Transient Analysis of Hauterive-Rossens Power Plant

Dr. Christophe NICOLET ¹
Henri BUTTICAZ², Lionel CHAPUIS², Jean-Pierre VAUCHER²

5th IAHR International Meeting of the Workgroup on Cavitation and Dynamic Problems in Hydraulic Machinery and Systems
Lausanne, Switzerland, September 9-11, 2013
Content

- Hauterive-Rossens Power Plant
- 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

Hauterive Power House

Owned and operated by:

Groupe e

Galery: L=5614m, D=5m
Penstock: L=490m, D=5/2.9m
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 \( H = H(Q) \)
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:

**Surge tank water level**

**Penstock**
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

---

![Graph showing transient analysis results](image-url)

**Pression maximales entrée groupes:** AU Zamont=677msm, G4 yo=0.9, modèle fermeture

- **Max pin_G1**
- **Max pin_G2**
- **Max pin_G4**
- **Max pin_G5**
- **pmax**
- **Qtot_o**

**Key Points:**
- **ESD part load NOK**
- **ESD full load OK**
Transient Analysis Case Study

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

Unit 2, ESD @40% Pn

Effective overpressure reduction
And reduced overspeed increase
Transient Analysis Case Study

- Load acceptance and rejection:
  - Overflow
  - Emptying
  - Diaphragm cavitation
Transient Analysis Case Study

Load acceptance and rejection:

- 3 successive loadings in phase with mass oscillations

No amplifications after second oscillation (diaphragm damping)
Transient Analysis Case Study

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

---

Pression minimales galerie de Hauterive-Rossens

- Prise charge + AU 3x, Zamont=662msm
- Prise charge + AU 3x, Zamont=655msm, Qmax=64m3/s
- Prise charge + AU 3x, Zamont=650msm, Qmax=48m3/s
- Prise charge + AU 3x, Zamont=646msm, Qmax=36m3/s
- Prise charge + AU 3x, Zamont=642msm, Qmax=19m3/s
- Profil en long axe conduite (Dref=5m)

---

- Gallery low pressure risk
- Surge tank Emptying risk
- No overflow risk amplitude saturation

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!

SIMSEN

http://simsen.epfl.ch