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# **THERMAL WATER-STEAM STORAGE FOR CSP: MODELLING AND IDENTIFICATION OF LIQUID LEVEL FLUCTUATIONS DURING UNLOADING PHASES**

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# THERMAL WATER-STEAM STORAGE FOR CSP: MODELLING AND IDENTIFICATION OF LIQUID LEVEL FLUCTUATIONS DURING UNLOADING PHASES

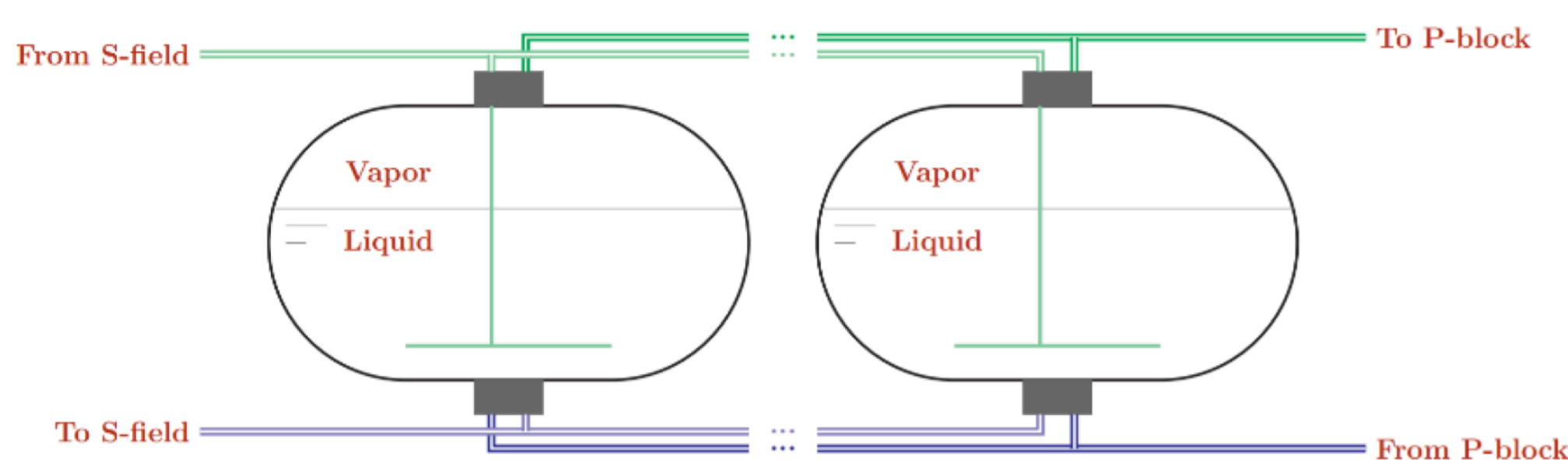
Mario PLOQUIN<sup>1,2</sup>, Edouard BUTAYE<sup>1</sup>, Samuel MER<sup>1</sup>, Adrien TOUTANT<sup>1</sup>, Fabien ROGET<sup>2</sup>

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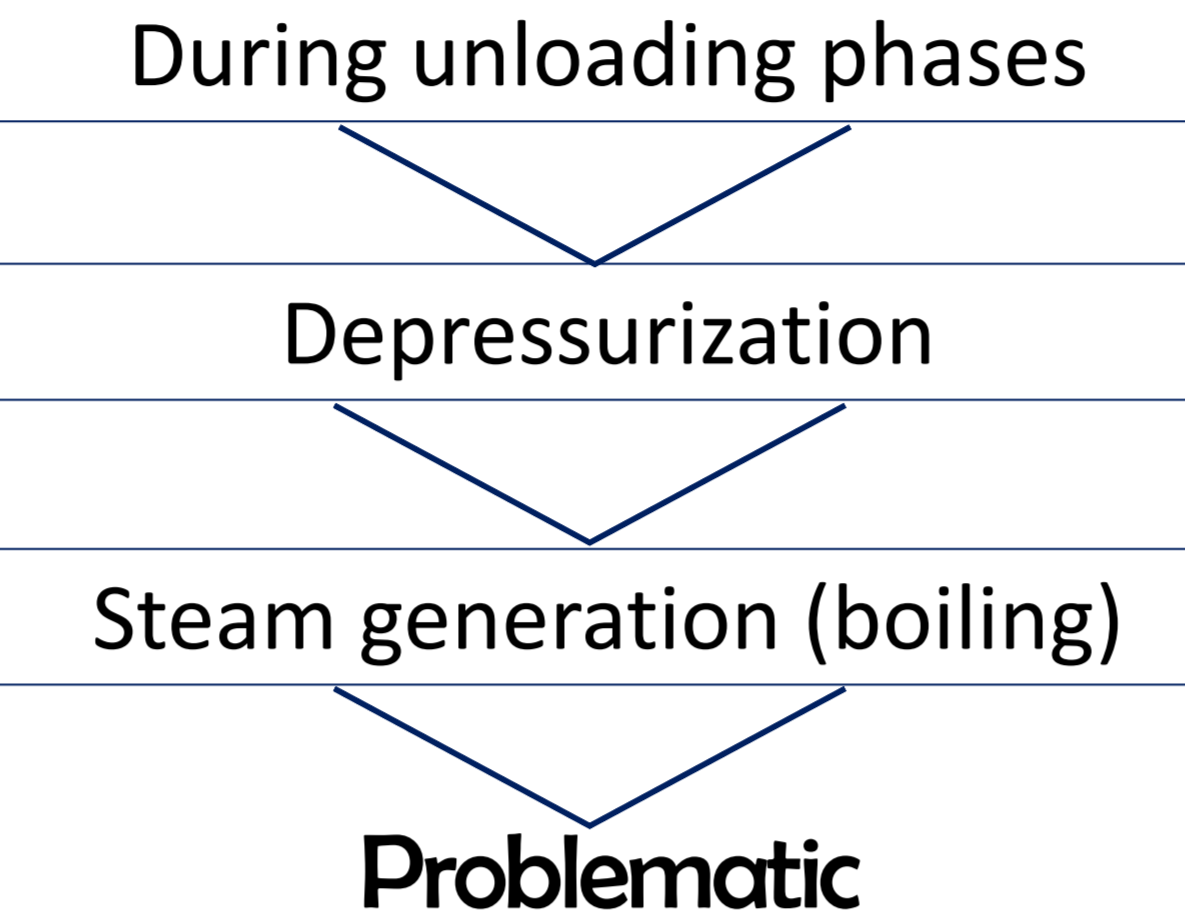
## SOLAR POWER PLANT OF LLO & PROBLEMATIC

The solar power plant of LLO :

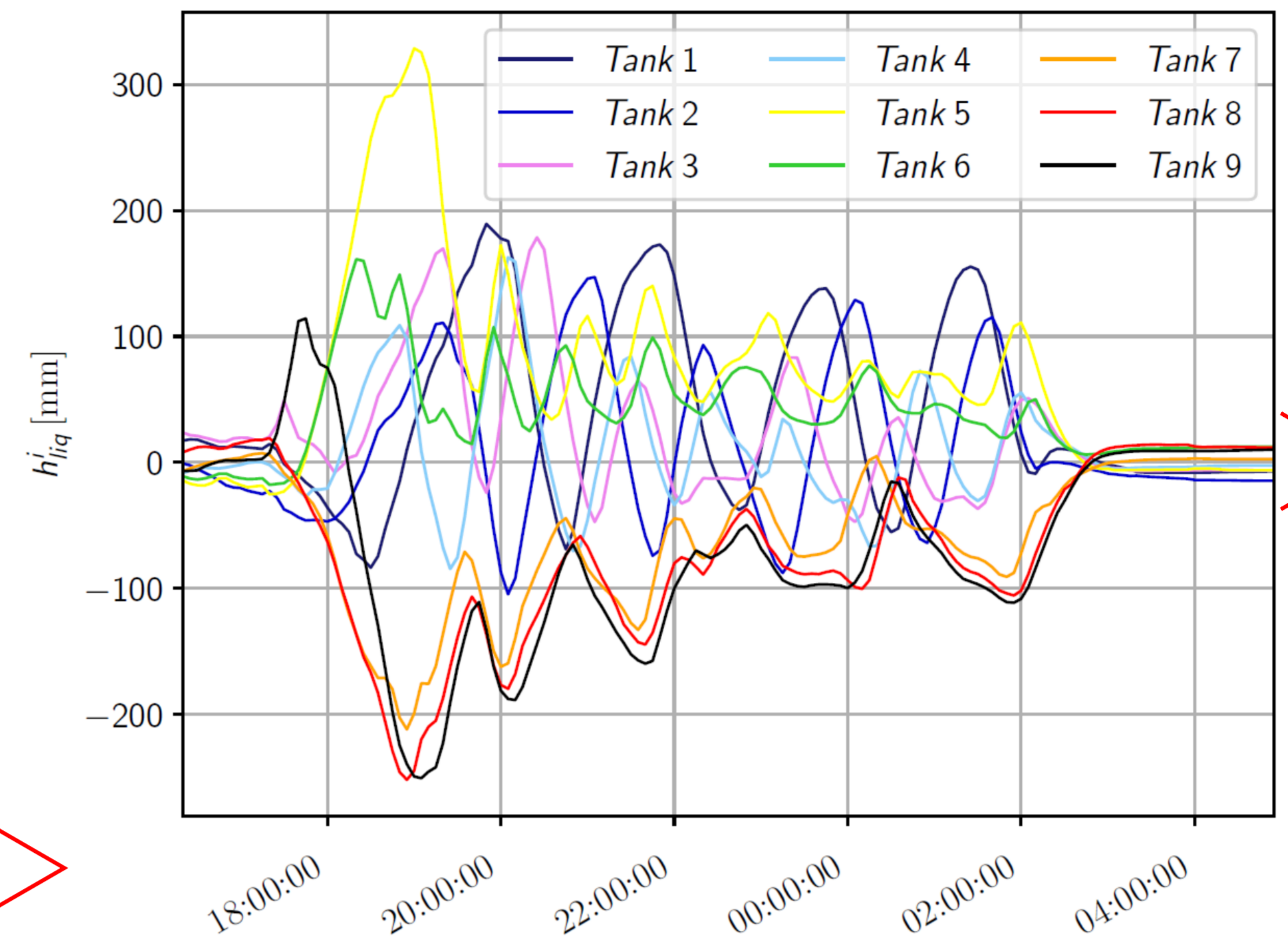
- Fresnel mirrors (150,000 m<sup>2</sup>)
- Direct Steam Generation (DSG)
- 9 MW steam turbine
- Nine steam accumulators connected in parallel (latent phase liquid-vapor)



How does the storage work?



⚠ Liquid Level Fluctuations ⚠



## TWO PHASES FLOW MODELLING: NEPTUNE\_CFD

Extended two-fluid model with n-phases

- Navier-Stokes resolution in each phase
- Closure terms at interfaces



Modeling Issues

- Detecting characteristic interface sizes and adapting physical closure to different scales
- Evaporation modeling
- Modeling of pressure drops

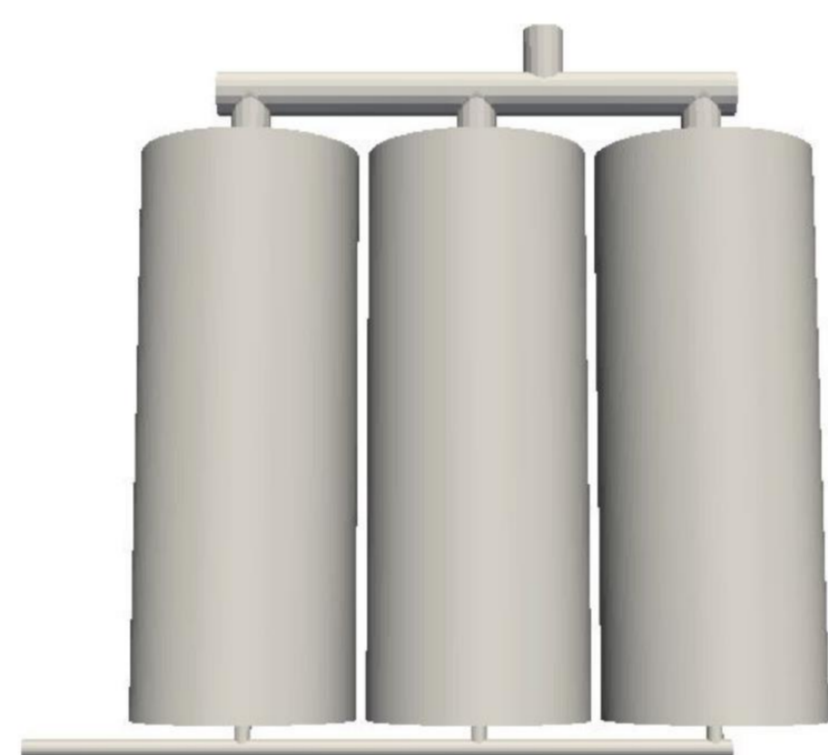
Calculation details

- 32,000 hours of CPU calculations
- 500,000 mesh
- 36 processors

## IDENTIFICATION AND SIMULATIONS OF THE OSCILLATION

Simplification of the system

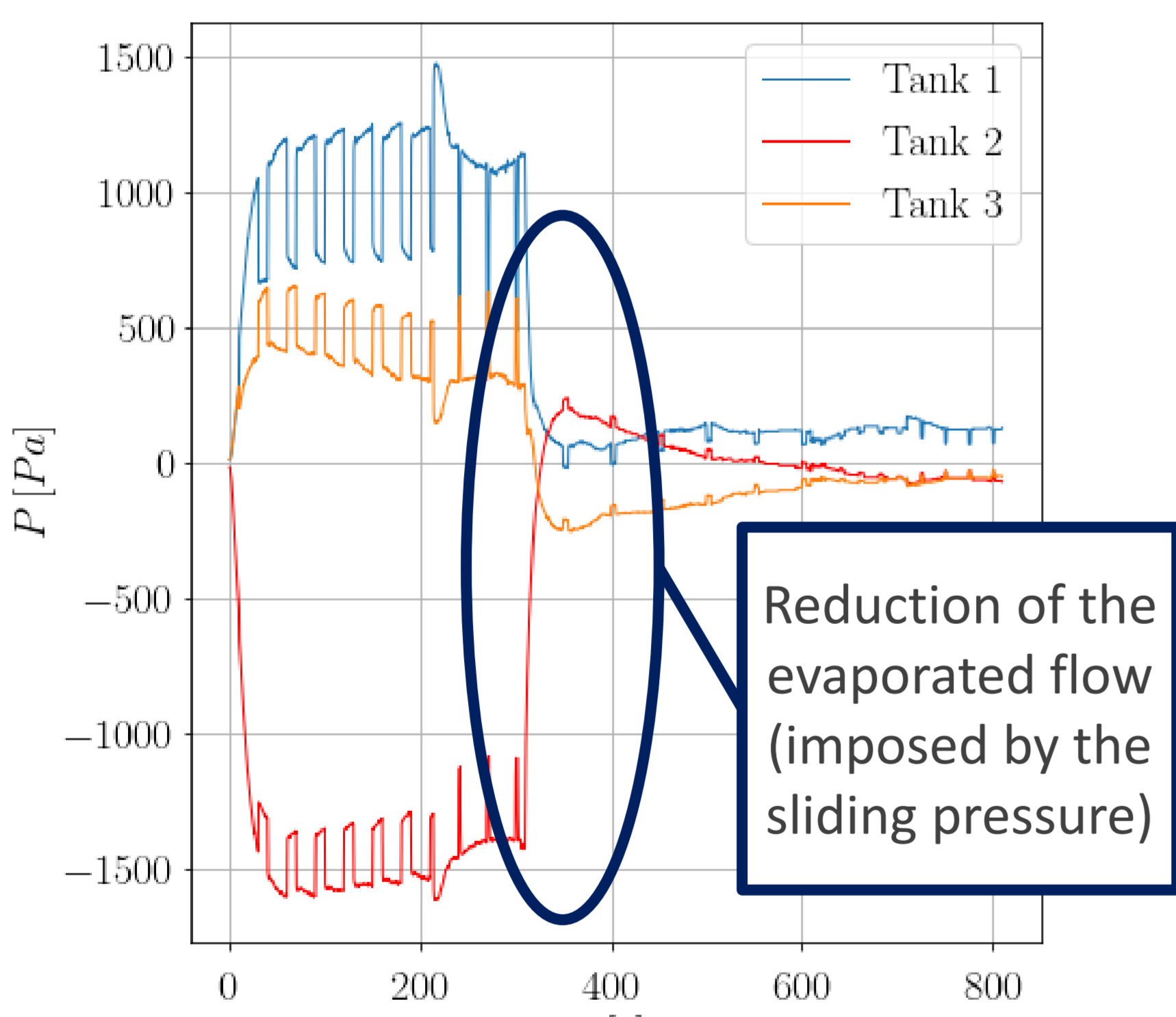
- Decrease of the tank volume (120 m<sup>3</sup> to <1 m<sup>3</sup>)
- Faster pressure decrease = reduction of oscillation period
- Tank number reduction (9 to 3)



Boundary conditions imposed

- Inlet close to the first tank
- Cold water injected to maintain the water mass in the tank
- Fluctuation imposed to reproduced the real system regulation defects
- Outlet between tank 2 and 3 -> sliding pressure imposed
- Pressure drops considered between tank on the inlet and outlet vapor lines (Presence of expansion hoses causing significant singular pressure losses on the pipes of the actual system)

Results

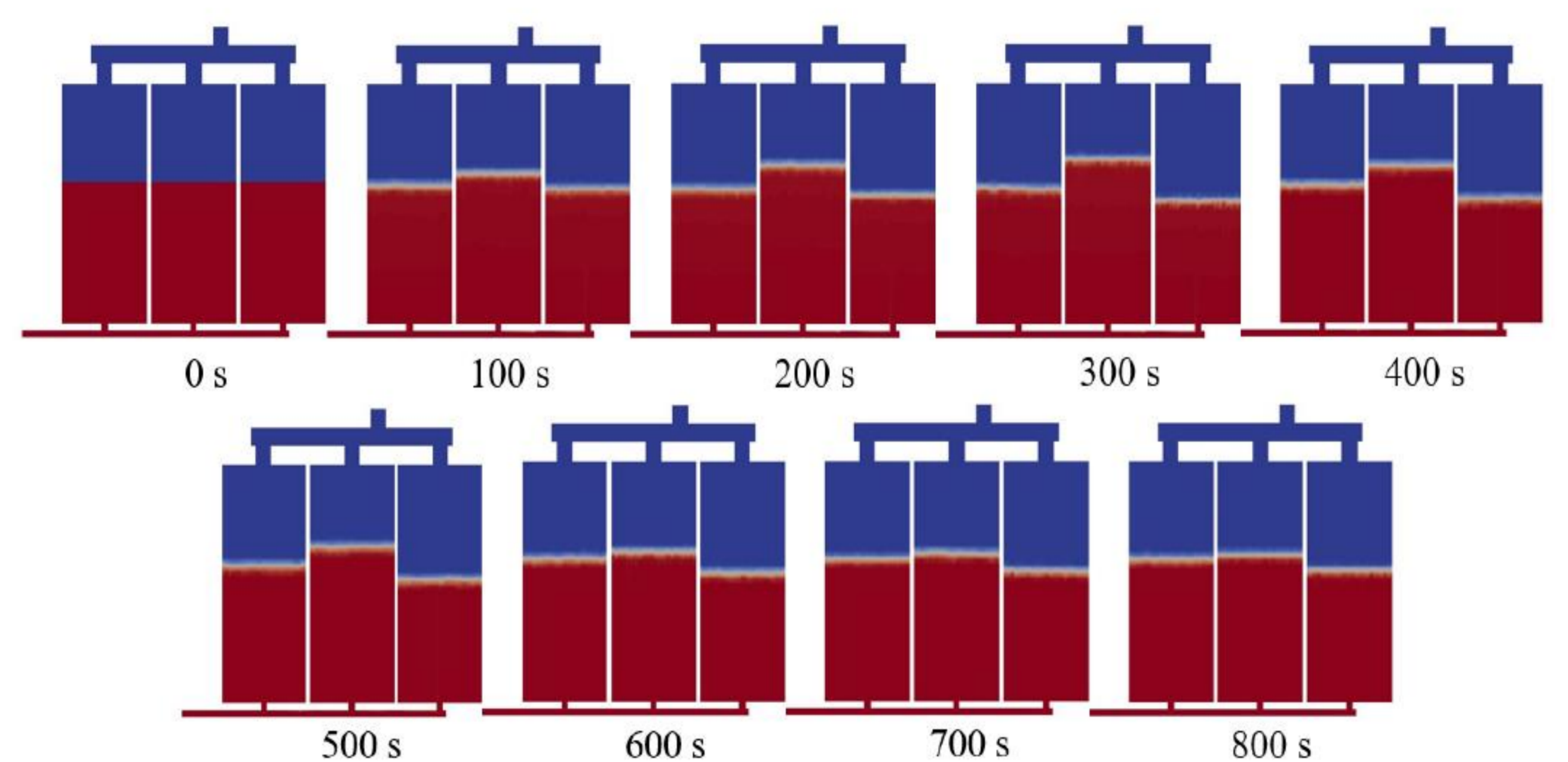


Pressures compared to the average

The evaporated flows in each tank are roughly identical

The evaporated flow in the tanks leads to pressure losses in the outlet pipes between the tanks

Liquid transfer between tanks to balance the pressure differences by hydrostatic compensation

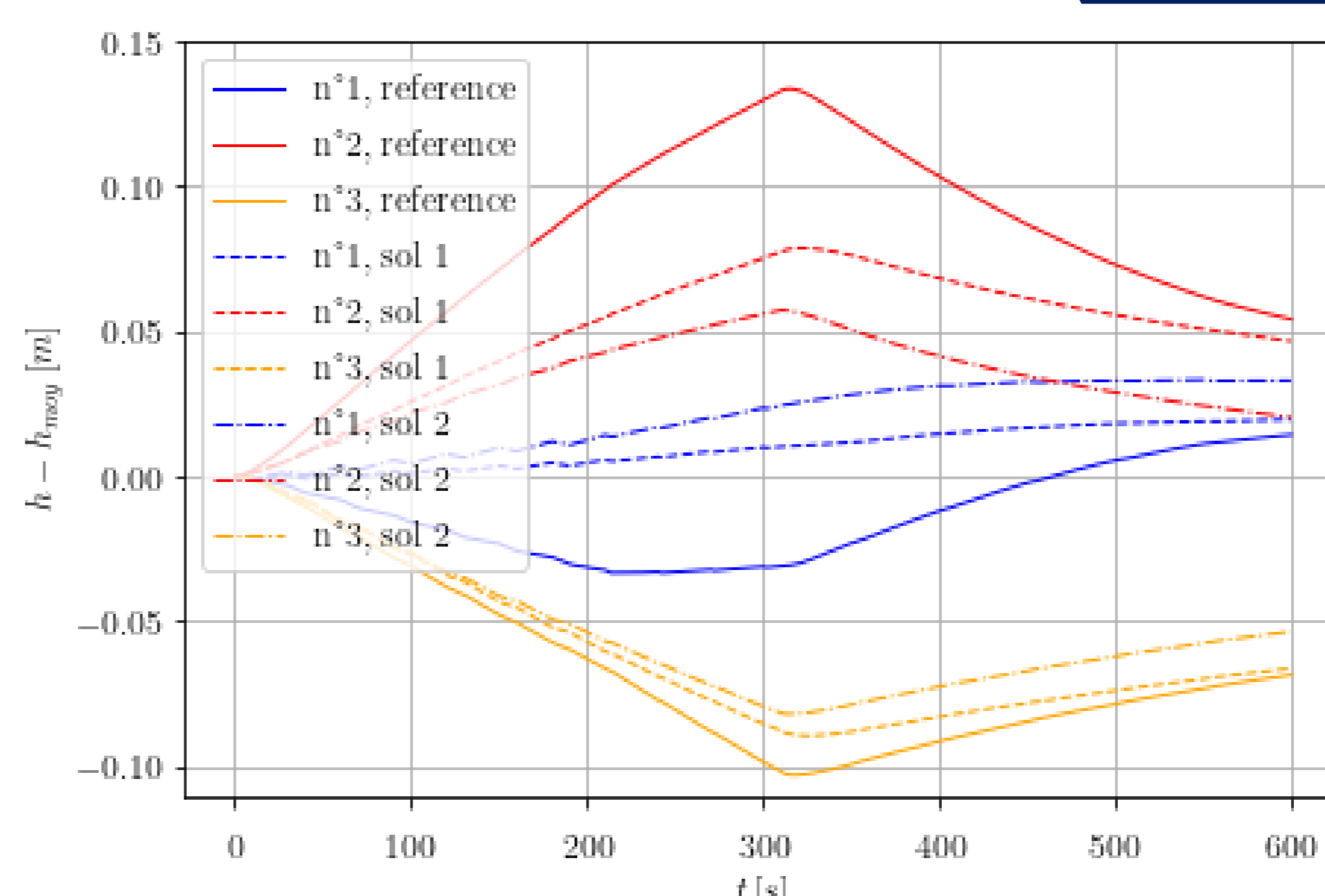
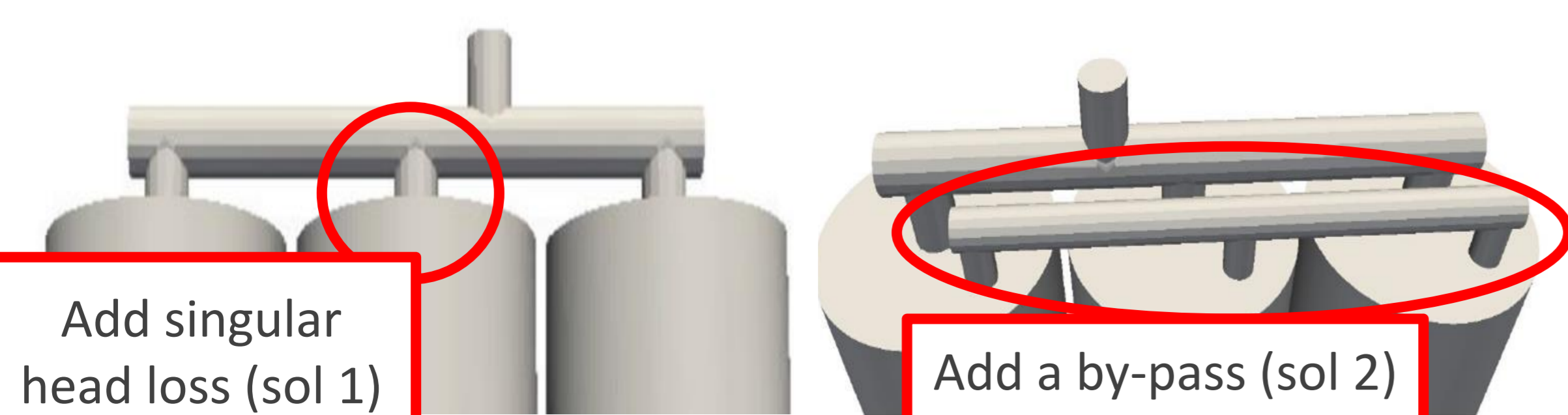


## ANALYSIS OF SOLUTIONS

Evaluation of two simple solutions

**Sol 1 :** Add singular head loss at the tanks closest to the outlet to balance the pressures

**Sol 2 :** Add a steam line (bypass) with very low pressure drops connecting the tanks to reduce pressure differences



Both solution reduce the amplitude of the level oscillation. For sol 1, a fine tuning of the added head loss would lead to further damping of the oscillation

## KEY-WORDS

- Thermal Storage
- DSG
- Liquid Level
- Oscillations
- CFD modelling