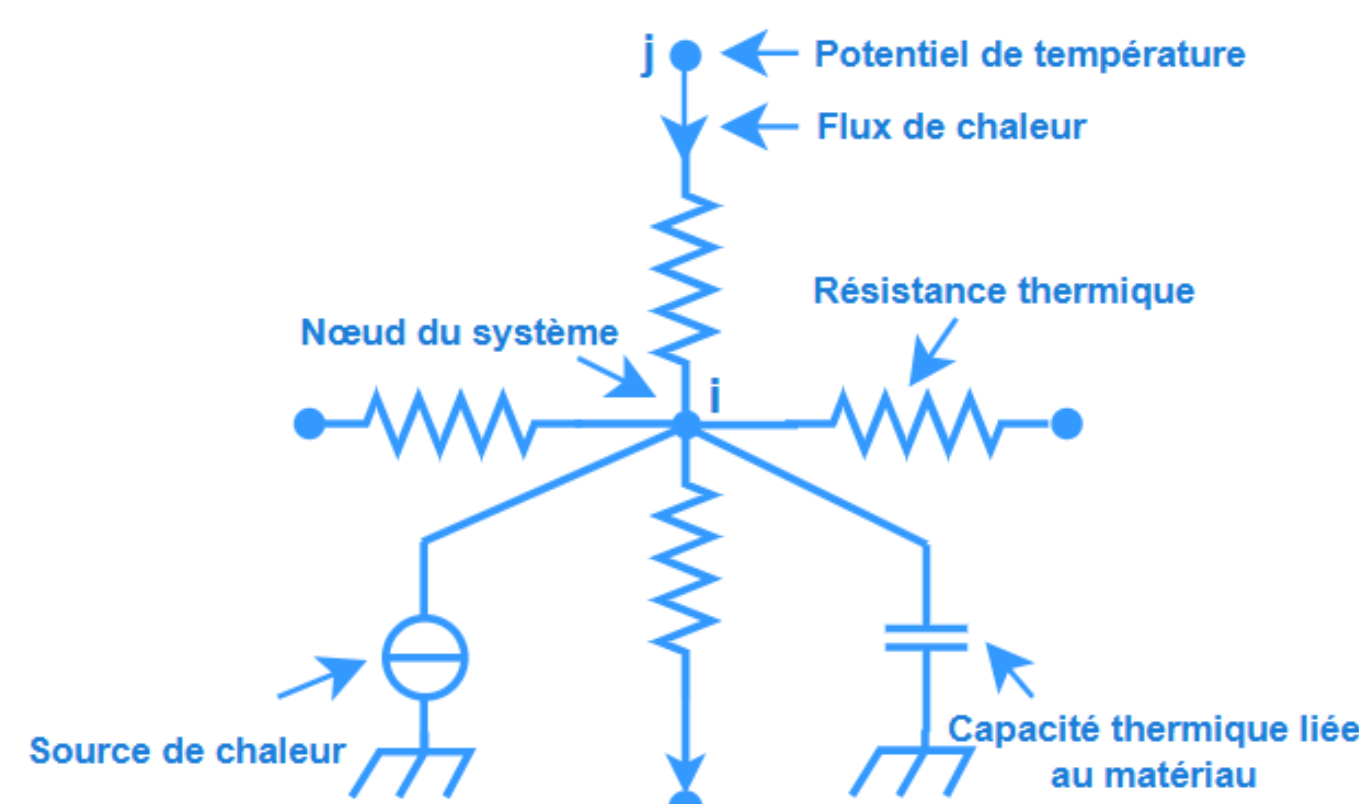
- T_i, T_j : temperatures of node i and neighboring node j (K)
- C_i : thermal capacity of node i (J/K)
- R_{ij} : thermal resistance between nodes i and j (K/W)
- Q : heat source

$$R_{ij-conv} = h \cdot S$$

$$R_{ij-masse} = \frac{1}{m \cdot cp}$$

$$Q_a = Q_f + Q_{dif} + Q_{a_ohm}$$

$$Q_c = Q_{act} + Q_{c_ohm}$$



Conclusion

A 2D nodal thermal model of a planar IT-SOFC stack was developed and implemented in MATLAB/Simulink. The model successfully reproduces the temperature distribution across cell components and allows the identification and localization of heat sources within the cell. Preliminary comparison with experimental data at 923 K shows encouraging agreement.

Outlook

- A sensitivity analysis on key thermal model parameters
- Characterization and testing of the E350 stack
- Experimental validation of the model
- Multi-fuel system modeling

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Reference :

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- A. Jaafar, C. Turpin, J. Lesmayoux, O. Rallieres, E. Bru, B. Sareni, S. Abbou, J. Göös, M. Noponen, and A. Alfano, "Quasistatic modelling for intermediate temperature solid oxide fuel cell stack (IT-SOFC)," *Next Research*, vol. 7, p. 101521, May 2026, doi: 10.1016/j.nexres.2026.101521.