D-Hydroflex. Digital solutions for improving the sustainability performance and FLEXibility potential of HYDROpower assets.

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Artur Machalski, Wrocław University of Science and Technology

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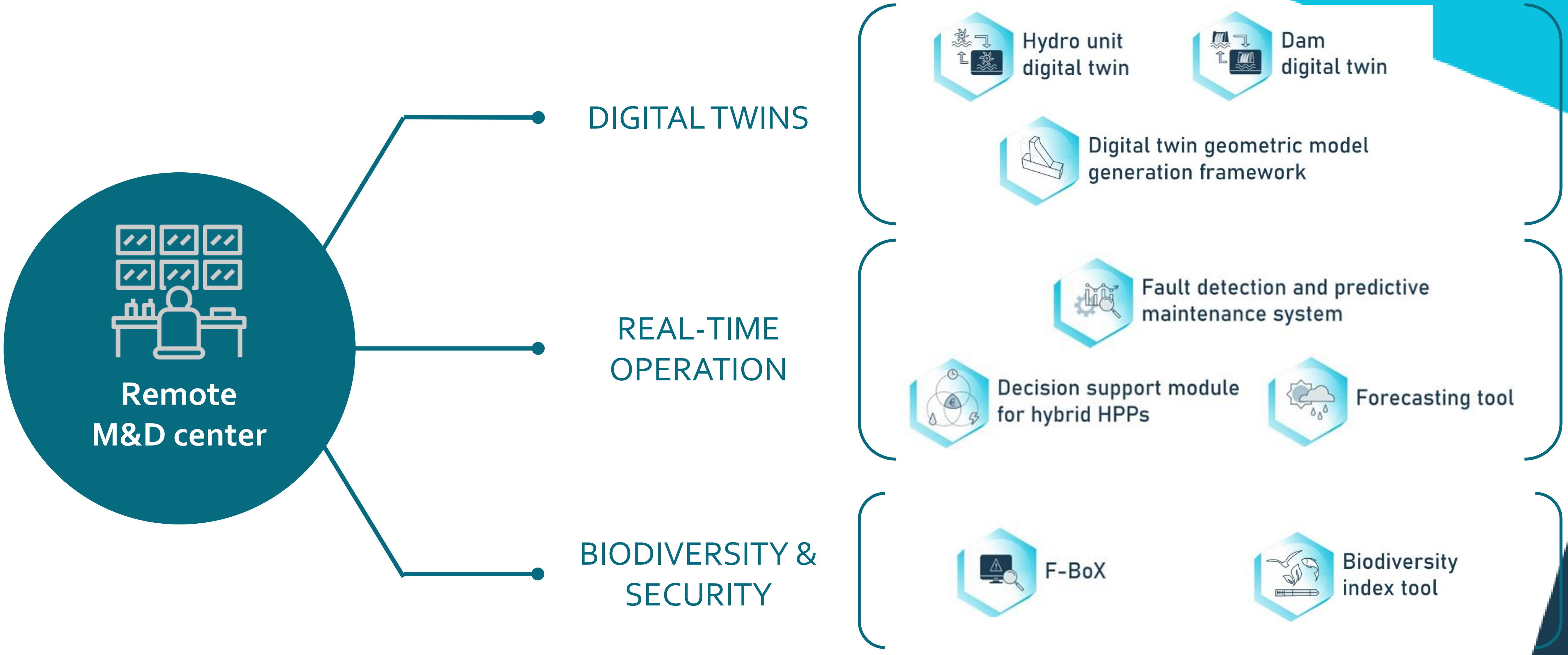
Partners

- Conduct a revision and analysis of the Hydropower Plant existing equipment.
- Develop and implement a measurement system to accurately monitor and analyze turbine and water flow metrics.
- Create hydrological models.
- Build digital models of the turbine and related systems to facilitate virtual testing and optimization.
- Perform Computational Fluid Dynamics (CFD) simulations to analyze fluid flow and optimize turbine performance.

- Provide documentation and data essential for all phases of the project.
- Grant access to Wały Śląskie Water Power Plant for practical engagement and data collection.
- Offer expert consultations and share industry-specific expertise to guide the project development.

D-HYDROFLEX



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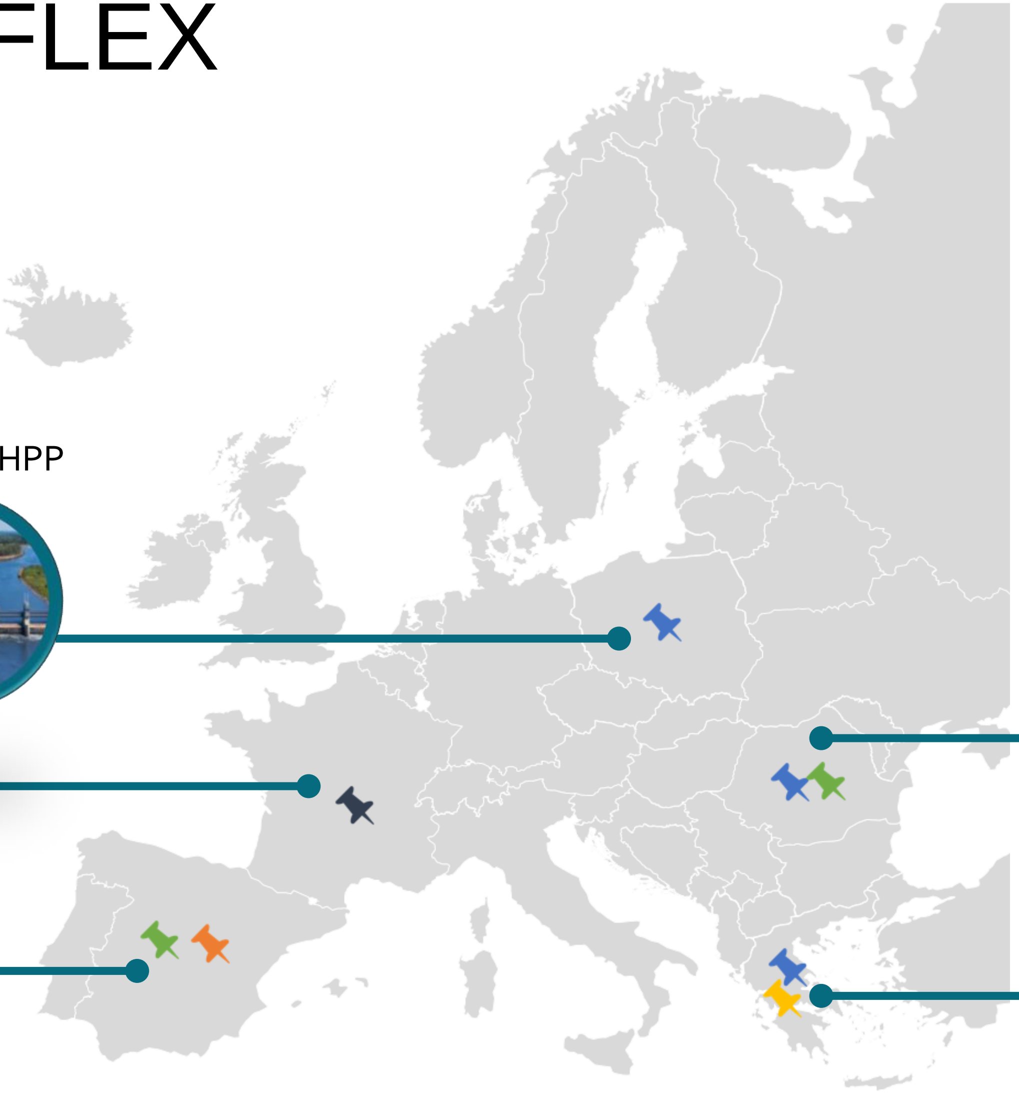
D-HYDROFLEX

Poland,
Wały Śląskie HPP

France,
Mauzac HPP



Spain,
Salto de Touro HPP

Romania,
Bratia HPP

Greece,
Ilarion & Platanovrisi HPPs

Demo use cases:

- Predictive maintenance and operational efficiency maximization in HPPs
- Hybridization of HPPs utilizing on-site hydrogen production in small HPPs
- Anomalies and intrusions detection in HPPs local networks
- Increasing HPPs' readiness for integration & operation into local smart grids
- Environmental impact monitoring in RoR plants

Demo site: Wały Śląskie

Parameter	Value
Plant type	Run-of-river
Number of turbines	4 × Kaplan
Installed capacity	9.8 MW
Power per turbine	2.45 MW (4 × 2.45 MW = 9.8 MW)
Head	4.7 m
Flow per turbine	60 m³/s
Turbine speed	88.2 rpm
Generator power	2,700 kVA
Output voltage	6.3 kV

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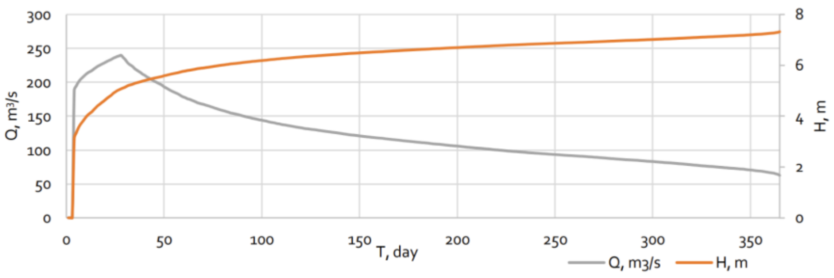
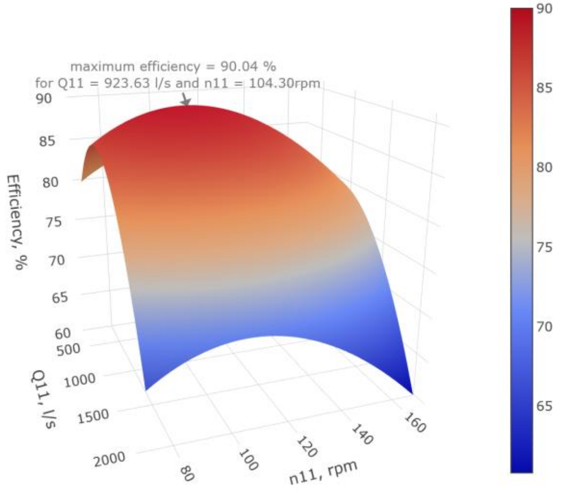
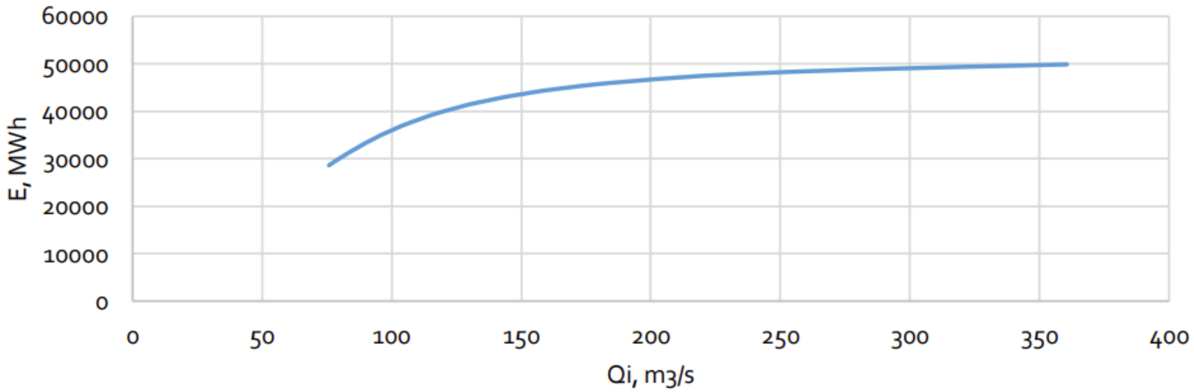
Turbine Efficiency & Power Estimations







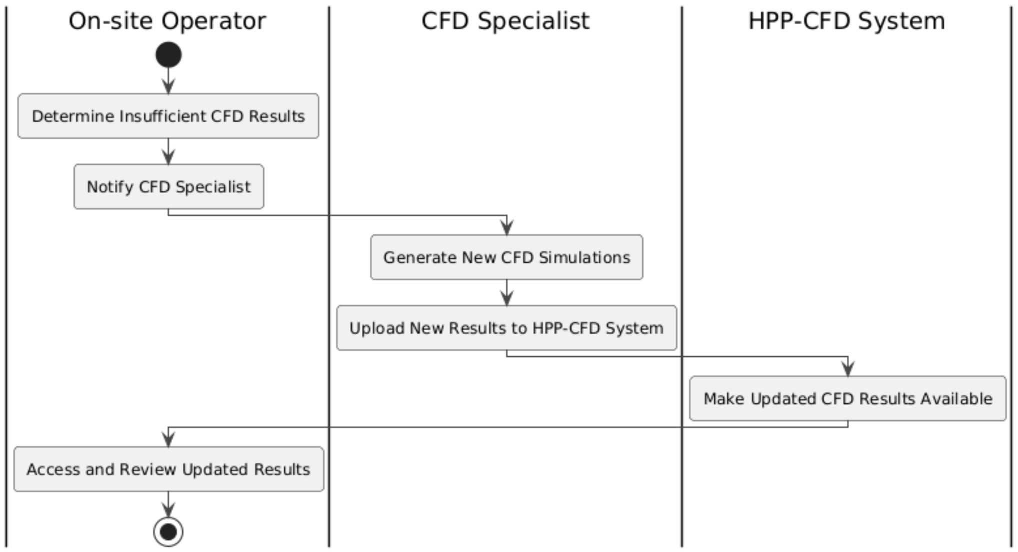
Energy potential of the hydropower plant

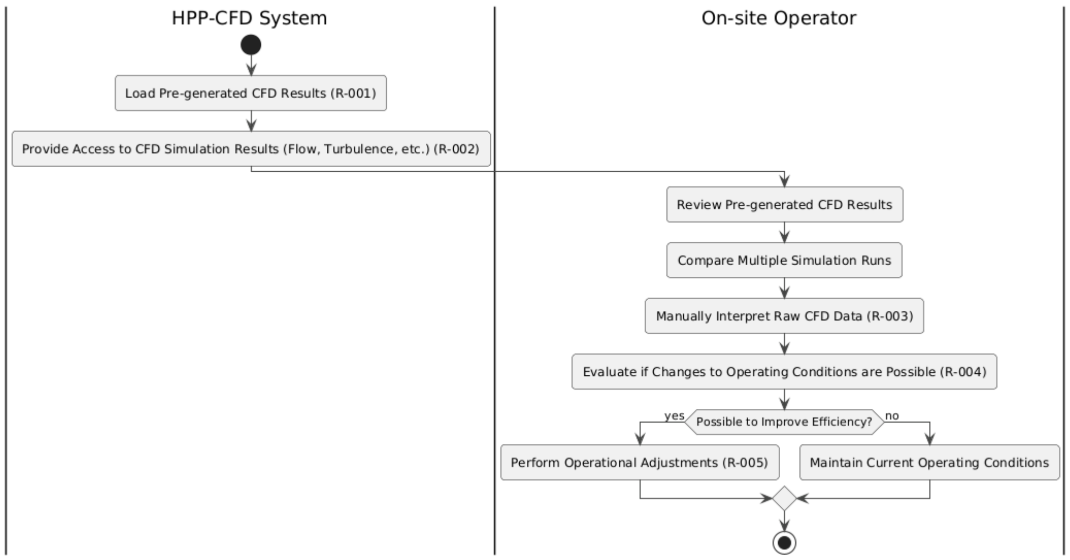
Estimated production, possible increase of **5%** compared to current average.

Use cases (UML)

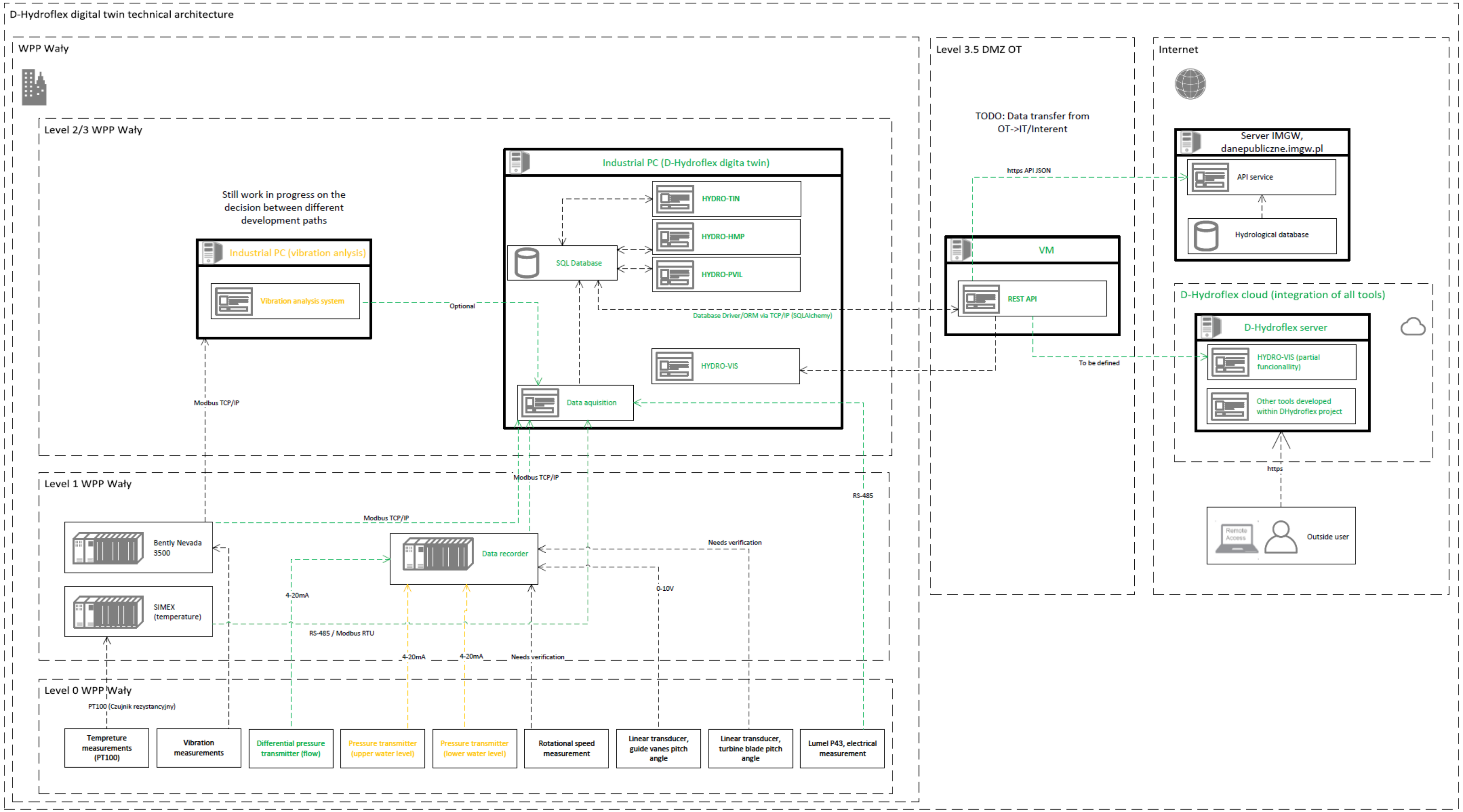
Use case scenarios:

1. Monitoring and Optimizing Plant Efficiency using HPP-TIN
2. Predicting Water Flow Variations
3. Reviewing CFD Simulation Results for Hydrodynamic Conditions
4. Request for New CFD Results
5. Detecting Mechanical Anomalies Using Vibration Analysis
6. Using Visualization Tool for Plant Operation





System architecture



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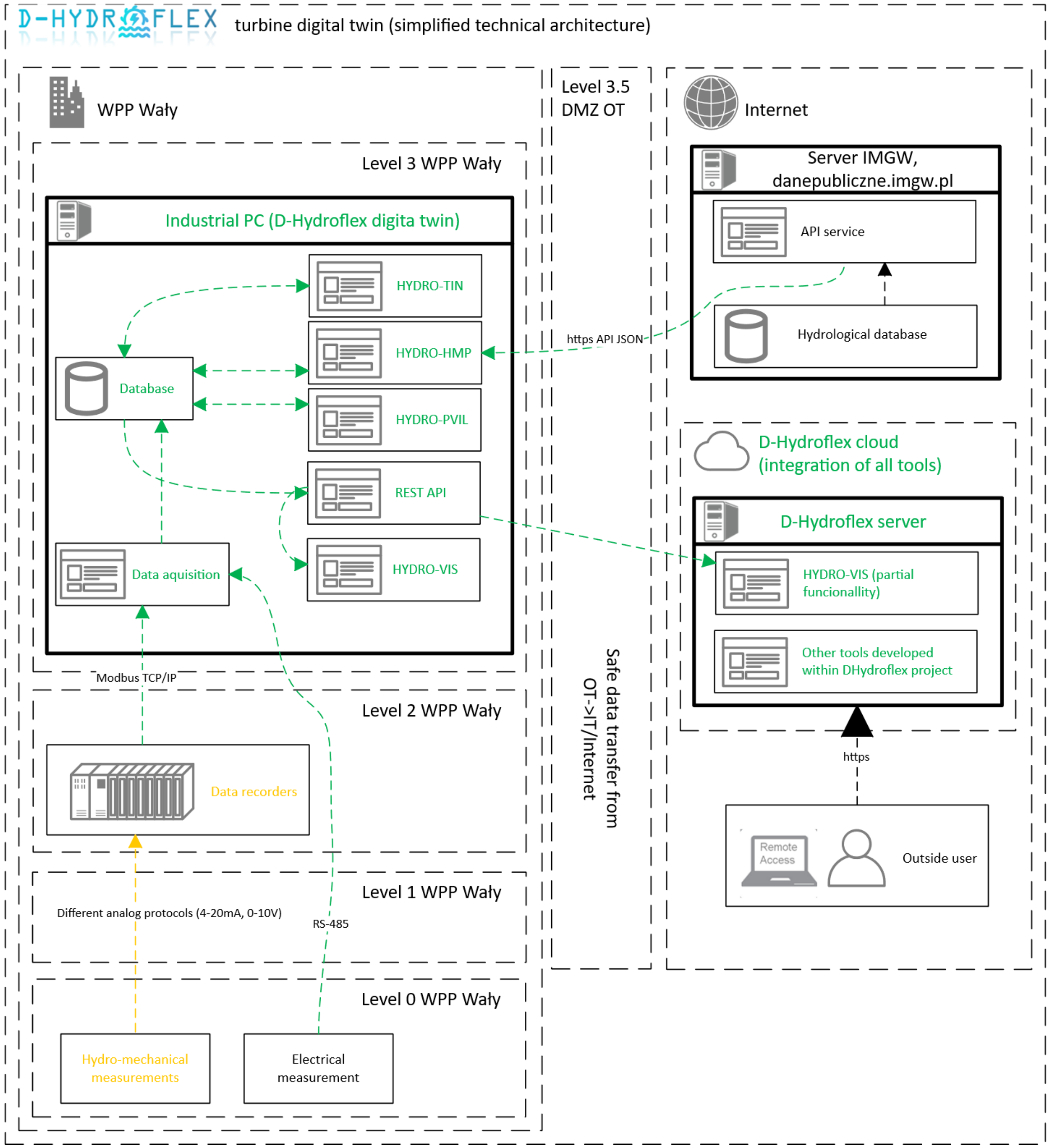
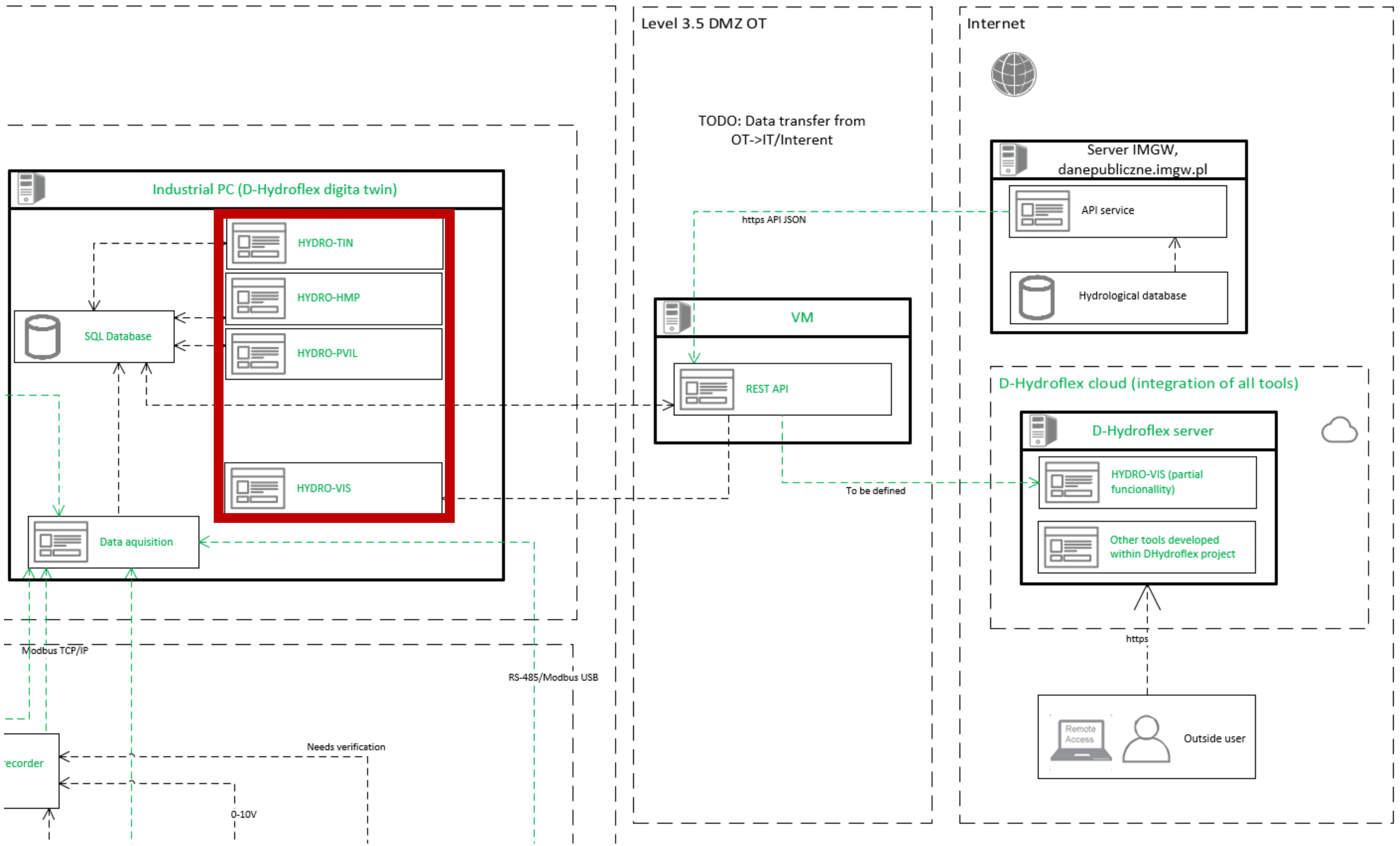
System architecture

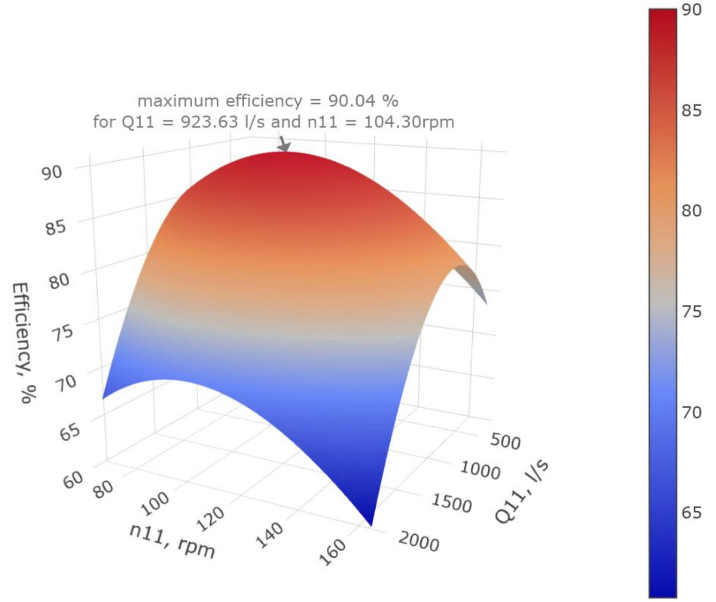


- Data Acquisition Layer: Gathers operational data (flow, water levels, blade angles, speed, vibration) via standard protocols (e.g., Modbus TCP/IP).
- Data Processing Layer: Computes parameters (efficiency, predictive indicators, forecasts) using tools like HYDRO-TIN and HYDRO-PVIL.
- Visualization Layer: Offers real-time interactive dashboards, charts, and 3D visuals for monitoring and decisions.
- Integration Layer: Ensures smooth communication between digital twin components, external data (CFD), and hydrological predictions, supporting interoperability and security..

Tools developed within digital twin



HYDRO-TIN



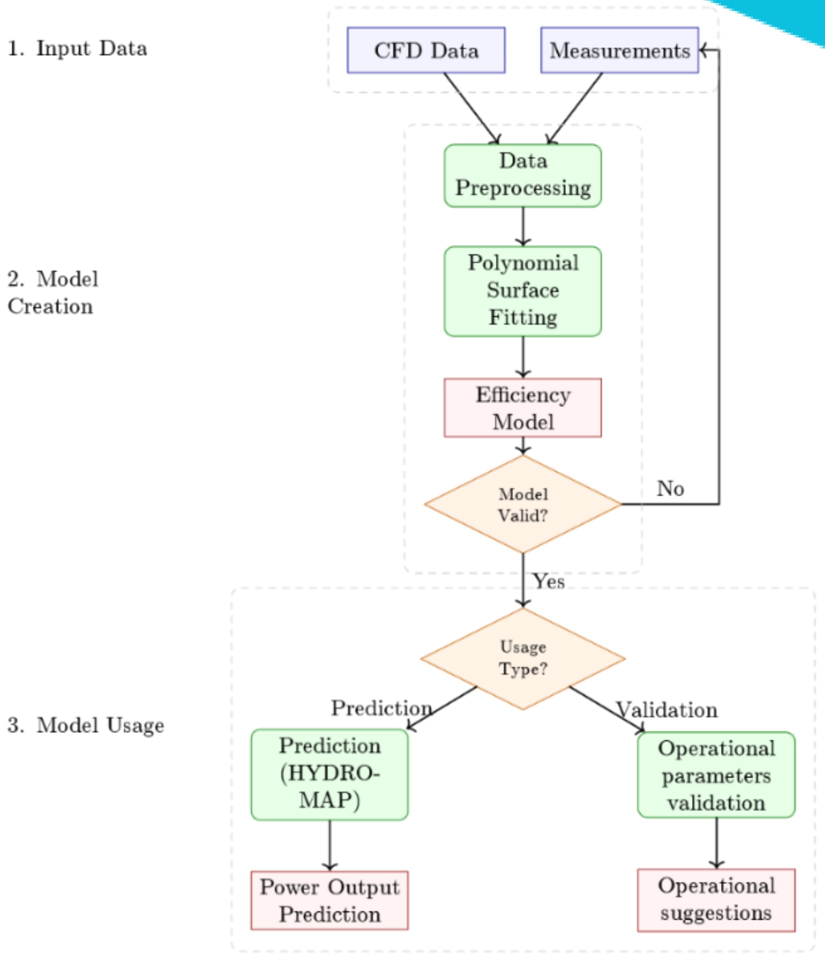
How it works:
It analyzes operational data in real time, such as flow rate, water levels, rotational speed, and turbine and guide vane angles. It generates efficiency curves and compares them with predefined models.

Requirements:
- Accurate efficiency characteristics (based on actual measurement data).
- Continuous model updates in case of turbine configuration changes.

Advantages:
It provides the operator with information on whether the turbine is operating at proper efficiency and whether further optimization of settings is possible to achieve higher performance. It enables quick identification of areas that may require improvement.
Development potential:
Extension with the ability to automatically update efficiency characteristics based on current measurement data.

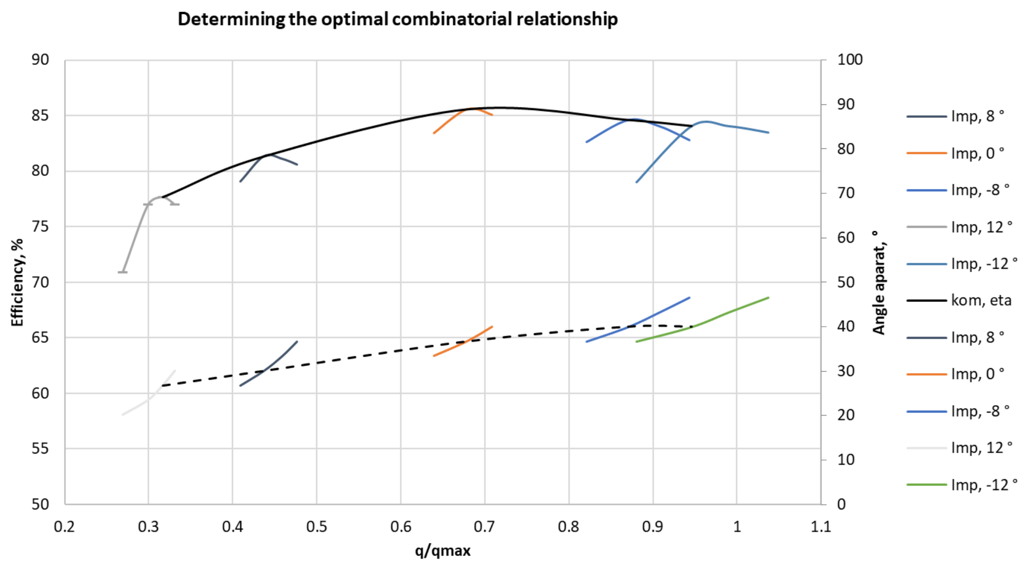
Digital model of the turbine –HYDRO–TIN

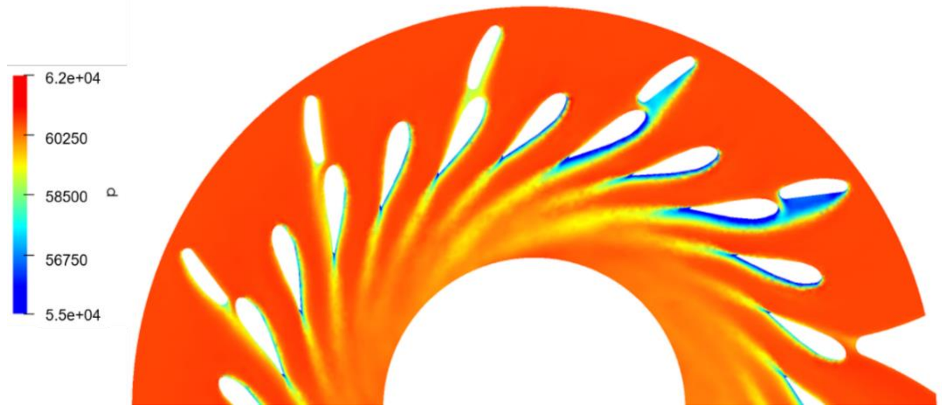
HYDRO-TIN is designed to assess turbine efficiency by processing data such as flow rate, water levels, rotational speed, and blade angles. The concept includes efficiency curve generation and comparison of measurements with model predictions to support optimization of turbine performance

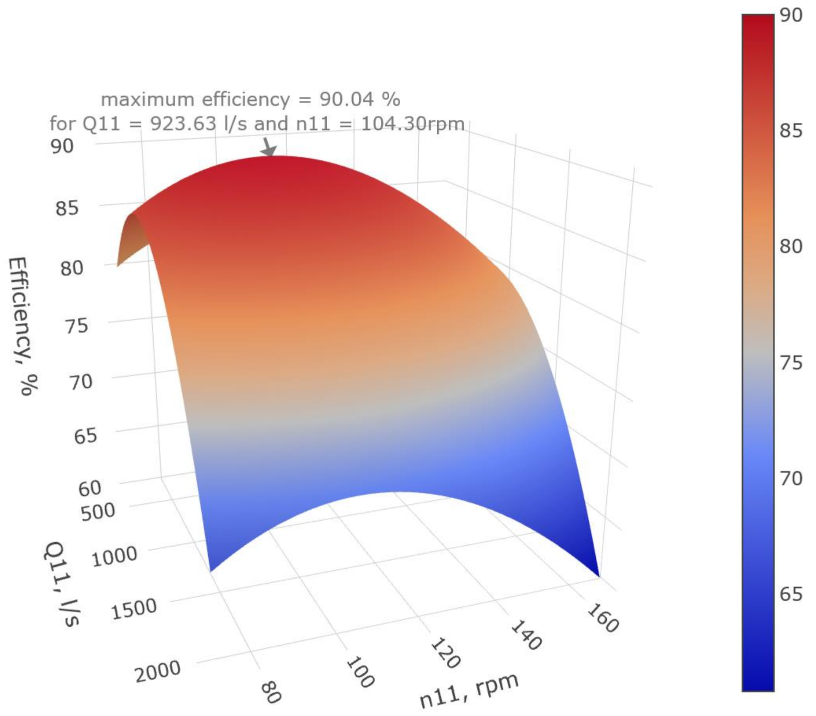


HYDRO TIN stages

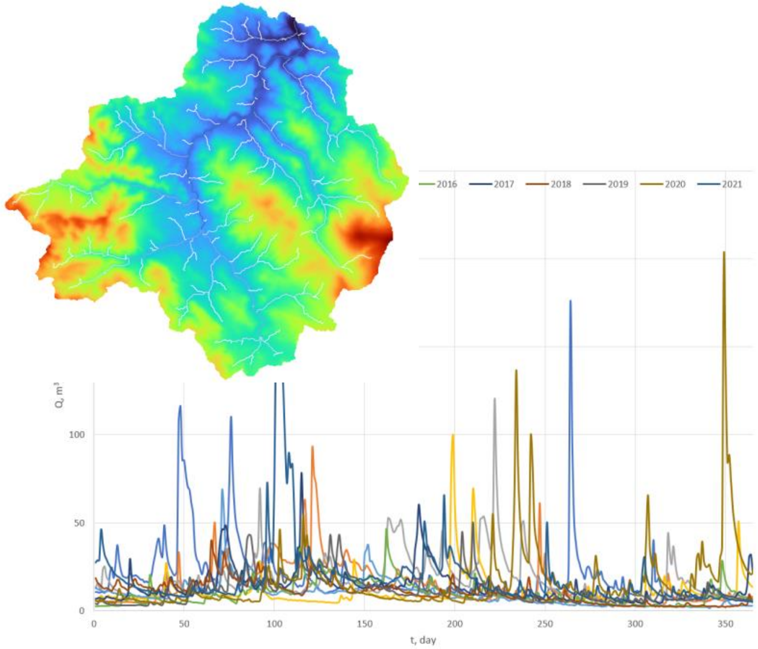
Efficiency curve of the turbine







HYDRO-MAP



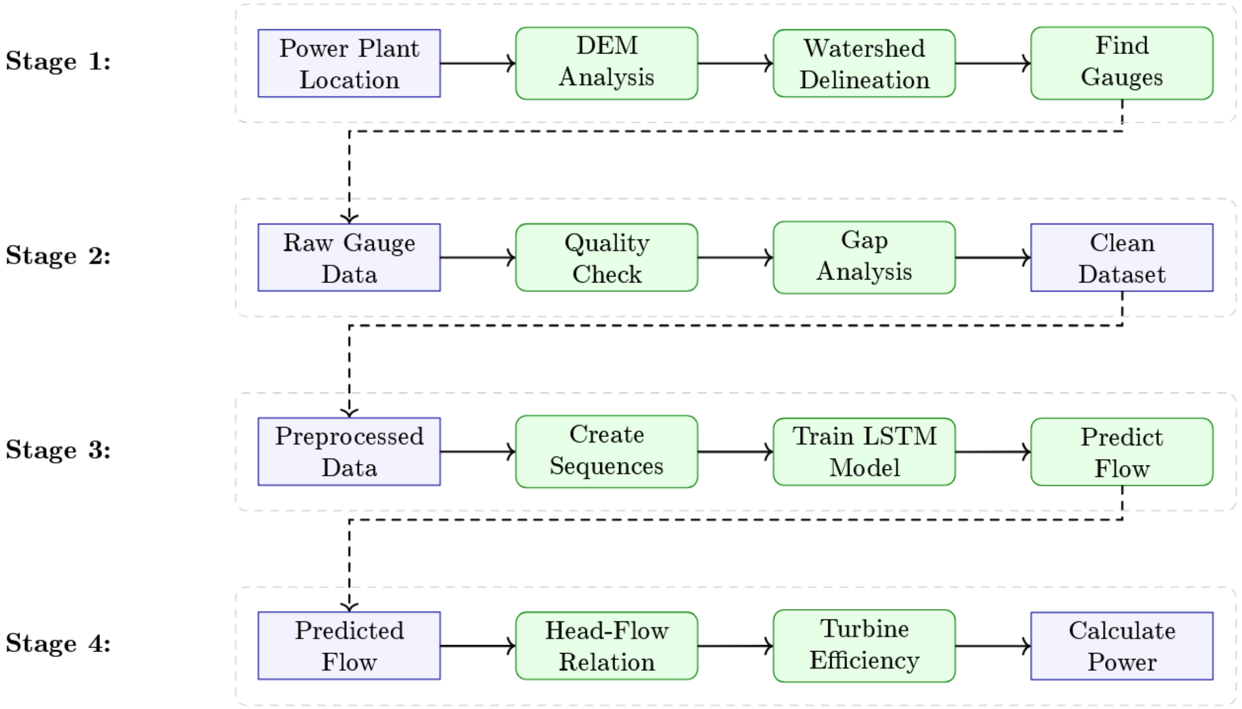
How it works:
It performs hydrological analyses based on historical and real-time data, provided, among others, by IMGW. It forecasts changes in water flow, supporting the operational planning of the power plant.

Requirements:
- Access to reliable and up-to-date hydrological data (integration with external systems such as IMGW).
- Verification and calibration of hydrological models for local conditions..

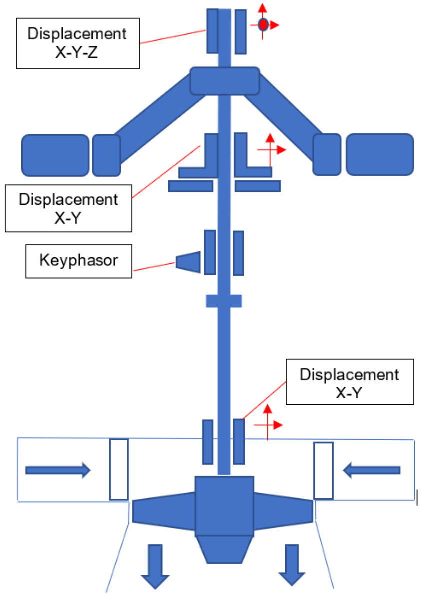
Advantages:
Enables the prediction of water flows, allowing for efficient management of power plant operations.
Development potential:
Extension with more precise flow forecasting algorithms that take into account weather and seasonal variables.

Digital model of the turbine – HYDRO-MAP

HYDRO-MAP employs a four-stage approach using gauge data and LSTM networks to forecast water flow, enabling proactive operational planning and resource management.



HYDRO-PVIL



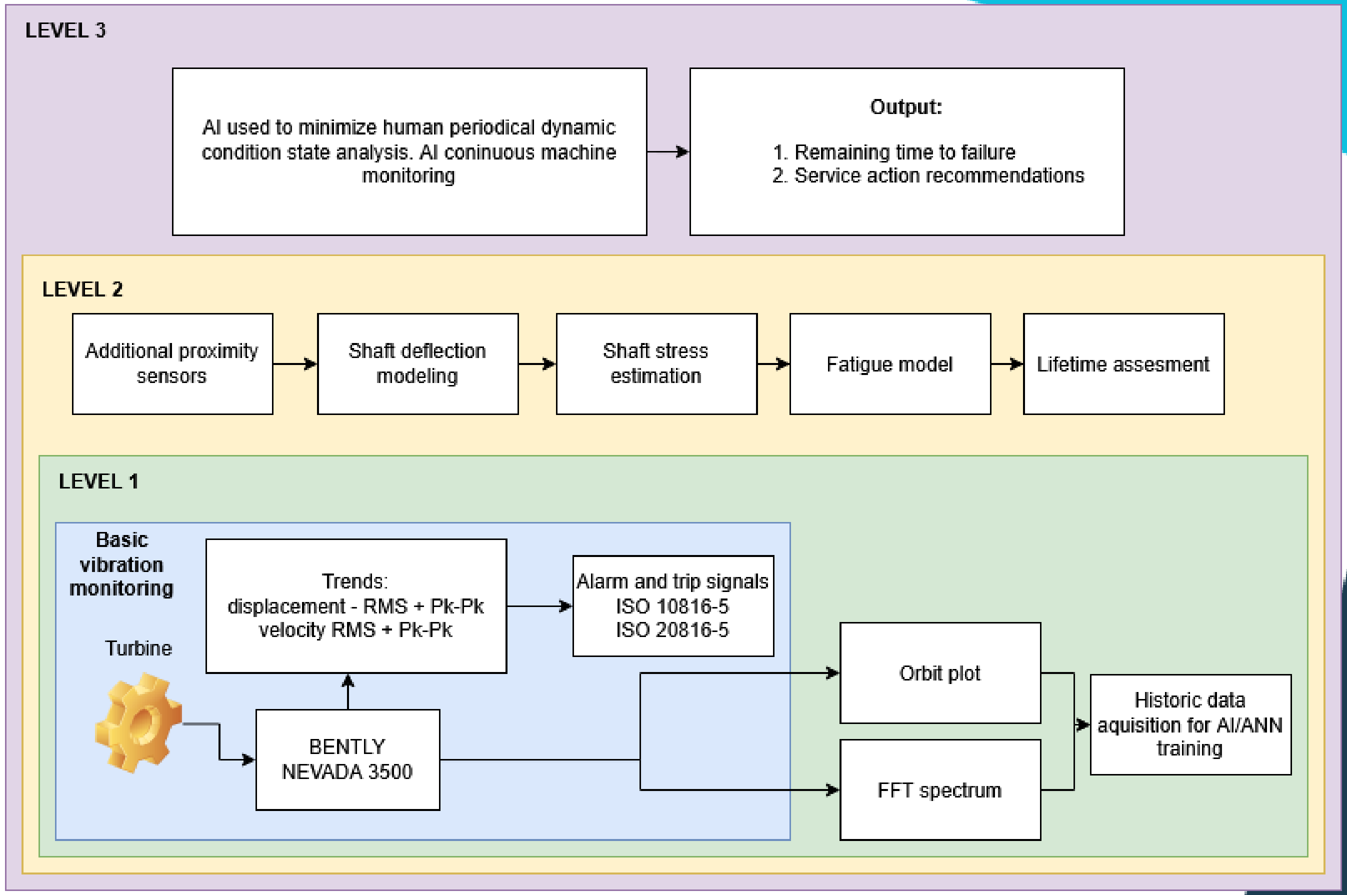
How it works:
It analyzes vibration and temperature data from key turbine components, identifies anomalies, and supports predictive maintenance actions.

Requirements:
- Sensors with appropriate accuracy.
- Alert mechanisms for operators when anomalies are detected.

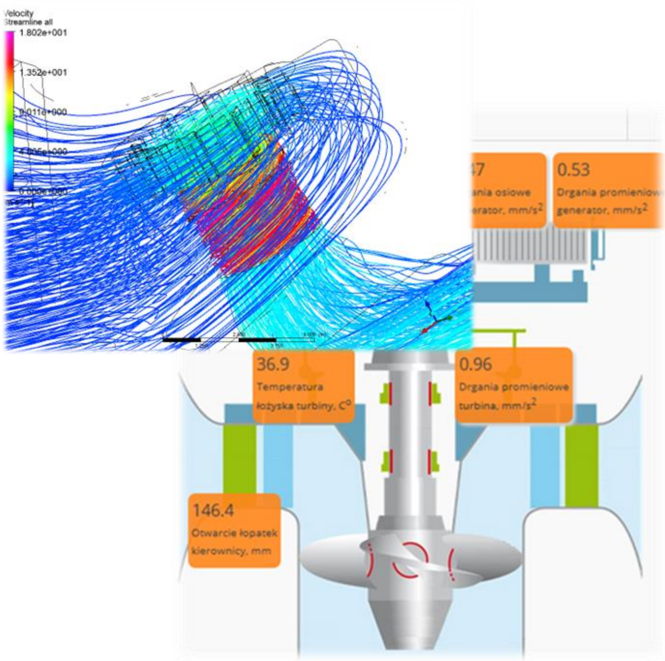
Advantages:
Supports predictive maintenance by helping prevent failures through early problem detection. Extends the lifespan of key components and improves operational safety.
Development potential:
Verification and validation of the implemented models, and if inaccuracies are found, updating or replacing them with better alternatives.

Digital model of the turbine –HYDRO-PVIL

HYDRO-PVIL presents a multi-level approach to vibration monitoring and analysis, beginning with basic threshold-based alerts (Level 0) and outlining a pathway toward advanced predictive maintenance capabilities. The framework aims to enhance reliability through early detection of mechanical anomalies.



HYDRO-VIS



How it works:
It integrates data from other tools, enabling visualization in the form of charts, tables, and CFD simulation results. It presents key operational parameters in a clear and accessible way.

Requirements:

- Intuitive user interface.
- Ability to customize visualizations to the operator's specific needs.
- Secure communication with data acquisition systems.

Advantages:
Helps operators quickly understand the current state of the power plant through comprehensive visualization. Centralizes data from various tools in a single, user-friendly interface.

Development potential:
Possibility to extend access to data from other tools, both current and future ones.

HYDRO-VIS

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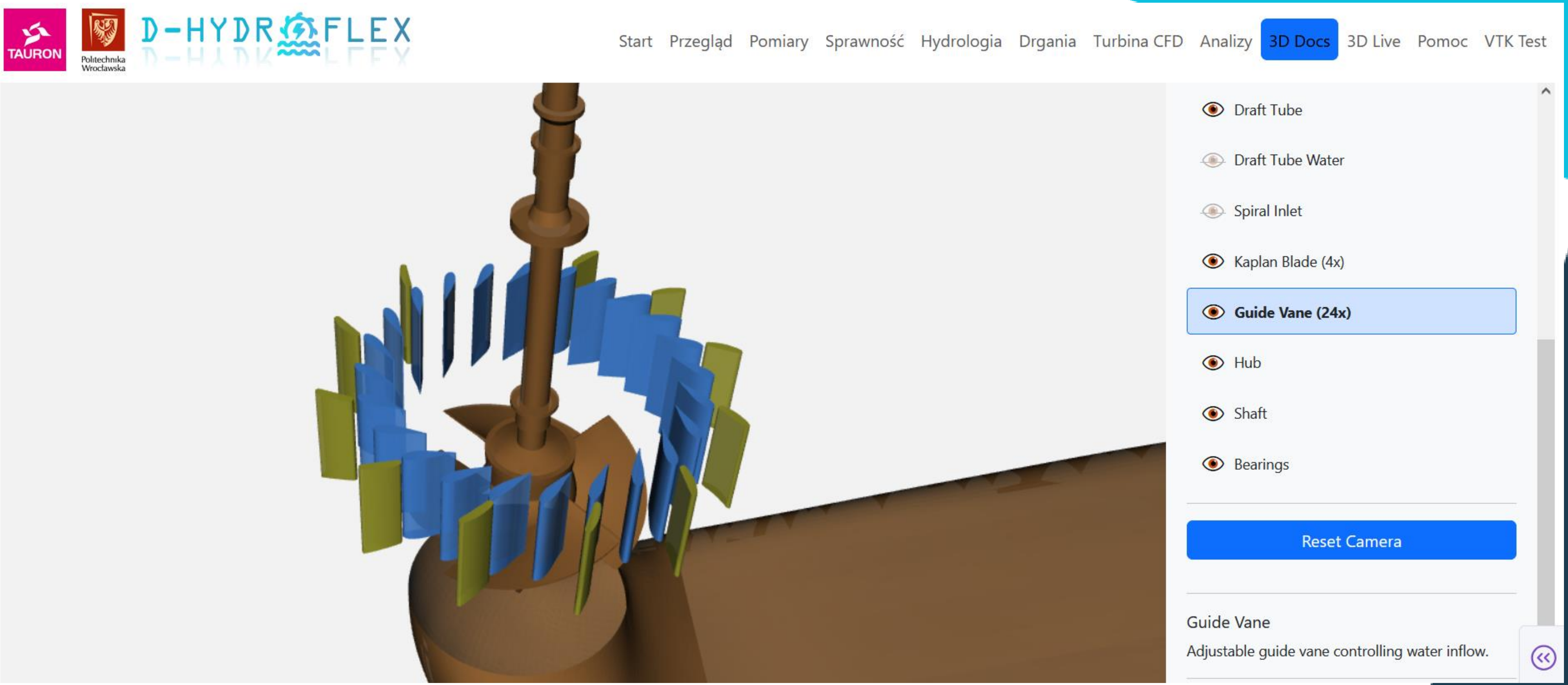
TAURON
Politechnika Wrocławska
Start
Przegląd
Pomiary
Sprawność
Hydrologia
Drgania
Turbina CFD
Analizy
3D Docs
3D Live
Pomoc
VTK Test
Live Measurements
Lower Level: 97.71 m
Upper Level: 105.25 m
Flow: 469.3 m³/s
Power: 1646 kW
Blade Angle: 18.6 °
Guide Vane: 15.9 °
Pressure: 0.31 bar
Live Turbine Monitoring
Components
Guide Vane Channel
Outlet Channel
Outlet Channel Water
Stay Vanes
Lower Water Surface
Draft Tube
Draft Tube Water
Spiral Inlet
Kaplan Blade (4x)
Guide Vane (24x)

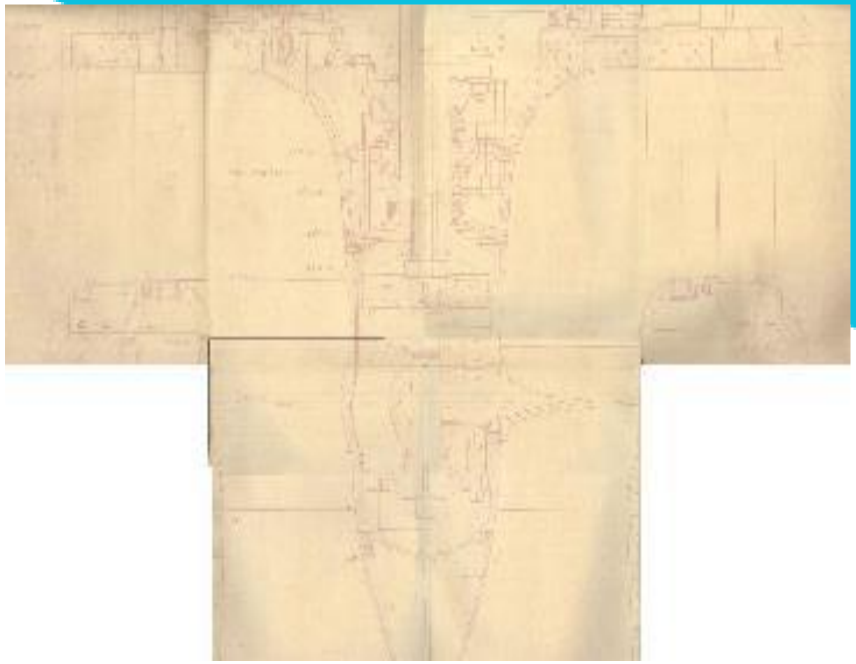
HYDRO-VIS

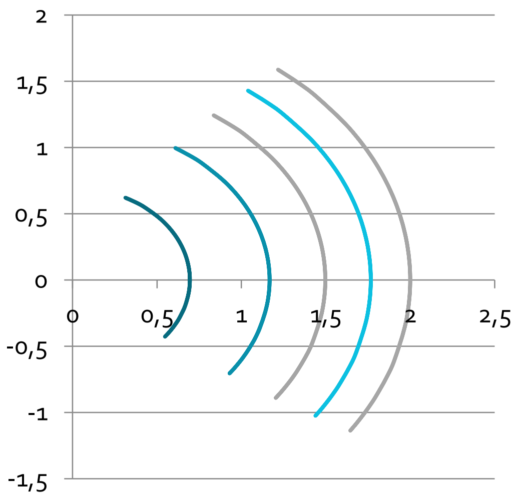

TAURON
Politechnika Wrocławska
D-HYDROFLEX
Start
Przegląd
Pomiary
Sprawność
Hydrologia
Drgania
Turbina CFD
Analizy
3D Docs
3D Live
Pomoc
VTK Test
Draft Tube
Draft Tube Water
Spiral Inlet
Kaplan Blade (4x)
Guide Vane (24x)
Hub
Shaft
Bearings
Reset Camera
Guide Vane
Adjustable guide vane controlling water inflow.

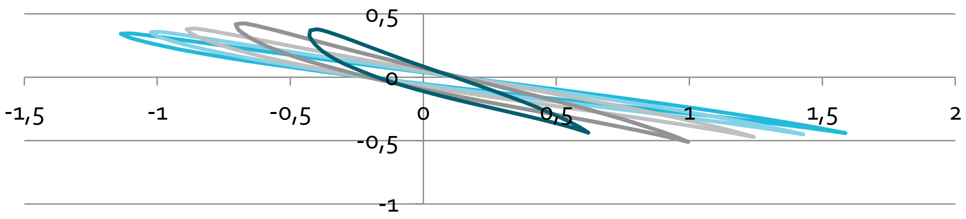
Development challenges

Issue:
A minor challenge was the absence of original documentation for the Kaplan turbine. While data for all other components was available, the turbine geometry had to be recreated based on existing measurements.

Solution:
For initial simulations reconstructed model was used for CAD, CFD simulations, and initial efficiency model.
In the future, during scheduled maintenance and turbine dewatering, a 3D scan will be performed to update and validate all models.







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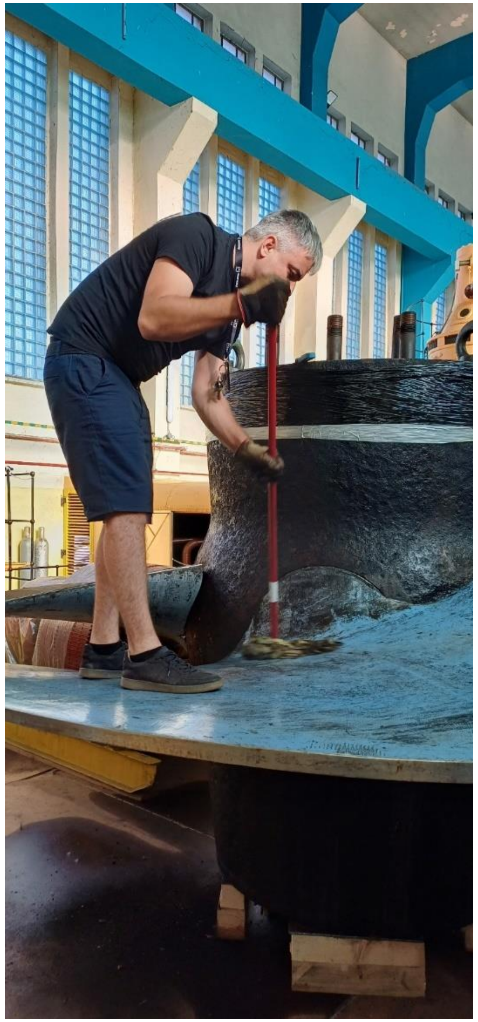
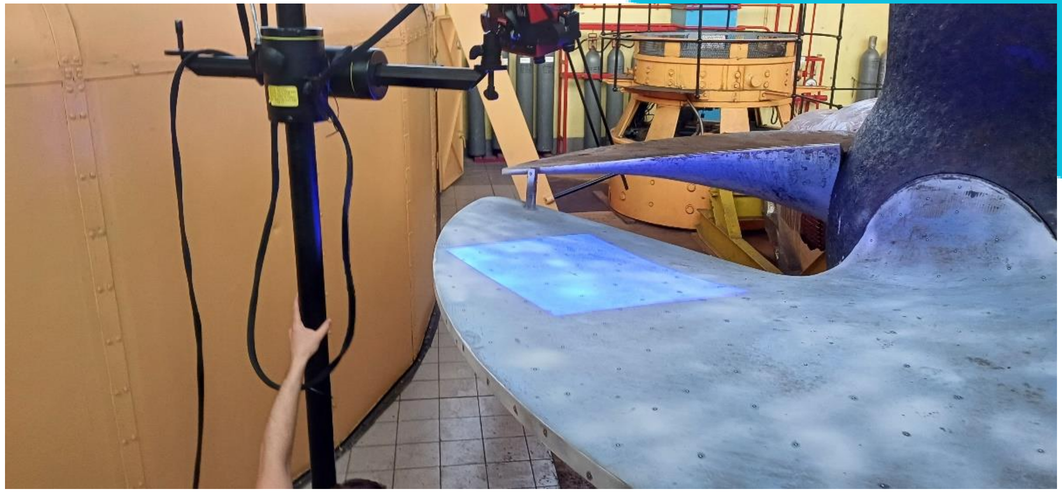
Development challenges



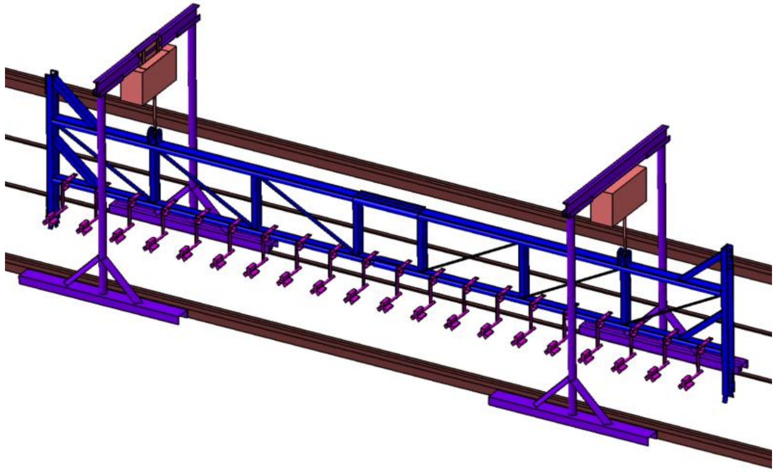


Development challenges

Issue:
The measurement devices at the power plant are older and originate from different time periods. As a result, not all key operational parameters are being measured.

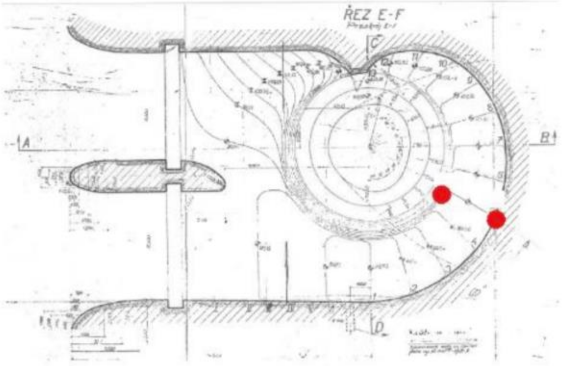
Solution:
A thorough review was conducted to identify missing or inaccurate measurements. Based on this, specific upgrades and additions to the measurement system have been planned.

Development challenges



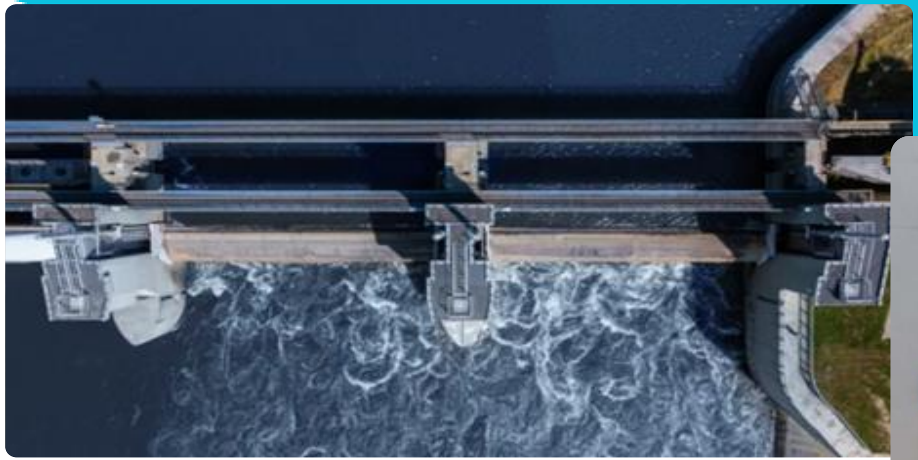
Issue:
Among all measurements, flow rate proved to be the most problematic due to the lack of dedicated and reliable instrumentation. Accurate flow data is essential for efficiency calculations and system calibration.

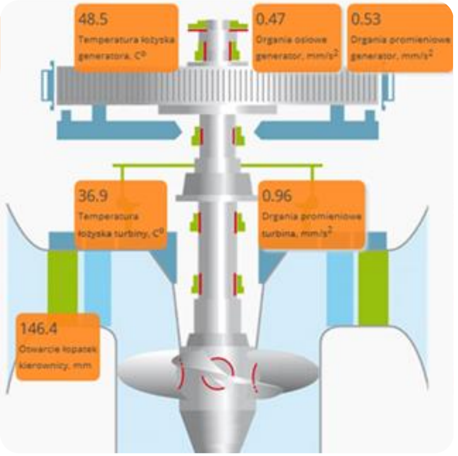
Solution:
It was decided to implement the Winter-Kennedy method, as pressure tap points on the spiral case were already available. This approach provided a cost-effective and sufficiently accurate solution for continuous flow monitoring..

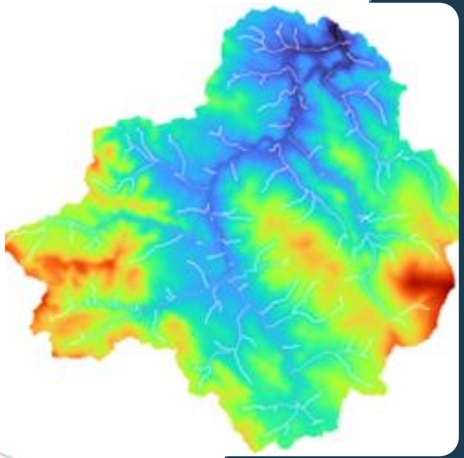


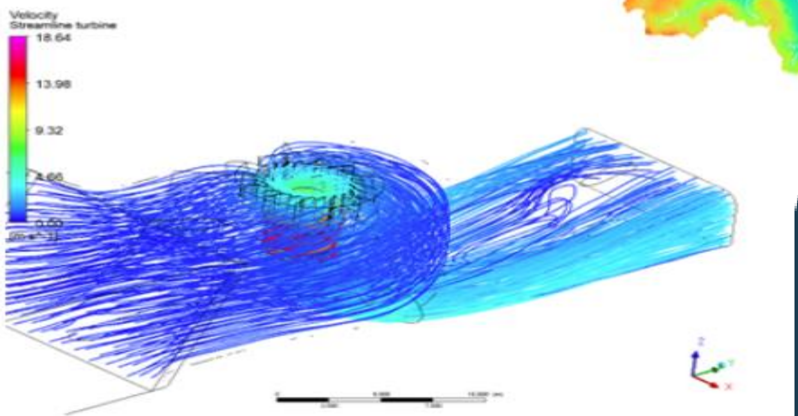
Work done

- Site inspection of HPP Waly Slaskie.
- Developed initial guidelines for the system.
- Performed hydrological analysis of HPP Waly Slaskie drainage basin.
- Created a digital CAD model of turbine using available documentation.
- Performed Computational Fluid Dynamics (CFD) simulations.
- Generated an initial characteristic curve of efficiency to assess performance metrics.
- Designed an expansion of the existing measurement system to fill all needs of the digital twin.



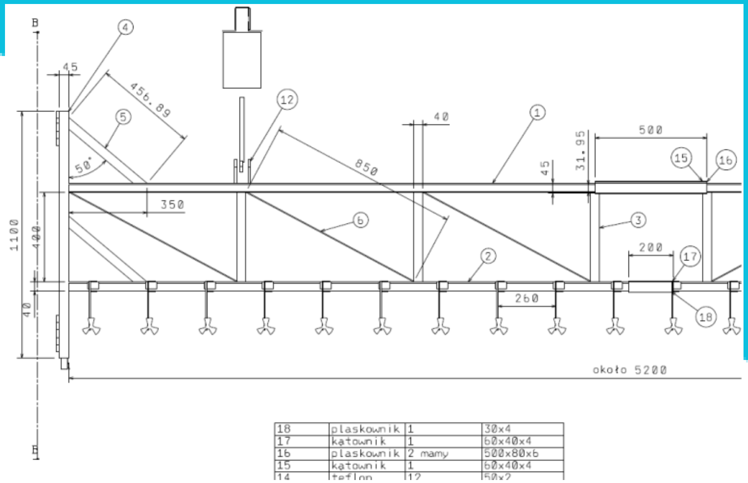


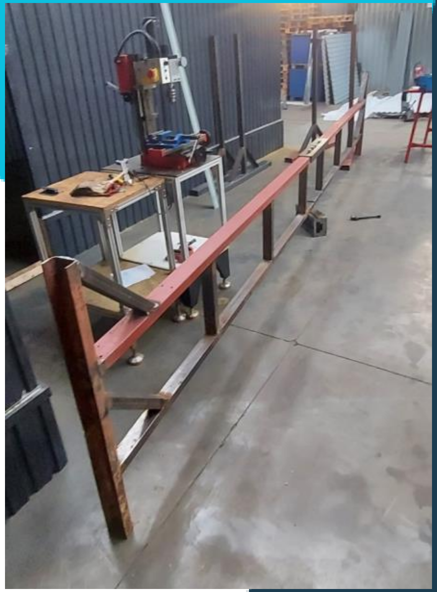


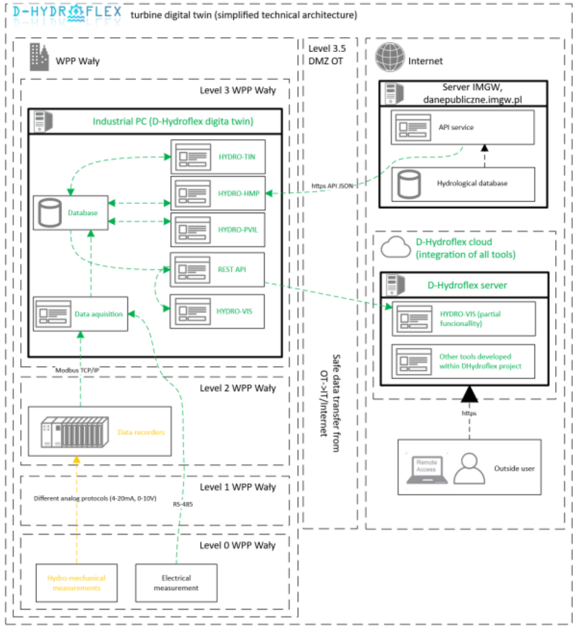


Work done

- Installed a differential pressure transmitter that will be used for flow measurements (first trials).
- Designed and manufactured a frame for propeller velocity meters.
- Designed architecture of a Digital Twin System
- Created concepts of tools that will compose the digital twin system
- **Developed initial version of all tools**
- **Updated water power plant infrastructure**







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Summary

The work is ongoing, and we are now entering the implementation phase. In the coming months, we plan to:

- deploy and configure the developed digital tools within the power plant environment,
- integrate all components into a functional system supporting day-to-day operations,
- carry out a series of tests and validations to ensure reliability and effectiveness in real-world conditions.

Thank you!

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