



Store2Hydro

Project Newsletter #2

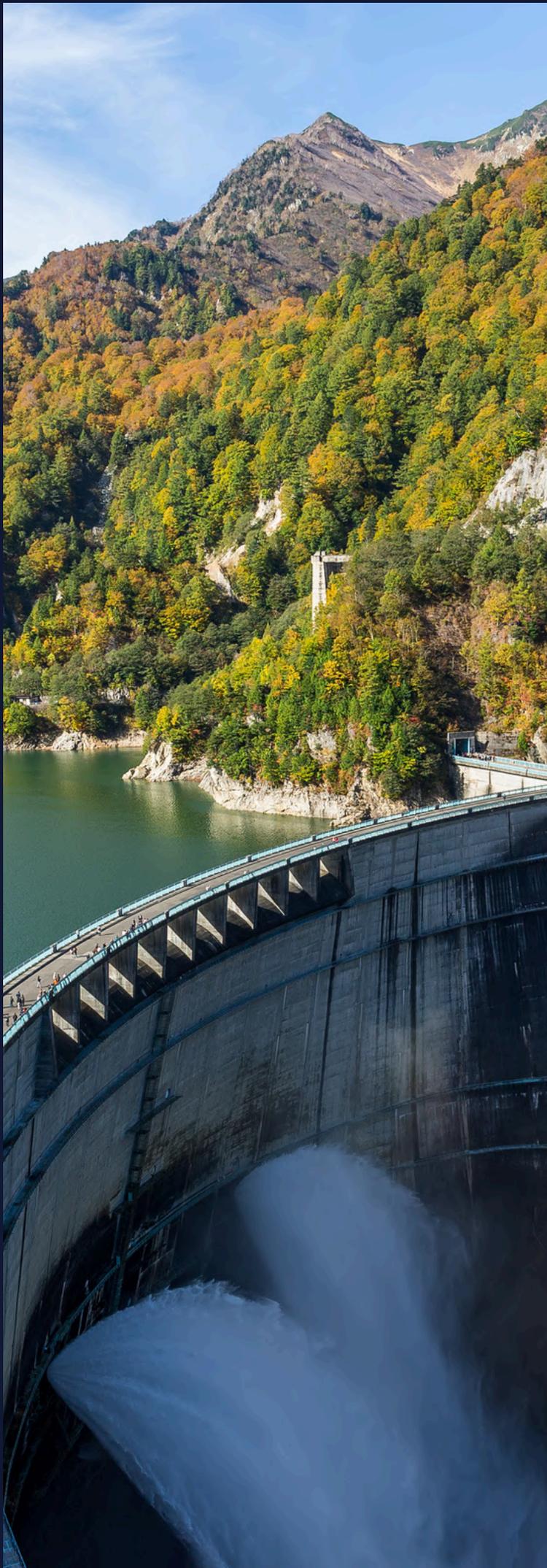
FEBRUARY 2026

DISSEMINATION LEVEL -PUBLIC



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From the Project Coordinator



Welcome to the second edition of the Store2Hydro newsletter!

Store2Hydro was launched with a clear ambition: to unlock the untapped potential of existing hydropower infrastructure and explore innovative pathways for integrating pumped storage solutions into modern energy systems. Today, that vision is steadily becoming reality. Across multiple work packages, our partners have advanced hydraulic simulations, grid integration studies, physical model validation, and digital analyses — all contributing to a deeper understanding of how hydropower can provide the flexibility Europe increasingly requires.

One of the strengths of Store2Hydro lies in its interdisciplinary collaboration. From river reach modelling and laboratory validation to distribution network characterisation and case study development, the project demonstrates how technical excellence and system-level thinking must go hand in hand.

The results emerging from Work Packages 3 and 4, in particular, highlight the importance of careful site assessment, river geometry considerations, and grid compatibility when evaluating pumped storage conversion opportunities.

I would like to sincerely thank all partners for their continued dedication and collaboration. The coming months will be equally important as we further validate our models, refine methodologies, and continue strengthening our contribution to Europe's clean energy future.

Prof. T. Staffan Lundstrom



KEY HIGHLIGHTS



DESIGN OF RIM-DRIVEN MOTOR (UU)



Over this year, the design of the radial-flux rim-driven permanent magnet synchronous motor (Figure 1 and 2) was finalized, following a structured assessment of motor topologies and configurations based on torque density, efficiency, disturbance rejection, and constructability. The radial-flux solution was selected to meet the stringent spatial and hydraulic constraints of the azimuth thruster application, while ensuring sufficient NPSH and scalability of torque via axial length. Detailed technical documentation of the motor design has been delivered in D2.3 (Month 24).

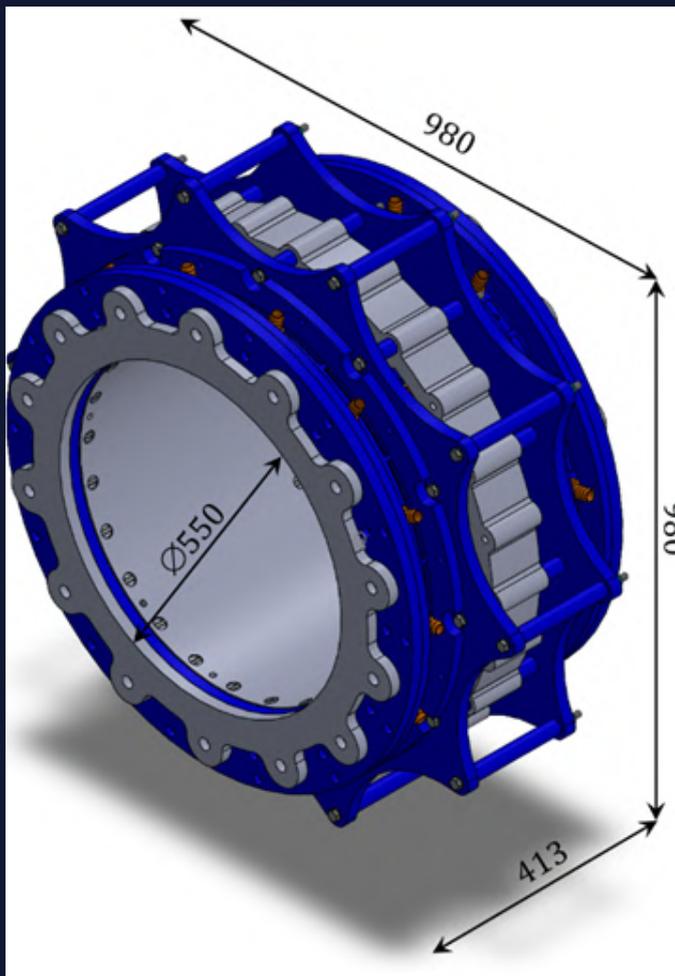


Figure 1 – Assembly of the radial flux PM-synchronous motor

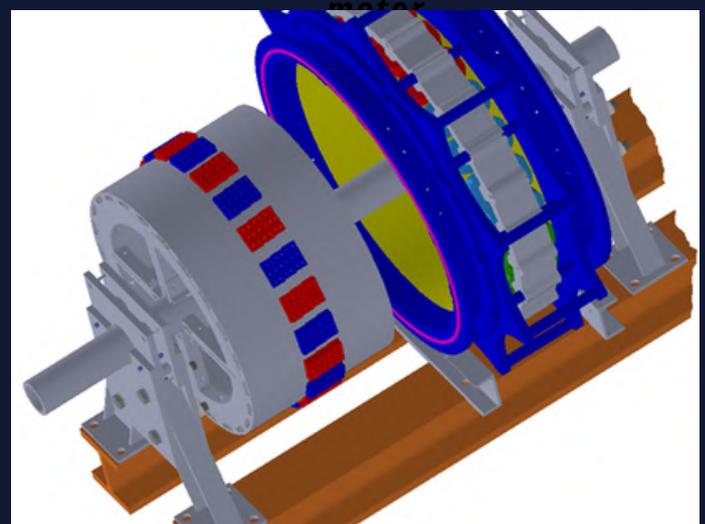
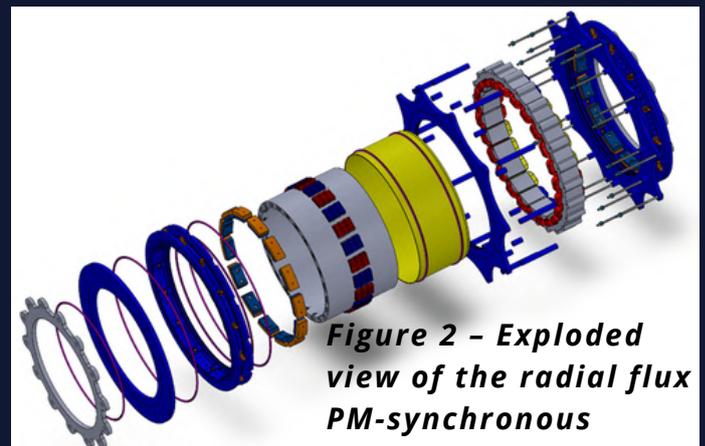


Figure 3 – setup for inserting the magnetized rotor into the stator

The mechanical design of the motor was completed by detailing more than 150 mechanical parts and 40 assemblies, including dedicated tooling for rotor-stator assembly (Figure 3).

In parallel, the electric driving system was analyzed, modeled, and simulated using Simulink, based on indicative hydraulic thruster performance data. A sensor-less ABB ACSM1 variable frequency drive was selected (Figure 4) and experimentally validated at UU using a dedicated test setup with dummy PM synchronous motor and generator (Figure 5 and 6).

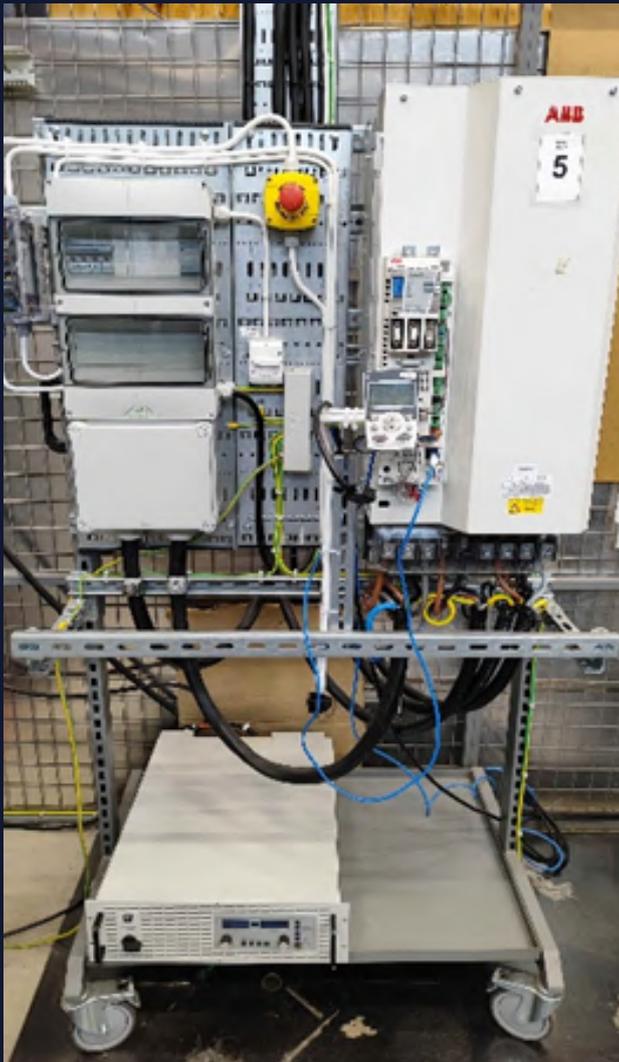


Figure 4 – the chosen VFD for the motor, ABB ACSM1

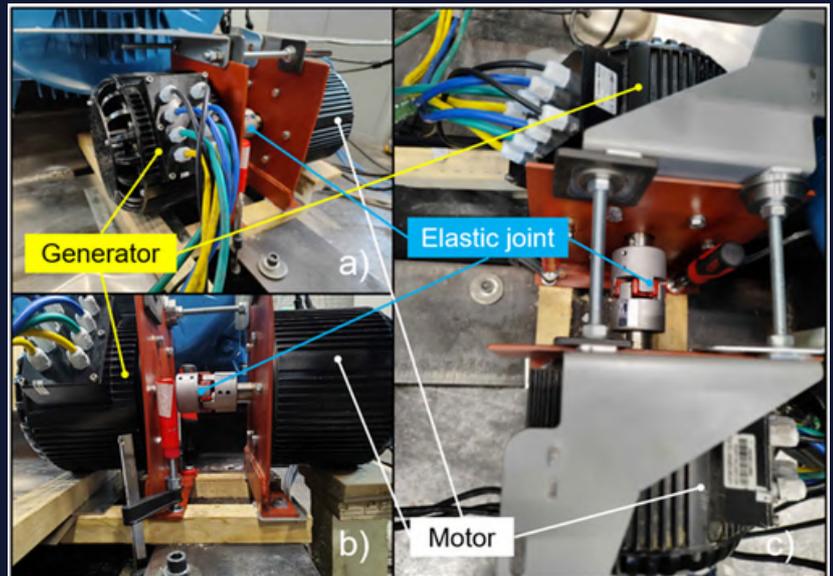


Figure 5 – the dummy test motor

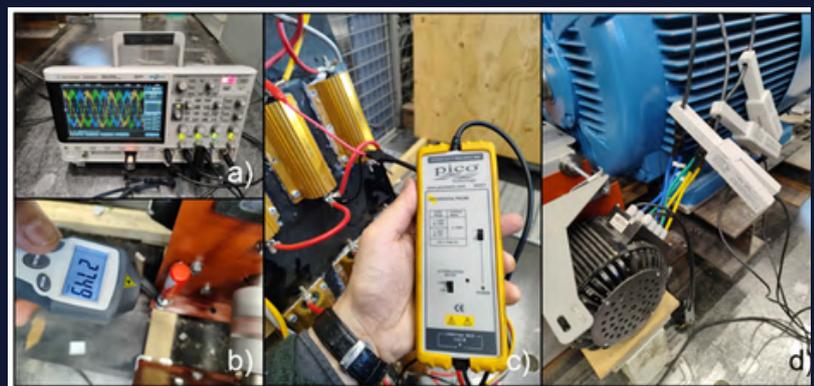


Figure 6 – the measurements during the test: a) current and frequency, b) speed, c) voltage probe, d) current probes

The drive successfully achieved the required operating conditions, fully covering the motor's operational envelope. The test results and system design are documented in D2.5 (Month 18). Electrical supply and protection requirements have been defined and shared with NTNU to prepare on-site integration (WP5).

Additionally, a current and voltage metering unit (Figure 7) was designed, built, and tested to enable real-time monitoring of motor electrical quantities during WP5 testing. The hardware, based on Hall-effect transducers and signal-scaling, has been validated experimentally (from an analogical point of view). The integration of A/D acquisition and data logging via NI MyRIO and LabVIEW is planned as a next step prior to the experimental deployment.



Figure 7 – the implemented electric-metering box

An hydraulic cooling system for the motor radial-bearings has been designed (Figure 8) and the procurement for its component has already started (Figure 9 and 10)

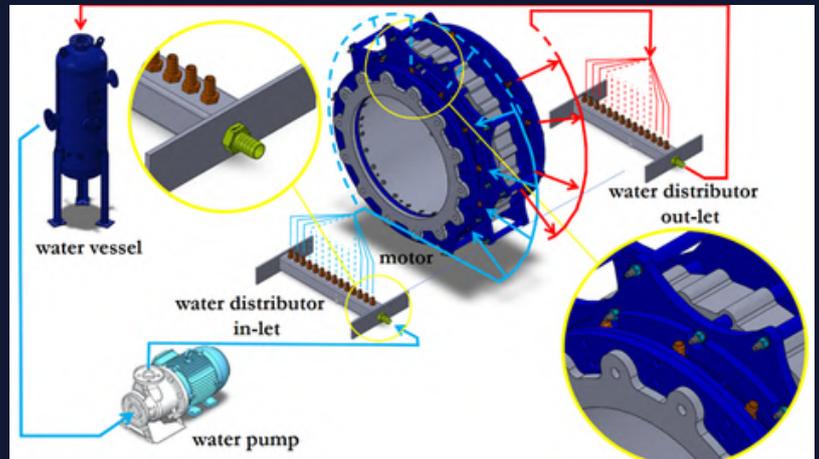


Figure 8 – the hydraulic system for cooling the motor radial bearings



Figure 9 – Water centrifugal pump for the bearing cooling system (340l/m x 40m head)

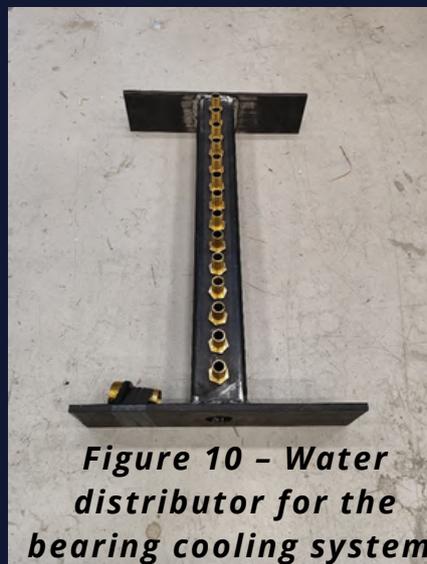


Figure 10 – Water distributor for the bearing cooling system

Procurement activities progressed. As a result, all main mechanical parts have now been ordered, and several components have already been delivered, including vertical supports (Figure 11), water-tight sleeve + laser-cut laminated sheets for the stator (Figure 12). A wooden frame for stator winding was designed and home-built (Figure 13), in order to send out the stator core for the winding.



Figure 11 – Vertical support for the assembling setup



Figure 12– Staple of stator laminates + water-tight polymeric sleeve



Figure 13– Wooden frame for the stator winding

UNDERSTANDING RIVER DYNAMICS IN PUMPED STORAGE CONVERSION (LTU)



Within Store2Hydro, advanced hydraulic simulations have been carried out to analyse pumping operations in generic river reaches featuring cascaded hydropower plants. The aim was to better understand the dynamic processes occurring both at the water extraction point and in the reach where pumped flows are reintroduced.

The results highlight that river geometry plays a crucial role — not only in determining storage capacity, but also in influencing water surface disturbances caused by stopping or reversing hydropower units. In particular, river slope emerged as one of the most critical parameters when assessing the feasibility of converting conventional hydropower plants into pumped storage facilities.

To validate the digital simulations, complementary physical model tests were conducted at Vattenfall's laboratory in Älvkarleby. Using downscaled yet hydraulically representative conditions, researchers examined surface-level dynamics through ultrasonic sensors and visualised the propagation of pumping jets into the reservoir. These experiments provide robust validation of the modelling approach and strengthen confidence in the project's technical assessments.

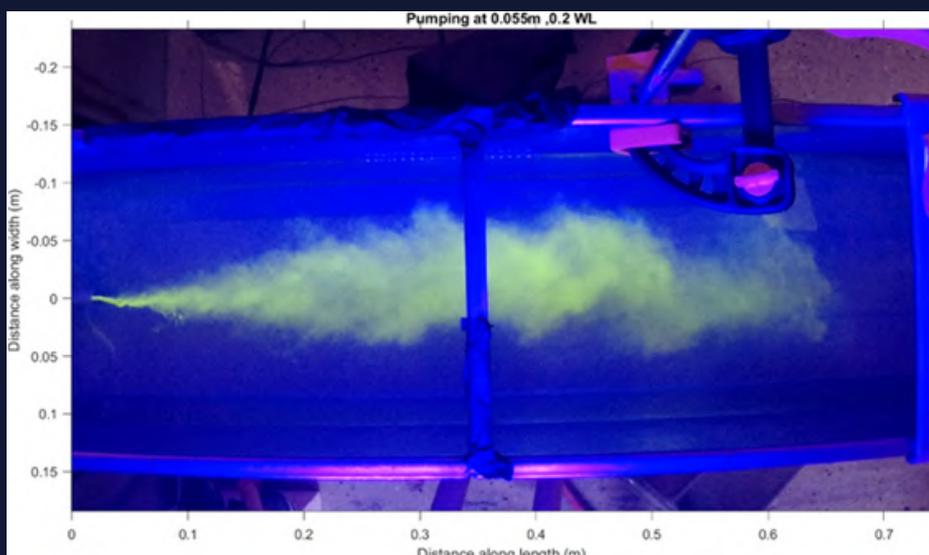


Figure 14. Propagation of a jet introduced by pumping in the downstream end of a simplified river geometry



PROGRESS IN INNOVATIVE PUMPED STORAGE: FROM RPT PERFORMANCE TESTING TO RIM-DRIVEN THRUSTER DESIGN

During the second year, a series of experimental and computational tasks has been carried out at **NTNU**, Norway, to develop innovative storage solutions in the project.

The year began with experimental study on the reduced-scale reversible pump-turbine (RPT) test rig to develop performance characteristics while operating at different flow conditions. Concurrently, a computational fluid dynamics (CFD) based numerical model is also developed for the same RPT. The numerical model is further validated using the obtained experimental data. Furthermore, a necessary condition which may cause cavitation during the pump mode operation is evaluated and used as a reference for the new technology development to maintain the lacking head.

Building on this foundation, the focus is on exploring innovative storage solutions that can effectively utilise the storage capacity in existing and retrofitted hydropower plants. For this instance, the use of a booster pump with the RPT is established. The design and optimisation of a rim-driven thruster (RDT) as a booster pump is carried out. The design methodology is parameterised using the MATLAB algorithm. Parametrised blade designs of RDT are optimised using surrogate modelling techniques. To make the process efficient, simplified models were used to estimate key characteristics such as lift, drag, and pressure. These characteristics were combined into a single performance measure, allowing the blade design to be optimised in a structured and automated way.



Figure 15. RDT blade section

Moreover, CFD-based flow field investigation is conducted to examine the blade loading, performance and cavitation characteristics of the optimised RDT. The developed mesh is used for the Eulerian-Eulerian CFD modelling with the implementation of the SST $k-\omega$ turbulence model. The performance is estimated in the form of pressure developed during the operation at the desired operating condition. The final and optimised profile of the blades will be manufactured and tested in the laboratory during 2026. The series of experiments is scheduled to evaluate the performance of the designed and developed RDT in NTNU.



DEVELOPMENT OF DIGITAL TWIN FOR SEDIMENT MANAGEMENT (UNIBO-DICAM)

To develop the digital twins on river reach scale, 8 synthetic case studies were constructed with the help of **Luleå University of Technology**, utilizing their parametrization tool developed in MATLAB. Each case reflects the dimensions of a standard river of each grain size, ranging from Cobbles to Silt.

The conducted simulations using HECRASS hydraulic model, showcase the riverbed celerity (i.e., rate of changing morphology) for each case in meter/year. Six order of magnitude change reflects the wide range of the synthetic case studies and inherent uncertainty in sediment transport formula (Figure 16). In fact, it is important to note the lack of correlation between celerity and grain size that is mainly due to the constantly changing transport formulas used. However, a trend can be noticed when using Laursen formula which indicates the celerity increases with decreasing grain size (i.e., D50) as finer material is easier to transport. The opposite can be observed when using a different transport formula (namely, Yang formula) that reflect the imposed equilibrium slope for different cases.

A real reservoir is chosen as the case study to investigate the impact retrofittable pump-storage reservoir operations have on sediment dynamics. Particularly a typical inflow/outflow structure is analyzed which enables storage to storage turbinning/pumping operations. Figure 17 portrays an overview of the main lake, the small reservoir (within right/down quadrant) and the powerplant layout. The detail of inflow/outflow structure location is implemented using the CFD (FLOW-3D).

Preliminary results show that the inflowing scenario produces high rates of erosion along the channel. Erosion didn't occur during pumping scenario (i.e., outflowing). However outflowing scenario might significantly entrain sediment particles from the whole water domain (i.e., lake section). These results elucidate that inflow/outflow structures are crucial elements for the designing and managing of hydropower system especially when using reversible machinery: (i) inflowing momentum has to be properly dissipated to avoid local erosion and possible structural failure, (ii) outflowing phase might be carefully evaluated during flood, this yields efficient entrainment of fine sediment, passive contaminant and other properties possible resulting in unbalances in water bodies.

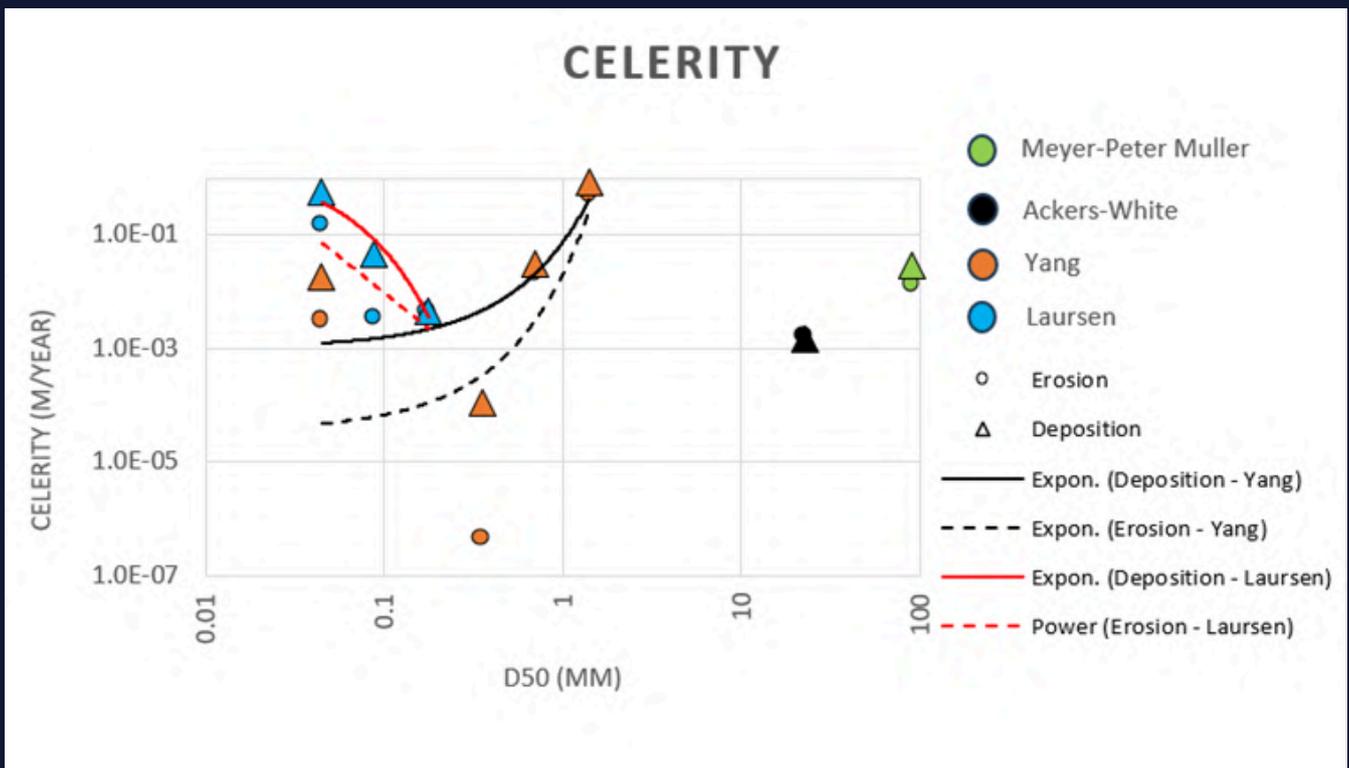


Figure 16. Celerity graph of the case studies under Deposition and Erosion condition, differentiating the different sediment transport formulae used.

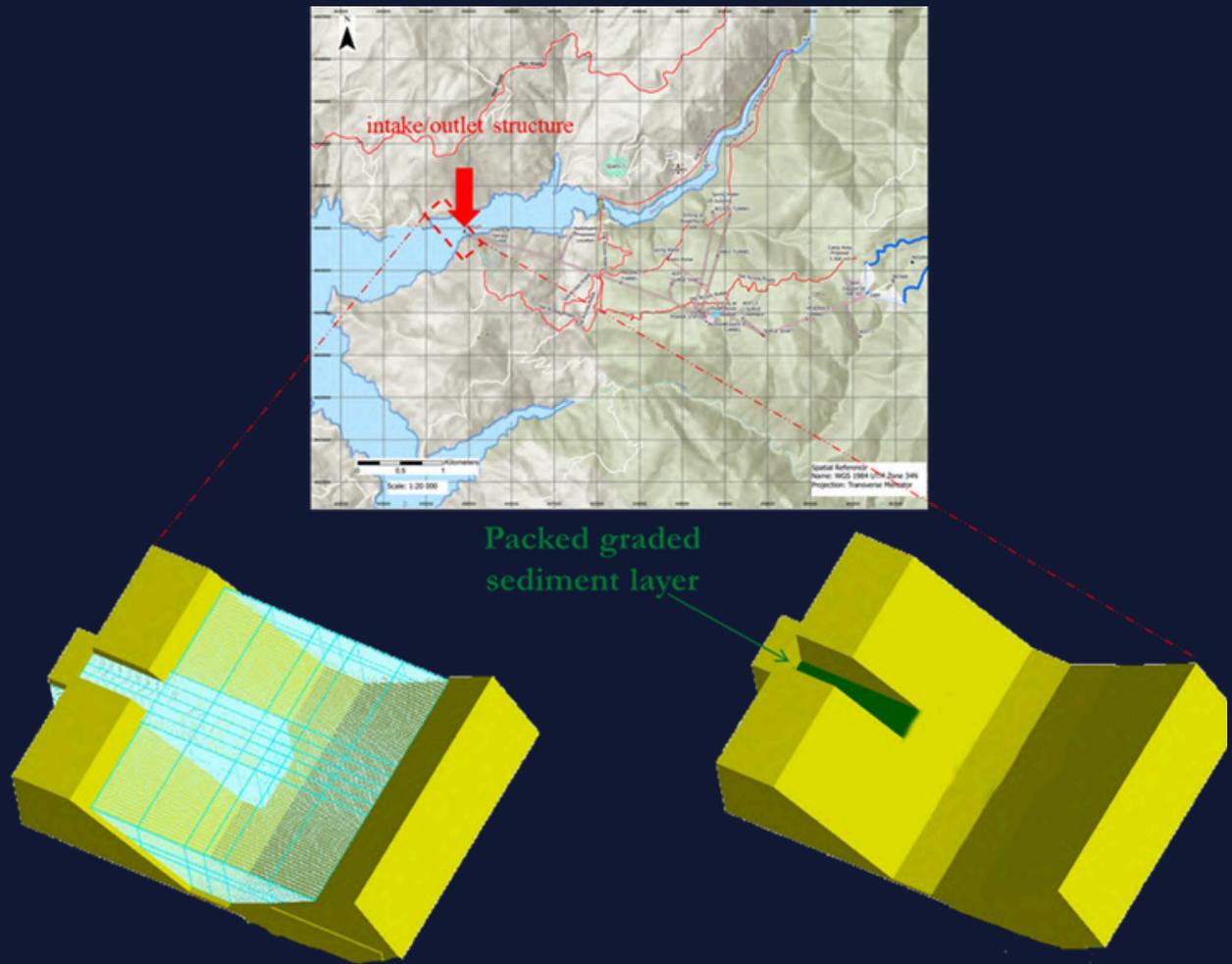


Figure 17. Powerplant layout and CFD model geometry for the inflow/outflow structure.

ADVANCING PSH INTEGRATION IN DISTRIBUTION NETWORKS



Over the past period, the Electric Power Systems Laboratory at the **University of Bologna** has focused on the characterisation of power distribution networks with a high penetration of distributed generation. The work also defined key technical requirements and operational constraints for integrating hydropower units — with particular attention to small-scale pumped storage hydropower (PSH) systems.

As part of this activity, a real medium-voltage feeder located in a hilly area was selected as a case study, with comprehensive data collection supporting the analysis. These activities contribute to Work Package 4 of the Store2Hydro project, strengthening understanding of how innovative pumped storage solutions can be effectively integrated into modern distribution networks.

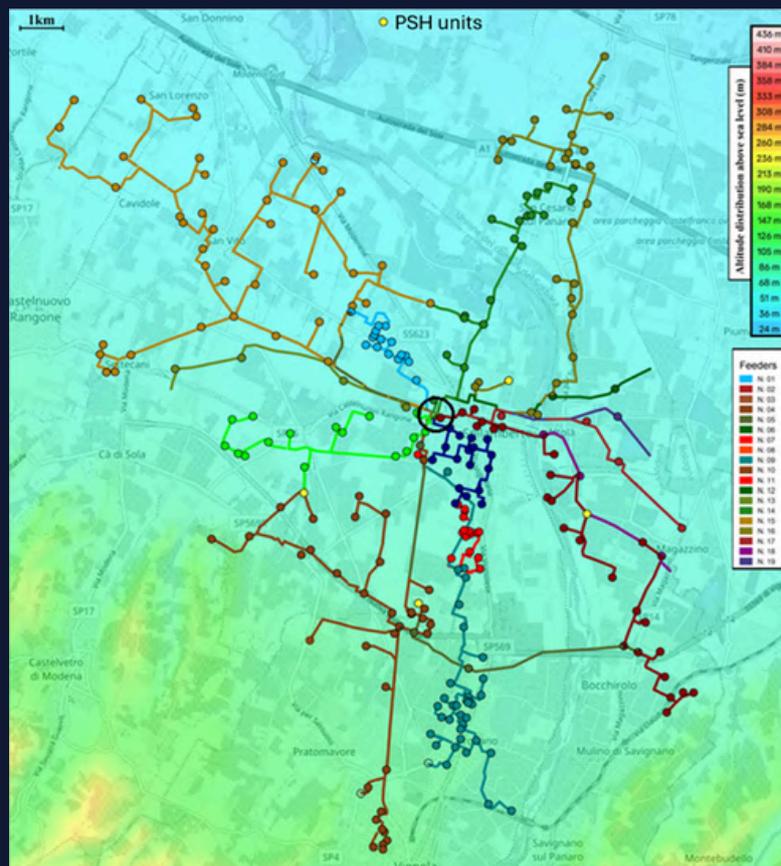


Figure 18. Layout of the 351-bus 15-kV test network: HV/MV substation is indicated by a circle, feeders distinguished by different colors, PSH units indicated in yellow.

An optimization model has been implemented that represents the behavior of energy communities (ECs) equipped with storage units, including batteries and PSH units. The framework accommodates multiple retailers and communities and also accounts for reactive-power exchanges and power-factor penalties. The model considers the uncertainty associated with the PV production and load forecasts by applying a scenario-based stochastic optimization approach.

The activity has been focused on the development of a realistic case study. The case study includes 17 real feeders connected to a 132/15-kV substation in a hilly region (part of the Apennine Mountain chain) south of Modena, Italy, shown in the figure. The system includes 351 buses and branches. In the network there are 168 PV units and 8 DG units with synchronous machines, including a run-of-the-river hydro station with two turbines of 800 kW each. The case study uses real consumption and generation data for various days in winter and summer with a discretization of 15 minutes. Users are randomly grouped into three energy communities or left out, with contracts assigned to retailers through a random process. PHS units with storage capacity around 1 MWh have been added. The study focuses on how PHS units help reduce energy procurement costs for communities and provide flexibility services to support congestion management. It also examines the impact of the number and size of communities on network performance.

The results show that PSH units provide economic benefits despite their small energy capacity. Compared with a case without PSH, EC operating costs decrease by approximately 1–6%. The structure of each community is equally important: disabling internal EC exchanges raises procurement costs by 10–50%. When PHS units are allowed to support reactive-power exchanges, penalty costs associated with low power-factor operation are reduced significantly.



DYNAMIC MODELLING FOR FUTURE RENEWABLE POWER SYSTEMS

The **University of Strathclyde** plays an important role in **Work Package 4**, focusing on system-level dynamic modelling to support the integration of hydropower-based storage into future electricity systems with high penetration of wind and solar energy.

A key achievement to date has been the development of a high-resolution dynamic simulation platform using MATLAB/Simulink. This platform enables analysis of short-term system behaviour—on the scale of seconds to minutes, following critical disturbances such as loss of large generation units, rapid changes in renewable output, and sudden load variations. The modelling framework incorporates wind, solar PV, hydropower, and conventional generation, with flexibility to represent components at different levels of model fidelity.

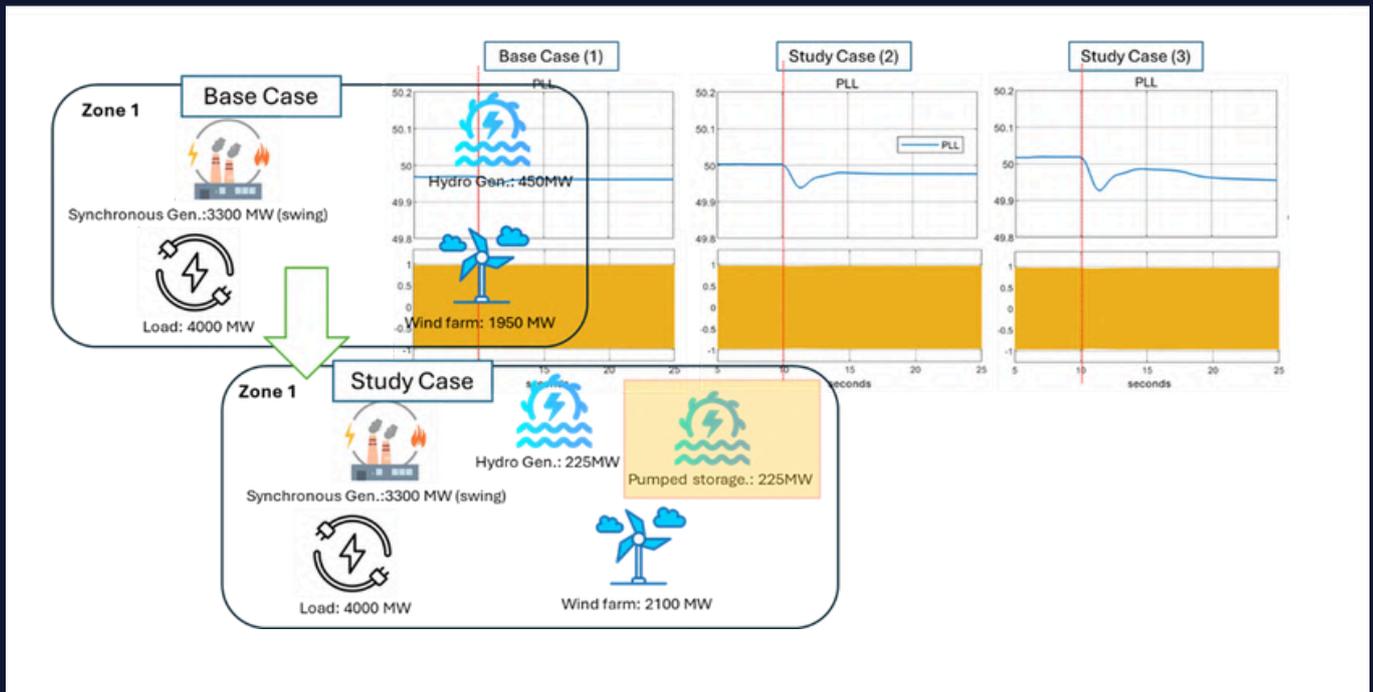


Figure 19. a modular grid modelling framework

Strathclyde has also done the definition of operating scenarios aligned with European renewable energy targets, accounting for reduced system inertia, increased use of power-electronic interfaces, and evolving grid code requirements. Key performance indicators such as frequency and voltage responses have been established to quantify system resilience and assess the contribution of flexible hydropower operation, including generation, pumping, and mixed modes.

In parallel, the team has delivered a modular grid modelling framework capable of representing both AC and DC networks and supporting interoperability between modelling tools. This framework supports the development and validation of innovative control strategies. Early results have been presented to demonstrate the effect of hydro power scenarios on stability services, reliance on synchronous generation, and enabling higher levels of renewable integration.



OPTIMIZING FUTURE GRIDS WITH RETROFITTED PUMPED HYDRO STORAGE

During the past year, **Aarhus University** has contributed to Optimization for Large-Scale Energy Systems by advancing the analysis of system flexibility and optimization under future electricity demand scenarios. This work combines detailed network modelling with long-term demand projections to assess how retrofitted pumped hydro storage can support cost-efficient and reliable power system operation.

A comprehensive dataset covering generation, storage, and time-series network information was developed based on a 37-bus system. In parallel, projected electricity demand for 2050 from reliable external sources was integrated to ensure a future-oriented analysis. Two system configurations were evaluated: a baseline scenario without retrofitting and a scenario involving the conversion of existing hydropower plants to pumped hydro storage. The assessment focused on key system-level indicators, including total system cost, installed capacity by energy carrier, and the deployment and contribution of storage technologies.

To support this work, several regional and European-scale case studies were developed using data provided by WP1. The Norway and Denmark case studies focused on system characterization and flexibility requirements, using detailed plant-level data for pumped-storage hydropower, including capacities, storage volumes, efficiencies, and ramp-up times. In addition, a simplified European model was used to conduct a techno-economic assessment based on aggregated national data for hydropower plants upgraded with booster pumps.



Strengthening Outreach and Collaboration

Over the past year, Store2Hydro has significantly strengthened its visibility, outreach, and collaboration activities, ensuring that project developments reach key stakeholders across the hydropower and energy storage sectors.

Clustering & Industrial Engagement

A major focus this year has been collaboration with other EU-funded initiatives and sector platforms. Store2Hydro actively engaged in hydropower-focused webinars such as Boosting Hydropower II and III, exchanging best practices and strengthening cross-project synergies.

The project also advanced its clustering efforts with initiatives including ETIP Hydropower, ReHydro, Renewat, COST Action PEN-HydroPower, Air4NRG, and the BRIDGE Initiative. These collaborations enhance knowledge-sharing, policy dialogue, and dissemination impact at EU level.

Events & Knowledge Exchange

Some of the Store2Hydro partners (**WRG Europe**, **Luleå University of Technology**, and **TUWien**) participated in HYDROPOWERDAY 2025 in Brussels, organised by ETIP Hydropower — a key European platform bringing together policymakers, industry leaders, researchers, and innovators shaping the future of hydropower.

The event provided an important opportunity to engage in discussions on the role of hydropower in delivering flexibility, storage capacity, and grid stability to support Europe's renewable energy transition. With increasing shares of wind and solar in the system, the conversations strongly reinforced the need for smarter, more adaptable hydropower solutions — directly aligned with Store2Hydro's mission.

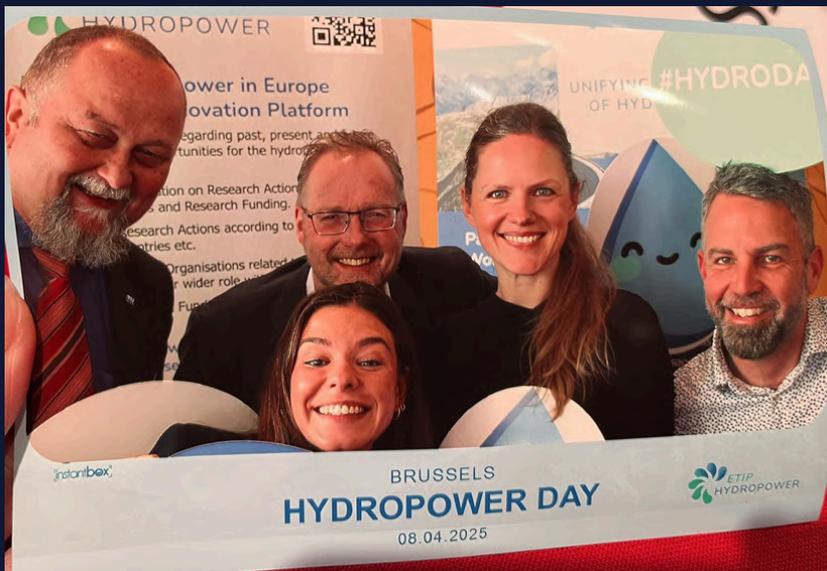


Figure 20 . Store2Hydro partners at HYDROPOWER Day

During the event, the Store2Hydro team connected with fellow EU-funded projects, technology providers, and policy stakeholders, further strengthening clustering activities and exploring new collaboration opportunities. Exchanges focused on pumped storage modernisation, digital tools, and strategies to optimise existing hydropower infrastructure without major environmental impact.

Participation in HYDROPOWERDAY 2025 once again highlighted the growing recognition of hydropower as a cornerstone of Europe’s clean and resilient energy system — and positioned Store2Hydro within this forward-looking dialogue.

Looking Ahead: Upcoming Events & Opportunities

IAHR Congress 2026 – June, Luleå, Sweden

Luleå University of Technology, Store2Hydro's Project Coordinator, will be hosting an upcoming hydropower-focused event — offering an excellent platform to highlight the project's latest achievements and its contribution to the wider hydropower community.

The event will feature dedicated Store2Hydro presentations showcasing recent technical progress, including developments in pumped storage integration, hydraulic modelling, and grid flexibility solutions. A special session has already been organised to foster dialogue with researchers, industry representatives, and policymakers, creating space for knowledge exchange and collaboration.

This event represents an important opportunity to strengthen Store2Hydro's visibility, reinforce clustering efforts, and position the project at the forefront of innovation in modern and flexible hydropower systems.

We look forward to welcoming participants and sharing Store2Hydro's progress with the broader energy community.



ViennaHydro 2026 – November, Vienna.

Store2Hydro will be participating in ViennaHydro 2026, organised by our project partner **TU Wien**.

This conference aims to shape a strategic and political vision for hydropower's role in the EU Clean Energy Transition, fostering dialogue between energy, environmental, and market actors. It provides an interdisciplinary platform connecting researchers, policymakers, industry representatives, and civil society.

ViennaHydro 2026 will play an important role in translating research findings into actionable insights, ensuring that evidence-based results and best practices contribute to informed decision-making at both European and international levels. Store2Hydro looks forward to contributing to this forward-looking discussion and strengthening its engagement within the hydropower community.



TU WIEN **VIENNA HYDRO** **TU WIEN INSTITUTE FOR ENERGY SYSTEMS AND THERMODYNAMICS**

VIENNAHYDRO CONFERENCE

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