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Transient Analysis of Hauterive-Rossens Power Plant

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- Motivations
- Modeling
- Validations
- Case Study:
  - ✓ Penstock Overpressure
  - ✓ Surge Tank Overflow or Emptying Risk
- Conclusions and Recommendations

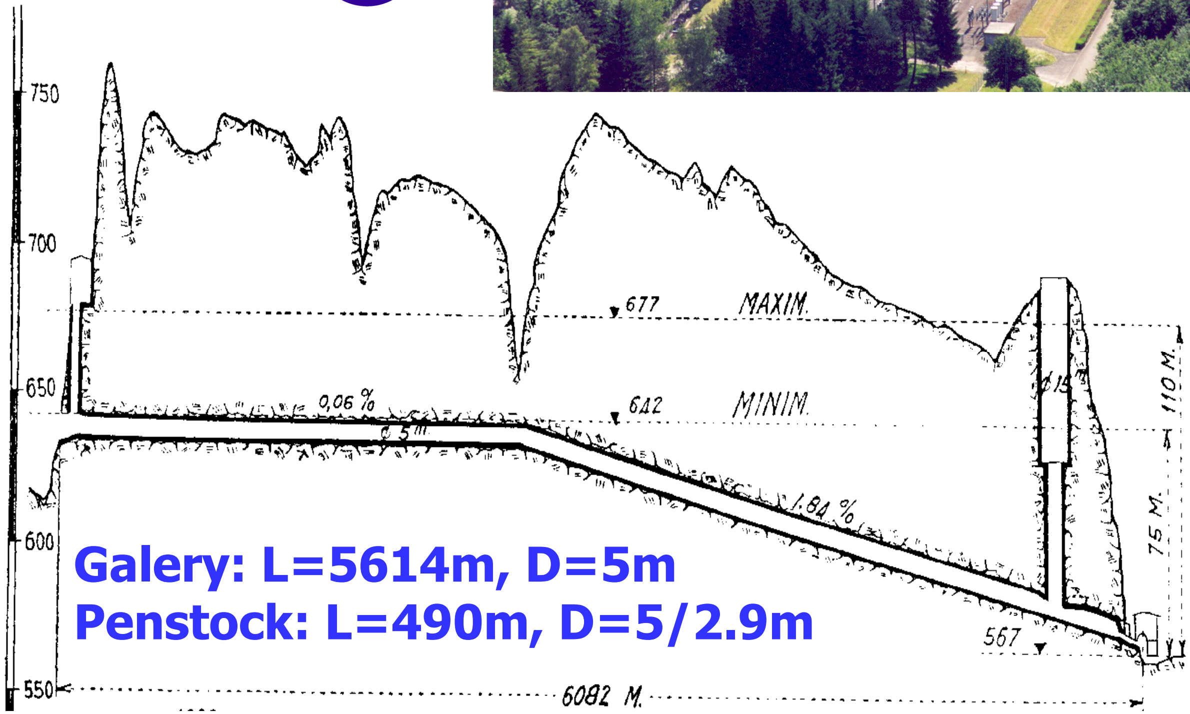
Hauterive-Rossens Power Plant (CH)

- General layout:


Rossens Arch Dam

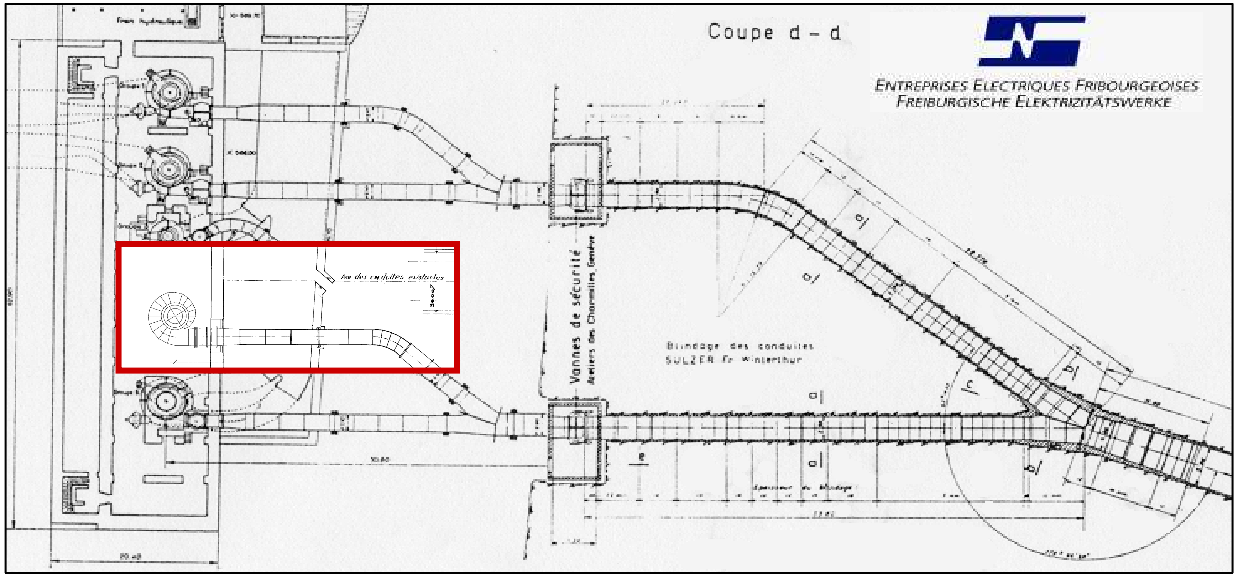
Owned and operated by: groupe e


Hauterive Power House



Hauterive-Rossens Power Plant

- Power House:
  - ✓ Total installed capacity: 78MW
  - ✓ Max. gross head: 107m
  - ✓ Nominal discharge: 75m³/s
  - ✓ Max. discharge: 88m³/s
  - ✓ 4 Francis turbines:
    - 3x17.5MW
    - 1x26MW
    - N=300tr/min
  - ✓ 3 pressure relief valves



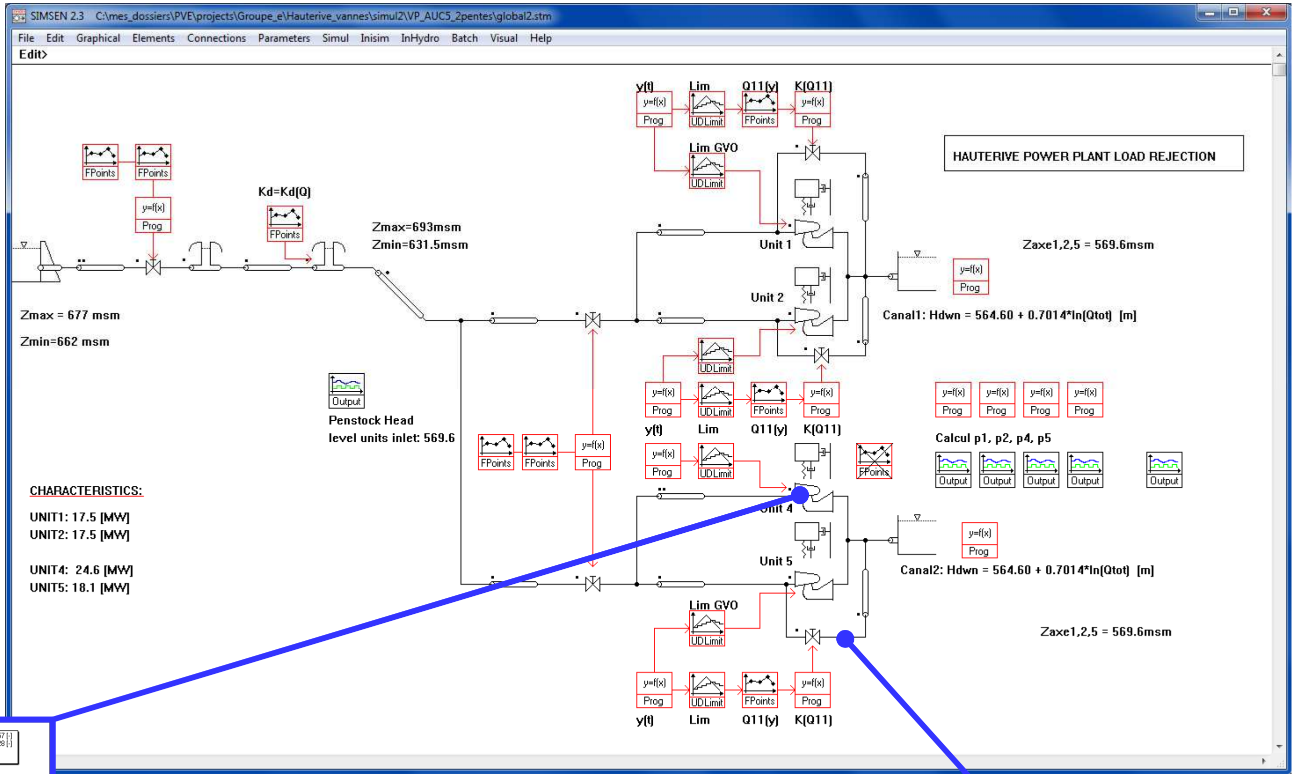
Motivations

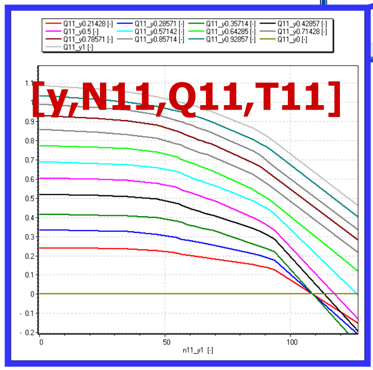
- Context:
  - ✓ Power plant modified 2 times with power increase
  - ✓ Modification of operating strategy:
    - Deregulated market
    - Willingness to provide control services

- Extensive transient analysis performed to:
  - ✓ Re-define safety margin with up-to-date simulation capabilities
  - ✓ Validate or optimize closing time and sequence of each protection device:
    - Intake gate at the dam
    - Safety butterfly valves at the penstock end
    - Turbine main inlet valves
    - Turbine wicket gates
    - Pressure relief valves
  - ✓ Determine the control services complying with power plant safety
  - ✓ Define the power plant operating range and eventual operating constraints

SIMSEN Simulation Model

- ✓ Reservoirs
- ✓ Gallery
- ✓ Surge tank
- ✓ Penstock
- ✓ 4 Francis Units
- ✓ 3 pressure relief valves
- ✓ 2 safety valves.
- ✓ 1 intake valve
- ✓ Downstream H=H(Q)





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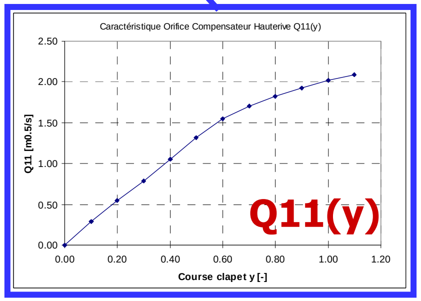
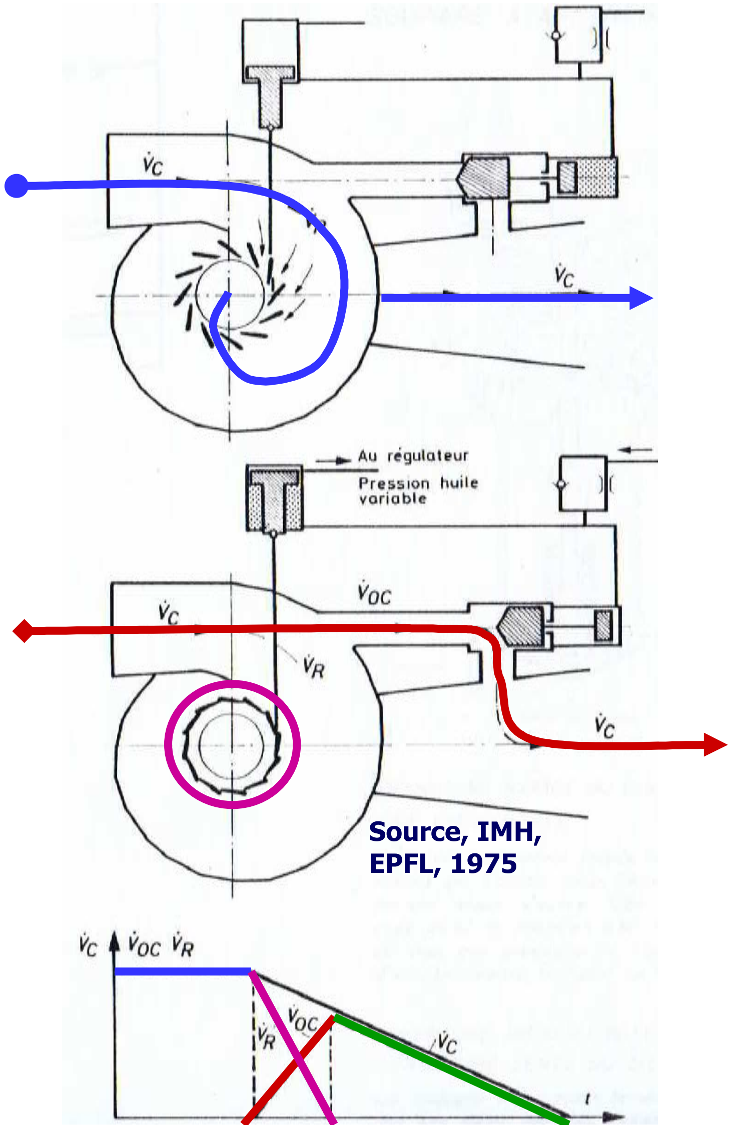
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE



Hauterive-Rossens Power Plant

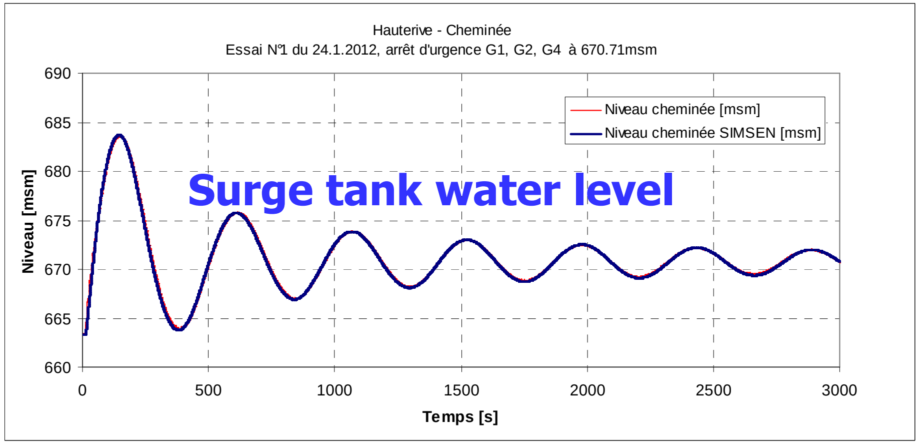
- Pressure relief-valves:
  - ✓ Reduce runaway speed and mitigate water hammer
  - ✓ Fast distributor closing (~4s)
  - ✓ Simultaneous pressure relief valve opening
  - ✓ Slow pressure relief valve re-closure

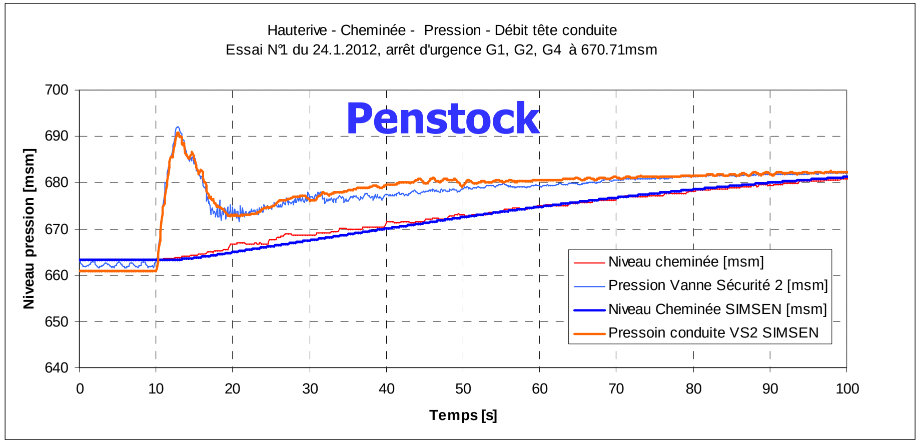


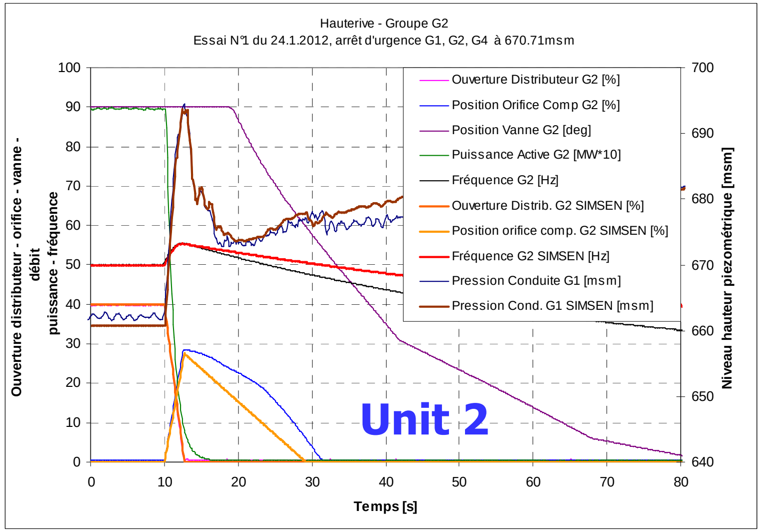
Source, IMH, EPFL, 1975

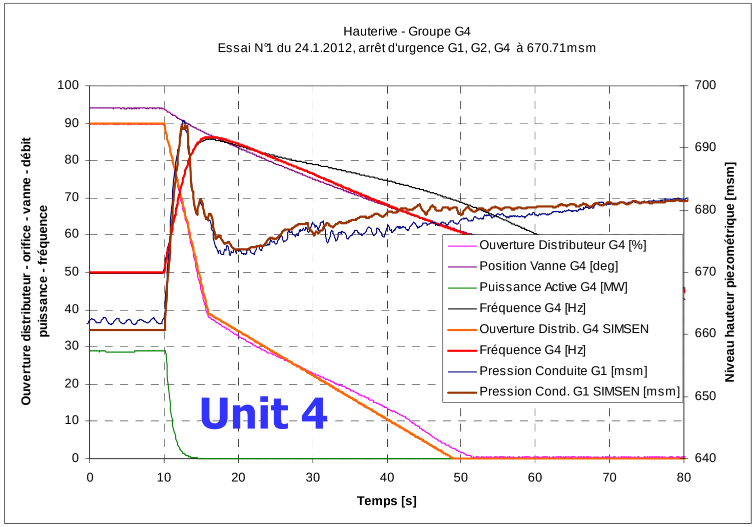
Model Validation

- On site emergency shutdown 3 units @ 47MW:
  - ✓ Tests performed on 24.1.2013:







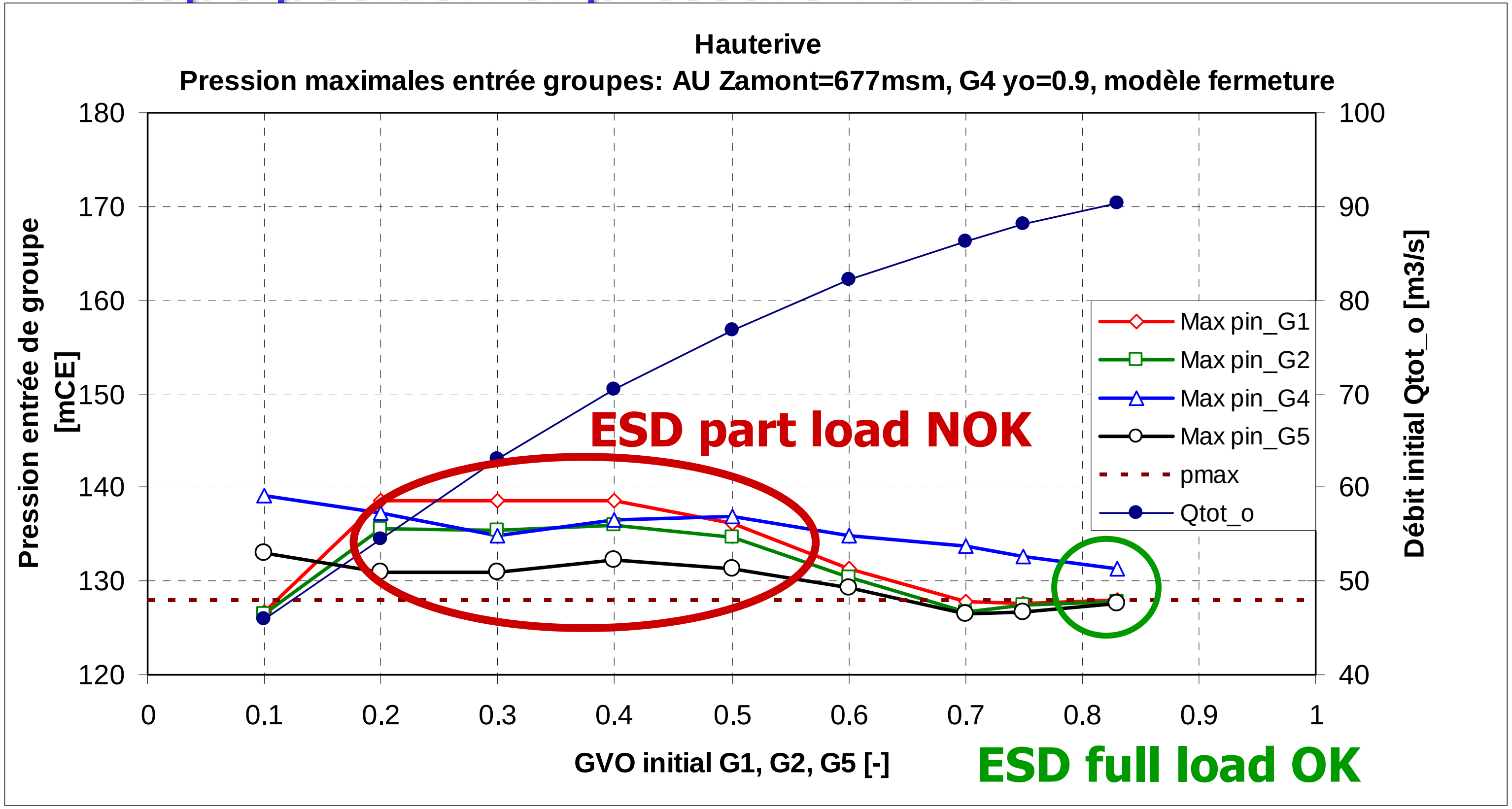


Transient Analysis Case Study

- Load cases considered:
  - ✓ Emergency shutdown
  - ✓ Load acceptance and rejection
  - ✓ Loading and emergency shutdown at worst conditions
  - ✓ Unexpected valve closure
  - ✓ Valve closure consecutive to pipe burst
  - ✓ Intake valve closure

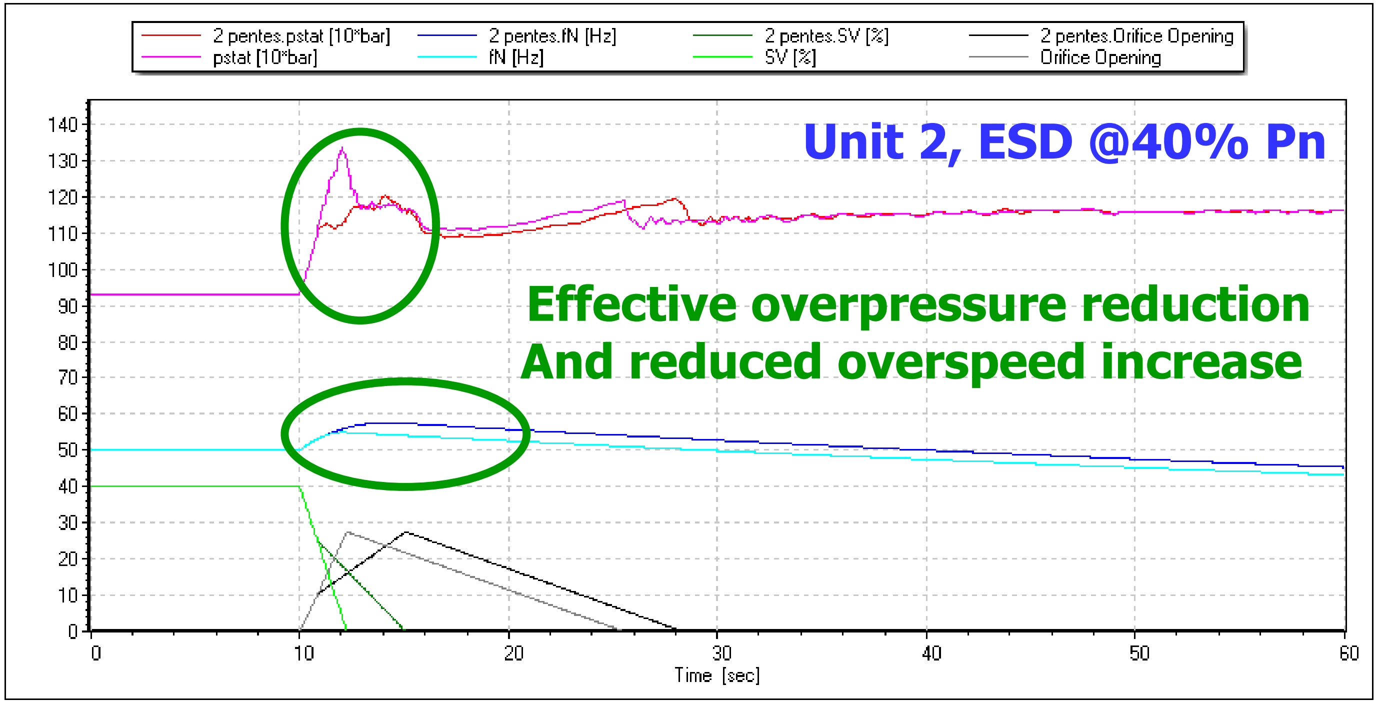
Transient Analysis Case Study

- Emergency shutdown:
  - ✓ 4 units shutdown: U4 max load + U1, 2, 5 part load
  - ✓ =>superposition of pressure waves



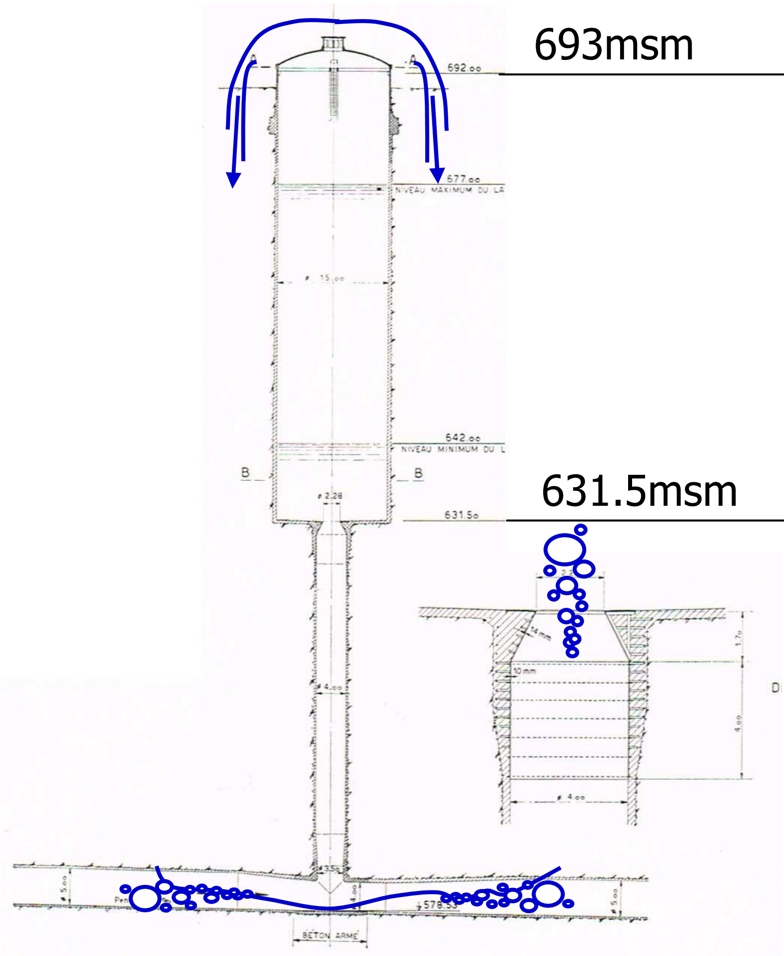
Transient Analysis Case Study

- Emergency shutdown:
  - ✓ 4 units shutdown: U4 max load + U1, 2, 5 part load
  - ✓ Solution: introduction of 2 slopes closures law



Transient Analysis Case Study

- Load acceptance and rejection:



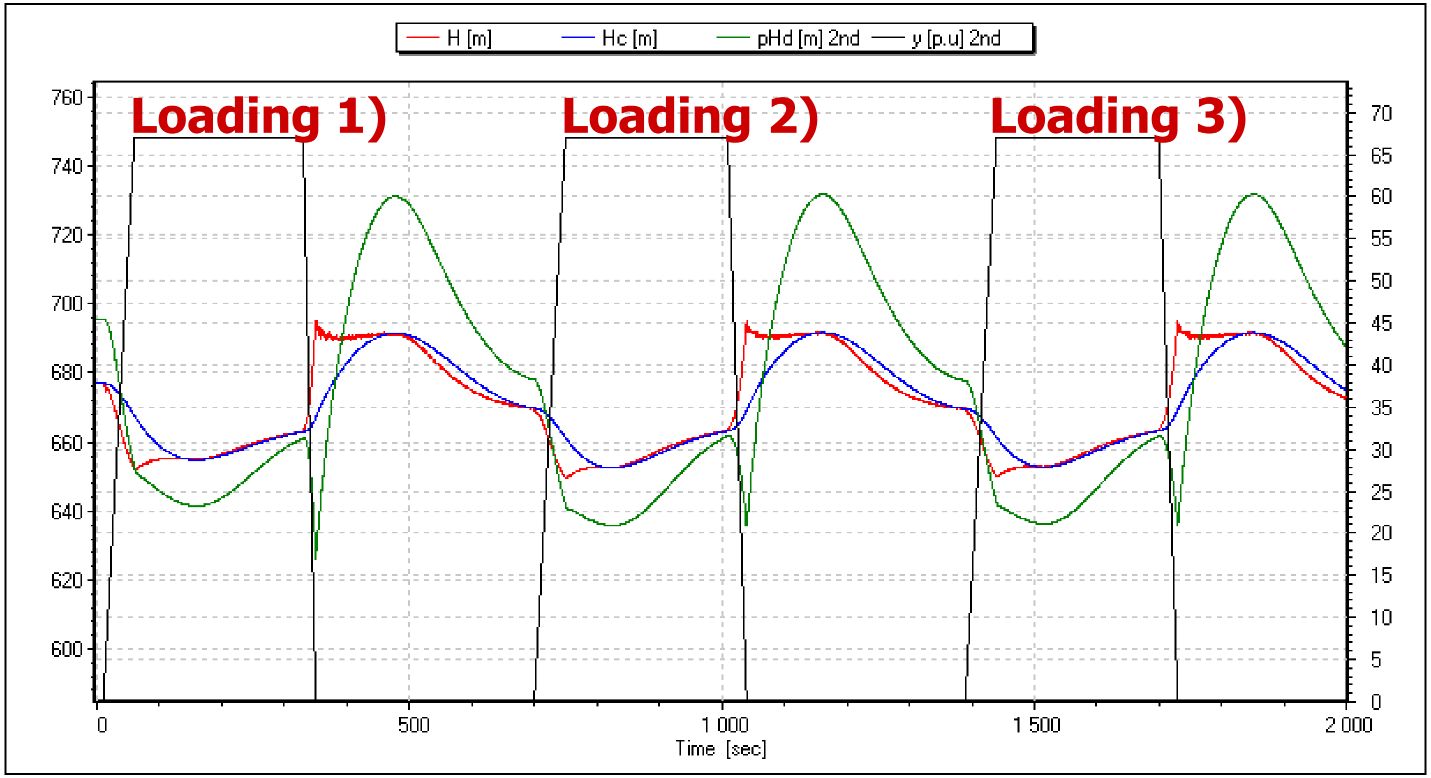
693msm → **Overflow**

631.5msm → **Emptying**

Diaphragm cavitation

Transient Analysis Case Study

- Load acceptance and rejection:
  - ✓ 3 successive loadings in phase with mass oscillations



Water level

Pressure in the gallery

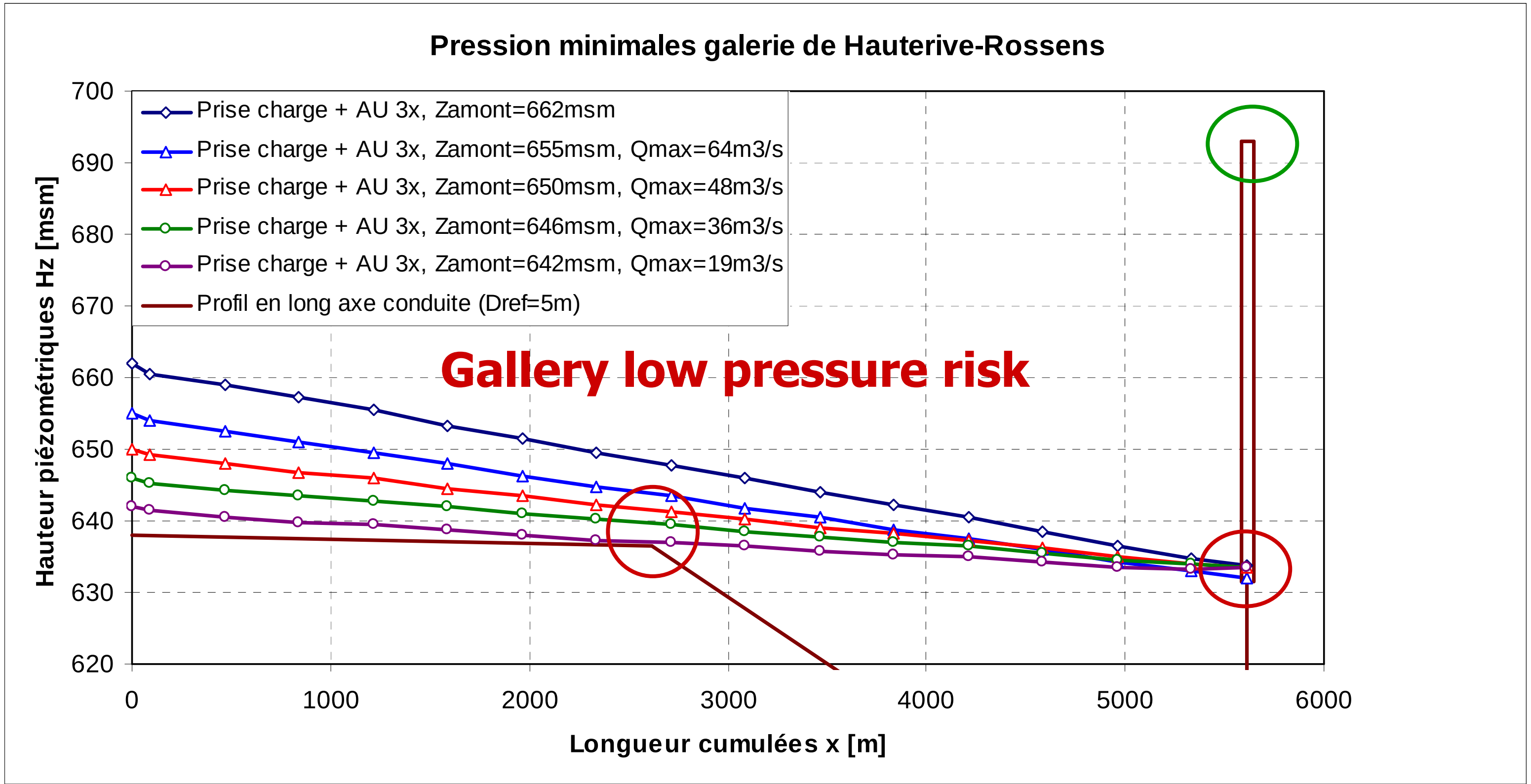
Diaphragm pressure

Distributor opening

No amplifications after second oscillation (diaphragm damping)

Transient Analysis Case Study

- Load acceptance and rejection:
  - ✓ Minimum pressure envelopes along the gallery



No overflow risk amplitude saturation

Surge tank Emptying risk

Introduction of Power Limitation as function of reservoir water level

Conclusions

- Existing power plants subjected to:
  - ✓ Aging equipment (penstocks, turbines, safety devices, etc)
  - ✓ Rehabilitation and power increase
  - ✓ Willingness to:
    - Increase power plant flexibility and operating range
    - Provide new services: primary and secondary control services

- Perform extensive transient analysis:
  - ✓ Up-to-date simulation capabilities including detailed turbine modeling
  - ✓ Perform on site-validations => reduce uncertainties

- Outcome/Benefits:
  - ✓ Better knowledge of power plant limits and capabilities
  - ✓ Reduced equipment solicitations
  - ✓ Increased power plant lifetime and safety

Thank you for your attention!

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