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PRECISE AI-AIDED SEDIMENT DETECTION TO PREVENT TURBINE DAMAGE

Sediment poses a direct threat to turbines, as can be seen here in a water channel at a power plant in Asia.

Sediments in the headwater are considered one of the greatest invisible dangers to turbines in high-pressure hydro systems. Up to now, turbidity sensors at the intake have been commonly used to minimise damage potential. However, this detection method has significant weaknesses. Global Hydro, the Upper Austrian hydropower specialists, set out to find alternatives – and identified a solution in the combination of structure-borne acoustic sensors and artificial intelligence. The new technology is being marketed under the name Hydrox SediSense, and enables precise detection of harmful where they actually have an effect– on the critical turbine components. This innovation marks a world first in hydropower, revolutionising the way operators protect their plants from abrasive damage, and opening up new possibilities for maximising economic efficiency.

TECHNIK

Climate change is affecting watercourses, in turn influe-ncing hydropower use. Heavy rainfall and flash floods are becoming more common, as are prolonged periods of drought and increased glacial melt. Consequently, sediment loads in the water used to drive turbines are increasing, particularly in the mountainous regions of Europe and Asia. Many operators are keenly aware of the effects microscopic particles in water driving their turbines have on turbine components – in particular, wear on the runners and other turbine parts. This results in declining efficiency, rising maintenance costs and, in the worst case, unplanned downtimes.

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"We are currently facing major challenges, particularly at power plants in glacial catchment areas and where water used for turbine operation comes from rivers with high sediment loads. So a few years ago we asked ourselves if we could counteract this risk with our existing digital

Francis turbine guide vane erosion caused by sediment loads.

solutions?" says Thomas Stütz, Head of Electrical Engineering and Software Development at Global Hydro Energy, explaining the initial situation. Stütz explains that for a long time there has been awareness of the sporadic nature of sediment contamination. Hence, above all it's precisely the extreme peak loads that cause the most damage to the runners, so it's the peaks which need to be mitigated. "Nevertheless, up to now the timely detection of these peaks has been problematic", the expert explains.

Limited reliability of data from turbidity measurement

To date operators have relied primarily on turbidity measurements to detect sediments in headwater. The methodology only provides data of limited reliability, mainly since the probes are in the water and are exposed to adverse environmental influences. The presence of algae, air bubbles and suspended organic matter can all lead to 'false positives'. Specifically, high turbidity may seem to have been detected, and can necessitate plant shutdown, although actually there may be no real potential for damage. "Such probes only measure water quality; not the actual potential for damage and they are often installed relatively inaccessibly, kilometres away from the turbine. They require maintenance and are susceptible to various influences," details Günther Weidenholzer, Data Science team leader at Global Hydro. Weidenholzer and his team set out to find an alternative to industry-standard turbidity measurements – and that set the ball rolling at Global Hydro.

Fossil fuel industry supplies key technology

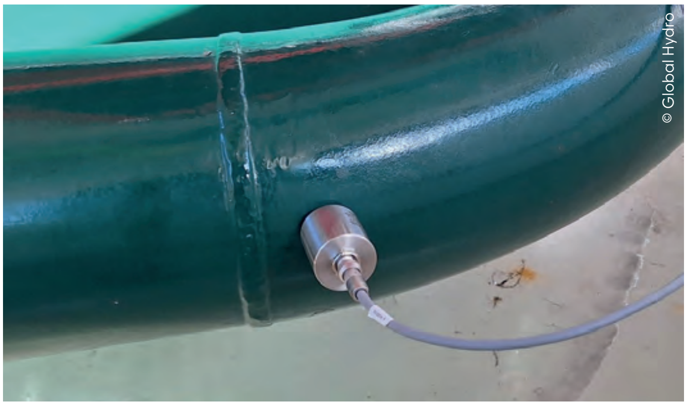
"We aimed to take a different approach by detecting the actual local damage potential," says Günther Weidenholzer, relating that the key to a new technological application was

Luggauerbach power plant in Dorfgastein (Austrian Federal Forestry Office) is a pilot plant for monitoring via Hydrox SediSense.

not found in hydropower itself, but came from the field of fossil fuel energy production. "Acoustic sand detection has been used in oil production for decades to detect abrasive sand particles in pipelines at an early stage. This robust and proven technology has now been adapted successfully for hydropower to develop Hydrox SediSense," the engineer reports.

But what exactly is the principle behind the technology? Reports on the problem of sand particles in conveyor systems and pipelines began to emerge in the 1980s. At high flow velocities, these particles cause damage to pipes, especially at points where the flow direction changes, such as in 90-degree bends and where there are obstacles. These are precisely the points where the first structure-borne sound sensors were mounted to detect sound events caused by particle collisions. The measurement principle is based on the fact that every particle collision generates an acoustic impulse, the intensity of which directly correlates with the extent of mechanical stress and thus damage caused. Double the sound intensity means approximately

Y-pipes are also suitable locations to mount a measuring probe.



The structure-borne acoustic sensor is simply attached to the bend.

double the damage. This applies equally to water pipes and oil or gas pipelines.

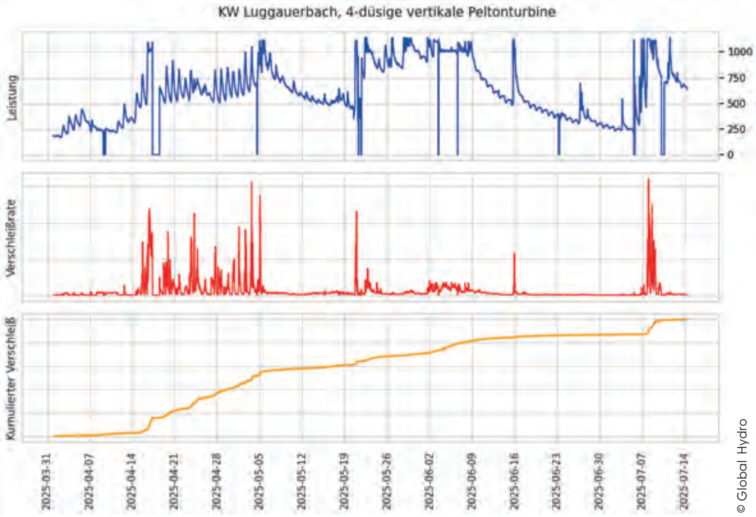
Simple installation for a cost-effective solution

A suitable application of this technology in hydropower is to attach acoustic emission sensors to turbine components that are subject to sediment wear. . One major advantage is that they can be installed in dry conditions, usually non-destructively – without drilling or welding, and mostly using adhesive adapters. No external infrastructure is required at the inlet. "This makes the solution particularly attractive for high-pressure systems in which inlets can often be kilometres away. Easy integration into existing systems ensures Hydrox SediSense is ideal for both new builds and retrofits," Günther Weidenholzer says. He adds: "Technically speaking, retrofitting is only really more demanding in the case of vertical, completely concreted Pelton turbines." To be specific, the sensors are installed on the inlet flap or on the cone in front of the valve. For Pelton turbines they can be installed on pipe elbows or Y-pipes and, in the case of Francis turbines, on the spiral casing, guide vanes or draft tube cones.

Structure-borne sound sensors are a very robust and completely maintenance-free technology. Furthermore, they offer the advantage of being extremely cost-effective. Conventional turbidity measurement in the industry can be several times more expensive.

From conventional physics to data analysis

Sediments transported by flowing water have the greatest effect where water is diverted, accelerates or hits solid structures such as guide vanes, inlet armatures, in bends and in constrictions. "This is exactly where we position the sensors – on the critical turbine components in the powerhouse. They detect ultrasonic-range sound waves in the structure generated by the impact of sediment particles. Impacts produce characteristic sound patterns, depending on particle size, speed and hardness," states Weidenholzer. The Global Hydro specialists are now introducing AI to evaluate these sound patterns. "The AI-based algorithms we have developed can identify various operating noises depending on the current operating status. This enables a special machine learning model to analyse the data and detect any deviations from normal operation," according to data specialist Thomas Stütz.



Evaluation by Hydrox SediSense from the 4-nozzle Pelton turbine at Luggauerbach power plant. The red line in the diagram displays the wear rate.

In other words, intelligence is used to separate relevant impact noises from operating noises, so conclusions can be drawn about possible damage scenarios. It sounds simple, but in practice it's no easy job. "One difficulty is the fact that hydroelectric power plants are complex and can vary very fundamentally. In data analysis, the challenge for us is to use AI to model the relevant data as accurately as possible in order to derive reliable conclusions," outlines Felix Minixhofer of the Global Hydro Data Science Team. Felix is currently writing his master's thesis on this topic and believes the benefit of this approach is obvious: "Our tools provide readings precisely where the turbine 'feels' the impact, rather than just from somewhere in the water intake."

Data Science Department team leader at Global Hydro, Günther Weidenholzer: "AI models enable acoustic information to become a reliable basis for decision-making, and digital intelligence to generate a real operational and competitive advantage".

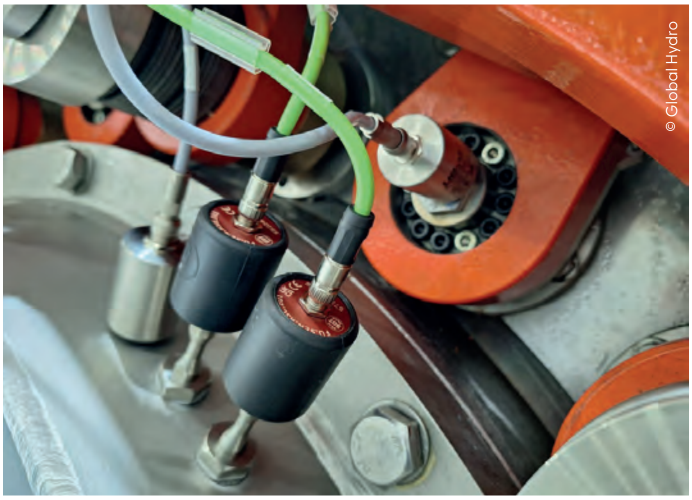
Business benefits from digital intelligence

The Hydrox SediSense AI model conducts a continuous analysis of the acoustic signature of the turbine during optimal operation. "Even minimal deviations from the norm can be detected. One example is the changed impact patterns that occur with an increased sediment load. The company's data science experts interpret these signals using machine learning and anomaly detection in order to derive crucial insights for key questions: When do harmful sediment loads occur? At what load level does it make more economic sense to shut down than to continue operating?" says Günther Weidenholzer, adding: "In this way, acoustic information becomes a reliable basis for decision-making – and digital intelligence offers a real operational and competitive advantage.

The conclusions drawn now enable precise recommendations for targeted action instead of blanket maintenance cycles. Pinpoint shutdowns are only carried out when erosion damage means operation is no longer economically viable. Decisions are informed by continuously trained AI models with a real-time supply of data from the turbine controller. Changes in status can be detected at an early stage, and the relevant information is forwarded to the operator in real time by means such as push notifications on mobile devices. One option is to usethis information to warn downstream power plants at an early stage. Another is to adapt and optimise load distribution between the turbines to answer operational questions: Which unit can tolerate sediments better under what load range? Support is provided here by IEC 62364, as it provides guidelines for assessing sediment erosion. Günther Weidenholzer explains: "The relationship between sediment load and efficiency loss is economically decisive. Our team has been able to demonstrate this in analyses conducted for renowned hydropower operators in Austria and elsewhere." Sediment changes the geometry of the runners over time, reducing efficiency and power yields. By using new machine learning models, Global Hydro has been able to create transparency in this area, providing a clear picture of the condition of the turbine – including wear and tear on seals and, in economic terms, identifying the best possible time for maintenance measures.

Interaction between sediment erosion and cavitation

One area that Global Hydro's engineers are still working hard on is how to factor in the complex interaction between sediment erosion and cavitation – two phenomena that not only influence each other but, in the worst case, even reinforce each other. The interaction reveals a previously underestimated aspect of hydropower as both processes generate structure-borne noise. In principle this noise can be measured, although it is usually difficult to locate precisely the parts affected, especially when damage patterns overlap. "Cavitation typically leaves fine, sharp-edged holes in the runner,while sediments grind the surface smooth again – creating cycles of damage and apparent 'repair'. It was difficult to differentiate between the two with structural sound analysis," explains Lorenz Neururer, head the HydroLab who is considered to be the expert on cavitation at Global Hydro. Turbines are in particular jeopardy when unfavourable operating conditions coincide with high sediment loads. Sediments can form cavitation nuclei, indirectly accelerating the rate of this type of damage.



One further advantage of structure-borne acoustic sensors over conventional turbidity sensors is their significantly lower cost.

Renowned hydropower operators such as TIWAG are already testing the opportunities opened up by Hydrox SediSense – as here at the ÖWK Tumpen-Habichen power plant in Tyrol's Ötztal valley.

Conversely, existing cavitation damage provides an ideal attack surface for abrasive particles. These processes reinforce each other mutually and are difficult to detect via conventional methods. New approaches that take advantage of structure-borne noise sensors have enabled Global Hydro to succeed in providing ever greater transparency to the complex interaction between erosion and cavitation. Nevertheless, the highly motivated team of Upper Austrian hydropower specialists is not content to sit on its laurels, and research is ongoing.

Tyrolean reference project delivers impressive results

Initial practical applications already demonstrate impressively how data-based decision-making can quickly deliver tangible value. One current pilot project is being implemented at the Tumpen-Habichen power plant in Tyrol, built by Ötztaler Wasserkraft GmbH and operated by TIWAG. The project is based on long-term measurements of sediment concentration in the Ötztaler Ache. The results have been more than convincing, as Thomas Stütz emphasizes: "The model for this application could be trained very quickly and required far less data than initially expected. The TIWAG operators now receive a stable and meaningful measurement of damage potential, which they can view in real time via the HydroxConnect portal. Comparisons with conventional turbidity probes show that Hydrox SediSense provides a more reliable and accurate reading." These findings also confirm: this world-first technology is far more than a diagnostic instrument – it is set to become a key to economically optimized power plant operation.

"Hydrox SediSense detects damage potential before it occurs, and enables operators to adapt operating modes dynamically in accordance. Individual measures combine to provide comprehensive holistic protection, taking damage prevention to a new level," reports Heinz-Peter Knass, Managing Director of Global Hydro.

AI integrated into an all-round prevention concept

Global Hydro's Hydrox SediSense tool marks a major advance in dealing with sediment-related wear in hydropower, particularly for high-pressure plants in alpine and glacial regions, as are frequently found in Europe and Asia. The system provides reliable real-time data for predictive operational management, especially where high sediment loads and inadequate desanding infrastructure coincide. The simplicity of integration makes the solution ideally suited for new plants, and for those retrofitting their infrastructure. "The real paradigm shift lies in the combination of proven wear prevention measures – such as high-strength materials, intelligent coatings and flow-optimised designs – supported by data-based analysis: Hydrox SediSense detects damage potential before it occurs, and enables operators to adapt their operating modes dynamically in accordance. Individual measures become part of a holistic protection concept – taking prevention to a new level," says Managing Director Heinz-Peter Knass, putting the innovation from Global Hydro into a broader context.Operators that value safety, cost-effectiveness and sustainability, see Hydrox SediSense as much more than a measurement and analysis system. It is an intelligent partner in the fight against sediment - the invisible enemy.

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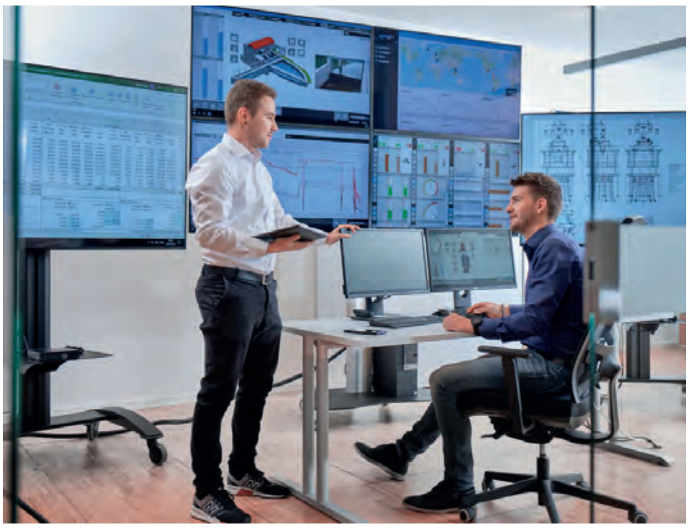

Global Hydro is setting new standards in the real-time detection of sediment wear on turbines, expanding its digital solutions with the innovative Hydrox SediSense product – an AI-supported measurement system.

Advantages of Hydrox SediSense

- *Direct indicator of damage: Unlike turbidity probes, which set indirect parameters, Hydrox SediSense measures the influence of the particles' kinetic energy by equating it directly with wear in that area.*
- *Cost-effective hardware with an intelligent algorithm*
- *Inexpensive sensor technology that is robust and easy to install. Key value lies in AI-supported evaluation – trained specifically for the situation at each plant.*
- *Easy to retrofit*
- *Installation outside the water body makes this solution perfect for hydropower plants with relatively inaccessible inlets, in glacial terrain or areas with high sediment loads.*

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