



Digital maintenance for sustainable and flexible
operation of HYDROpower plant

HPP Digitalization

Digital Twin and Predictive Maintenance Features



ATLANTIS
ENGINEERING

Vangelis Zikopis



ACCELIGENCE

Stelios Vourakis



This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311



Di-Hydro

HPP Need for Predictive Maintenance



The ageing fleet of HPPs increases the risk of failures.



Traditional maintenance is insufficient under dynamic operating conditions that affect asset performance.



Large volumes of operational data (e.g., SCADA, sensors) remain underutilized.



Unplanned downtime leads to significant economic losses and impacts grid reliability.



Critical components require continuous monitoring to detect early degradation and prevent severe failures.



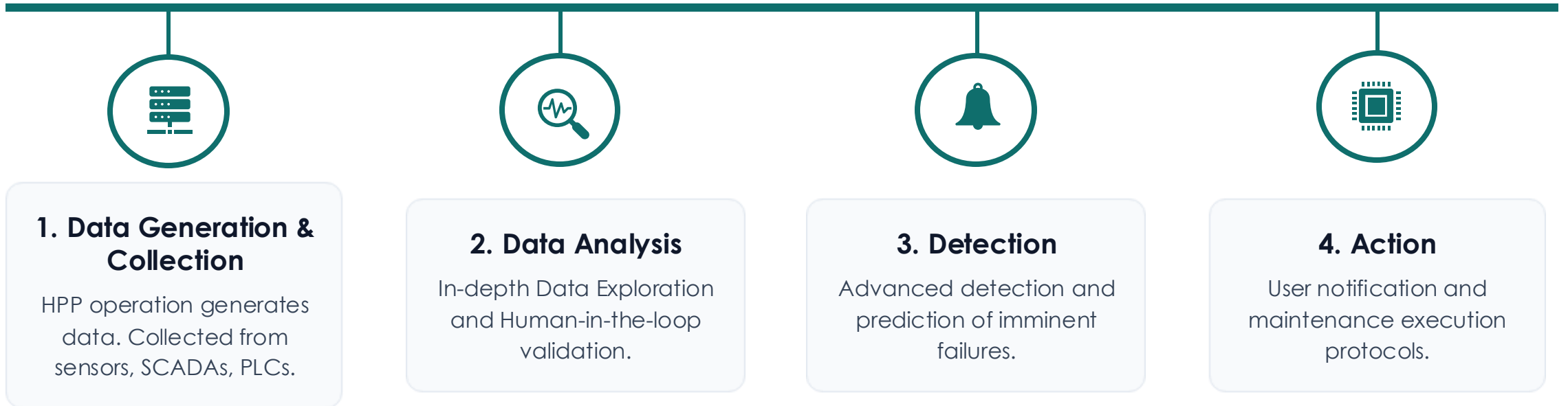
Safety and risk considerations demand more proactive and reliable fault detection.

Predictive maintenance is becoming a key enabler in the digital transformation of the hydropower sector, supporting more efficient, flexible, and reliable operations.

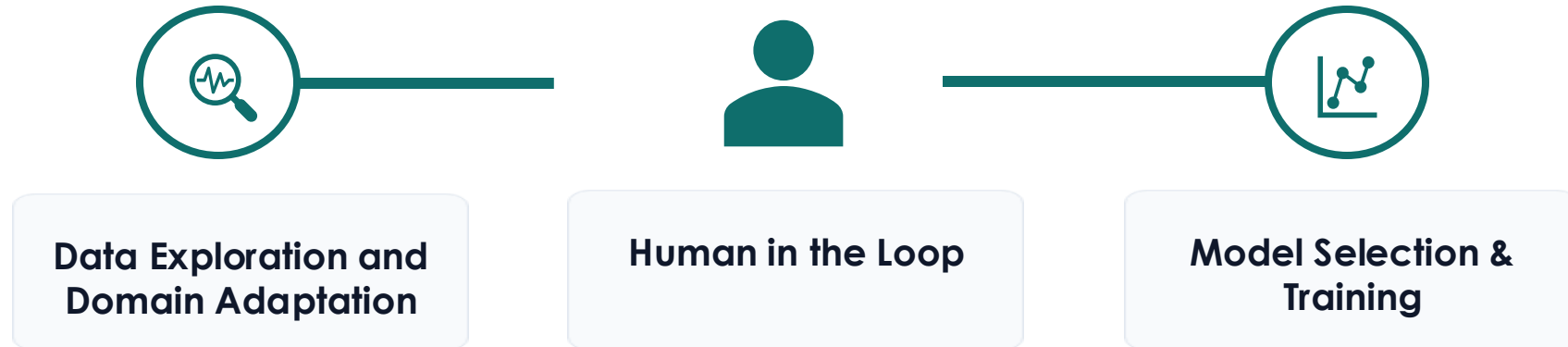
Solutions leveraging AI, advanced analytics, and sensor data are essential to enable timely interventions and optimize asset lifecycle management.



This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311



Predictive Maintenance Pipeline



Predictive Maintenance Models



Supervised Models

Require historical data with annotated failures.

- ✓ Failure Detection
- ✓ Failure Identification
- ✓ Failure Prediction



Unsupervised Models

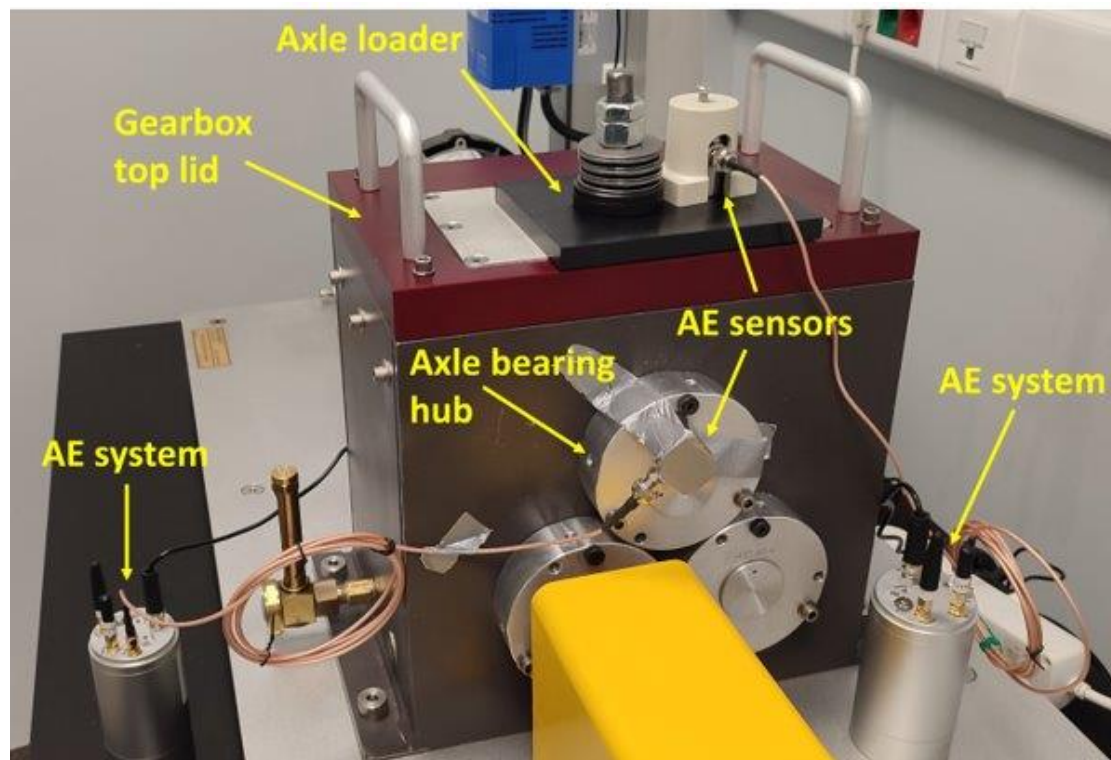
Require historical data but do not need known failures.

- ✓ Anomaly Detection
- ✓ Identification of operational drifts



Di-Hydro

The Drivetrain Simulation Example

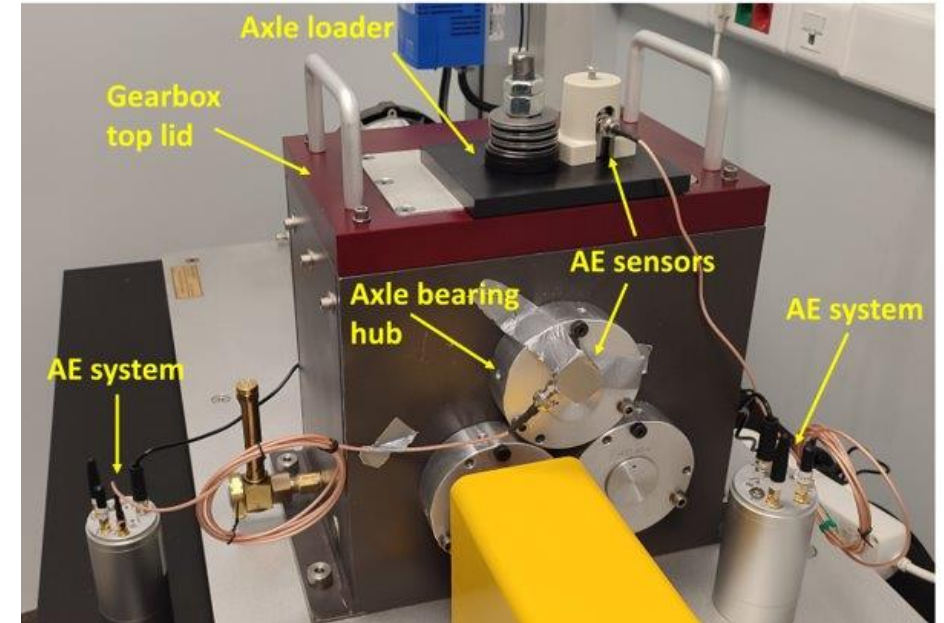


This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311

Generated Simulation Data States:

- ⚙️ Motor operates under normal (healthy) state
- ⚠️ Motor operates with a faulty bearing
- ⚠️ Motor operates with a faulty gear

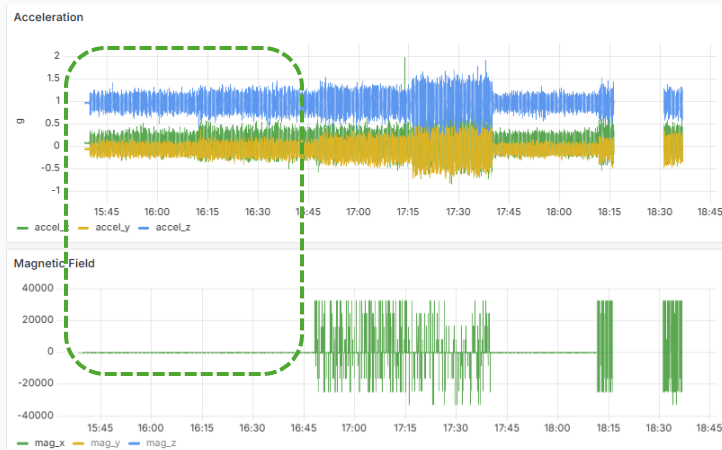
Model is trained on all operational states. The models receive data related to vibrations, RPMs, temperatures, and other metrics.



What does the model see?

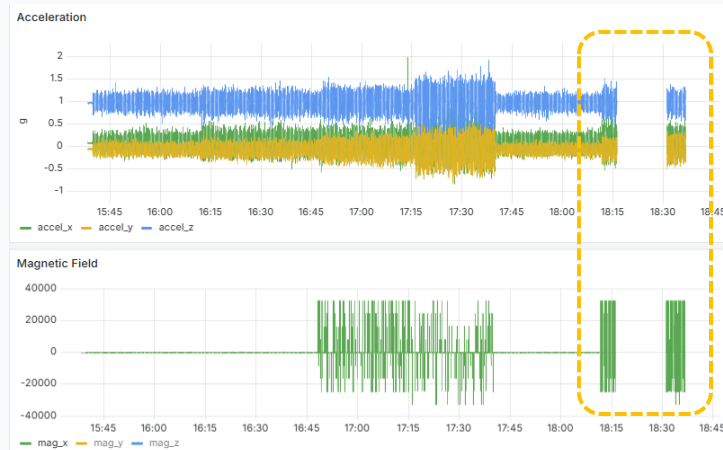
Normal Operation

Baseline vibration and thermal patterns.



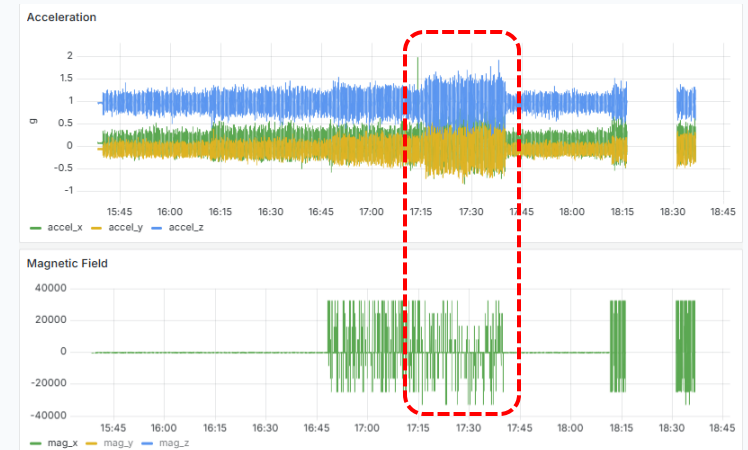
Faulty Bearing

High-frequency acoustic emissions detected.



Faulty Gear

Periodic impact vibrations at specific RPMs.



What can we get from the models? Actions

Normal Operation



No Actions Required

Equipment operating within healthy parameters.

Faulty Bearing



Check the Bearings

Schedule inspection during next planned downtime.

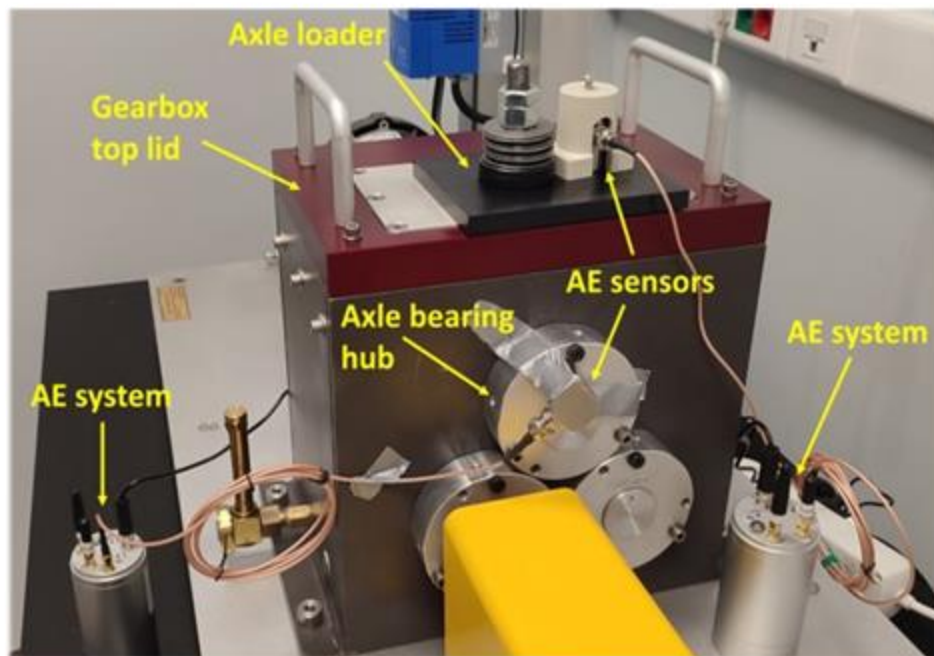
Faulty Gear



Replace the Gear

Critical intervention required in this gearbox.

From the Lab to the Field



Labelled Data from the Lab



Real Data from the Field

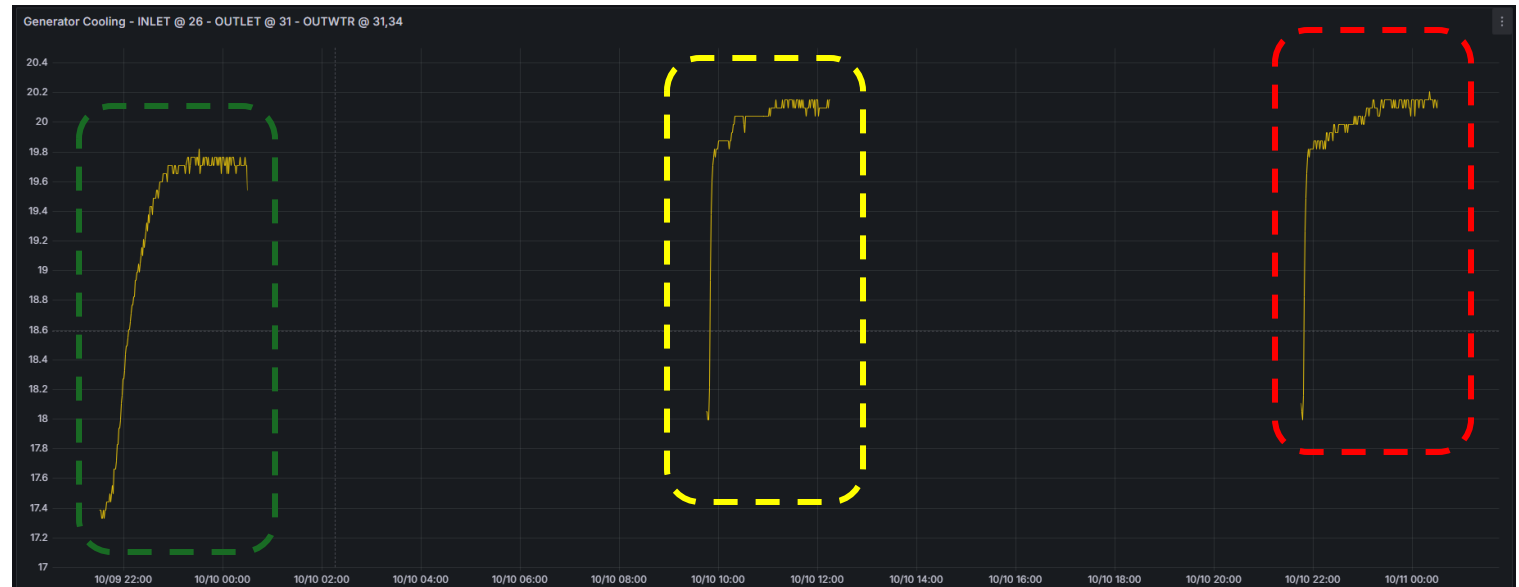
Transfer Learning used to bridge the gap

Remaining Useful Lifetime

By using data that include complete equipment lifecycles, the models can learn the progressive degradation and provide remaining useful lifetime (RUL) estimations.

This translates to proper in-time equipment maintenance or replacement and avoidance of unexpected downtimes.

Degradation Estimation - RUL



Utilization of **Predictive Maintenance** for **Decision Support & Production Planning**



Predictive Maintenance

Trained models are used on the digital twin's data to assess asset condition and predict behavior



Digital Twin

Simulates the Plant's operation under a simulation scenario

Digital Twins in Hydropower

What is a Digital Twin?

- **A model-based virtual replica** of a physical asset that continuously mirrors its real-world state.
- Fuses live sensor streams, historical data, engineering models and forecasts into one living model.

Why it matters for hydropower

- **A risk-free sandbox** to trial “what-if” scenarios and control strategies.
- **Data-driven decisions** validated virtually before touching the live plant.
- **Still rare in hydropower** - Di-Hydro is a pioneering deployment.





The DI-HYDRO Digital Twin

An active, AI-driven platform — not a passive mirror — maintained by continuous data streams and forecasts.

Mirror

An always-current virtual replica of the plant's state.

Experiment

Trial strategies and scenarios virtually, at zero risk.

Predict

AI models forecast inflows, weather and equipment health across multiple horizons.

Optimize

Multi-objective optimization balances generation, wear, environment and market value.



This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311

Case Study: Ilarionas HPP

A pioneering full-scope Digital Twin — physics-based models of every major subsystem.



Hydraulic
Reservoir
Penstock
Outflow



Mechanica
Turbine
Gate position



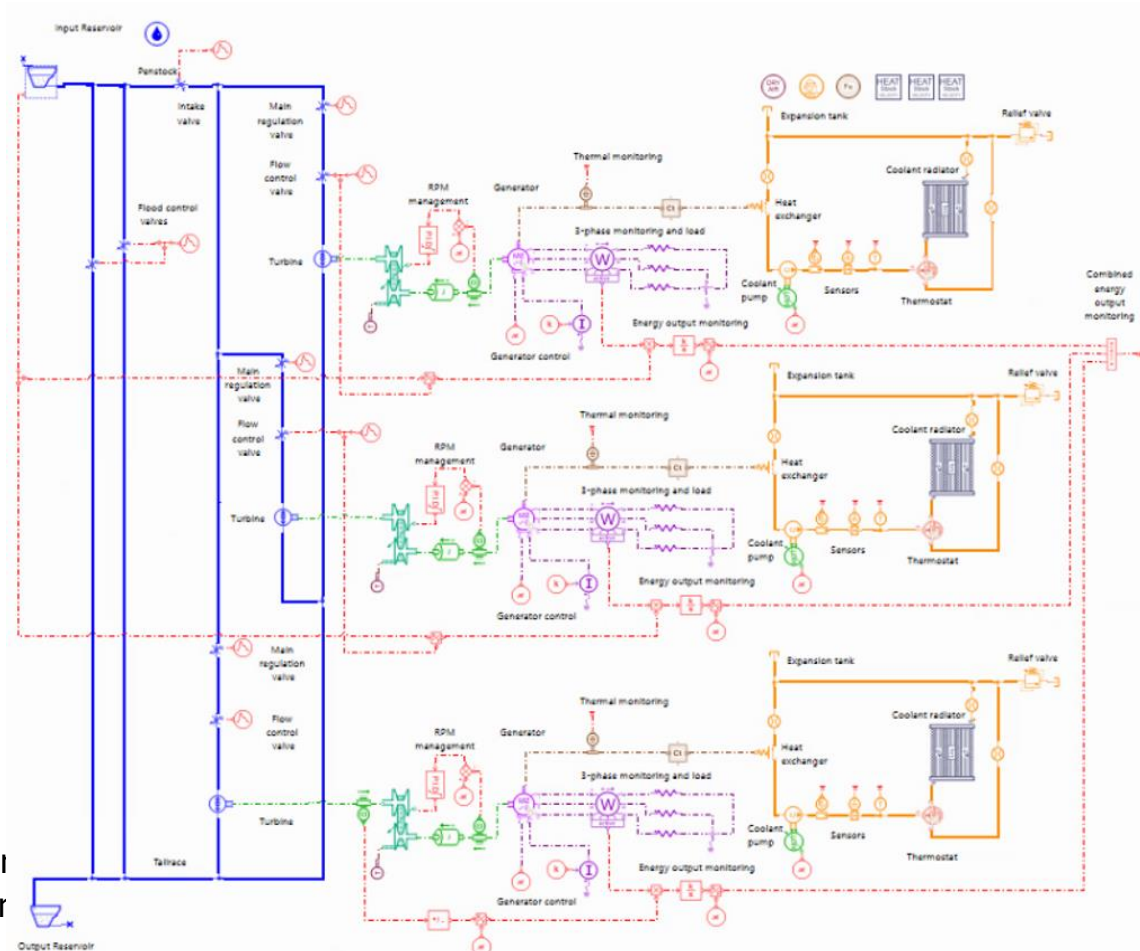
Electrical
Generator
Excitation



Control
Water-flow
regulation



Thermal
Cooling
systems



This project has received funding by the European Union under the Horizon Europe and innovation programme under Grant Agreement 101019718.

Technology & Modeling Process

Why Siemens Amesim

- Extensive multi-domain libraries - hydraulic, mechanical, electrical, control, etc.
- Real-time simulation with SCADA-system integration.

- 1 System architecture**
Identify and connect components: reservoir → penstock → turbine → cooling.
- 2 Component selection**
Choose the most suitable Amesim components and their submodels to ensure accurate and resource-saving simulation.
- 3 Parameterization**
Input physical detail - pipe diameters, blade geometry, flow rates, etc.

Scenario Testing & Validation

Input & Simulation

- The DT receives real-time inputs (e.g., reservoir level, gate position) to update the virtual plant's state.
- It then simulates forward under configurable scenarios.

Multi-Objective Optimization

Operators can virtually test complex, conflicting goals, such as:

- Maximizing power generation vs. minimizing water use.
- Pre-emptive spill vs. flood risk management.

Visualization

- Built-in tools allow monitoring and visualization of power generation, flow dynamics, and system efficiency.

- This trial-and-error process is key to achieving simulation objectives (e.g., improving turbine efficiency).
- **Validation against real-world data** ensures model accuracy and reliability.

Iterative validation

1

Steady-state run

Confirm basic functionality.

2

Transient runs

Load changes and start-up scenarios.

3

Optimize & validate

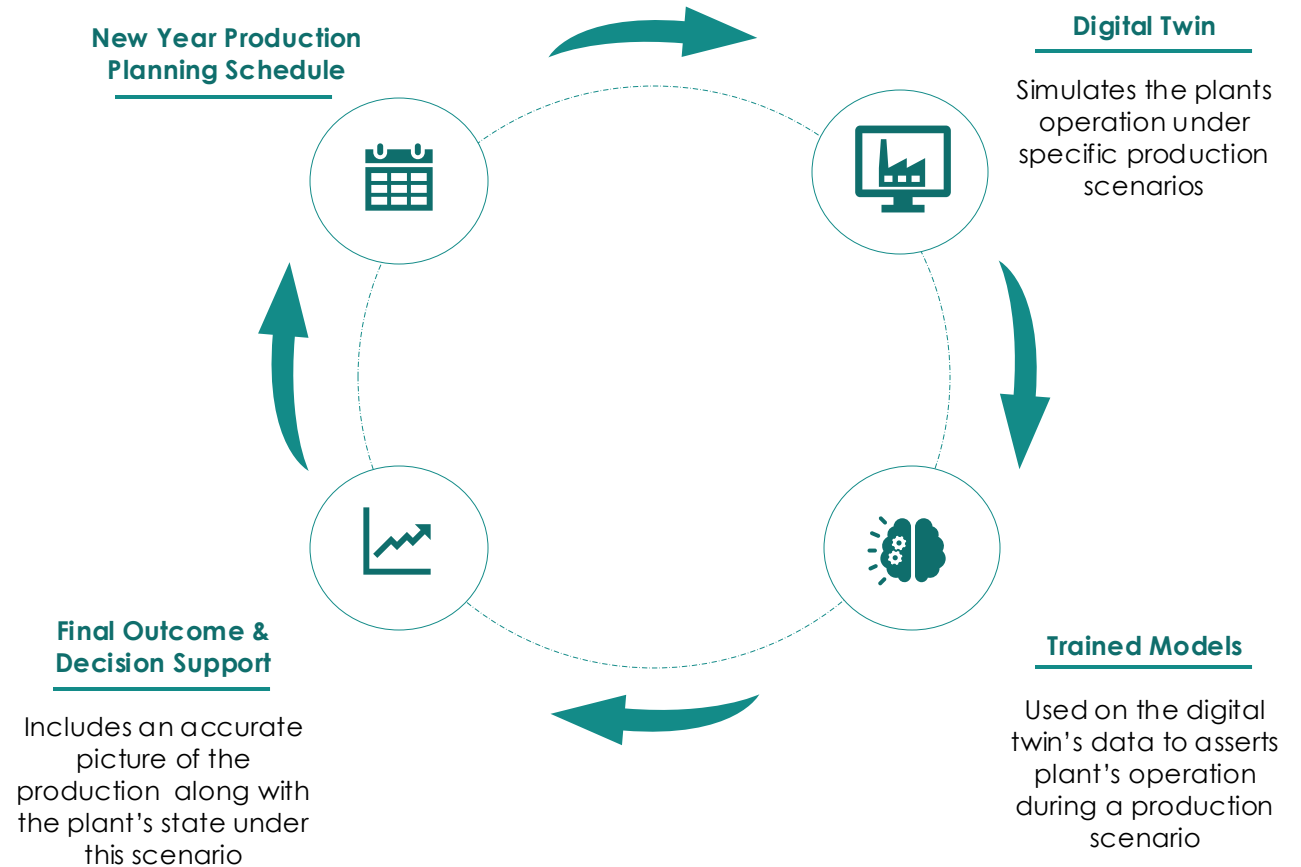
Mainline + corner cases against real-world data.



Utilization of Predictive Maintenance in Digital Twins



Towards Future Digitization





Increased Availability & Productivity

Simulates the Plant's operation under a simulation scenario

01



Asset Lifecycle Extension

Trained models are used on the digital twin's data to assess asset condition and predict behavior

02



Reduced Maintenance Costs

Future production planning schedule can be optimized using reliable asset and production insights

03



Improved Resource Exploitation

The final outcome provides an accurate picture of production along with the plant's state under this scenario

04

Impact & Outlook

A shift from reactive to proactive management — turning an ageing hydropower fleet into a data-informed, agile operation.

Smarter operations

Maintenance becomes condition-based and prognostic — potential failures are addressed before they cause downtime.

Grid stabilization

Coordinated dispatch lets plants absorb surplus renewables and step in when wind or solar wavers.

Climate resilience

Multi-horizon forecasts guide reservoir management, flood protection and drought response.

Sustainable by design

Environmental and socio-economic feedback keeps operations within ecological limits and serves community water needs.

Built to scale — a federated property-graph data framework and decentralized ML extend the solution from single plants to a continental network of digital twins, supporting Europe's clean-energy transition.



This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311

Visit the **Di-Hydro website**, where you'll find all the Di-Hydro Materials, such as flyers, reports, our newsletter issues, as well as what they say about Di-Hydro around!

Di-Hydro Website: <https://dihydro-project.eu/>

Follow us also on **LinkedIn**:

<https://www.linkedin.com/company/di-hydro-project/>

Check out the **Di-Hydro Podcast Series**:

https://youtube.com/playlist?list=PLna5U7-OPgOtFKTmZXYVby8mP_Daibnwh&si=5n1tL1Ikj0KBLZIZ

Subscribe to our LinkedIn Newsletter:

<https://www.linkedin.com/build-relation/newsletter-follow?entityUrn=7406647955916541952>



Check out the
Di-Hydro Innovation Handbook,
featuring the main results from
the project!



Digital maintenance for sustainable and flexible
operation of HYDROpower plant

Thank you.



Questions?



This project has received funding by the European Union's Horizon Europe research and innovation programme under Grant Agreement N° 101122311