

Towards Hard Real-Time Simulation of Complex Fluid Networks

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Real-time simulation is a very useful tool, especially since it is a key enabler for virtual testing: control units can be tested against a virtual plant model or single components can be tested with software-in-the-loop in order to emulate a yet unavailable environment.

Unfortunately, complex fluid systems created with Modelica have often been difficult to simulate under hard real-time constraints since they typically involve non-linear equation systems that are difficult to solve especially within a predictable finite time.

This paper explores the usage of a new approach that avoids non-linear equation systems and its suitability for real-time simulation. This progress was triggered by the needs to achieve a high level of robustness. Robustness in this context means that the simulation shall not return any errors due to solvability of non-linear equation systems and that the modeler shall not have to care overly about initialization of the system.

To this end, a computational scheme was developed that ensures that once the components robustly compute, also the complete system will robustly compute. We can use the same scheme to avoid non-linear equation systems altogether. If every single component has a form that enables an explicit computation of the thermodynamic state in downstream direction, then the thermodynamic states of the whole system can be computed explicitly in downstream direction.

In order to enable the application of explicit ODE-solvers with fixed stepsize, the stiffness of the system needs to be reduced. To this end, we present methods to manipulate the mass flow dynamics without distorting the steady-state solution and the time-constants of the main thermal dynamics.

A model of an aircraft environmental control system is taken as a use case for this study. Figure 1 shows a Modelica example system that (simplistically) describes the flow of fresh and recirculation air on board of a conventional aircraft.

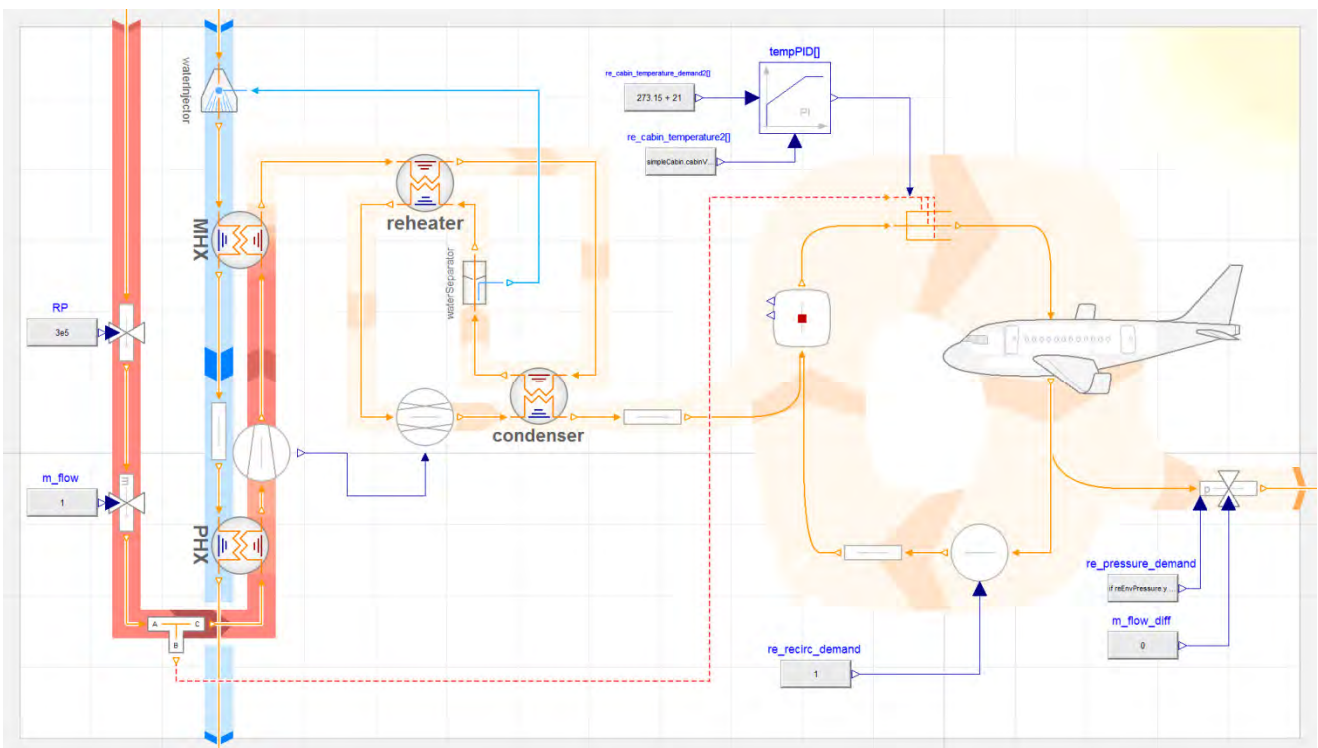


Figure 1: Modelica model of a simplistic aircraft ECS: bleed-air is being cooled against the ram-air channel and flows in a unit where it mixes with recirculated air. This mixture is then being warmed for 3 zones by further bleed-air and let into the cabin. From the 3 upper floor zones, the air flows to the underflow zone where a valve controls the cabin pressure. This model is derived from the work of Alexander Pollok (Pollok, 2017)