Isolated-grid biomass Organic Rankine Cycle

C. Gantiez[1], S. Quoilin[1], L. Sanchez[2], A. Berkane[2],
G. David[2], V. Lemort[1]

Environmental concerns and the recent increase of energy costs open the door to innovative techniques to produce electricity. Among these techniques, Organic Rankine Cycle represent an area of growing interest. **Organic Rankine Cycle are nowadays one of the best way to recover low grade heat and to produce electricity**. For medium output power (lower than 2MWe), it turns out to be more cost-effective than the conventional steam cycle. However, at present time, there is no commercial application available for off-grid or isolated grid ORC operation. Innovative control strategies must be set up and simulated in order to maintain the grid frequency in an acceptable range.

Project

In 2009, Enertime started to develop an Organic Rankine Cycle for waste heat recovery. In this work the opportunity to use such a cycle to generate electricity from biomass sources in remote areas is evaluated. The aim of the project is to promote the most efficient combinations of control strategies in order to avoid excessive frequency variations on an isolated grid.

Context

- Investment costs of an ORC increase when plant size decreases
- On isolated-grid area, electricity is mainly produced by diesel gensets → high fuel & generation costs
- Biomass is generally available on site & at low cost

→ The higher investment costs can be justified by high electricity prices in these areas

Main Goals

- Allow a quick identification of biomass Organic Rankine Cycle potentials in remote areas;
- Develop a dynamic model of an Organic Rankine Cycle using the TIL Modelica library
- Develop a simplified grid model
- Discuss several control strategies of the cycle to maintain frequency.

Modelling

- Pump : constant effectiveness, controls the superheating
- Heat Exchangers : Finite volumes method, Shell & Tube
- Turbine : characteristic curves for axial turbine
- Grid : Quasi Steady State (QSS) approximation & common frequency assumption:

$$M_i \frac{d}{dt}\omega_{pu} = P_{m,pu,i} - P_{e,pu,i}$$

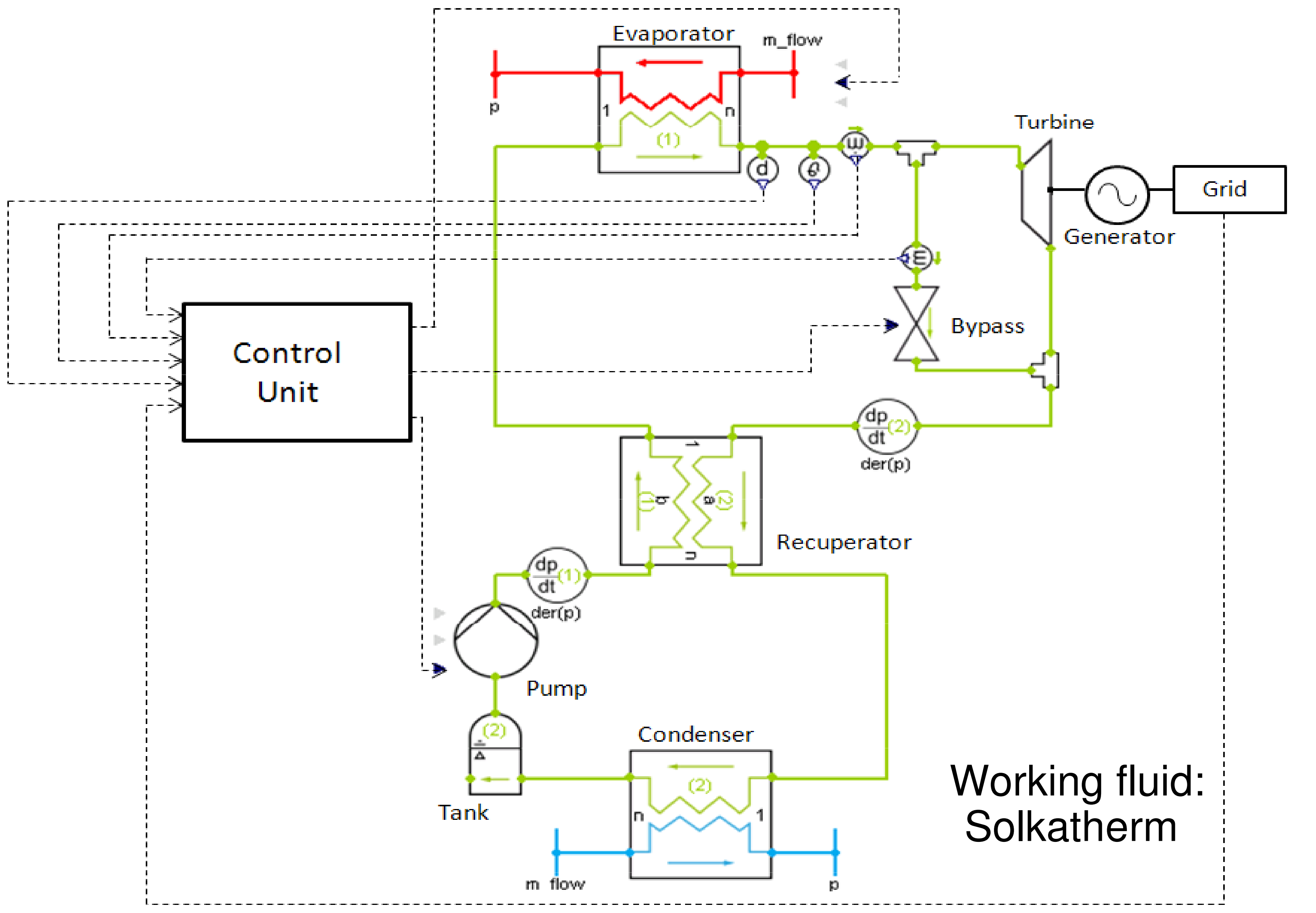
The frequency, ω, is thus provided by :

$$\frac{S_B}{\omega_N} 2 H_{ORC} \frac{d}{dt}\omega = P_{ORC} - P_{grid}$$

Electricity generation and control strategies

Use of an arbitrary load profile and evaluation of frequency deviation. An overheating of 2K is fixed by varying the mass flow rate (pump)

1. No vapor reserve: → The heat transfer fluid flow rate is regulated to maintain the frequency while load varies
2. Vapor reserve (bypass of the turbine): →The bypass valve is controlled to avoid frequency deviation and the oil flow rate is controlled to keep a constant bypass rate.



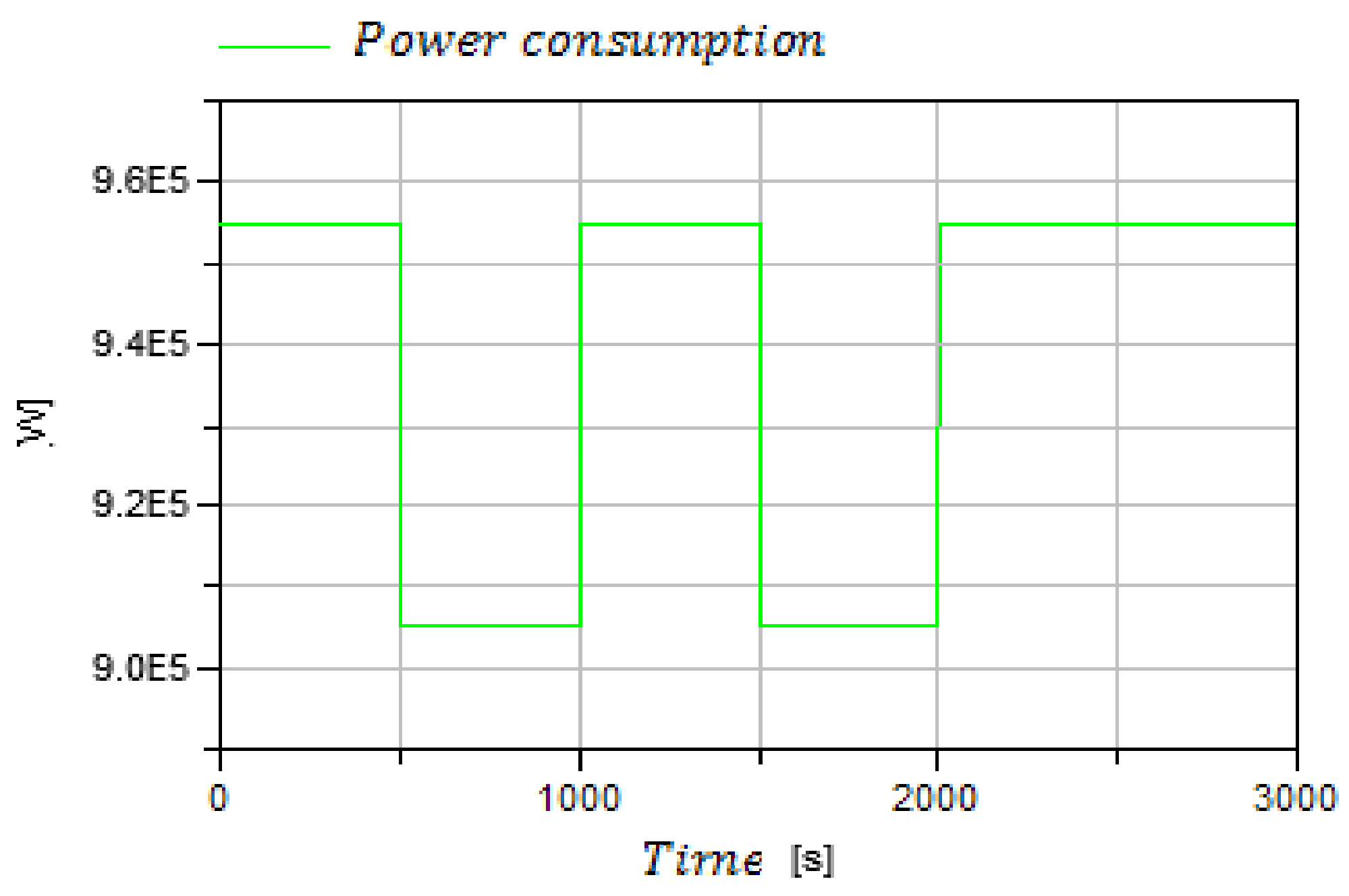
Working fluid: Solkatherm

Conclusions

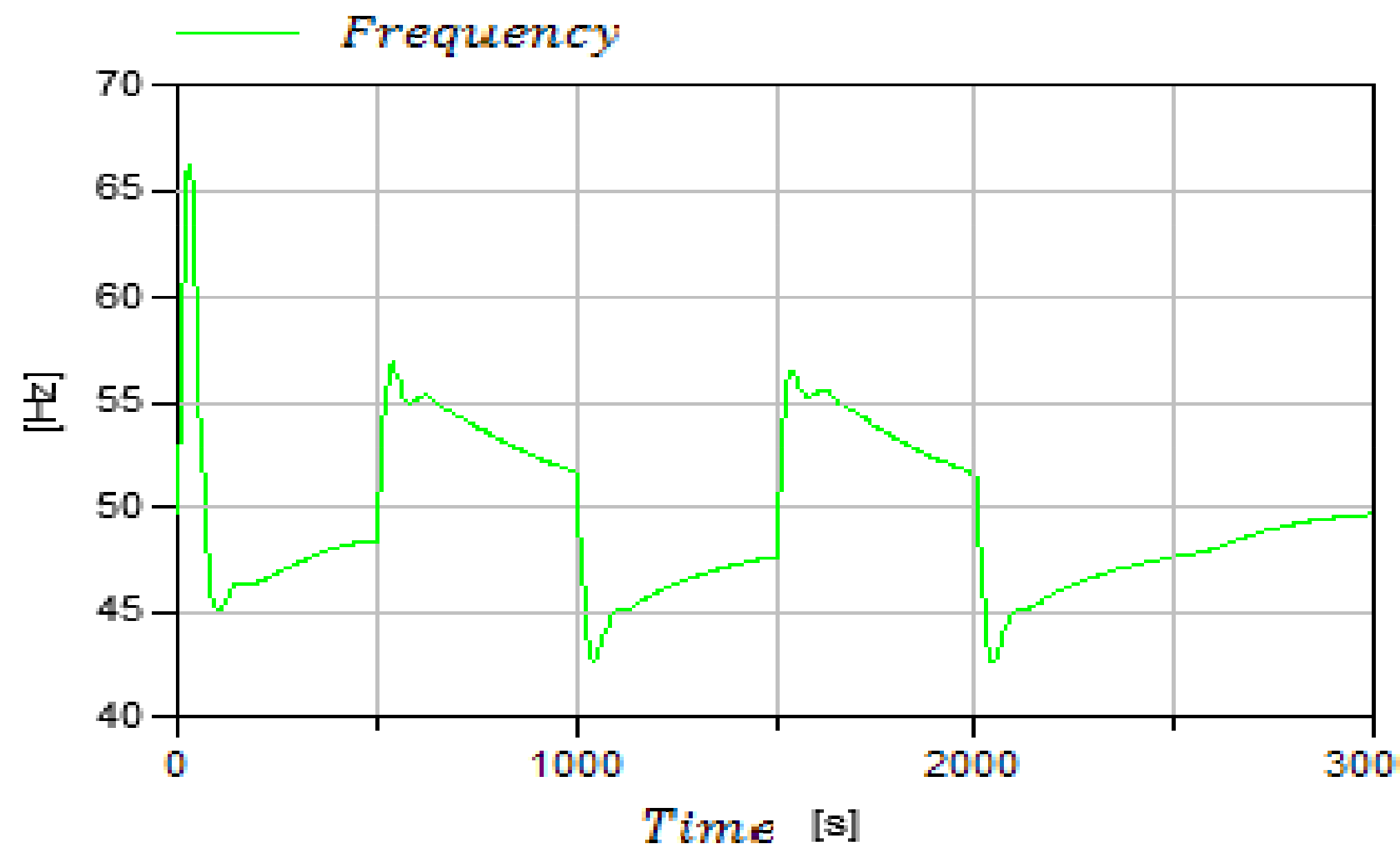
In the current state of the technology, the high thermal inertia of the evaporator impedes keeping the isolated grid frequency in an acceptable range. It is therefore necessary by-pass a small faction of the vapor to counterbalance rapid load changes. However, increasing the inertia (for example by adding a flywheel) shows a positive impact since it reduces rapid frequency fluctuations.

Acknowledgment

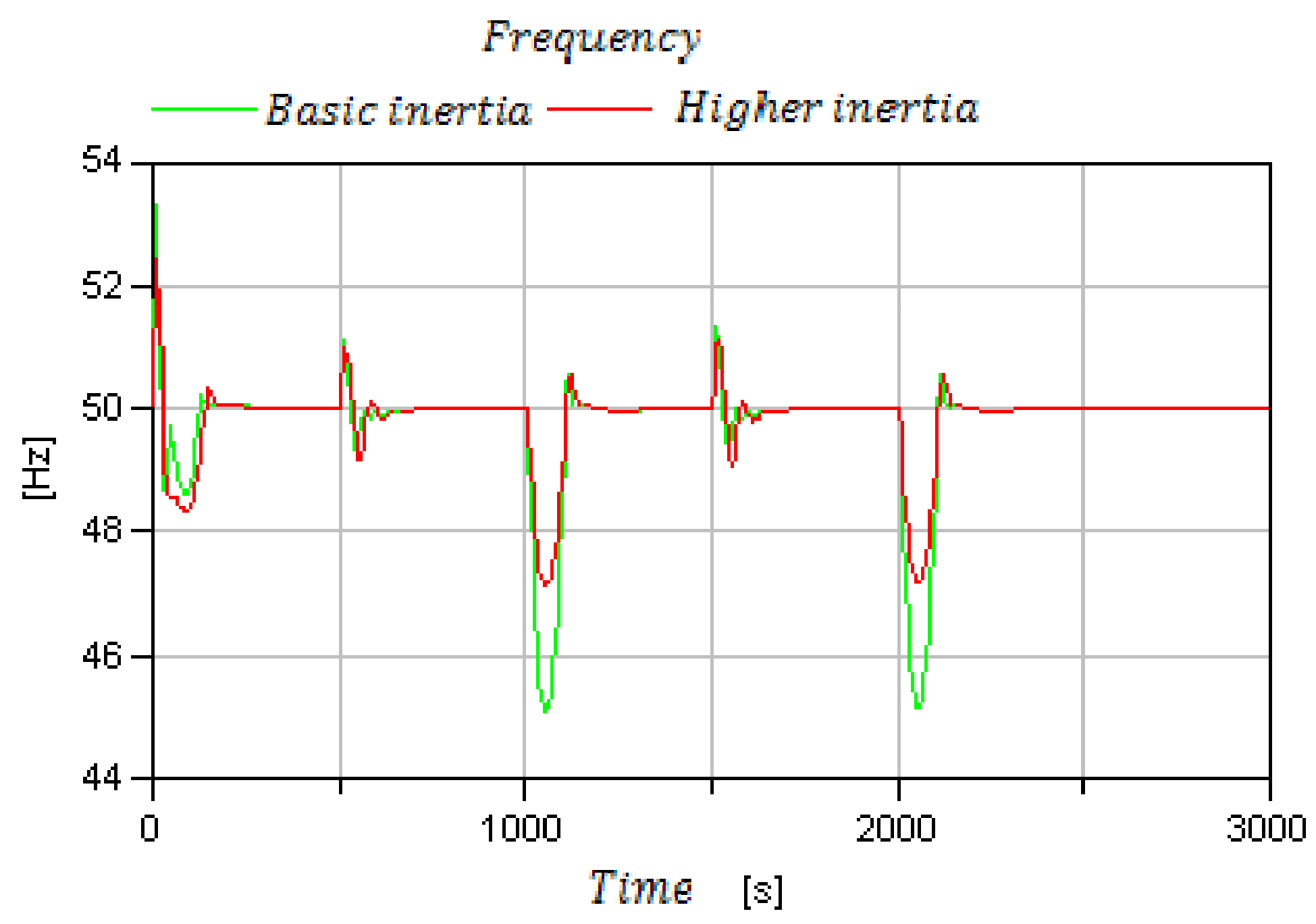
The authors wish to acknowledge TLK-Thermo GmbH (www.tlk-thermo.com) and TU Braunschweig for their support and for providing the TIL Library.



Load profile



Evolution of the grid frequency without vapor reserve



Evolution of the grid frequency with vapor reserve

[1]Laboratoire de Thermodynamique, Université de Liège
B49, Campus du Sart Tilman, 4000 Liège, Belgium

[2]Enertime SAS, 62-64 rue Jean Jaurès
92800 Puteaux, France
Contact: s.quoilin@ulg.ac.be