# WHEN FLEXIBILITY EXTENDS POWER PLANT LIFE: BATTERY STORAGE AND RUN-OF-RIVER


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Funded by
the European Union

ETIP HYDROPOWER

# Vogelgrun RoR: the challenges

- REN integration
  - Flexibility need increases
- Ageing units :
  - Reduce Wear & Tear due to grid frequency control FCR
- FCR provision :
  - stick to contractual regulating band
- Grid code rules :
  - Improve FCR control dynamic
- Achievement under XFLEX Hydro EU project

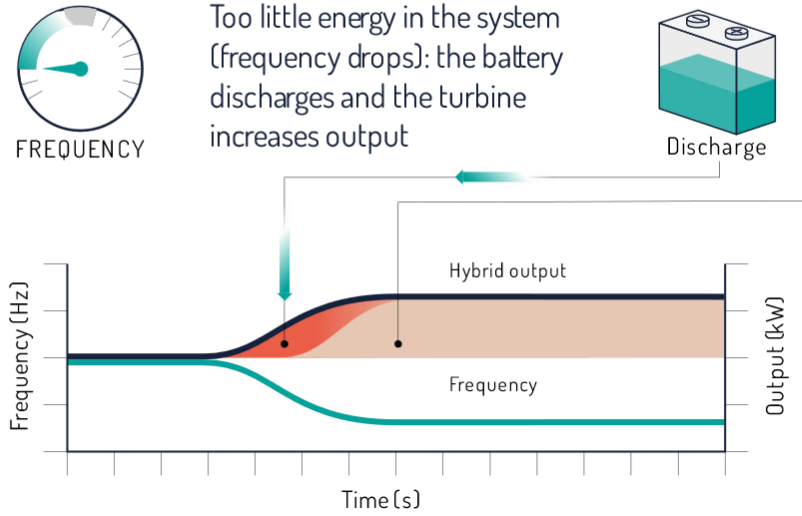
XFLEX HYDRO FUTURE OF HYDRO

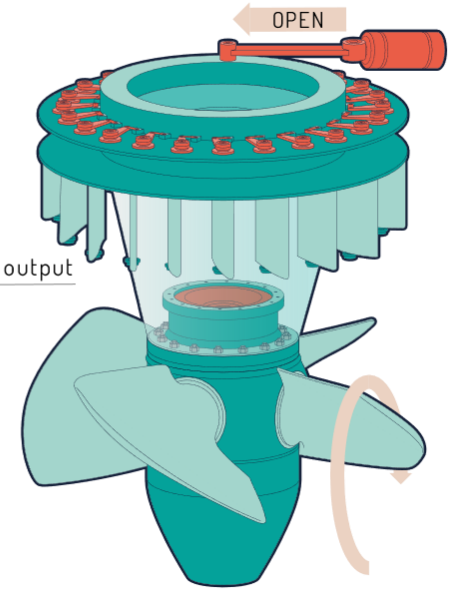
# VOGELGRUN in brief

- Four vertical Kaplan units, 1956
  - $P$ = 35 MW, $H$ = 12 m, $Q$ = 325 $m^3/s$
- Battery Hybrid : BESS 650kW/300kWh
- 750GWh annual generation
- Two locks: 20 000 boats/year

# Hybrid mode implementation

- Real time joint control : BESS + Hydro Unit
  - located at the same grid connection point
- Easy fall back to hydro stand alone mode
- Innovative approach: reduced size battery
- Compliance to TSO/RTE grid code
- Two W&T KPIs :
  - ServoMotor mileage
  - Stroke sign changes



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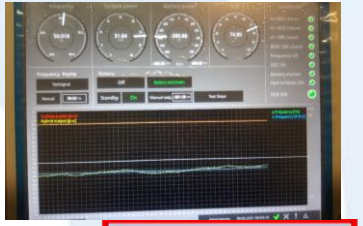


**CONTROL**
Turbine &
Battery

runner

wicket

$P_{grid}$

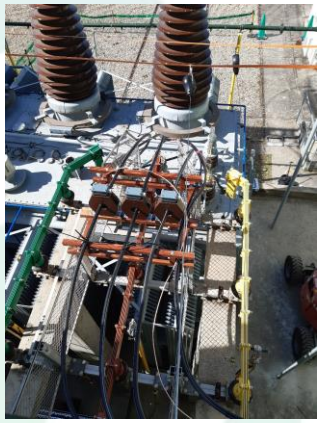
frequency

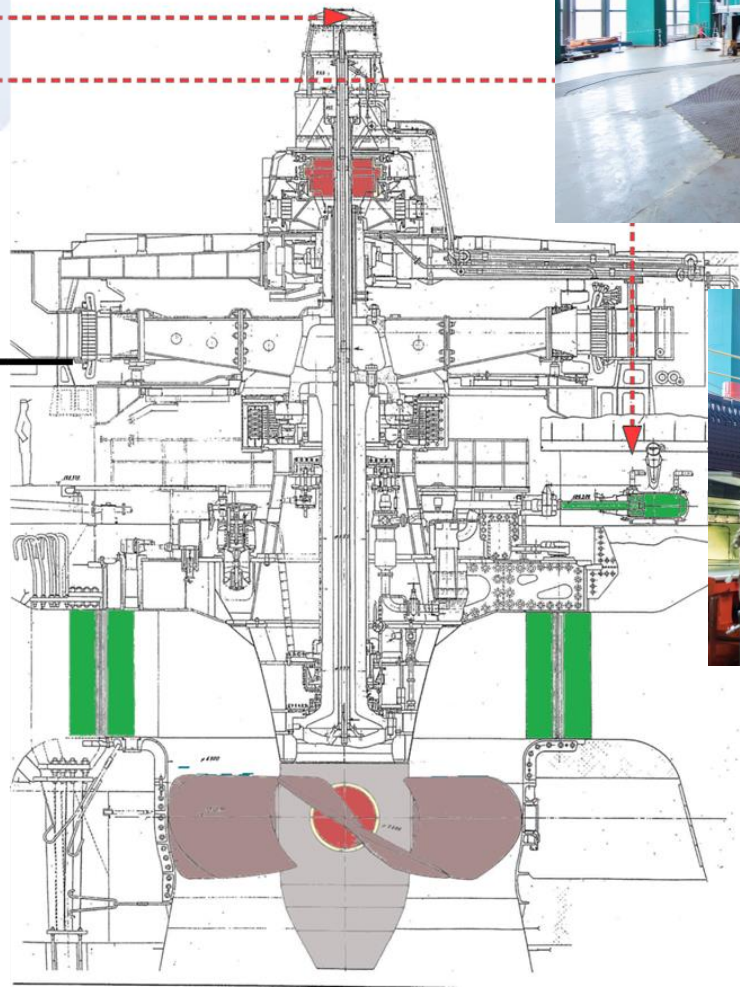
state of charge

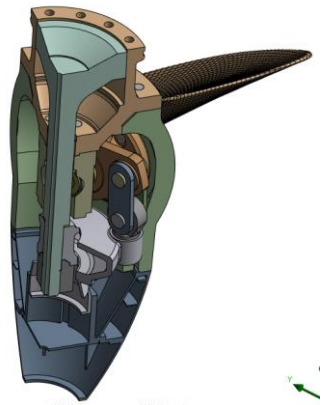
power

$P_{generator}$

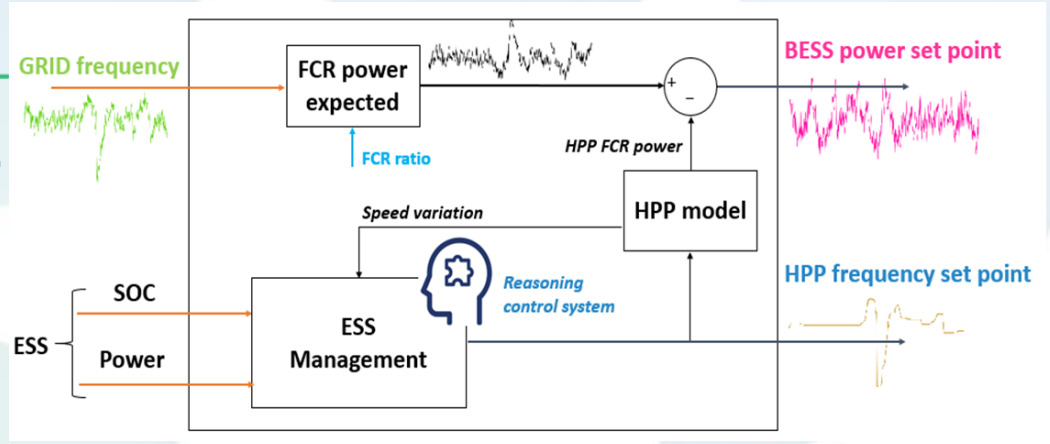
$P_{battery}$

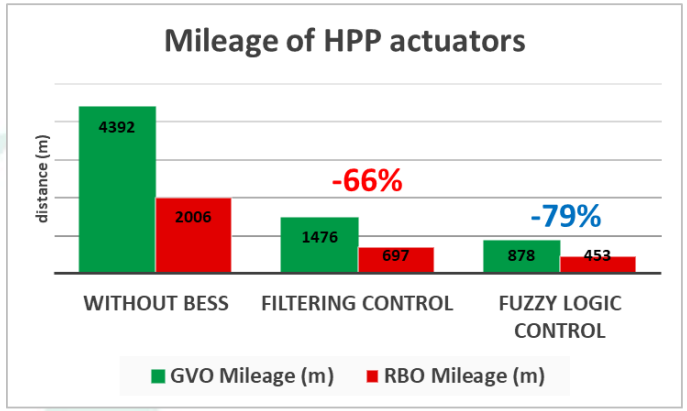




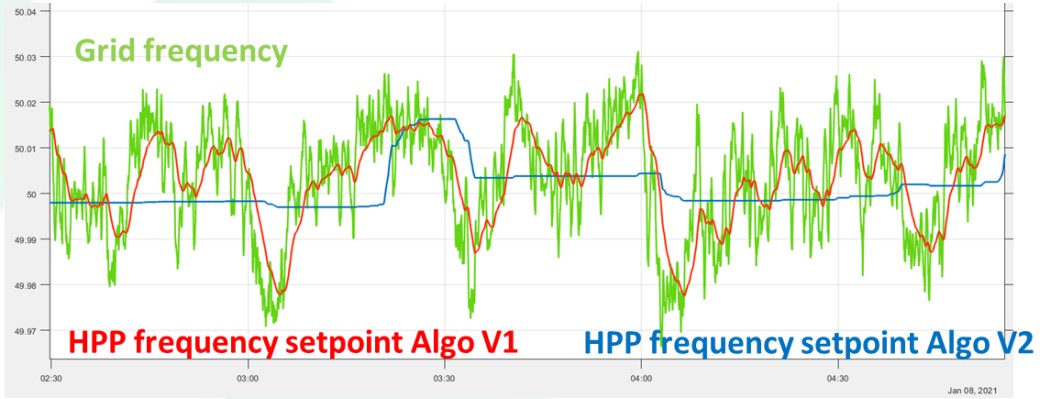


# HYBRIDIZATION ALGORITHM



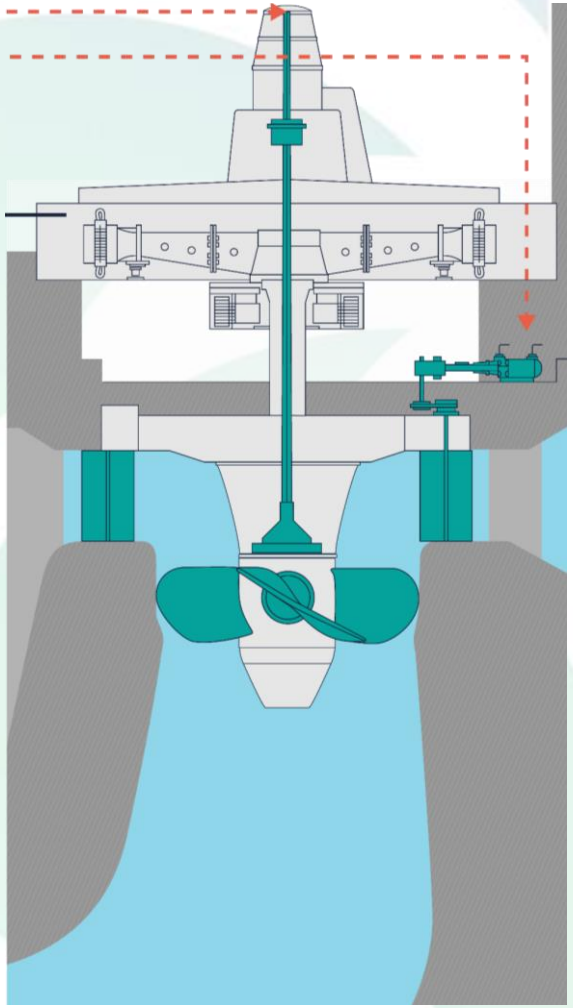

➔ *2 years* ***simulations with real data***

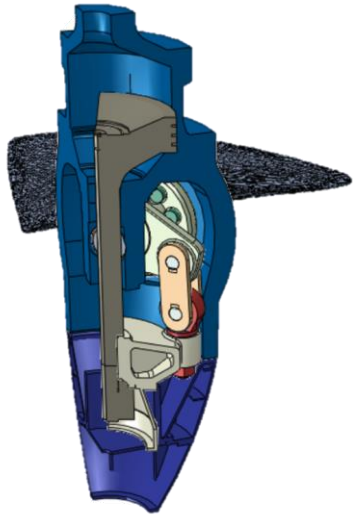



- Aim: decreasing HPP unit movements compared to algorithm V1 → use BESS
- Method: based on reasoning system

  With simple rules … *for instance « IF SOC is low THEN use HPP to charge BESS »*
- Expected Result: mileage reduction -79 %
- Demo: operated for 3 years
- Analysis: on site based on actual measurement and dgital twins

# Wear & Tear Assessment





Detailed **CFD/FEM studies** to identify most risk prone components

## Runner: the most critical part of the turbine

- Fatigue of runner blade mechanism
- Wear of runner blade bearings

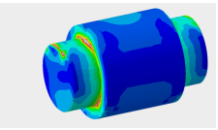
## Digital twin

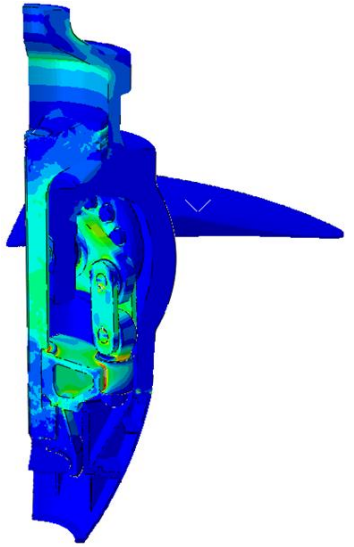
Neural Network based

Hydraulic model based

## Model test

Lab platform



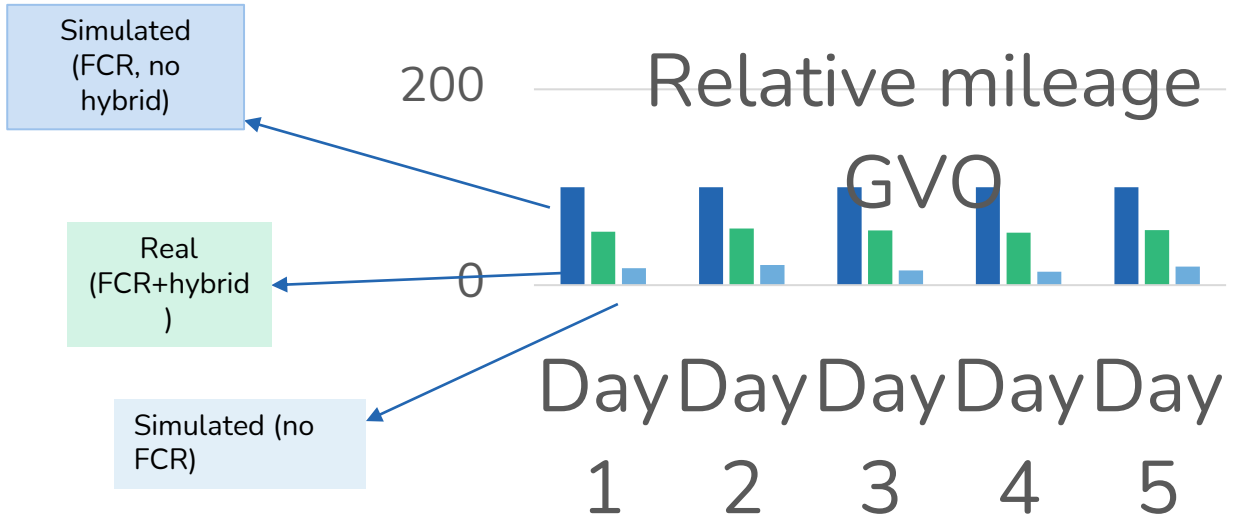


# NEURAL NETWORKS FOR DIGITAL TWINS (WEAR)

❖ **Wear of the regulation mechanism: KPI MILEAGE of the Servomotors**

**Simulated scenarios with NN:**

- 1) Real input (**Hybrid Unit**): Prediction error in Mileage is 2%
- 2) FCR without battery and
- 3) No FCR.



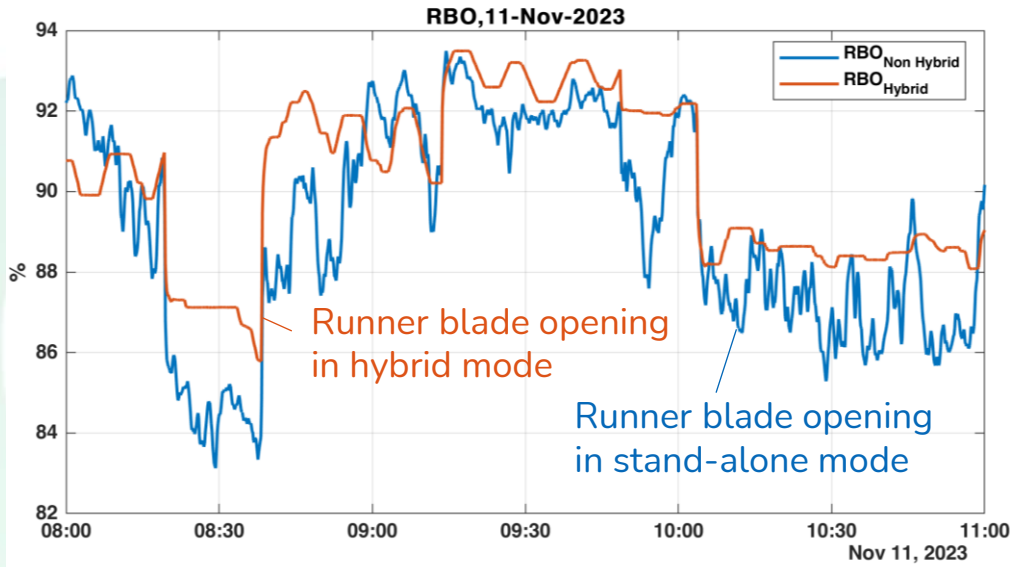

❖ **FCR** represents actually the **80%** of the **mileage**.

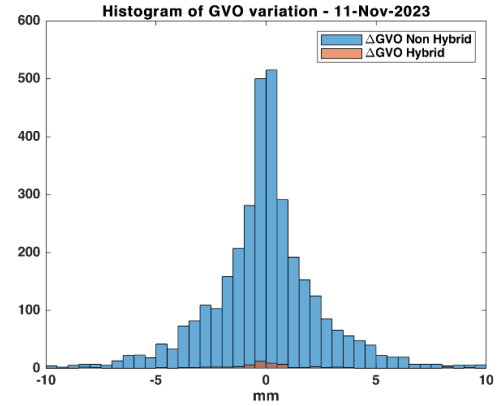
❖ **Mileage reduction about 50%-60% thanks to the hybridization** with a small size battery (around 2% of the Power of the Turbine).

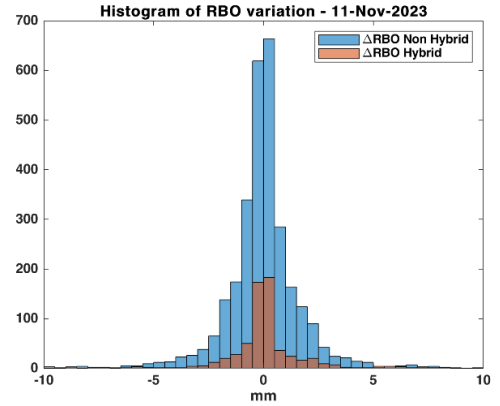
# Hydro-Clone® digital twin

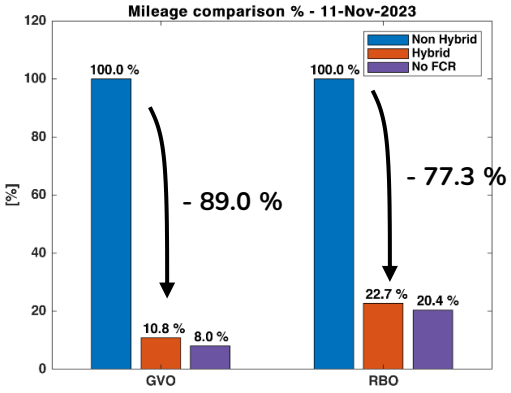
## Mileage assessment

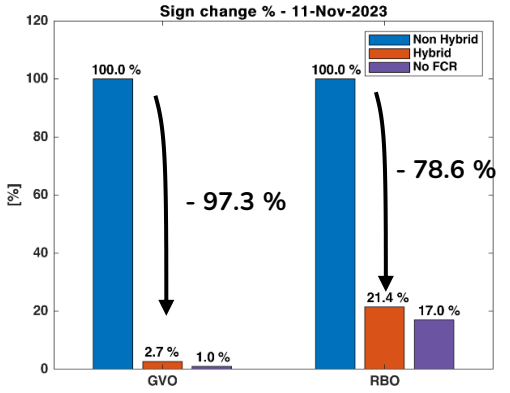
- Stand-alone vs hybrid with Fuzzy Logic

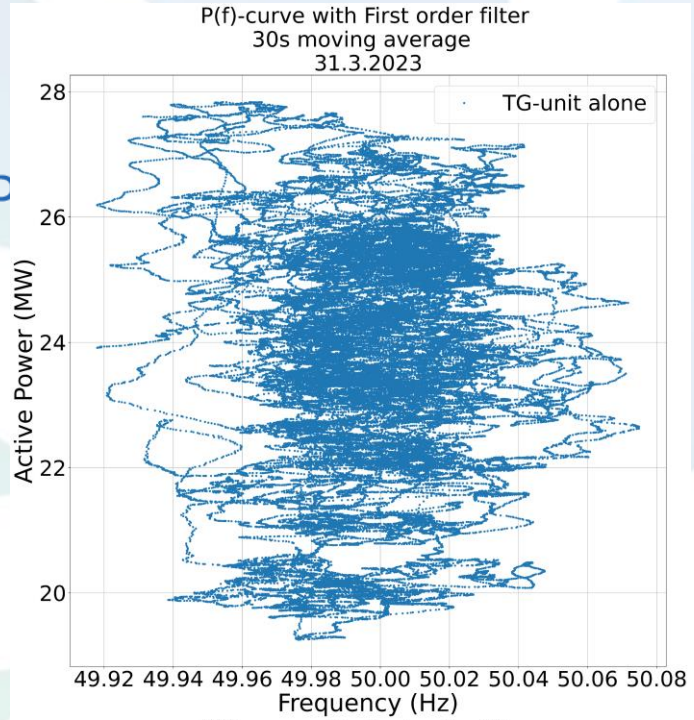


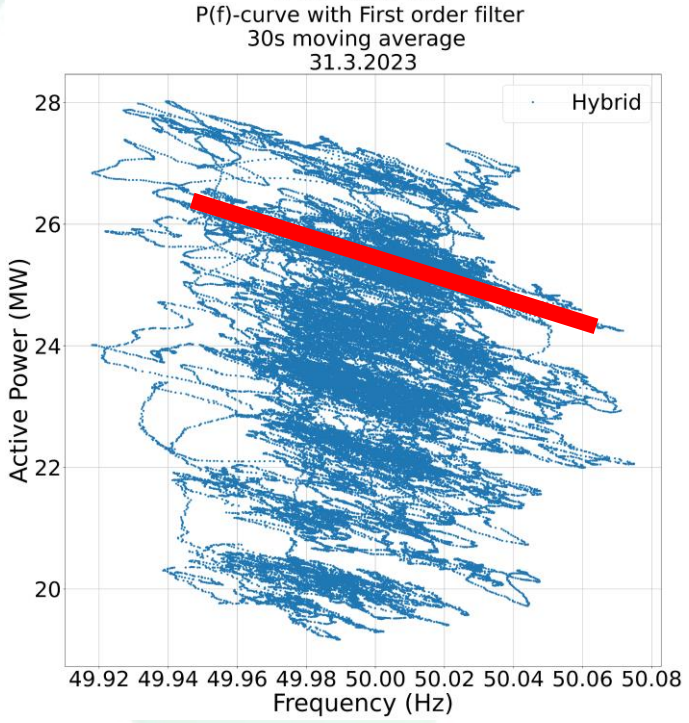



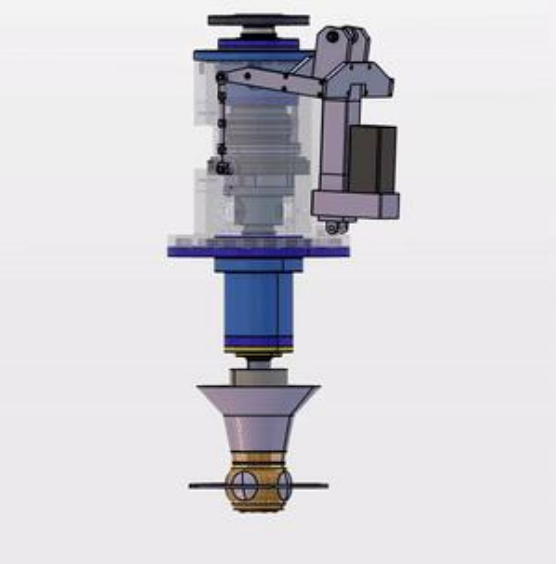



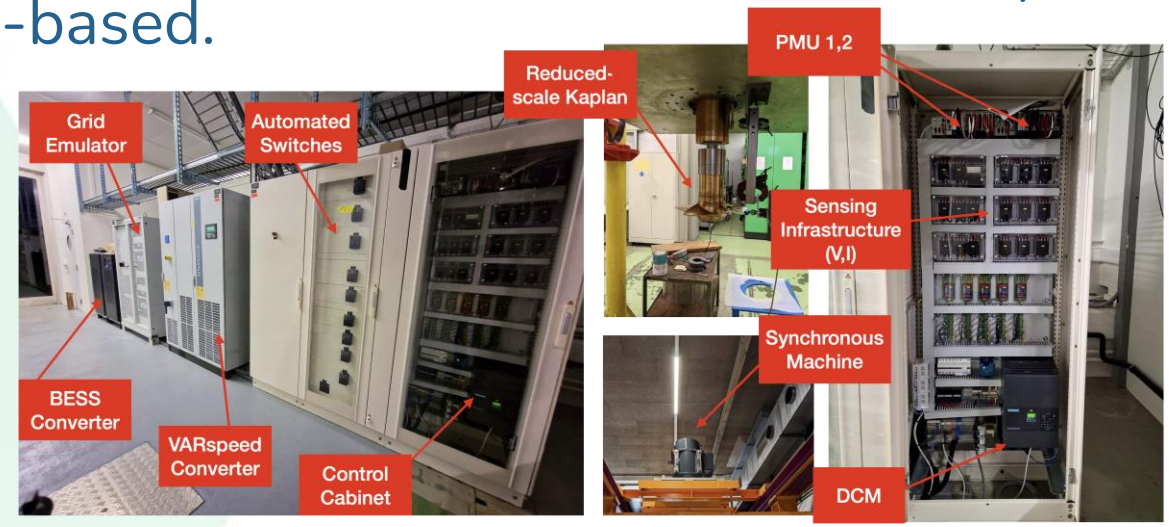

## Functionalities of Hybrid Control

- FCR setpoint distribution to BESS and speed-governor and SoC-Management
- Discharge mode
- Battery test profile
- Setpoint test: BESS, Turbine

# Battery-hybrid –run-of-river

- Reduced scale modeling:
  - Test rig including hydraulic, mechanical and electrical component.
  - Runner with movable blades on line
- Study
  - full energy conversion process accurately.
  - Several control strategies
- Results beyond state of the art:
  - Most of the literature's contributions on BESS-hybrid HP is simulation-based.

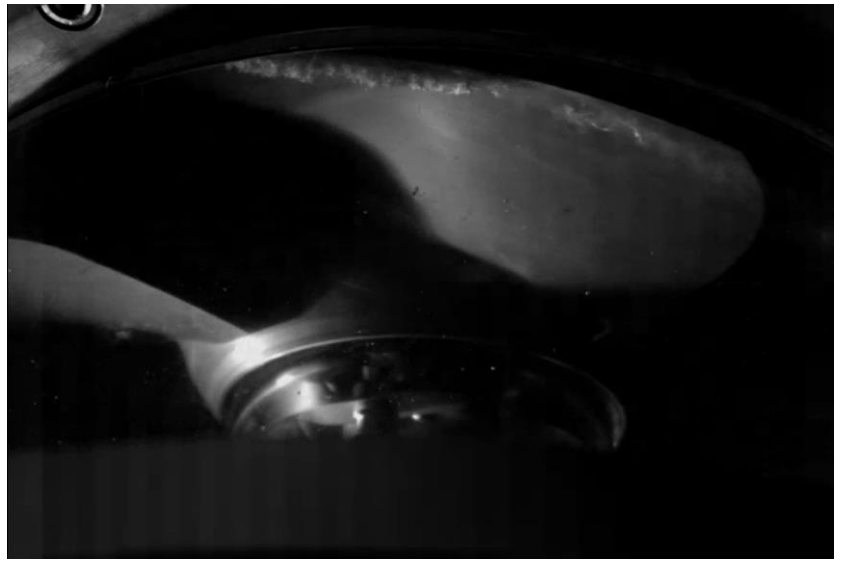




# Battery-hybrid –run-of-river

EPFL – PTMH Testing platform

- Validate control strategies.
- Show the improvements in movement reductions.
- Show the impact of BESS size.



| Configuration | Guide Vanes Opening (GVO) | | Runner Blade Angle (RBA) | |
|---|---|---|---|---|
| | **Mileage** | **NoM** | **Mileage** | **NoM** |
| DLMPC (5 kW BESS) | 3.33 (-93.2%) | 292 (-96.8%) | 1.98 (-94.0%) | 258 (-97.1%) |
| DLMPC (9 kW BESS) | 0.99 (-98.0%) | 64 (-99.3%) | 0.61 (-98.2%) | 52 (-99.4%) |
| Only Hydro | 49.03 (+0.0%) | 9261 (+0.0%) | 32.93 (+0.0%) | 8970 (+0.0%) |
| VARspeed | 109.09 (+122.5%) | 13484 (+45.6%) | 0.0 (-100.0%) | 0.0 (-100.0%) |

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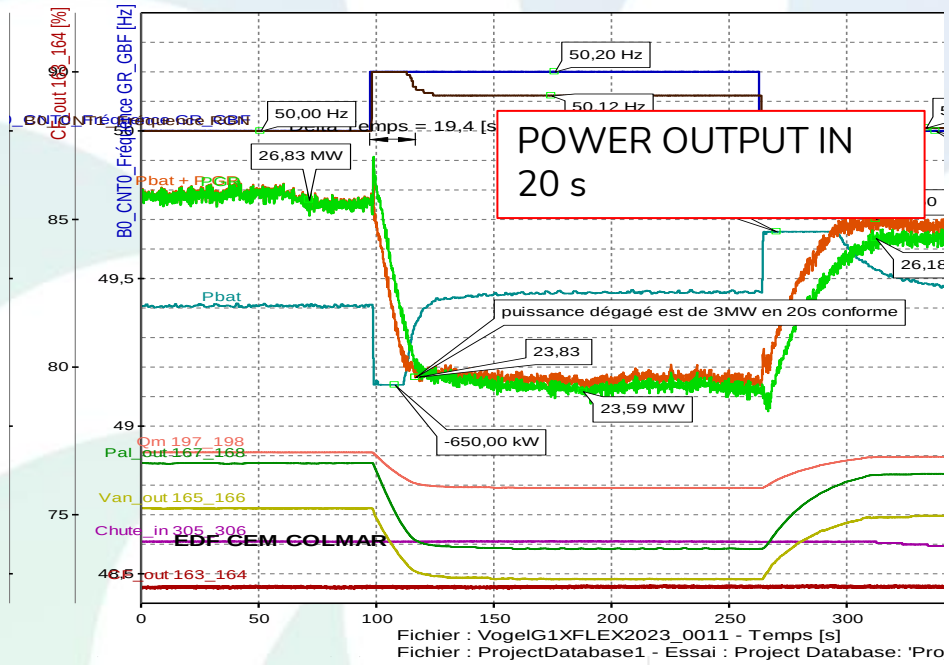
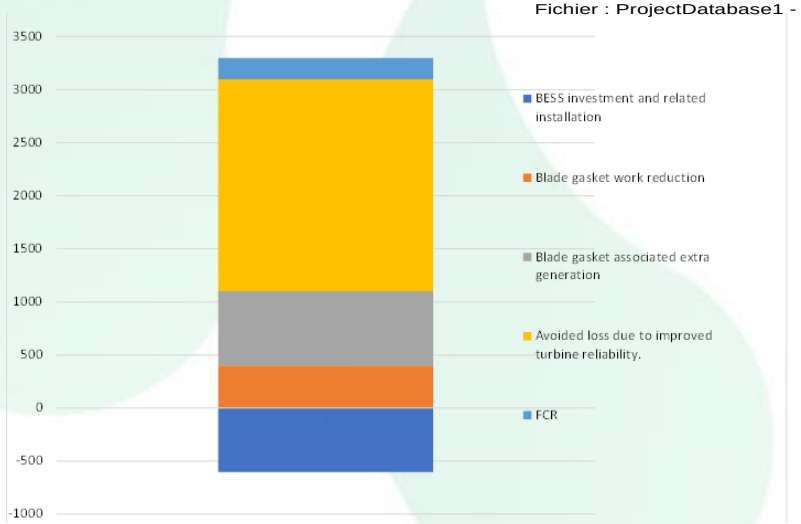
# Technico economic performance




- Hybrid performance
  - Compliant with Grid Code dynamic requirement
- Economic value
  - Net Present Value computing
  - Hybridisation is most relevant for aged turbines
    - in order to extend operating life
    - To reduce outage risk and related revenue loss risk

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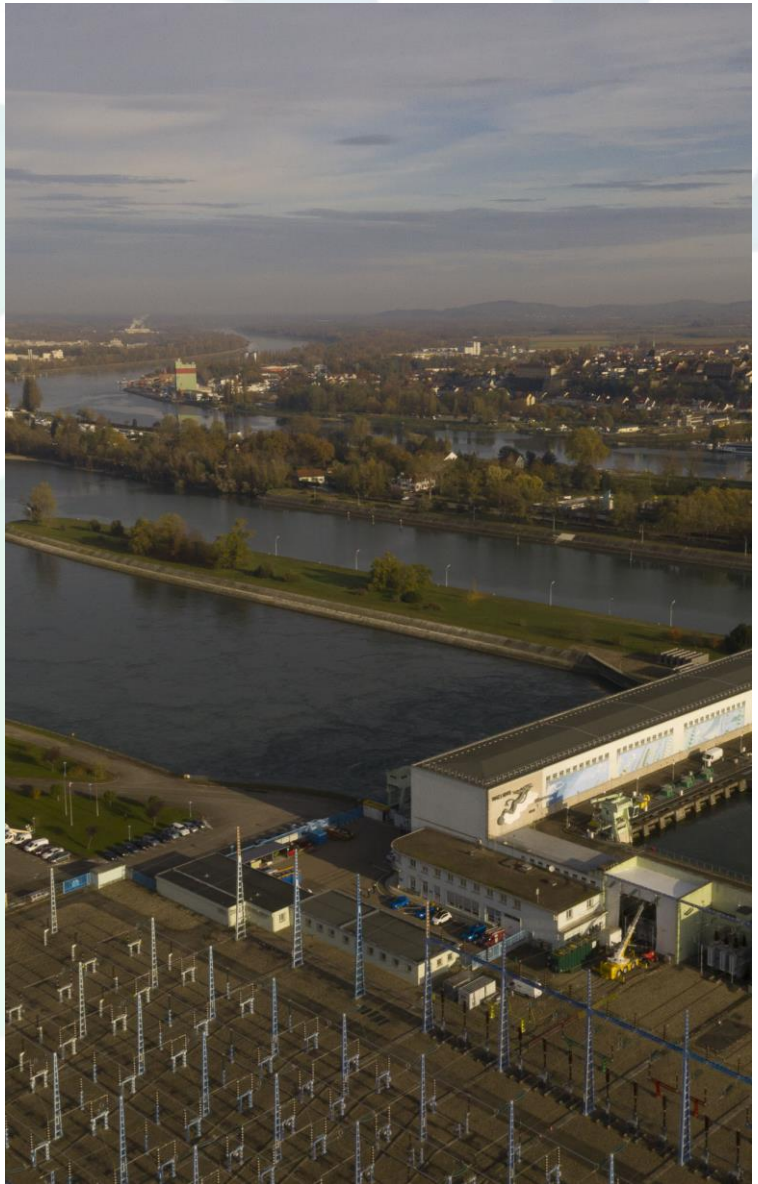

## Key Takeaways

Hybridisation study of RoR unit:

- Provides regulating power while reducing W&T and minimizing BESS size
- Provides suitable solution to extend RUL of hydro units thanks to BESS addition
- Quantifies cost of generating FCR
  - Hence provides minimum FCR market value to balance W&T cost

Check On Line at : xflexhydro.com