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MULTI-OBJECTIVE OPTIMIZATION of the THERMAL-HYDRAULIC BEHAVIOR for a SODIUM FAST REACTOR with a GAS POWER CONVERSION SYSTEM

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Abstract— CEA and its industrial partners design a gas Power Conversion System (PCS) based on a Brayton cycle for the Sodium-cooled Fast Reactor (SFR) ASTRID (Advanced Sodium Technological Reactor for Industrial Demonstration). Investigations of regulation requirements aiming at operating this PCS, during normal, incidental and accidental scenarios, are necessary to adapt core heat removal. In this frame, a PhD work develops a methodology to optimize the reactor piloting procedure. This methodology carries out a multi-objective optimization for a specific sequence, whose objective is to improve component lifetime by reducing simultaneously several thermal stresses, to consider safety constraints and to respect studied procedure. To solve this multi-objective problem, optimization parameters are setpoints and parameters of the controllers associated with regulations included in the sequence. The methodology allows designers to define an optimized and specific control strategy of the plant for the studied sequence and hence to adapt PCS piloting at its best. The multi-objective optimization is performed on evolutionary algorithms coupled to surrogate models built on the thermal-hydraulic system code, CATHARE2.

The methodology is applied for a loss of off-site power sequence. Three variables are controlled: the sodium outlet temperature of the sodium-gas heat exchanger, turbomachine rotational speed and water flow through the heat sink. These regulations are chosen in order to minimize thermal stresses on the gas-gas heat exchanger, on the sodium-gas heat exchanger and on the vessel. The main results of this work are desired setpoints for the three regulations, which solve the multi-objective optimization problem. Moreover, Proportional-Integral-Derivative (PID) control setting is considered and efficient actuators used in controls are chosen through sensitivity analysis results. Finally, the optimized regulation system and the reactor piloting procedure, that have been elaborated with surrogate models, are verified through a direct CATHARE2 calculation.

Keywords**—**CATHARE2, incidental regulations, loss of off-site power, multi-objective optimization, surrogate models.

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