DE LA RECHERCHE À L'INDUSTRIE

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Dynamic study of a nuclear reactor Steam Rankine cycle during normal and accidental transients.

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Internal collaborations:

IRESNE – ISAS – LITEN

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ABOUT THE SUBJECT

Context / State of art

- Rankine cycles are widely used in industry, but today : variants investigated to **diversify use** of reactors and **increase flexibility**

  → cycles with **cogeneration** (Fig. 1), **storage**, **innovative management**.

  → **modifications of the cycle, load increased on key components**

Main scientific question

- To develop physical models **at the right level** by associating **several scales** (1D, porous 3D)

→ Describing the **internal behavior** of components AND allowing **transient simulation** of the complete cycle.

- Two-phase flow phenomena and complex system effects + large range of thermodynamic conditions

Methods / strategy

- **Transient bi-fluid** approach of flow for all components
- Primary circuit and cycle modeled with a single tool → **coherency**

(level of modeling, physico-numerical methods, fluid properties)

- **Two-scale** methodology of validation : component/system

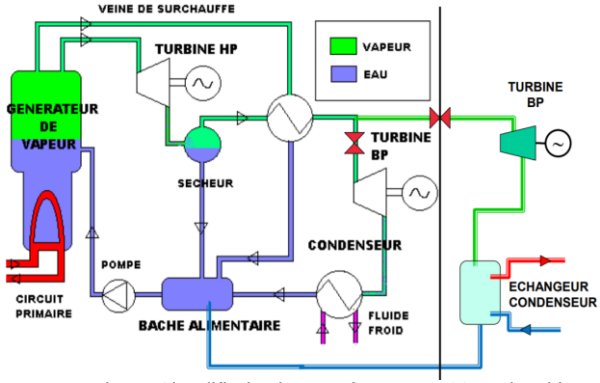

Fig.1 : Simplified scheme of a REP1300 cycle with cogeneration.
H. Safa, « LA COGÉNÉRATION DANS LA TRANSITION ÉNERGÉTIQUE », ECOCLIM – le 13 juin 2018, Orsay.

Expected results

- Modeling of the **internal physics** of **condenser** and **turbine** (all regimes)
- **6-equation** transient model of the complete cycle, **validated** against experiment
- Study of **innovative configurations** (**cogeneration, vapor storage inside the cycle**)

ASSETS OF THE SUBJECT

Challenges

Decarbonization of heat and transport → cogeneration [1], multi-vectors (electricity, heat, H2 production)

Flexibility of nuclear reactors → innovative management, storage [2]

Contribution to the **means of simulation of the future energy mix → model developed** [3]

Energy efficiency → system efficiency, waste heat recovery (Organic Rankine Cycles)

Team positioning against state of art

[1] Validation of CATHARE2 against Oberhausen II data, *N. Tauveron et al., NED, Volume 238, 2008*

[2] Modeling of a complete **Brayton cycle + cold storage** (patent) : *Mauger G., Tauveron N., NED, Volume 371, 2021*

[3] Two-phase flow modeling of **turbomachines :** *Matteo L., PhD thesis, 2019.*

- First, to search configurations of interest: **it's natural to use simplified models** (averaged, 0D)
- For normal operation studies, slight regime variations: to use models describing **partials regimes**.
- But to analyse retroactions (impact of an innovative management on the primary circuit) and accidental behaviors : **reference calculation** able to simulate **fast dynamic and complex thermo-hydraulic phenomena** with a **nuclear safety recognized code.** ➔ **aim of this thesis**

Scientific contribution of the thesis

- **Push current limits on modeling of key components in system codes: condenser and turbine**
- **Obtain validated and modular numerical models able to study different configurations** of cycles

Special effort / risk: No experimental or calculation means constraint. But **special effort of modeling of key components (condenser, turbine)**.

ENVIRONMENT AND PLANNING

Means for the thesis

- **Simulation tools developed at CEA :**

Transient code to simulate thermo-hydraulic systems: **CATHARE3** (reference calculation, safety)

Stationary code to optimize thermodynamic cycles: **CYCLOP**

Collaborations

- **Inside CEA : 3-institute collaboration**

DES/**IRESNE** (two-phase flow modeling, transient studies, expertise on turbomachines)

DES/**ISAS** (CATHARE3 simulation tool development)

DRT/**LITEN** (expertise on thermodynamic cycles, ORC, storage solutions)

- **At international level :** interest for partners of **TANDEM European project** (Small Modular ReacTor for a European sAfe aNd Decarbonized Energy Mix)

Planning

D + 6 months : Bibliography, synthesis of available data for validation, tools training

D + 18 months : Development and validation of **advanced physical models for condenser and turbine**.

D + 24 months : **Complete cycle** modeling : components assembly, modeling of rackings and calculation of the nominal operating point. First publication.

D + 30 months : Simulation of **transients of interest** on reference configuration and study of **innovative configurations (cogeneration, storage)**

D + 36 months : Thesis dissertation and defense, second publication.