Webinar
Boosting Hydropower Flexibility with Active Flow Control (AFC4Hydro)

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Agenda

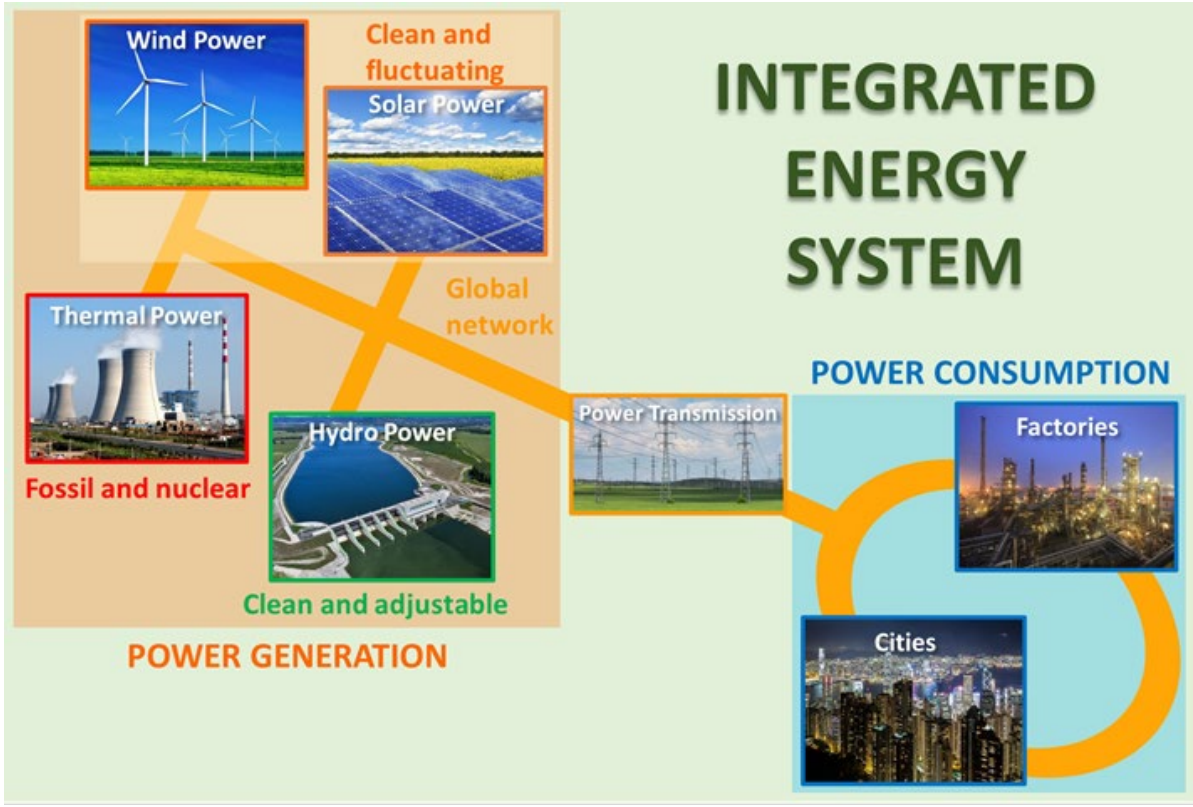
- Motivation (grid flexibility + operating range)
- The issue (RVR / pressure pulsations)
- AFC4Hydro concept (IPM/ICM/SHM + control)
- Validation pathway (lab → test stand → full-scale)
- Results + impact + next challenges

Role of Hydropower in Europe

- EU energy policy priorities include:
  1. Efficiency
  2. Renewables
  3. Affordability/security
- Hydropower is a low-carbon alternative to fossil fuels
- Hydropower can support climate adaptation by providing flexibility and storage, helping integrate variable renewables

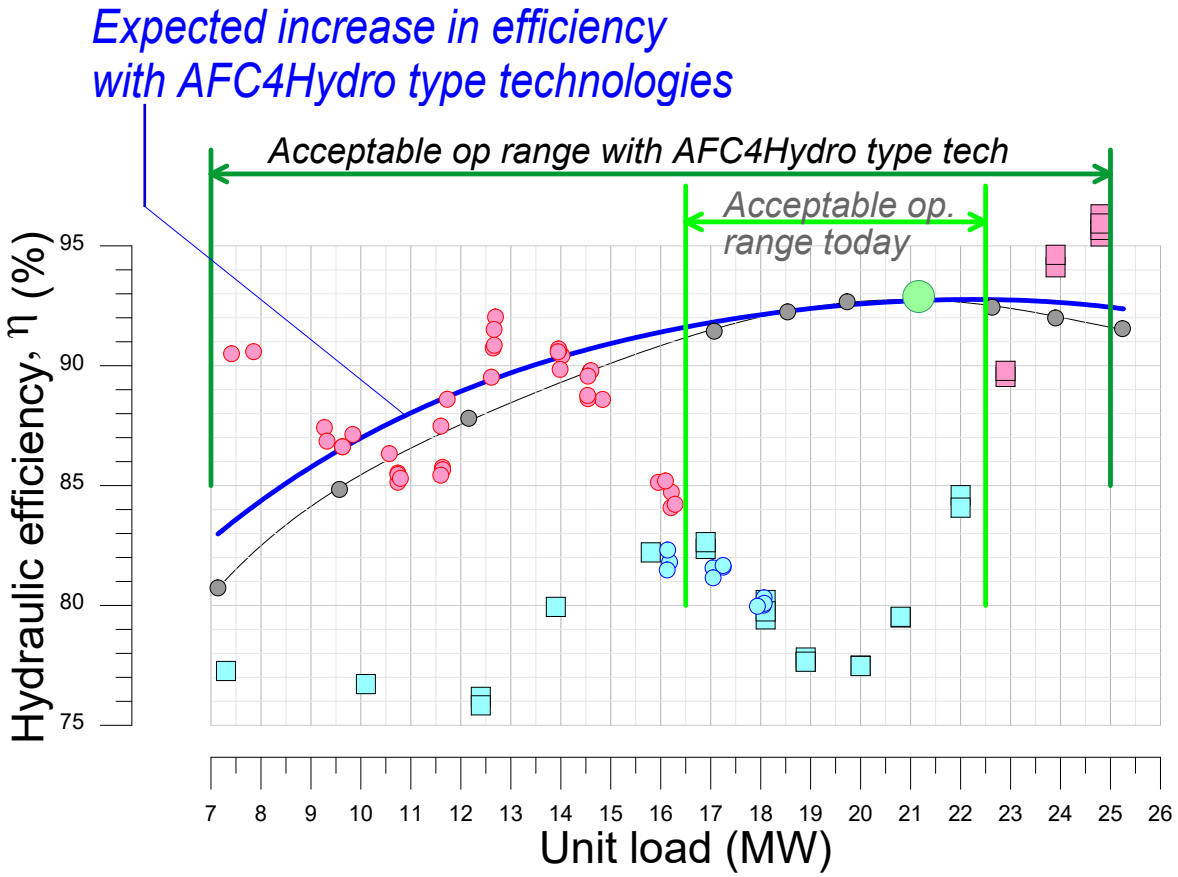
European Union Integrated Energy System

- Wind and solar power generation are less predictable and experience greater variability
- Hydropower plays a central and complementary role as:
  1. Frequency regulation
  2. Energy storage



Benefits of Improving Hydropower Technology

- For existing hydraulic turbines of any size and capacity
- Turbines must improve:
  1. Efficiency
  2. Stable and wide operation range
  3. Reduced dynamic loads (fatigue/cavitation)



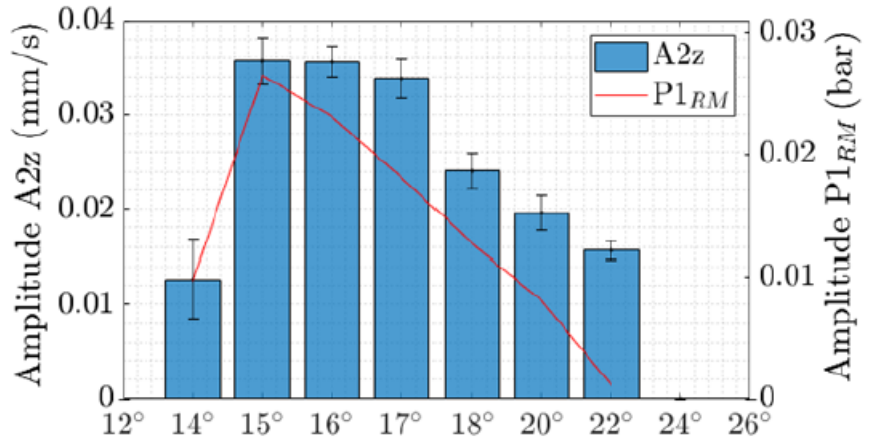
Measured efficiency
Acceptable pressure pulsations
Unacceptable pressure pulsations
Best Efficiency Point (BEP)
Acceptable cavitation levels
Unacceptable cavitation levels

Rotating Vortex Rope (RVR) at Part Load

- **Helical vortex** that develops in the **draft tube cone,** inducing high-amplitude rotating and axial **pressure pulsations**

- Efficiency loss, vibration, fatigue, and constraints on grid services

Vibrations and pressure pulsations



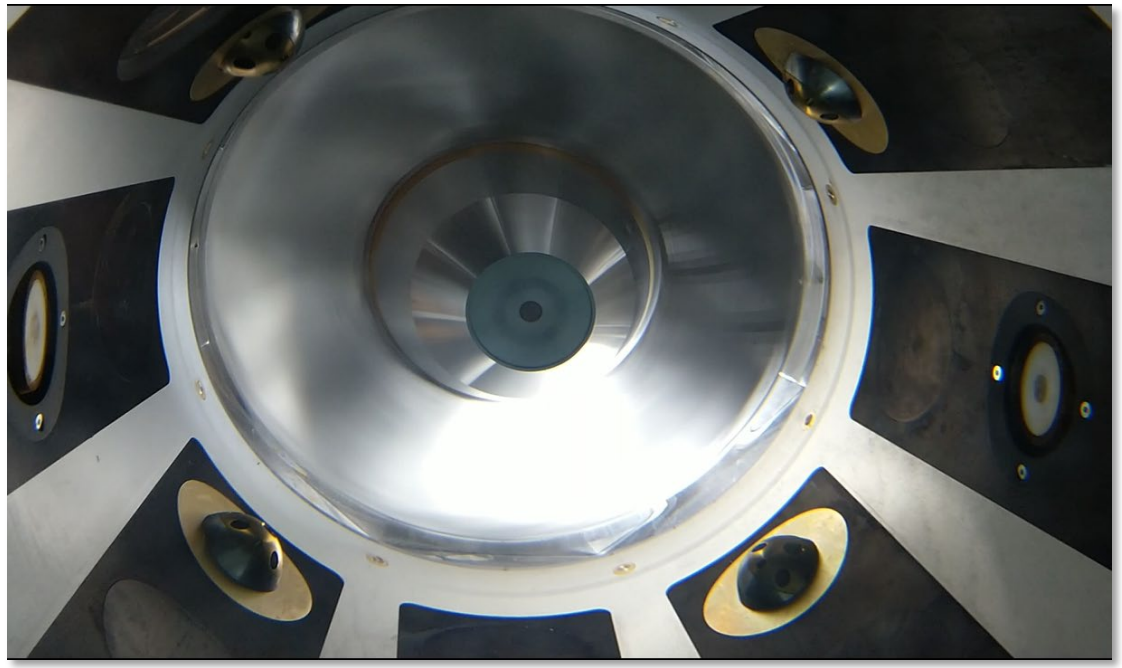
Guide Vane Opening

AFC4Hydro Research Project

- **Active Flow Control system for improving hydraulic turbine performance at off-design operation**
- **Objective:** increase the machine performance and reduce the dynamic loads on the structure at off-design operating conditions and during ramp-up and ramp-down phases
- **Validated on:** full-scale prototype unit(s)
- **Website:** https://afc4hydro.eu/

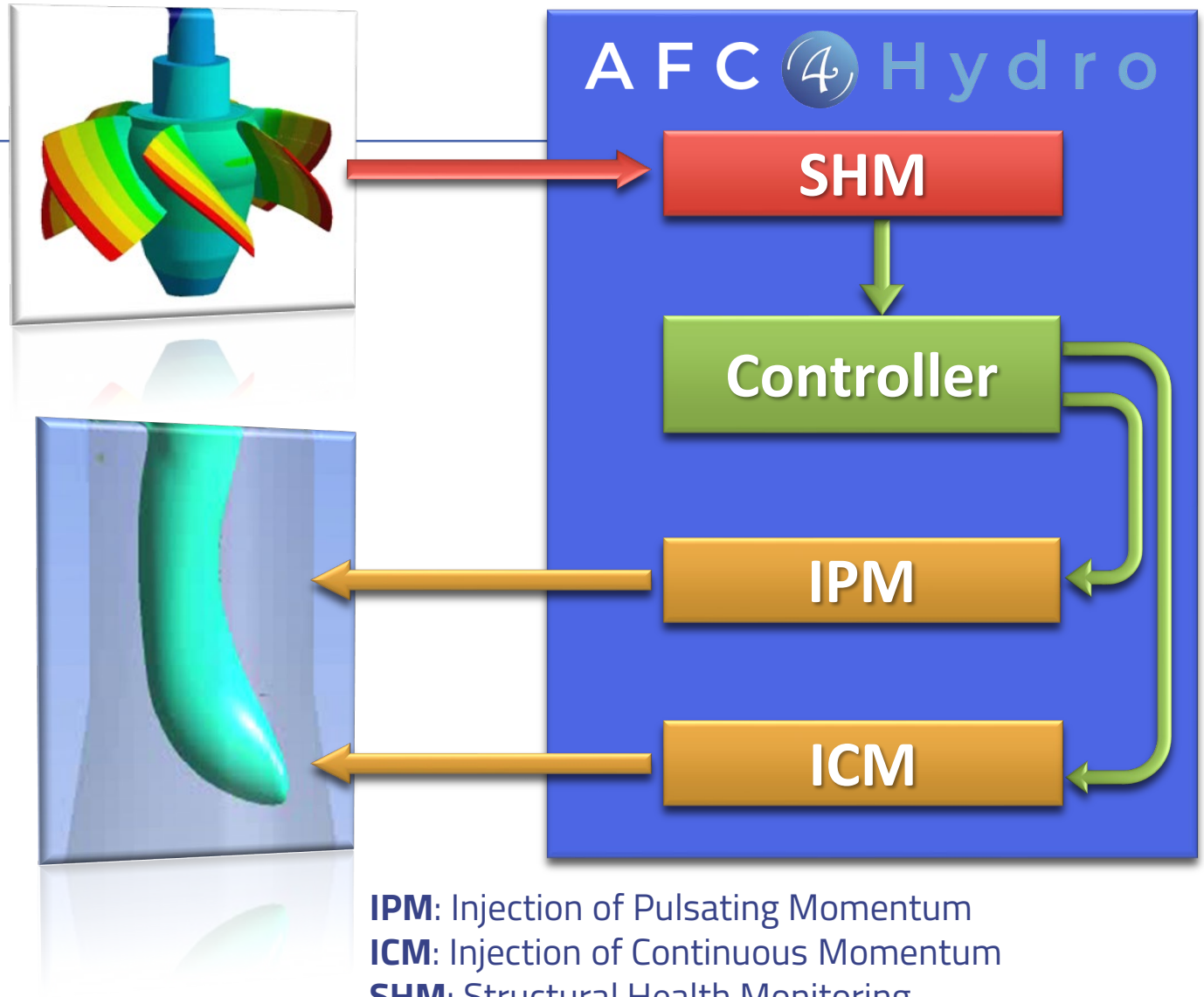
AFC4Hydro Technologies

- **IPM: Protrusion** of rods inside the draft tube cone
- **ICM: Injection** of water jets into the draft tube cone
- **SHM: Monitoring** the turbine structural health
- **AFC**: Use of **control** algorithms



Solution

- Controlled and optimized injection of momentum in the draft tube flow based on turbine health status
- Retrofit-friendly for existing high-power units



IPM: Injection of Pulsating Momentum
ICM: Injection of Continuous Momentum
SHM: Structural Health Monitoring

Consortium

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

SPAIN

LULEÅ UNIVERSITY OF TECHNOLOGY

SWEDEN

FDB Flow Design Bureau

NORWAY

SPV

SWEDEN

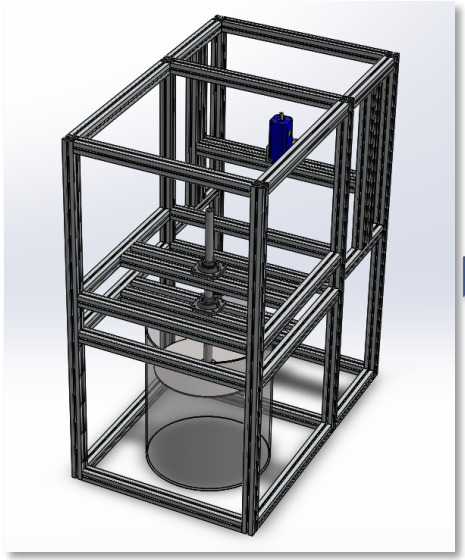
VATTENFALL

SWEDEN

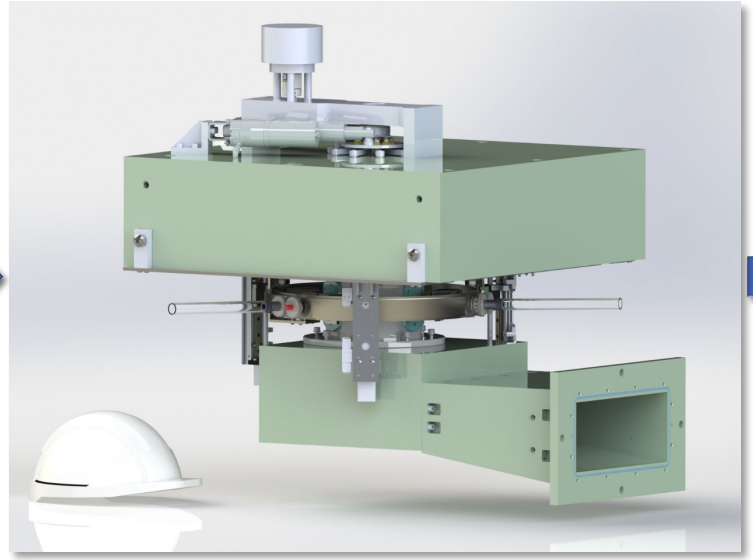
Statkraft

NORWAY

Scaled-down Laboratory → Test Stand



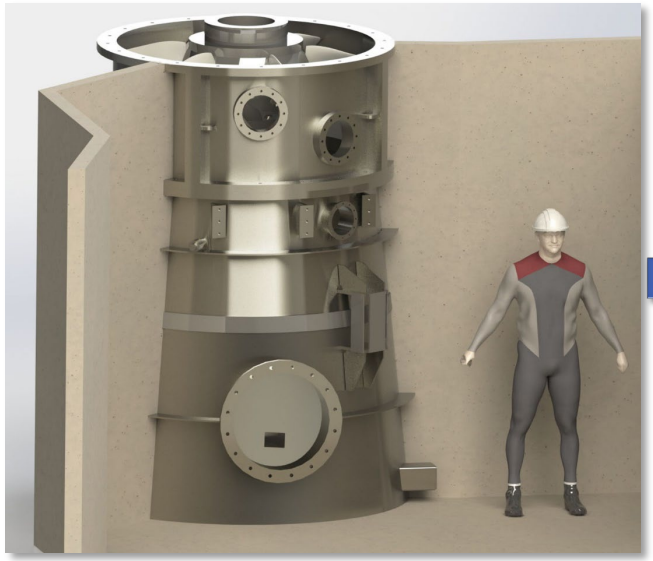
Rotating submerged structures test rig (UPC)



Downscaled turbine test rig (LTU)

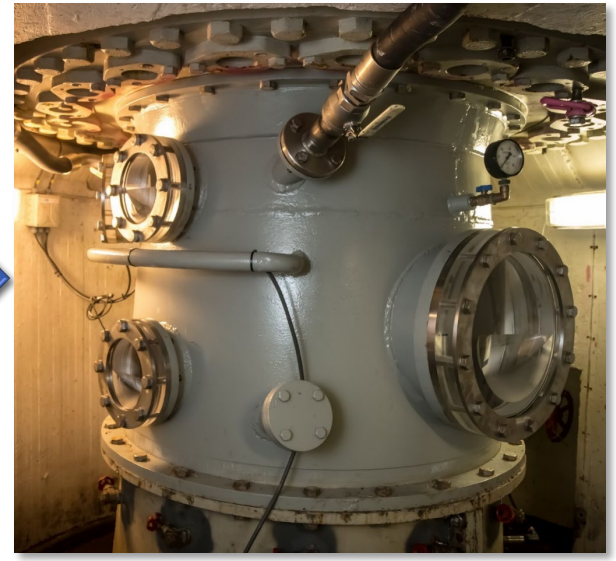
Turbine test stand at Älvkarleby Laboratory (Vattenfall)

Test Stand → Full-scale Prototypes



Porjus 10 MW Kaplan turbine power plant (Porjus Foundation)

Oksla 210 MW Francis turbine power plant (Statkraft)



Svorka 25 MW Francis turbine power plant (Statkraft)

10 MW Kaplan Unit

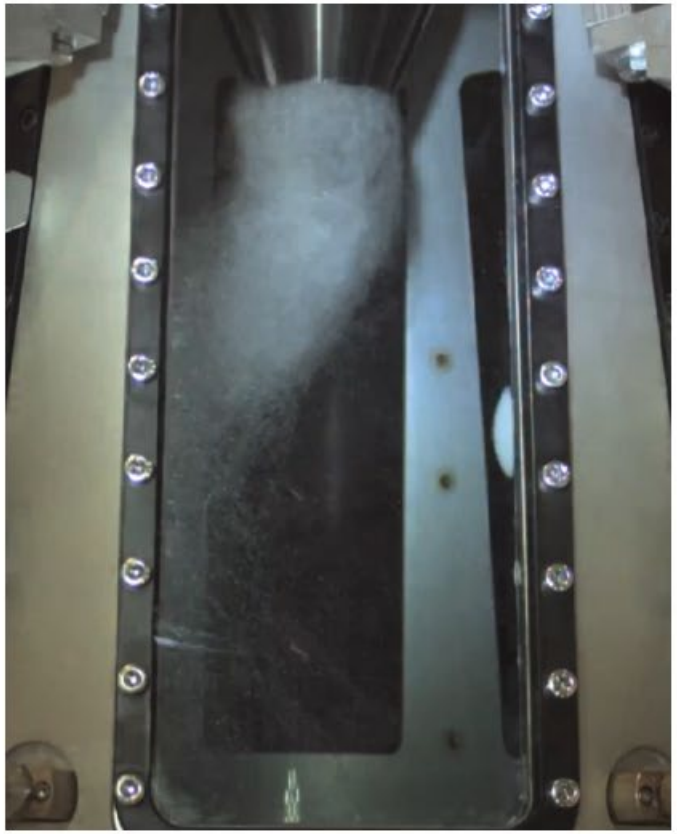
- Rods and injection nozzles in the draft tube cone

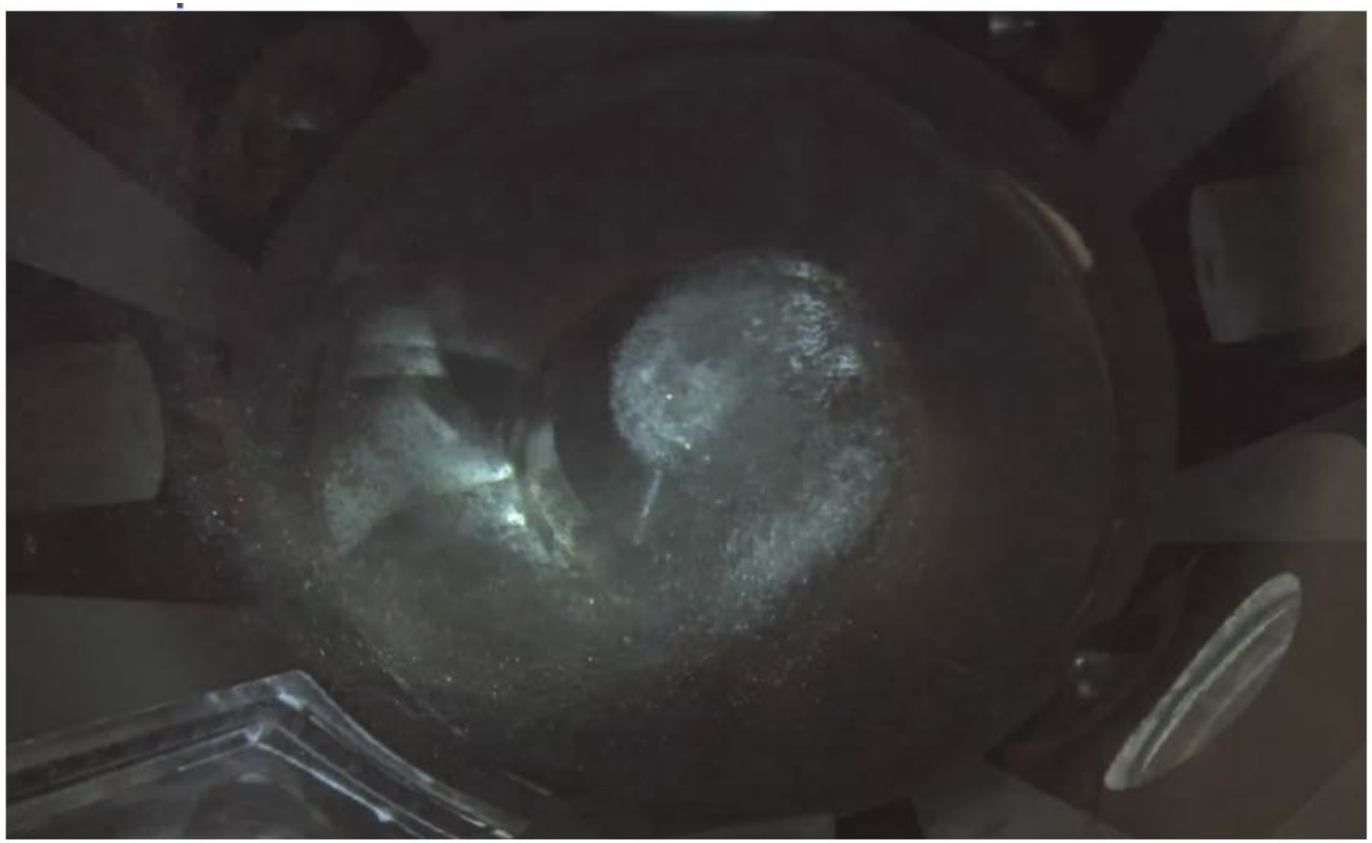
210 MW and 25 MW Francis Units

- Rods and injection nozzles in the draft tube cone

Visual observation of RVR mitigation

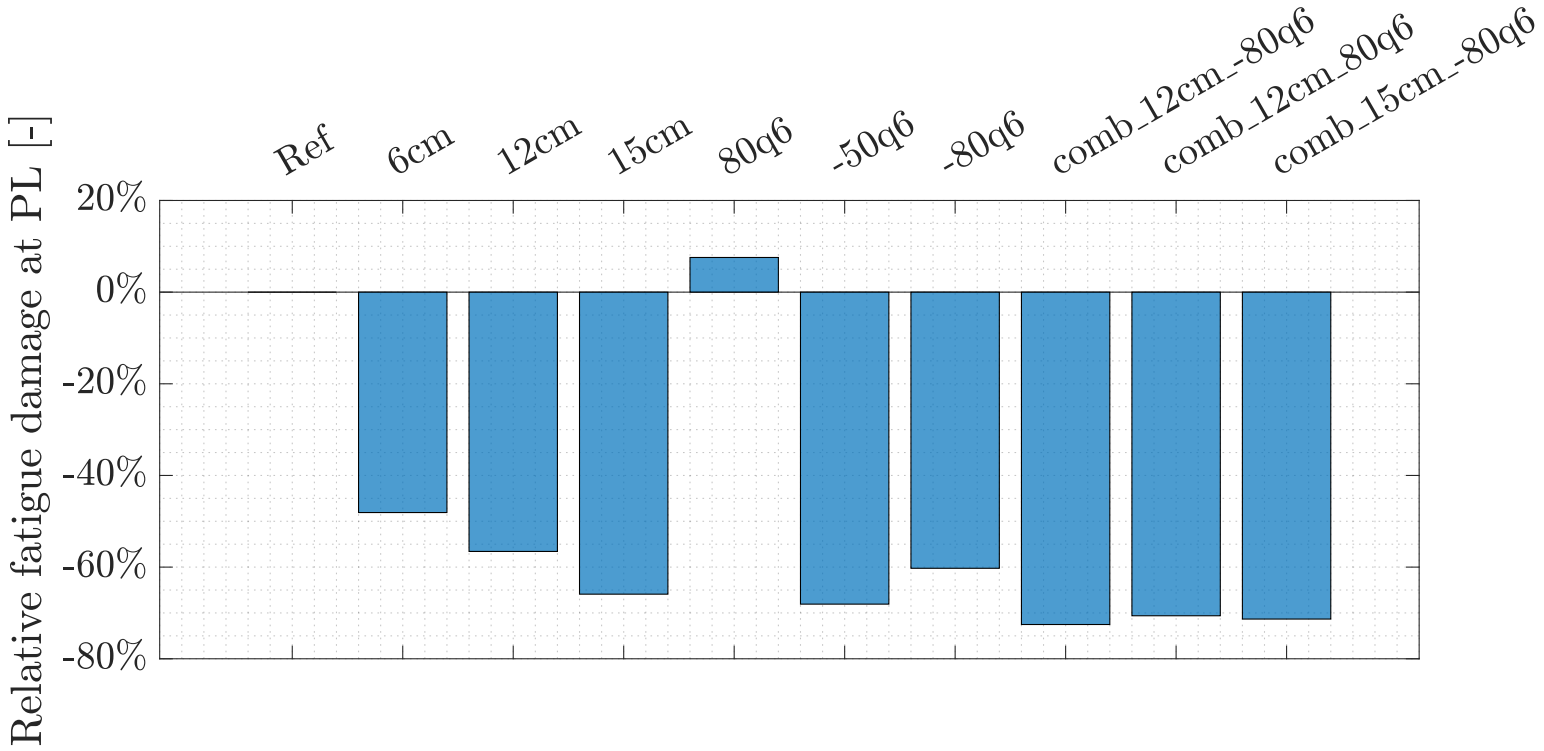
- Video: baseline vs AFC at part load with cavitation





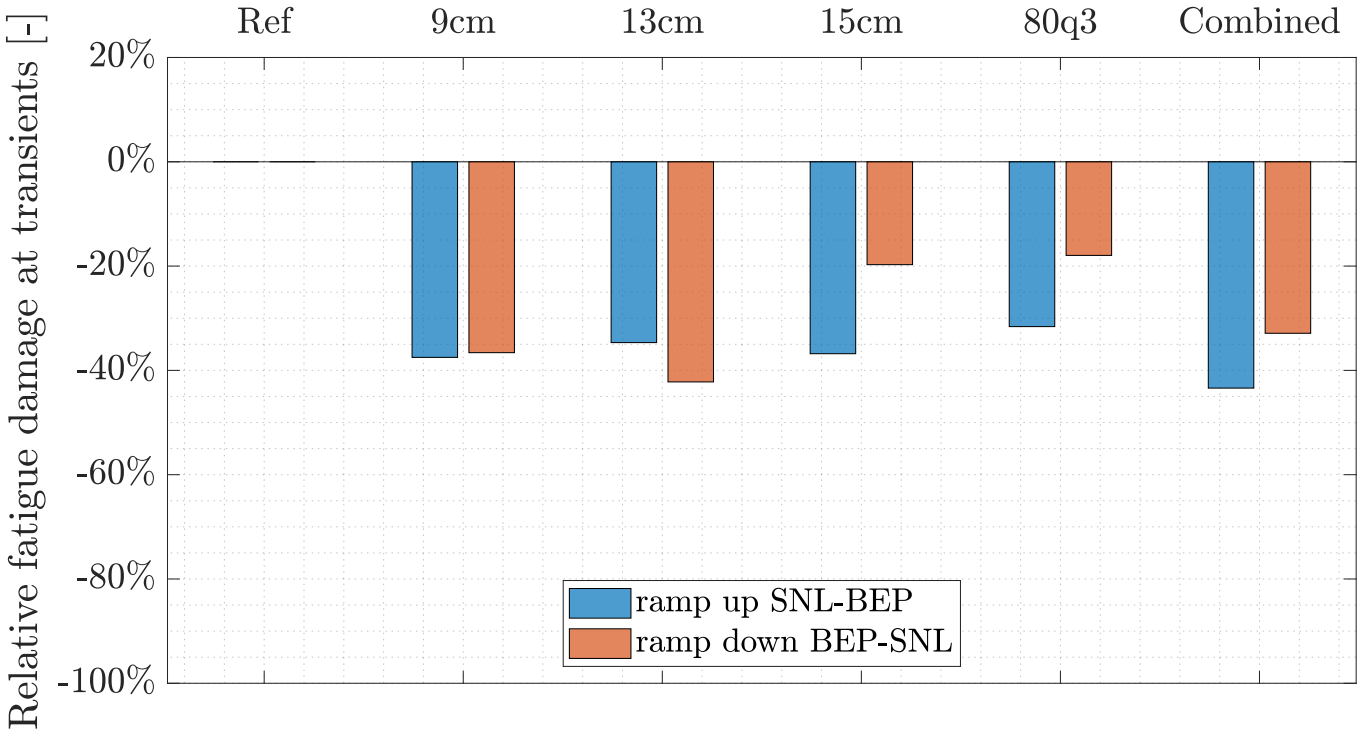
Damage Reduction at Off-design

- Up to 70% reduction in relative fatigue damage (normalized to baseline) induced at part load depending on configuration



Damage Reduction During Transients

- Up to 40% reduction in relative fatigue damage during load ramps



AFC4Hydro Technological Impact

- **Extend the operating range** of the turbines towards lower part load
- **Extend the service life** by reducing fatigue damage at off-design conditions such as Speed-No-Load, part load and during ramping of load
- **Reduce** the maintenance **costs**
- **Develop** better **numerical models** to **design** the AFC systems (fluid + rotor + generator)
- **Develop** new **methods** and more reliable and sensitive **sensors** to **measure** the dynamic response of the turbine

Major Challenges for the Future

- Make the AFC4Hydro technology suitable for different turbines and draft tube cone configurations
- Test and validate the technology in full scale prototypes of different sizes and designs
- Evaluate the damage reduction achieved with the technology in hours of life, saved money and avoided outages
- Evaluate the potential benefit of installing the technology in relation to its cost of installation, operation and maintenance (CAPEX and OPEX)
- Develop guidelines/standards for design, retrofit, and verification

Funding

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AFC 4 Hydro