XFLEX HYDRO

THE HYDROPOWER EXTENDING POWER SYSTEM FLEXIBILITY PROJECT (XFLEX HYDRO)

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

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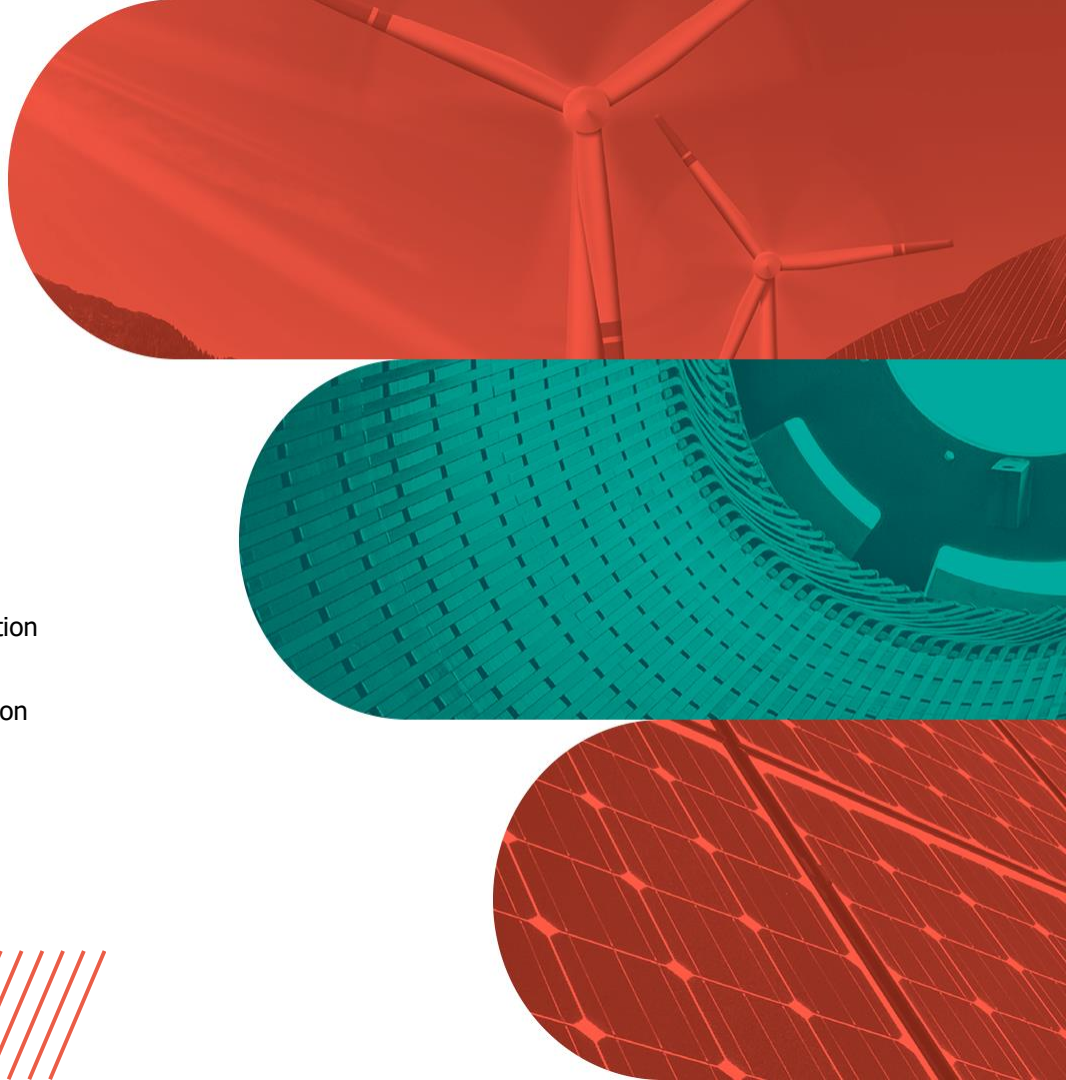
CONTEXT
EU RENEWABLES TARGETS

The contribution of renewable energy (including hydropower) has increased dramatically – now estimated to be >33% in Europe.

As part of the European Green Deal, the European Commission is currently raising its targets further. This calls for even faster integration of variable wind and solar energy sources.

Hydropower already provides critical power services for the integration of other renewables, but the need for even greater flexibility and storage services is growing rapidly.

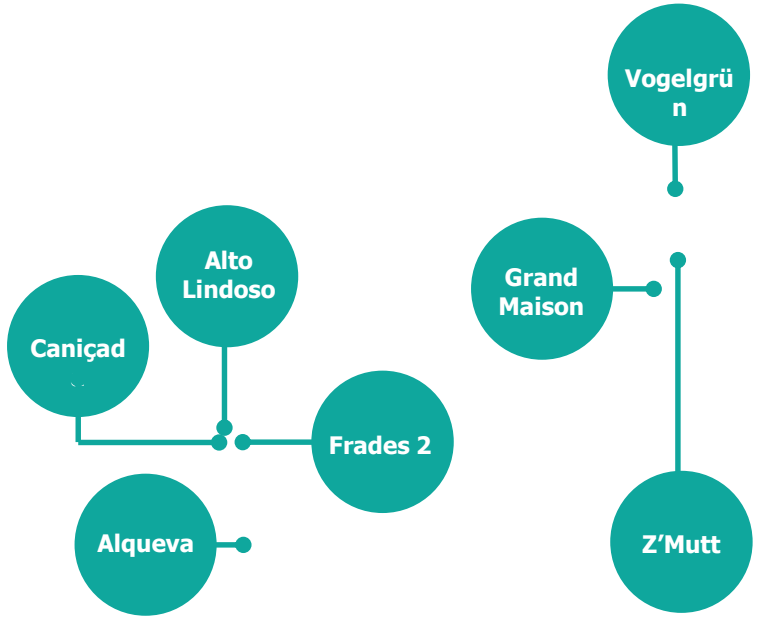


THE PROJECT

With increasing levels of variable renewables in the energy system, a consortium of partners are collaborating on a four-year EU-funded project (XFLEX HYDRO) to enhance hydropower's flexibility services and potential impact in modern power markets.

19 project partners

ALPIQ · ANDRITZ · ARMINES · cea · EPFL · GE Renewable Energy · EDF · edp · NEW by EDP & CTG · Hes·so · INESCTEC · iha · POWER VISION ENGINEERING · MINES ParisTech · SuperGrid Institute · Universität Stuttgart · UPC · VOITH · zabala



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HYDRO

INTERNAL

BUDGET & RESOURCES

The overall cost of the XFLEX HYDRO project (including non-EU funded) is €18M of which the EU grant amount totals €15M (83% of overall cost). Work packages (WP) have been set up to deliver the project, each involving relevant partners.

WP 1
Project management
Lead: EPFL

1. **Project management**
   Lead: EPFL
2. **Flexibility services and specification**
   Lead: INESC TEC
3. **Smart Power Plant Supervisor**
   Lead: EPFL
4. **Demonstrator (Z'Mutt)**
   Lead: ALPIQ
5. **Demonstrator (Frades 2)**
   Lead: EDP P (Voith)
6. **Demonstrator (Grand Maison)**
   Lead: EDF (GE)
7. **Demonstrator (Alqueva)**
   Lead: EDP CNET (GE)
8. **Demonstrator (Alto Lindoso & Caniçada)**
   Lead: EDP CNET (GE)
9. **Demonstrator (Vogelgrün)**
   Lead: EDF (Andritz)
10. **Demo coordination and monitoring**
    Lead: EPFL
11. **Benefits, impacts and deployment**
    Lead: SUPERGRID
12. **Communication and dissemination**
    Lead: IHA
13. **Ethics**
    Lead: EPFL

EPFL

SCHEDULE & OUTPUTS

1 INNOVATION

Optimal collection of data to allow a precise estimate of plant KPIs, and refinement of flexibility services needs.

2 DEMONSTRATION

Validation and demonstration of XFLEX HYDRO results across seven complementary and challenging HPP real-world scenarios.

3 DEPLOYMENT

Building methodology and tools to bring the project activities to their markets, maximising and optimising the potential of XFLEX HYDRO solutions.

2019

- Flexibility matrices
- SPPS

- Demonstrators

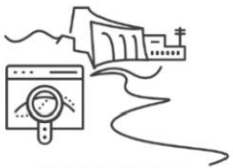
- Roadmap & White paper

2023

- Market uptake
- Dissemination cross-cut

Flexibility matrices

Smart Power Plant Supervisor (SPPS)



6 demonstrators
1 follow-up

Pumped storage
Variable speed
Hydraulic short circuit

Reservoir storage
Extended modes

Run of river
Battery hybrid

White paper and roadmap

Market uptake

Dissemination cross-cut

HYDRO

WP **4**

Demonstrator (Z'Mutt)
Lead: ALPIQ

DEMONSTRATOR

Z'MUTT SWITZERLAND

x1

5MW

PUMPED STORAGE

196
4

VARIABLE SPEED (FSFC) TECHNOLOGY

Z'Mutt is a pumping station feeding the main reservoir of the Grande Dixence hydroelectric scheme in Canton Valais, Switzerland. During XFLEX HYDRO, a new variable speed pump-turbine will be enhanced with modern electronics to demonstrate highly flexible performance.

Key Objectives:

- Demonstrate use of a 5 MW variable speed pump-turbine, equipped with full size frequency converter (FSFC) and smart software supervision for advanced control.
- Enhanced services will include variable pumping load, fast power injection or absorption, synthetic inertia, and fast start and stops in pumping and generating modes.
- Validate component lifetime and safe long-term operation under high flexibility operation.

ALPIQ EPFL Hes·so Haute Ecole Spécialisée de Suisse occidentale POWER VISION ENGINEERING

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WP **5**

Demonstrator (Frades 2)
Lead: EDP (Voith)

DEMONSTRATOR

FRADES 2
PORTUGAL

x2

390MW

PUMPED STORAGE

2017

VARIABLE SPEED (DFIM) TECHNOLOGY

Frades 2 is a new pumped storage plant in Portugal, built with the most powerful and advanced hydro equipment in Europe. In XFLEX HYDRO, variable speed will be demonstrated with doubly fed induction machine (DFIM) technology; also, demonstration of hydraulic short circuit for enhanced flexibility services will be included.

Key Objectives:

- Extend power range through integration of hydraulic short circuit for variable speed machines, rated at 390 MW each.
- Enhance flexibility services by implementing synthetic inertia and frequency containment reserve.
- Optimise maintenance intervals and minimise outages using smart supervisor control and mode change procedures.
- Increase annual production by reducing auxiliary power load.

edp NEW by EDP & CTG VOITH Universität Stuttgart UPC INESCTEC EPFL POWER VISION ENGINEERING

HYDRO

WP **6**

Demonstrator (Grand Maison)
Lead: EDF (GE)

DEMONSTRATOR

GRAND MAISON
FRANCE

x8

150MW x4

150MW PUMPED STORAGE

1986
HYDRAULIC SHORT CIRCUIT (WITH PELTON) 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 innovative systems into a very high head pumped storage plant, with simultaneous use of 140/150 MW fixed-speed pumps and 150 MW turbines in hydraulic short circuit.
- Using smart supervisor control optimisation, a number of pumps will be operated to ensure net power consumption from the grid, while in parallel a Pelton turbine will regulate the load for frequency support and flexibility service.

EDF Hes·so Haute Ecole Spécialisée de Suisse occidentale GE EPFL POWER VISION ENGINEERING

HYDRO

WP 7
Demonstrator (Alqueva)
Lead: EDP CNET (GE)

DEMONSTRATOR

ALQUEVA PORTUGAL

x4

130MW

PUMPED STORAGE

2010

HYDRAULIC SHORT CIRCUIT (WITH REVERSIBLE UNIT) TECHNOLOGY

Alqueva comprises Alqueva I and II pumped storage stations in Portugal, each installed with two reversible Francis pump-turbines. In XFLEX HYDRO, hydraulic short circuit, extended operating range and smart supervisor control will improve power flexibility.

Key Objectives:

- Evaluate low CAPEX opportunities to enhance services offered by an existing pumped storage plant, equipped with 130 MW fixed-speed reversible units. In particular, the operating range will be extended targeting an almost continuous power output from near zero to rated power in generating mode.
- Demonstrate simultaneous pumping and generating through hydraulic short circuit operation.
- Use advanced control to adapt and optimise plant dispatch under various criteria (efficiency, wear and tears, maintenance, etc.)

HYDRO

WP **8a**

Demonstrator (Alto Lindoso & Caniçada)
Lead: EDP CNET (GE)

DEMONSTRATOR

ALTO LINDOSO
PORTUGAL

x2

317MW

RESERVOIR STORAGE

1992

ENHANCED FIXED SPEED (HIGH HEAD) TECHNOLOGY

Alto Lindoso is a reservoir storage plant in Portugal, built with 110m tall dam and two high head Francis turbines (without pumping). In XFLEX HYDRO, low cost opportunities to extend operating range and optimise power flexibility will be tested including smart supervisor control.

Key Objectives:

- 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 to adapt and optimise plant dispatch under various criteria (efficiency, wear and tears, maintenance, etc.).
- Compare these low cost options to potential conversion to variable speed, through numerical analysis and experimental investigation.

HYDRO

WP **8b**

Demonstrator (Alto Lindoso & Caniçada)
Lead: EDP CNET (GE)

DEMONSTRATOR

CANIÇADA PORTUGAL

x2

35MW

RESERVOIR STORAGE

1955

ENHANCED FIXED SPEED (MEDIUM HEAD) TECHNOLOGY

Caniçada is a reservoir storage project in Portugal, recently refurbished, with two Francis turbines. XFLEX HYDRO aims to evaluate and compare flexibility options for the medium scale hydro plant, including a potential conversion to variable speed.

Key Objectives:

- Following the Alto Lindoso case, evaluate opportunities to enhance flexibility at Caniçada, representing a conventional hydro storage site with 35 MW medium head generating units.
- Assess the potential of integrating variable speed technology using full-scale frequency converter, at this type of hydro site. Due to the high cost of a potential conversion, adaptation to variable speed and validation of its possible benefits will not be implemented in full-scale – but rather carried out through numerical analysis and experimental investigation on electrical test bench.

HYDRO

WP **9**

Demonstrator (Vogelgrun)
Lead: EDF (Andritz)

DEMONSTRATOR

VOGELGRÜN
FRANCE

x4

39MW

RUN-OF-RIVER

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, and in XFLEX HYDRO one unit will be equipped with a battery hybrid. The battery system will add energy storage to share response capability with the hydraulic unit, and use a master control to optimise flexibility services and wear and tear.

Key Objectives:

- Hybridise the turbine unit with a battery of suitable energy capacity and power converter rating, to improve fast and dynamic frequency response of the combined system.
- Significantly reduce turbine wear and tear, and quantify it.
- Evaluate the possibility of upgrading the 39 MW fixed-speed, double-regulated Kaplan turbine unit – with an enhanced variable speed, single-regulated propeller unit.

EDF cea ANDRITZ EPFL UPC ARMINES POWER VISION ENGINEERING MINES ParisTech PSL

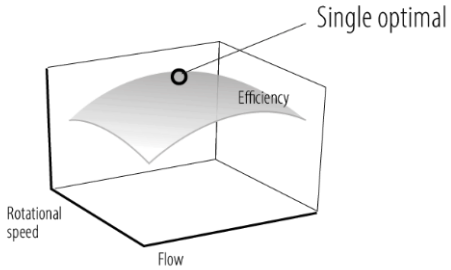
HYDRO

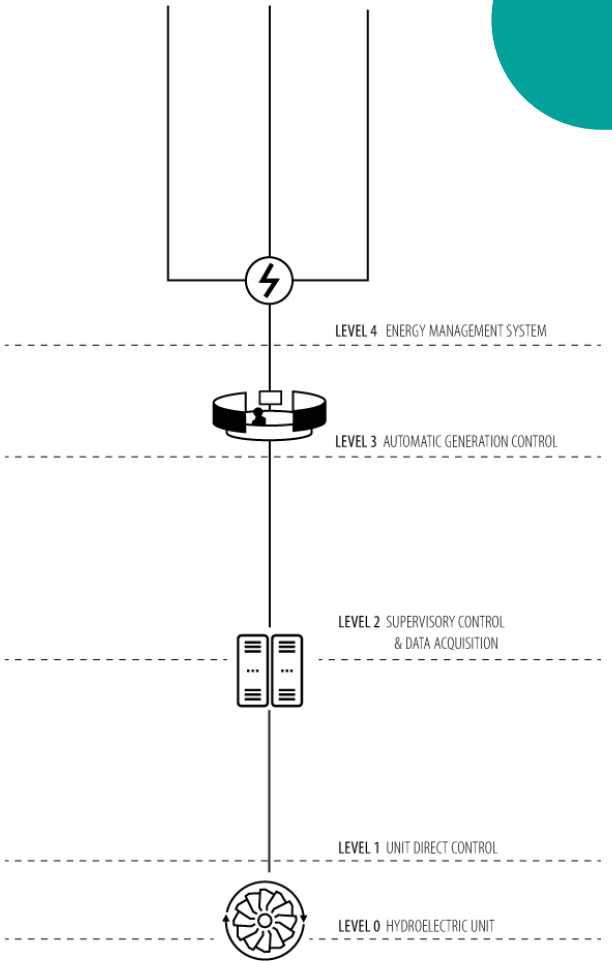
WP 3
Smart Power Plant Supervisor
Lead: EPFL

SMART POWER PLANT SUPERVISOR (SPPS)

Brings the turbine dynamics and conditions knowledge into advanced control unit operation and predictive maintenance

BEFORE
Limited range of operation based on functions that exclude grid needs





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HYDRO

WP 3
Smart Power Plant Supervisor
Lead: EPFL

SMART POWER PLANT SUPERVISOR (SPPS)

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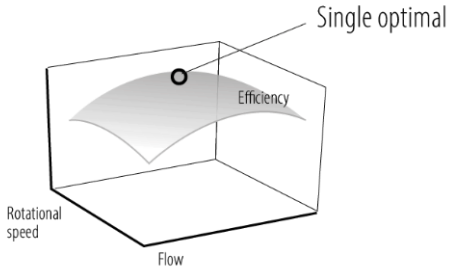
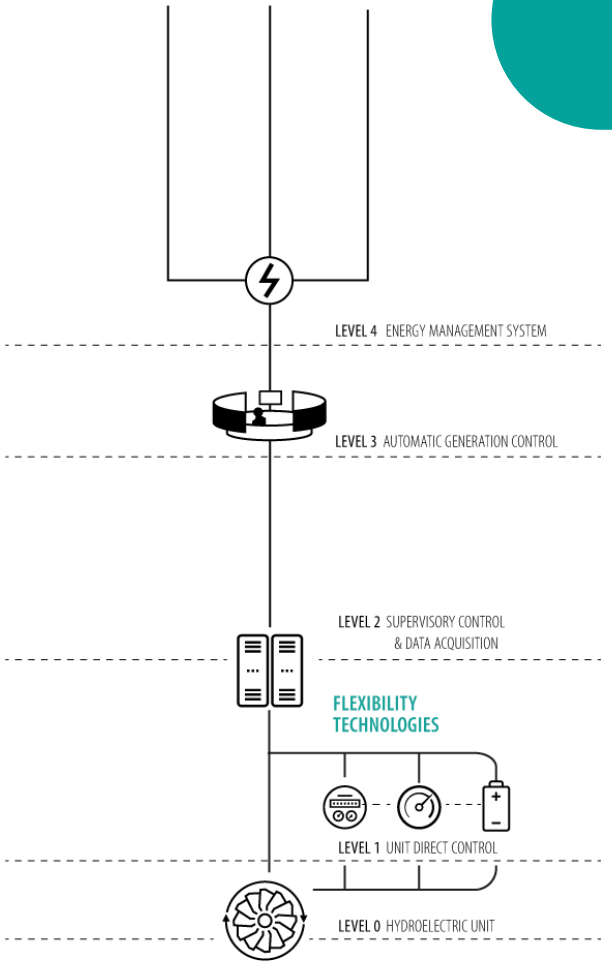




EPFL

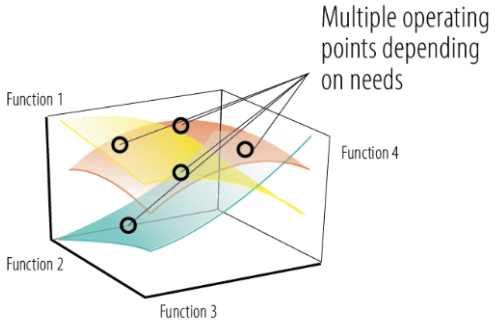
HYDRO

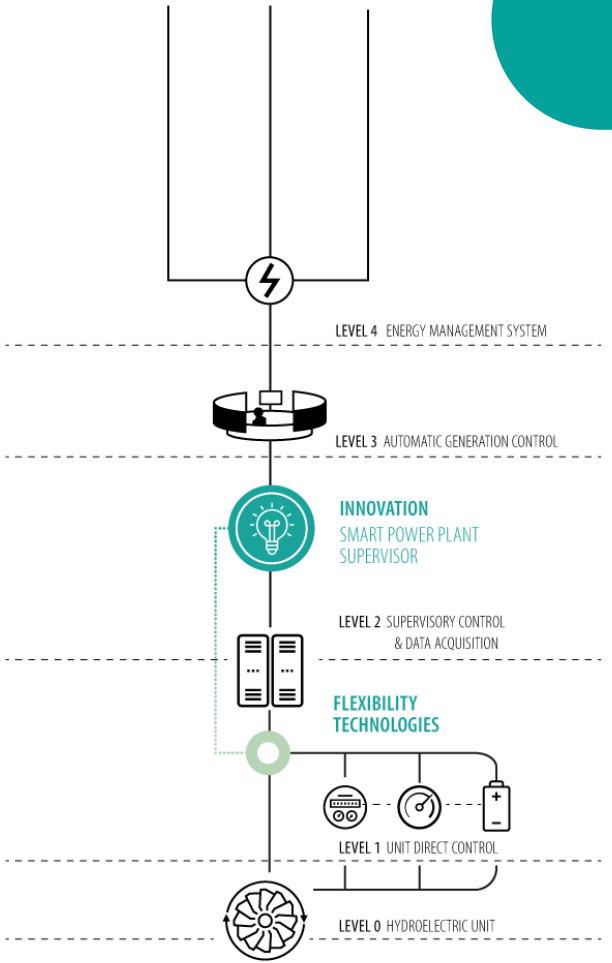
WP 3
Smart Power Plant Supervisor
Lead: EPFL

SMART POWER PLANT SUPERVISOR (SPPS)

Brings the turbine dynamics and conditions knowledge into advanced control unit operation and predictive maintenance

AFTER
Flexible range of operation based on a multidimensional analysis including energy grid needs





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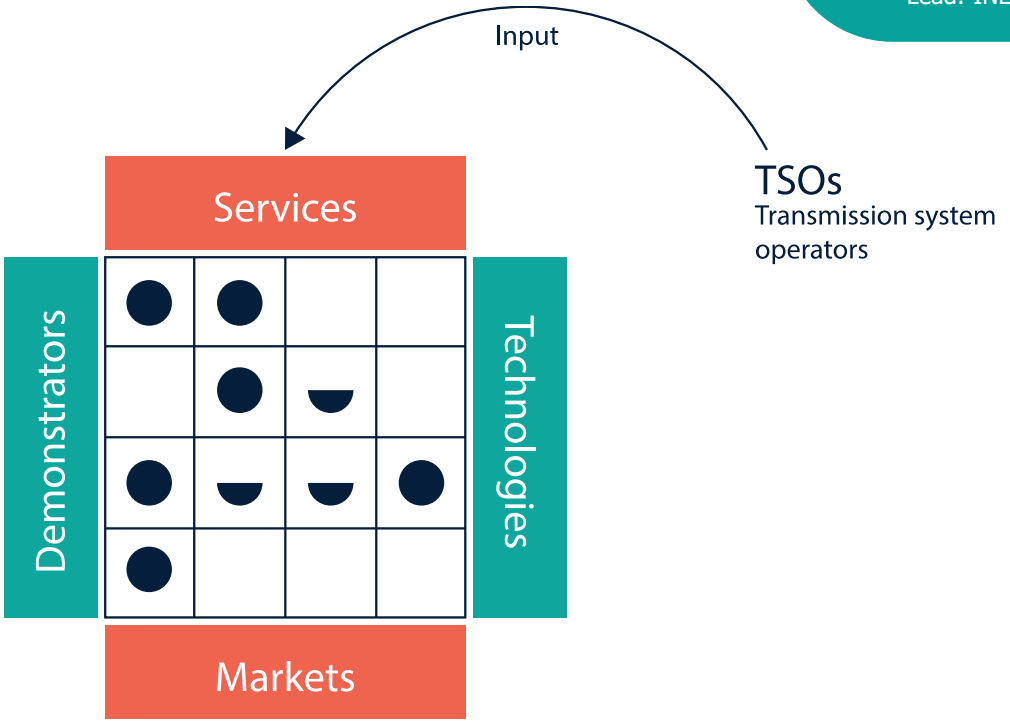
ANCILLARY SERVICES MATRIX

The ancillary services matrix will play a key role in providing a mapping of hydro technology supporting flexibility services and how they enable hydropower to take part in new power markets. It will combine information about the latest flexibility products, flexibility markets and innovative hydroelectric technology solutions that enhance the ability of HPPs to respond to EPS flexibility needs.



ANCILLARY SERVICES MATRIX

ANCILLARY SERVICES

DEMONSTRATIONS	SYNCHRONOUS INERTIA	SYNTHETIC INERTIA	FAST FREQUENCY RESPONSE (FFR)	FREQUENCY CONTAINMENT RESERVE (FCR)	AUTOMATIC FREQUENCY RESTORATION RESERVE (aFRR)	MANUAL FREQUENCY RESTORATION RESERVE (mFRR)	REPLACEMENT RESERVE (RR)	VOLTAGE/VAR CONTROL	BLACK START	TECHNOLOGICAL SOLUTIONS
Sites/Timescale	0 s	< 500 ms	0.5-2 s	< 30 s	30 s - 15 min	< 15 min	> 15 min	< 1 s	N/A	
Z' MUTT	T P	T P	T P	T P	T P	T P	T P	T P		FS
										VS (FSFC)
										VS & SPPS
FRADES 2										FS
	T P	T P	T P	T P	T P	T P	T P	T P		VS (DFIM)
										VS & SPPS & HSC
GRAND MAISON	T P	T P	T P	T P	T P	T P	T P	T P		FS
										FS, SPPS & HSC
ALQUEVA	T P	T P	T P	T P	T P	T P	T P	T P		FS
										FS & SPPS
										FS & HSC
										FS, SPPS & HSC
										VS (FSFC) & SPPS
ALTO LINDOSO & CANIÇADA										FS
										FS & SPPS
										VS (FSFC/DFIM) & SPPS
VOGELGRUN										FS Kaplan
										FS, SPPS & HBH
										VS (FSFC) Propeller
										VS, SPPS & HBH
Original terminology	Inertia		Primary frequency control (FC)		Secondary (FC)	Tertiary (FC)		Voltage control	System re-start	
Emerging frameworks	BILATERAL CONTRACTS (GB)	-	GB/IR/NORD	FCR coop.	PICASSO/IGCC	MARI	TERRE	BILATERAL CONTRACTS	BILATERAL CONTRACTS	

MARKET FRAMEWORK

LEGEND

TYPES OF HYDROPOWER STATIONS

- PSP — Pumped storage plant
- T — PSP turbine mode
- P — PSP pumping mode
- RSH — Reservoir storage hydropower
- RoR — Run-of-river hydropower

TYPES OF HYDRO EQUIPMENT

- Reversible Francis unit(s)
- Francis unit(s)
- Pelton unit(s)
- Kaplan/propeller unit(s)
- Electro-chemical battery

FLEXIBILITY TECHNOLOGY

- SPPS — Smart Power Plant Supervisor (XFLEX product)
- FS — Fixed speed
- VS — Variable speed
- VS (FSFC) — VS with full size frequency converter
- VS (DFIM) — VS with doubly fed induction machine
- HSC — Hydraulic short circuit (PSP)
- HBH — Hydro-battery-hybrid

MARKET FRAMEWORKS

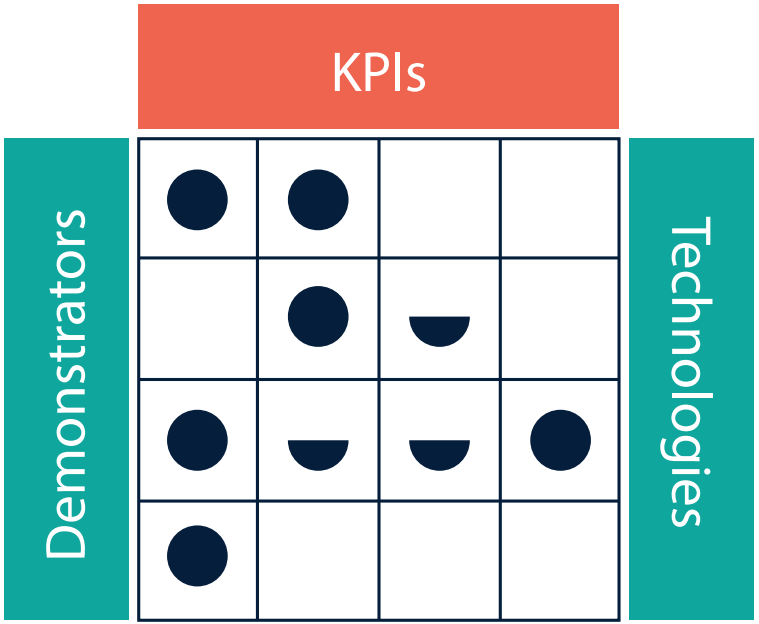
- CE — Continental European market
- GB — UK market
- IR — Rep. & Northern Ireland market
- NORD — Nordic market
- EBGL — EU Electricity Balancing Guideline (2017/2195)
  - IGCC — International Grid Control Cooperation
  - PICASSO — Platform for International Coordination of Automated Frequency Restoration and Stable System Operation (aFRR)
  - MARI — Manually Activated Reserves Initiative (mFRR)
  - TERRE — Trans European Replacement Reserves Exchange (RR)

CAPABILITY OF ANCILLARY SERVICE

- Not currently capable of providing the service
- Capable, but could be enhanced
- Currently capable of providing the service

KPIs MATRIX

- Extended operation range
- Fast Start and Stop
- Fast Ramp-up/Ramp-down
- Fast turbine-pump / pump-turbine transition
- Optimised maintenance intervals
- Extended availability
- Increased annual efficiency
- Performance maximization
- Digitalisation



HYDRO

WP **10**

Demo coordination and monitoring

Lead: EPFL

ADVANCING KNOWLEDGE

Using numerical and physical modelling along with full-scale demonstrations, the project will inform professionals and decision-makers, who will be connected through the communications network.

The project will demonstrate flexible technologies covering: pumped hydropower storage, reservoir storage hydropower and run-of-river hydropower.

It will deliver the hydropower flexibility matrices (ancillary services and KPIs) and the Smart Power Plant Supervisor (SPPS) concept and methodology. Other outputs include a technical whitepaper setting out a step-by-step methodology for adapting hydropower assets, and a roadmap for the sector.

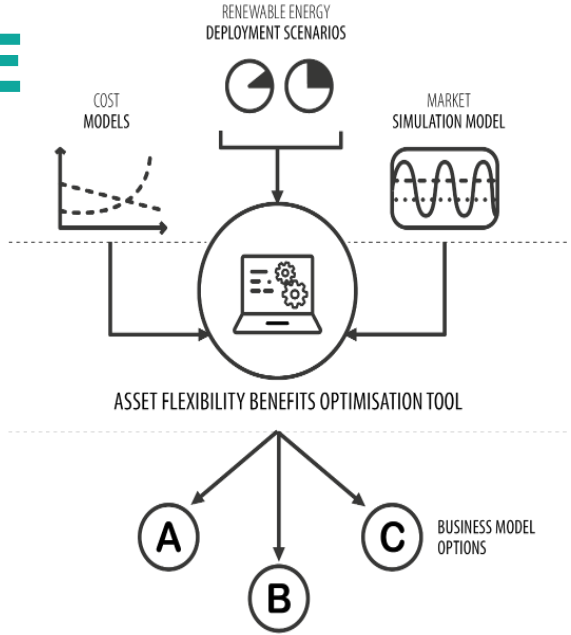
EPFL

HYDRO

HELPING DECISION-MAKERS

SUPPORTING MARKET UPTAKE

The deployment of any flexible technology depends, among other things, on its cost-benefits analysis and its socio-environmental impacts, which can be difficult to evaluate for plant operators and technology providers. This set of activities is important to ensure that the new technologies will be adopted by the market. The Flexibility Benefits Optimisation Tools (FLEXBOTs) will be developed and validated on each XFLEX HYDRO demonstrator business case. Cost models will be mapped against each technology and the overall benefit of using a flexible technology assessed comprehensively. Market scenarios, in day-ahead or over long-term timeframes will be taken into consideration to help the investment decisions. These tools will provide a deep understanding to plant owners of their potential to provide flexibility services to the electric power system.



SuperGrid Institute
Shaping power transmission

WP 11

Benefits, costs and deployment
Lead: SUPERGRID

1. Cost models of flexible technologies
2. Market-based tools to optimise hydro operation in Modern markets
3. Industrial Scalability of Cost/Benefit Performances
4. Socio-Environmental Impacts
5. Guidelines and recommendations towards industrial deployment
6. Exploitation plan

HYDRO

WP **12**

Communication and dissemination

Lead: IHA

COMMUNICATIONS & DISSEMINATION

Sharing knowledge during the four-year project will raise awareness of XFLEX HYDRO and disseminate project outcomes to stakeholders.

Target audiences include the hydro and energy industry, governments and markets as well as the wider public. A programme of actions will deliver multimedia, news, branding and events to communicate progress and improve understanding. The website will become an online knowledge hub providing access to resources and published materials.

Communications strategy

Knowledge Hub

Multimedia & reporting

Events & webinars

iha international hydropower association

XFLEX HYDRO

Stay in touch for project updates

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www.xflexhydro.net

Follow us on social media:
Twitter @xflexhydro LinkedIn XFLEX HYDRO

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SuperGrid Institute

Une participation actives aux projets Européens

Projets passés et en cours :

PROMOTioN
PROGRESS ON MESHED HVDC OFFSHORE TRANSMISSION NETWORKS

FastGrid

LOLABAT
LONG LASTING BATTERY

XFLEX HYDRO

READY4DC

Janvier 2022 : dépôt de 5 projets Horizon Europe → 4 financés dont 1 en coordination

Avril 2022 : dépôt de deux autres projets, réponses en attente

XFLEX HYDRO

Retour d’expérience sur le montage du projet

- **Un noyau dur de consortium existant avant le montage du projet**
  - Expérience sur 2 précédents projets EU
  - Confiance mutuelle
  - Complémentarité des partenaires malgré la concurrence entre certains

- **Un élargissement du consortium durant le montage de la proposition**
  - Cibler les faiblesses de la proposition de valeur
  - Répondre correctement à l’appel à projet

XFLEX HYDRO

Retour d'expérience sur le montage du projet

Des démonstrateurs déjà identifés

- Les décisions d'investissements étaient déjà en discussion chez les producteurs
- Le projet H2020 n'a été qu'un « facilitateur »
- L'organisation des workpackages s'est adaptée aux possibilités de démonstrateur

La forte implication de tous les partenaires a été une clé de succès

- Le rôle du coordinateur a été important…
- … mais chaque partenaire a réussi à se dégager du temps pour prendre sa part

XFLEX HYDRO

La vie du projet après 3 ans de vie commune

Dans l'ensemble, le projet se déroule comme prévu

- La pandémie a provoqué quelques retards non impactant
- La plupart des démonstrateurs fonctionne
- Des relations se tissent au fur et à mesure de la vie du projet

Quelques points de vigilance

- Exécution des taches multi-partenaire : ce n'est pas une relation client/fournisseur
- La coordination entre les lots et les taches est essentielle durant toute la phase d'exécution

SuperGrid Institute
Shaping power transmission

Merci pour votre attention