

Increasing the flexibility of hydropower assets

AQUAWATT | 29/10/2024 Matteo Bianciotto – Senior Policy Manager



The Hydropower Extending Power System Flexibility (XFLEX HYDRO) project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 857832.



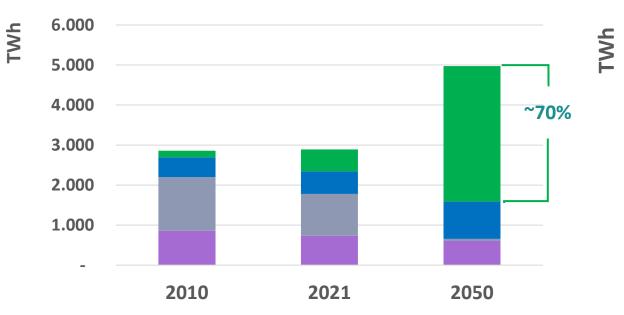
What we will cover

- Background
- Project introduction
- The flexibility technologies studied
- 2 examples of applications
- Policy recommendations

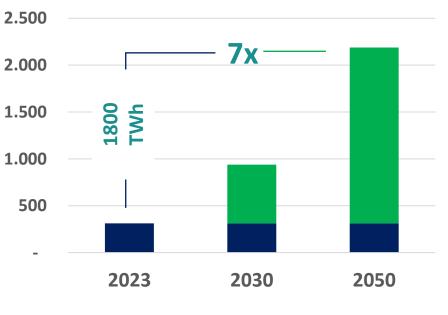
The call for more flexibility

EU Electricity Mix (Announced Pledges Scenario, IEA)

EU Demand for flexibility (JRC, EU)



- Variable Renewable Energies
- Other Renewables (Including Hydro)
- Coal, oil and gas
- Nuclear



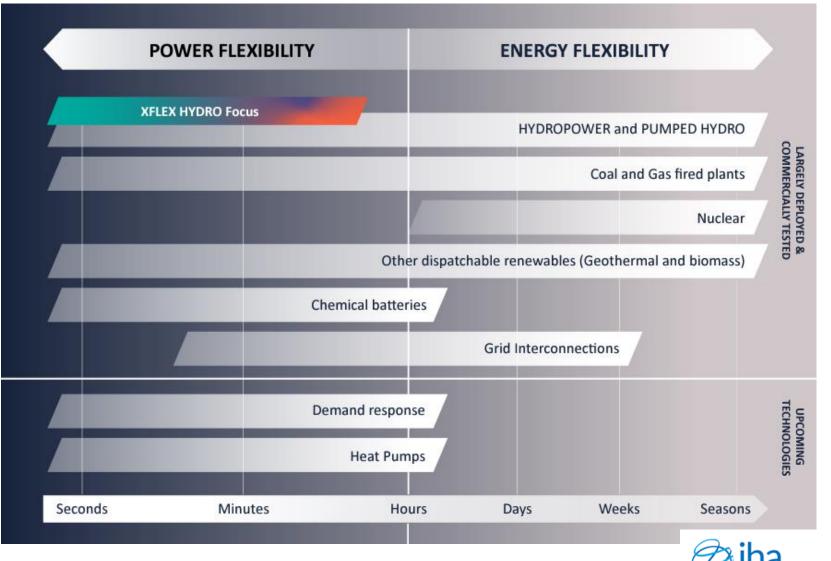
Existing demand for flexibility

Additional demand





Available flexibility solutions





GENERAL/POLICY

BACKGROUND

The project

4.5-year R&I project funded by the European Union' Horizon 2020 programme.

4 innovative flexibility technologies implemented and tested.

€18m budget

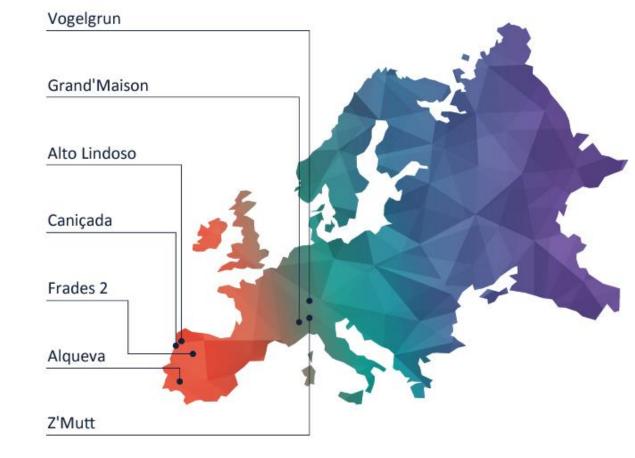
7 demonstration sites in Portugal, France and Switzerland (EDF, EDP, and Alpiq).

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19 project partners







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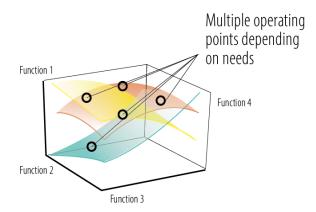
The 4 flexibility technologies:





31/10/2024

Smart power plant supervisor (SPPS)



Applicability: All type of units

- Real time optimisation of power plant operations based on multiple factors: Efficiency, wear & tear, water consumption, unit start and stop.
- ✓ Operators can prioritise one or multiple factors;
- Optimised integration of other technologies;
- ✓ Paired with extension of operating range;





Hybridisation with battery energy storage systems (BESS)



Applicability: All type of units (studied on RoR plant)

- Improved provision of fast frequency control services;
- Reduced wear & tear on hydraulic components;
- ✓ Enhanced regulating margin.





Hydraulic short circuit (HSC)



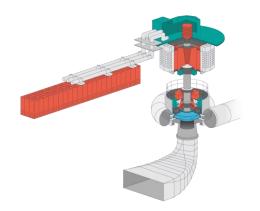
Applicability: Pumped storage plant

- Extended operating range and regulations in pump mode;
- Provision of frequency control services in pump mode;
- Faster switch from Pump mode to Turbine mode.





Variable speed turbines (VS)



Applicability: All type of units

- ✓ Extended operating range;
- ✓ Improved operations at partial load;
- ✓ Faster regulation in turbine mode; and
- Regulations and provision of frequency control services in pump mode.







BACKGROUND

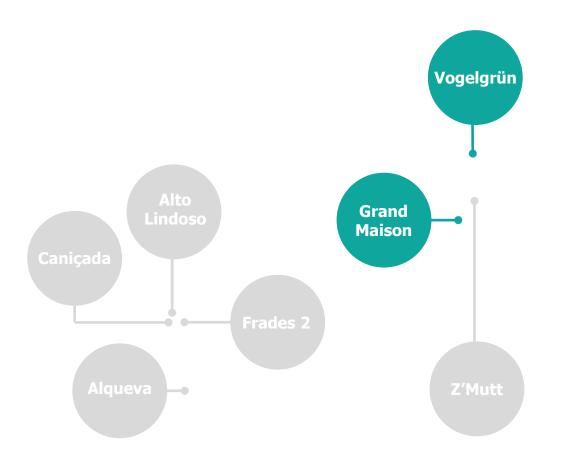
CASE STUDIES

Today's presentation will focus on the experience gained at two of the XFLEX HYDRO demonstration projects:



- **Vogelgrun**: Low-head fix speed Kaplan units with moving blades.

- **Grand Maison**: High-head pump storage plant with a combination of Pelton and reversible pump-turbines;





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DEMONSTRATOR

VOGELGRÜN FRANCE



1959

BATTERY/ TURBINE HYBRID TECHNOLOGY Vogelgrun is a run-of-river hydropower plant located in France near the border with Germany. The plant has four low-head turbines, with one unit being equipped with a battery hybrid. The battery system adds energy storage to share response capability with the hydraulic tear and use a master control to optimise flexibility services and wear and tear. Demonstrator (Vogelgrun) Lead: EDF (Andritz)

PSL



ARMINES

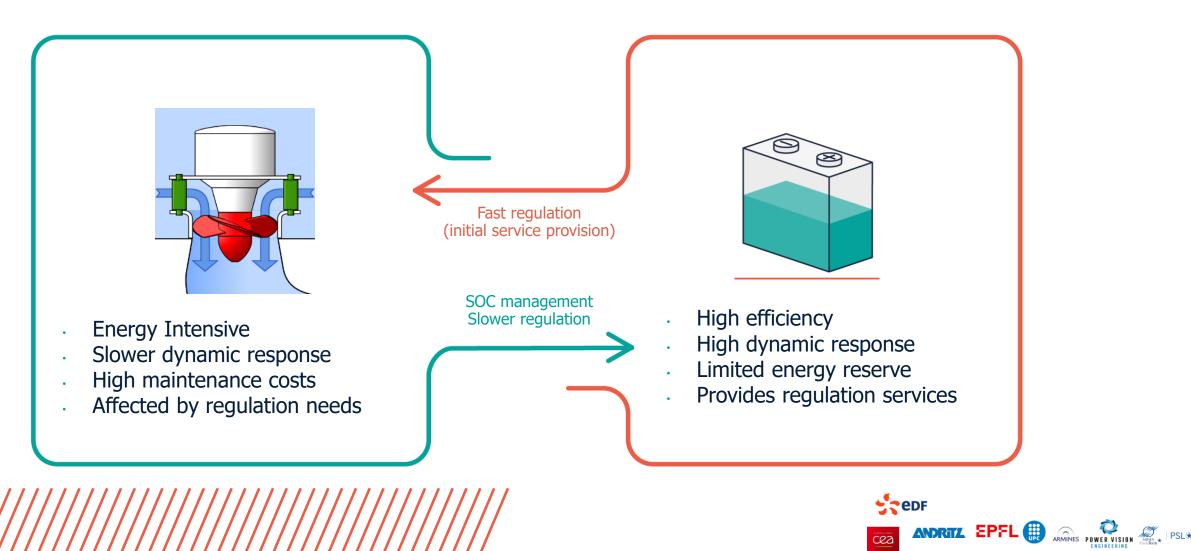
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Demonstrator Review (Vogelgrun)

VOGELGRUN: THE RATIONALE



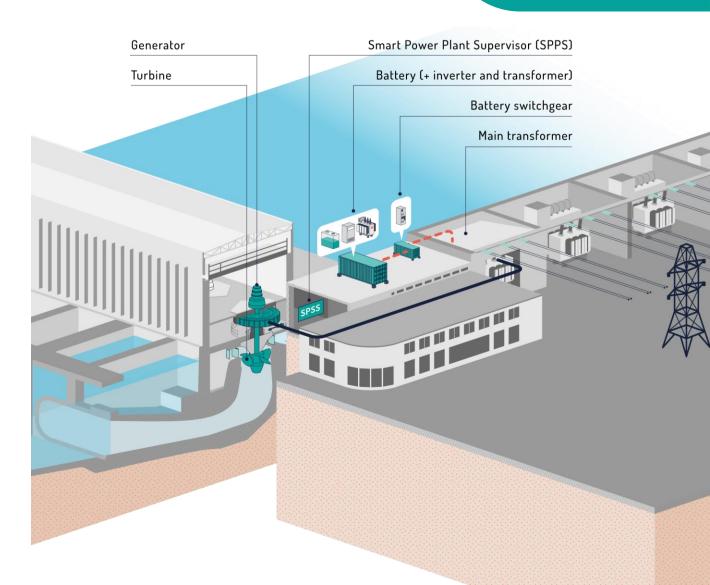
Demonstrator Review (Vogelgrun)

OBJECTIVES

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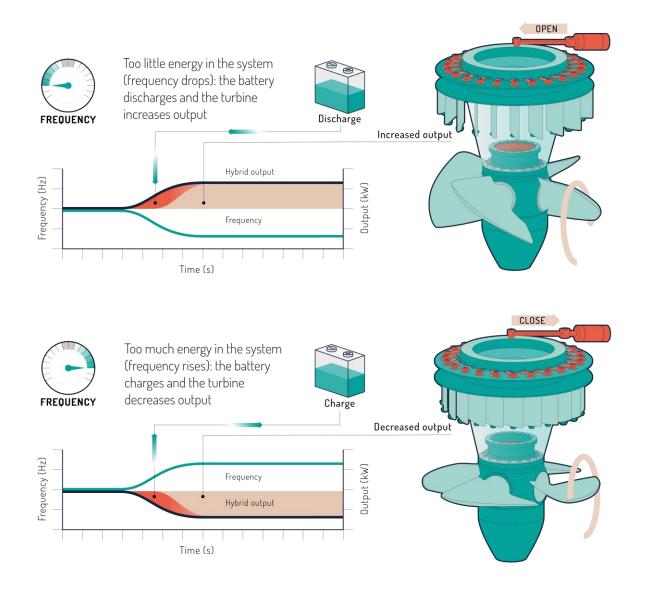
Primary objective:

- Improve provision of Frequency Containment Reserve (FCR).
- Reduce turbine wear and tear (and quantify it).
- Minimize CAPEX of the solution





Demonstrator Review (Vogelgrun)



THE SOLUTION IMPLEMENTED VOGELGRUN Hybrid Layout

- One turbine (35 MW) hybridised with a small battery (0.65 MW/0.3 MWh)
- SPPS technology:
 - Hybrid controller (turbine + battery set point)
 - Digital twin (unit status)



Demonstrator Review (Alto Lindoso)

VOGELGRUN: RESULTS

- Reduction of regulation carried out by the mechanical parts (because of FCR provision): 8 to 10 times (despite the small size of the BESS applied; 1.9% of the turbine capacity)
 - \rightarrow Great improvement on the turbine reliability
- Expected time until end of life of critical components (ex: blades bearing) can be extended by of a factor of 3x.

 → Reduced need for maintenance and downtime;
- Provision of FCR service of the hybrid unit was improved in terms of dynamic response and it is now compliant with local grid code.

Additional notes:

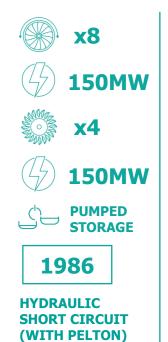
- Carefully choose the algorithm splitting the power set points to the BESS and the turbine!
- Hybridisation of the Kaplan unit was proven more effective on older units. It should be considered as an opportunity to extend the remaining life of aged units.





DEMONSTRATOR

GRAND MAISON FRANCE



TECHNOLOGY

Situated in the French Alps, Grand Maison is Europe's largest pumped storage facility. Equipped with 12 units, XFLEX HYDRO will demonstrate hydraulic short circuit using new turbine runners and automation techniques, for advanced control and efficiency.

Key Objectives:

- Integrate hydraulic short circuit in a very high head PSH plant.
- Improve provision of <u>Automatic Frequency</u>
 <u>Restoration Reserve</u> (aFRR) service.





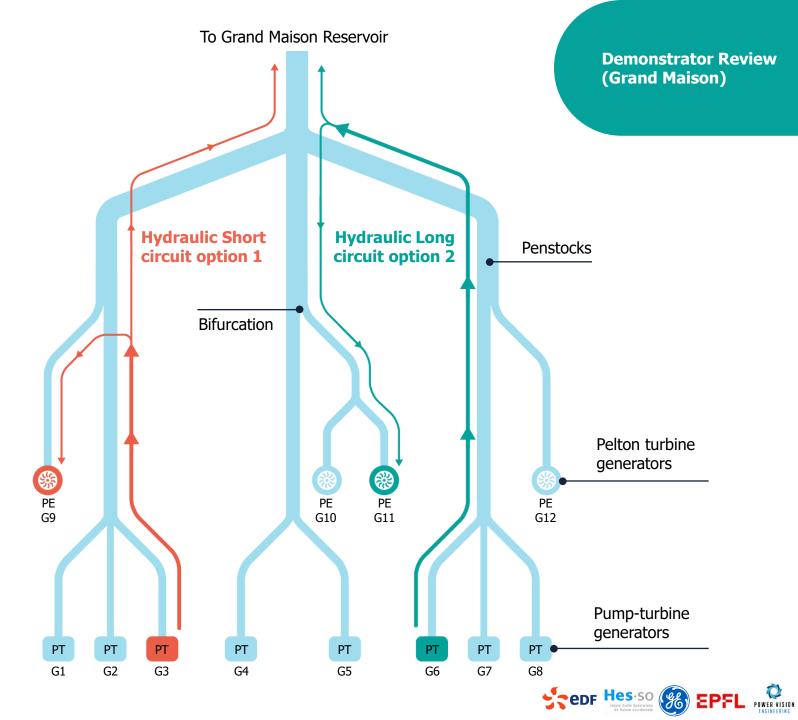
GRAND MAISON INITIAL CONSIDERATIONS – HYDRAULIC SHORT CIRCUIT

< HYDRO

- Units not designed for HSC
- Multiple option to operates pumps and Pelton units together
 - Short route or long route
 - Bifurcation or Trifurcation

2 hydraulic short circuit options studied:

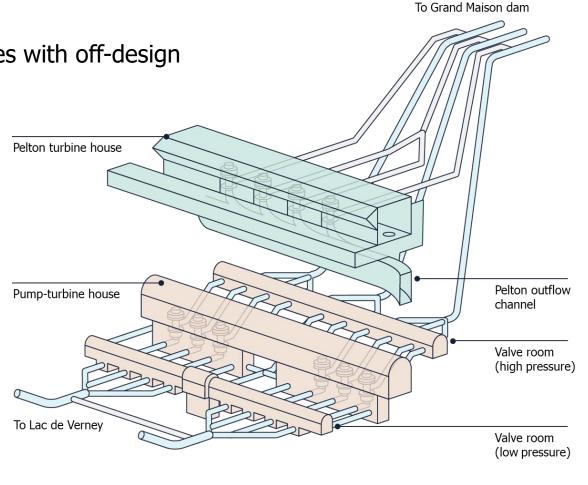
Option 1 - Short route & bifurcation Option 2 - Long route & trifurcation



GRAND MAISON INITIAL CONSIDERATIONS – HYDRAULIC SHORT CIRCUIT

- Extensive CFD analysis and simulations to detect issues with off-design operations
 - Check hydro transient behaviour

- Run Emergency Shut Down scenario
- Demo includes a digital twin of the whole scheme



Demonstrator Review (Grand Maison)

POWER VISION



GRAND MAISON – RESULTS

RESULTS FROM CFD ANALYSIS

• No critical risk identified & power plant can operate safely in HSC

RESULTS FROM OPERATIONS

- HSC in service since 18 Sept 2021
- HSC proved to be relatively cheap to implement and also easy to operate
- 56% of pumping time was performed in HSC (during 2022)
- In 100 days of services HSC saved over 10,000 kgCO2 as it avoids gas plant utilisation

Predominantly used to provide regulating power during low demand periods and the plant is in pumping mode

Demonstrator Review (Grand Maison)



Do we have the regulatory framework to support the development of hydropower flexibility?



POLICY RECOMMENDATIONS

Recognise Hydro Flexibility as an Essential Service to Achieve a Successful Energy Transition

Streamline Licensing Renewals for Optimised Hydropower Operations

Remove Regulatory Barriers for Unrestricted Implementation and Operation of Hydro Flexibility Technologies

Conduct System-Level Analysis to Anticipate Future Flexibility Needs

6

Provide Remuneration Mechanisms Enabling Investment in Flexibility Promote Supporting Mechanisms for the Modernisation of Ageing Hydropower Infrastructures

Facilitate Cross-Border Collaboration for Efficient Exchange of Flexibility Services

FINAL PUBLICATION

- Guidelines to the sector
- Barriers to implementation
- Policy recommendations
- **Research & Innovation needs**
- Road map to flexibility



XFLEX HYDRO

RECOMMENDATIONS TOWARDS INDUSTRIAL **DEPLOYMENT OF HYDROPOWER FLEXIBILITY TECHNOLOGIES**

7.2 THE ROADMAP: A PATH TOWARDS HYDROPOWER FLEXIBILITY The following sections present a series of key power systems evolution up to Phase 6. These are actions which will need to be considered and divided by category of stakeholders explaining what mplemented to make sure that the European these parties are accountable for, the key actions hydropower will be available and equipped to that they need to undergo and the associated provide the flexibility required to support the

Objective

The roadmap is designed to achieve	ve the following three overarching ob	jectives on three different scales
 SYSTEM LEVEL: Provide the flexibility needed to achieve a secure, cost-effective, and sustainable energy transition; 	ii. SECTOR LEVEL: Secure hydropower's role as the recognised champion of flexibility in a carbon neutral economy;	iii. TECHNOLOGY LEVEL: Ensu the opportunities behind the XFLEX HYDRO's flexibil technologies are understo and recognised.

The roadmap has been structured to enable Some of these responsibilities/actions a the appropriate stakeholders to engage, both on an individual and collective basis, towards shared across parties, and some speak directly to the different entities coming together for the the objectives laid out above. Each stakeholde collective good to drive this movement forward. has specific responsibilities to attend to, as well This roadmap sets the stage for the direction. as direct key actions to follow up on to ensure accountability, and collaboration the sectors and it they are actively playing their part in achieving a stakeholders want and need to see as this challeng decarbonised economy is embraced together



raditional PSP are equipped and stored in the upper reserve with fixed speed pumps This additional flexibility can also which are characterised by an be exploited for the provision of extremely limited pumping range equency control services during and therefore no capability of pumping operation, enabling regulating the power absorbed the participation in the ancillar from the grid and the flow water service markets for frequency control such as ECR_aERR_mERR Hydraulic Short Circuit and RR while absorbing excess (HSC) operation allows the energy on the grid.

The hydraulic short circuit

can be implemented in both reversible and ternary PSP units as well as in guaternary units with separated generating an pumping units.

•	and regulations in pump mode; Provision of frequency control services in pump mode Faster switch from Pump mode to Turbine mode.	simularicoc pumping and generating on different units of the same pumped-storage power plant. This operation extends the operating range of the plant, enabling the plant to regulate the power absorbed when in pumping mode and to control the flow of water move		
4.2.4. HYBRIDIZATION WITH BATTERY ENERGY STORAG				
		The hybridisation of a HPP		

numped

simultaneous pumping and

onnected Battery Energ Storage System (BESS) in parallel with an existing HPP The applications of batteries power systems are becoming of increasing interest thanks t ADDI ICABILITY their decreasing cost and high ALL TYPE OF UNITS (STUDIE ONLY ON ROR PLANTS ramping duties compared to conventional generation units CORE BENEFITS: BESSs consist of batteries, grid Reduced wear & tear on interfacing inverters as well as control and protection systems. Lithium-ion batteries are the Fast provision of freque most suitable and most used battery technology when high Enhanced re efficiency is desired

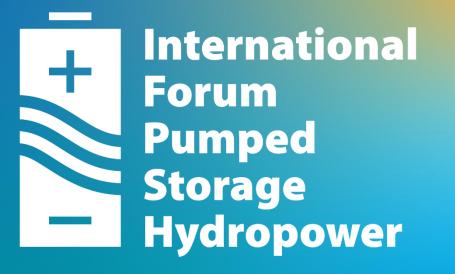
GE SYSTEM (BESS) Existing research demonstrated that BESS can be used to enable or improve hydropo participation in the FFR and FCR markets. It was also show that slower dynamics of the hydropower unit enabled by the combined operation reduces turbine guide vane movement which are related to mechanical wear and tear. The slower dynamics of hydropower control systems lower the mileage and total number of guide vane movements.



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GENERAL/POLICY

THANKS – QUESTIONS?







DEMONSTRATOR

ALTO LINDOSO PORTUGAL



Alto Lindoso is a reservoir storage plant in Portugal, with 110m high dam and two high-head Francis turbines.

Key Objectives:



1992

ENHANCED FIXED SPEED (HIGH HEAD) TECHNOLOGY

317MW

• Evaluate low CAPEX opportunities to enhance services at an existing reservoir storage plant with high head, 317 MW Francis turbines. In particular, extend the operating range targeting an almost continuous power output from near zero to rated power.

• Use advanced control based on SPPS to adapt and optimise plant dispatch under various criteria (efficiency, wear and tears, maintenance, etc.).









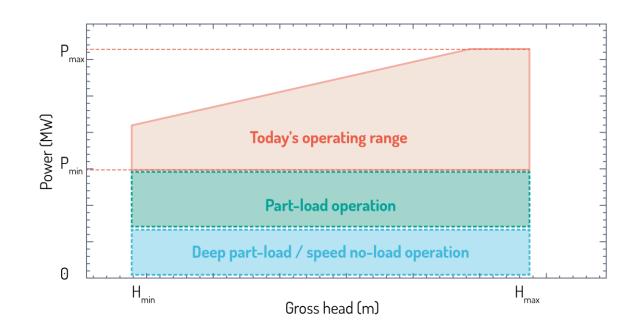
Demonstrator Review (Alto Lindoso) Lead: EDP CNET (GE)

ALTO LINDOSO OPERATING RANGE EXTENSION OF HYDROELECTRIC UNITS

 Turbine are usually designed to operate between 50% and 100% of the rated power.

HYDRO

- To provide flexibility and grid balancing, units will need to be ramped up and down over an operating range. Often with consecutive start & stop procedure during the same day.
- Studies to identify the risks of operating at low power have been undertaken; higher efficiently and safe operating across a wider band from 0 to full power (P)

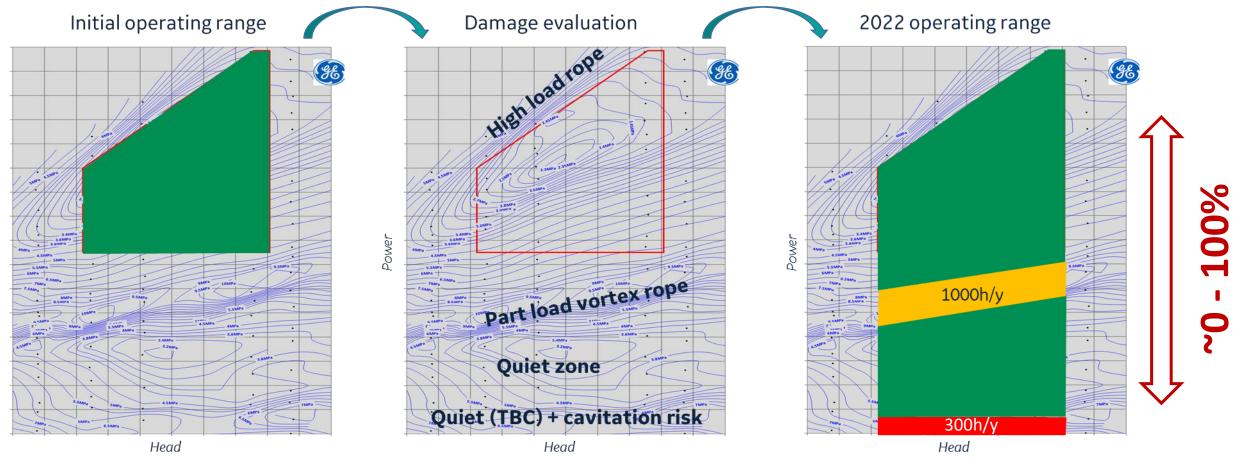


Demonstrator Review (Alto Lindoso)



Power

ALTO LINDOSO EFFECTIVE OPERATING RANGE EXTENSION



Demonstrator Review (Alto Lindoso)



Demonstrator Review (Alto Lindoso)

ALTO LINDOSO: RESULTS

The project demonstrated that the unit can operate at deep partial load without damaging the hydraulic components.

This has the following advantages:

- Each 317 MW unit has now an increased regulating margin of circa +/-150 MW (x2 the original regulating zone)
 - \rightarrow Enhanced range for the provision of ancillary services;
 - → Reduced the number of start & stop sequence and improved the operating reserve available to the operator/TSO.
- It can operate at a very limited flow
 - → Better upstream and downstream water management;
 - → Better resilience against extreme meteorological conditions;
- Overall enhanced plant flexibility → Better participation in spot markets.

