HYDRO GRID

WHITEPAPER

The impact of digitalization and data-driven decisions in hydropower

The promise of digitalization in hydro

Hydropower has immense potential to help accelerate the global energy transition. While wind and solar are powerful forms of renewable energy, water remains a ubiquitous and reliable contender.

Pumped Hydro energy storage also provides a more cost-effective renewable alternative[1] to battery storage with a longer lifespan, and a fully sustainable aid to a stressed network. These factors make hydro a significant piece of the energy puzzle.

However, for your hydropower plant to reach its potential and contribute fully to net zero, a rapid generation shift towards digitalization and modernization is needed. Our industry must urgently bring hydro plants up to date to make production planning, operations and reactivity streamlined, strategic, and efficient.

Armed with the right digital tools and insights, you can quickly gain control over equipment, operations and the daily challenges you face as a hydropower professional, whether your plants are old or new, large cascades or run-of-rivers.

In fact, more and more hydropower plants are embedding digitalization and reaping the rewards. Technology is also giving them the ability to deal with some of the big challenges inherent in our industry. We look at these more closely in the next section.

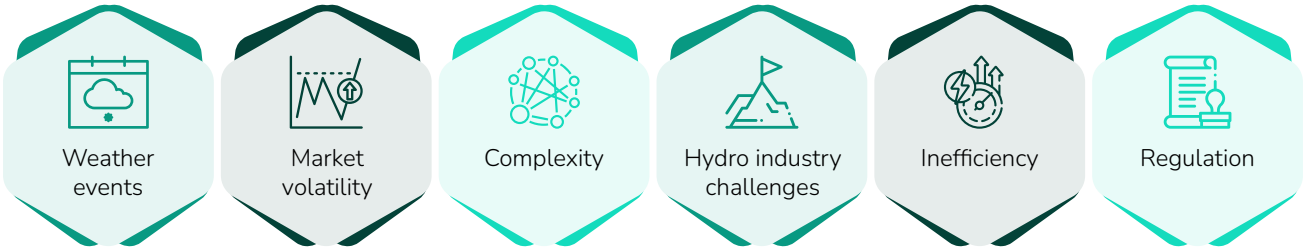
[1] Battery Storage vs. Pumped Hydro Energy Storage, Flare Compare, October 28, 2021. https://flarecompare.com/Energy%20Storage%20Technology/Battery%20Storage%20vs.%20Pumped%20Hydro%20Energy%20Storage/

Heading off the challenges

The hydro industry is contending with some increasingly urgent challenges, not least of which is the weather itself which can be both unpredictable and hazardous.

Market volatility is another major concern, and both have grown more pronounced than ever, making it harder to carry out long-term planning. Added to these are internal operational and regulatory issues.

These daily challenges can block you from pursuing hydropower modernization in favor of short-term action and firefighting. But by putting off hydro digitalization you affect your ability to keep up with the rapidly changing energy market.



Weather events

Your hydropower business wants to position hydro as a flexible and safe generation agent in the renewable mix, against solar and wind, so you can increase your power market share. Yet, more and more events are putting plant operations in danger.

One notable incident that made the headlines is the Brisbane, Australia 2011 flood class action suit. It led to 7,000 victims collectively winning a $440 million payout.[2] Complainants alleged that the dam operator failed to follow its own manual and didn't make sufficient room for heavy rainfall until it was too late, heightening flood levels and damaging more properties.

A more recent event was the partial collapse of the dam in Brazil's southern Rio Grande do Sul state in May 2024 during extreme rainfall[3]. This led to widespread flooding, loss of life and a state of emergency declaration.

Market volatility

Alongside weather volatility, factors such as supply variability, demand fluctuations, storage constraints, and market dynamics continually result in price volatility in the market.

In response, grid operators have increased the granularity of their expectations from all market agents, adjusting prices more frequently to reflect real-time conditions.

For example, in the EU's Nordic region, market granularity is down to 15 minutes. Market volatility and granularity are a major challenge for hydropower operators as they require constant vigilance and responsiveness to fluctuating data.

Another example is the increasing frequency of negative power prices which are becoming commonplace throughout Europe and which are calling for quick energy production adjustments.

[2] Brisbane flood victims awarded $440m settlement over Wivenhoe Dam disaster, news.com.au, February 26, 2021: www.news.com.au/national/queensland/news/brisbane-floods-victims-of-wivenhoe-dam-mismanagement-get-440m-settlement/news-story/440288c76f07aa7b9e861938441915fe

[3] Partial dam failure reported at 14 de Julho hydroelectric project in Brazil, Hydro Review, 5th March 2024: www.hydroreview.com/dams-and-civil-structures/dam-safety/partial-dam-failure-reported-at-14-de-julho-hydroelectric-project-in-brazil/

Complexity

On top of unpredictable weather events and market volatility, hydropower professionals live in an intricate world. You may be wrestling with complex optimization across multiple time horizons and power markets – with yearly hedging, day-ahead and intra-day pricing, and reserve products.

Plus, you need to react in real time, 24/7. Intra-day and day-ahead gains are potentially left untapped due to a lack of solutions or resources to realize them, which leaves money on the table.

Complexity can also come from unpredictable weather events, and the complex water management that cascades require. It also arises from the need to prioritize between the conflicting requirements of authorities, stakeholders, hardware use and market demand. The right balance between these is often not linear, but changes with the season and weather.

Inefficiency

As for your hydro business itself, inefficiencies can arise from various sources including manual or fragmented operational processes, siloed and/or unstructured data flows, and disjointed team collaboration.

All of these can hinder your decision making, duplicate work, delay response times, waste money, and give rise to errors.

Regulation

Lastly, companies face complex environmental regulations and operational requirements. Existing manual or legacy systems and operations tend to have a lack of transparency.

Consequently, it can take a lot of time and effort for you to present regulating authorities with the right documentation.

These challenges can easily preoccupy you as a hydropower professional, who may also be experiencing a lack of resources, prioritization or urgency to address them all.

So, how do you embrace the opportunities of digitalization in hydro amidst the challenges? And is digitalization a help or a hindrance in the current hydro climate? We examine these questions next.

Hydro digitalization: help or hindrance?

Your hydro plant requires continual vigilance and the ability to stay on top of day-to-day tasks and operations. Your mission-critical processes have been tried and tested, and your teams know how to follow and adhere to your operational guidelines and frameworks. The thought of introducing an additional layer of technology can seem a luxury rather than a necessity, right?

Plus, with all the talk of AI, cloud and automation in the news, it's easy to be overwhelmed by the potential of technology and the complexity it could bring.

However, the right technology can help small and medium hydro plants to address current market volatility. And it can help larger plants to create valuable efficiencies and cost savings.

For hydro plants of all sizes, digitalization can give back valuable time to your teams by eliminating manual and repetitive tasks. This allows them to use their expertise to their full potential. But that's just the start: digitalization can empower your plants to do so much more, as illustrated here.

Advantages of hydro digitalization

01

Support net zero

Digitalization is the first step in the urgent transformation hydropower needs to achieve net zero. Our current hydro plants cannot meet this goal if they continue operating as they have been.

02

Upskill your experts

Hydro digitalization will also support our industry experts with future-facing skills that come, for example, from understanding and acting on unified data from across the organization, predictive production analytics, or real-time trading insights.

03

Sustainability

Digitalization also supports your sustainability agenda by enabling more efficient use of water resources and better management between power, irrigation and drinking water needs.

04

Data-driven decisions

Digitalization enables your teams to make more accurate and timely data-driven decisions. Indeed, trusting data is proven to increase the resilience of your hydropower plant over longer timeframes.

05

Prepare for Black Swans

Finally, digitalization and AI-powered data insights can help you detect, prepare for and cope with 'Black Swans' - those unpredictable events that have potentially severe consequences.

Top market challenges

Hydro digitalization has the potential to modernize plants across the world. But they face different challenges depending on the region in which they operate. Here are some of the top issues and concerns in three key regions.[4]

North and Central America

- There is little new greenfield conventional hydropower planned, with a strong emphasis on refurbishment. Existing hydropower potential is concentrated within Canada (160GW potential), the US (65GW), and Mexico (20GW).
- North America favors solar and wind over hydropower, with the latter industry lobbying hard for government support.
- The US market is tightly regulated with profits taxed highly.
- The market is not incentivizing plants to engage in the US-wide re-licensing that is underway.
- Canadian plants are deciding whether they prepare for and engage with recently established day-ahead markets for energy trading.

Europe

- Europe's combined hydro plants have a total installed capacity of 258GW, with well-established plants in countries across the region.New projects are harder to establish because the continent is small and well-developed.
- Europe has a developed free market with many players, but legacy infrastructure and related capacity constraints are big issues.
- Solar and wind are driving a rapid increase in the number of yearly negative power prices hours.
- Some plants find intraday and day-ahead markets challenging to operate in.
- Other concerns are developing ancillary services and integrating with the rest of the renewable ecosystem - particularly hydro storage.
- Market volatility is driving producers to enter more profitable short-term markets and seek technology solutions to assist them in this.

South America

- The hydropower front-runner, with a large installed base of hydropower assets, already supplying about 45% of the continent's power.
- Plants tend to operate in the state regulated market, which does not offer price freedom, but guarantees a certain price at which units can be sold.
- However, some countries now offer hydro power generators the option to send part of their outputs towards a new liberalized market.
- As a result, the same power plant can trade on both markets at the same time.
- The Brazilian government offers strong funding incentives to modernize hydro through digital technology solutions.
- Climate-related changes make extreme weather a challenge for South American hydro plants, especially droughts and heavy rainfall.

[4] 2024 World Hydropower Outlook, International Hydropower Association: https://www.hydropower.org/publications/2024-world-hydropower-outlook

Digitalization concerns for SME and mid-sized plants

If you are a small or medium-sized hydro plant practitioner, it can seem more daunting to approach the idea of digitalization than it is for a larger player. Bigger plants arguably have more resources to grapple with issues around operational complexity, legacy processes, IT scalability, and so on.

Smaller plants, on the other hand, have a wide range of pressing concerns which can hinder digitalization, though they recognize technology can also help alleviate them. These include the following.

01 Lack of resources and expertise for real-time decision-making.

02 No effective data sharing or visualization and internal coordination.

03 Little IT resource to implement digitalization and modernization.

04 Siloed collaboration and a reliance on manual processes.

05 Compromising on profit and water management due to regulatory compliance.

06 The need to recruit and train a new generation of hydropower operators.

07 A small team doing the planning and manually carrying out operational tasks.

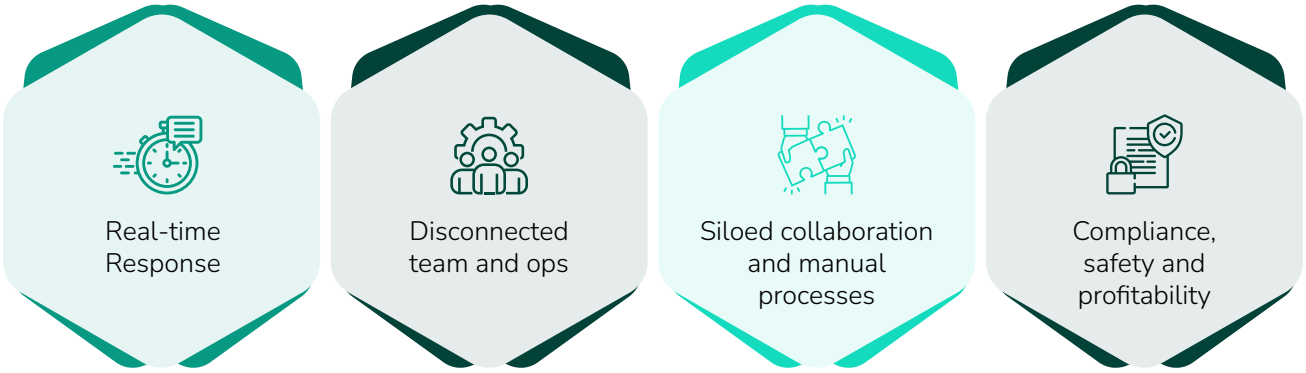
08 Budgetary constraints or lack of support for IT modernization.

Easing daily pain points through digitalization

Regardless of the challenges we face, hydro digitalization needs to be the answer if we are to make our plants more efficient, optimized, and ready to supply the higher levels of energy output the future will require.

This is where technological breakthroughs like AI, predictive analytics, automation, real-time intelligence and remote access to data are truly proving their worth. It's why we incorporated them into HYDROGRID Insight[5], to enable hydropower plants to combat the common pain points they experience daily, such as the ones that follow.

Daily pain points



The need for real-time response

Hydro digitalization can help you become more proactive and have shorter response times, for example by continually monitoring and analyzing a massive range of data points from across your plants. With this in mind, we built our algorithms to handle complexity and deliver real-time intelligence, allowing immediate reaction to every telemetry input.

We also use automation technology to create efficiency gains in hydro. We can optimize production planning for highest revenues, considering all given environmental and operational restrictions. And our integrated tools allow you to responsively steer constraint-guided optimization.

Disconnected teams and operations

Hydro digitalization can deliver integrated solutions for plant management and optimization, uniting your teams. For example, HYDROGRID brings all plants under a single data management and optimization platform, increasing the connectivity between all the components of your plant, teams and relevant stakeholders.

This connectivity improves reaction times and the quality of outcomes by helping you to work out the implications of each operational decision, and optimizing all parameters impacted by it.

[5] Make hydro a power for the future, HYDROGRID: https://hydrogrid.ai/#utm_source=digitalization-whitepaper&utm_medium=resource&utm_campaign=Digitalization+Whitepaper

Siloed collaboration and manual processes

Through our solution you can gain collaboration tools that embed data-driven decision-making and transparency. For siloed organization, this brings much-needed organization-wide cooperation to deal with the fast-changing hydro environment.

Operational, trading and other teams benefit from having a unified web interface, the HYDROGRID Insight 'Cockpit'. This gives you a detailed outlook of our optimization outputs, and control over how you want to optimize.

Through it your personnel can input new data, and replace or delete current information, such as constraints, strategy adjustments, and telemetry updates. They can also apply powerful new machine learning techniques to create new efficiencies.

Take smart inflow prediction as an example, which is all about learning from the past to forecast the future and minimize imbalance costs. HYDROGRID Insight makes it easy to collect, structure and organize 'raw' data into actionable insight on future reservoir inflows with a high level of accuracy and reactivity[6]. We use multiple machine learning forecast models tailored to different time scales, and to each hydro basin, to ensure the best predictions.

Compliance, safety and profitability

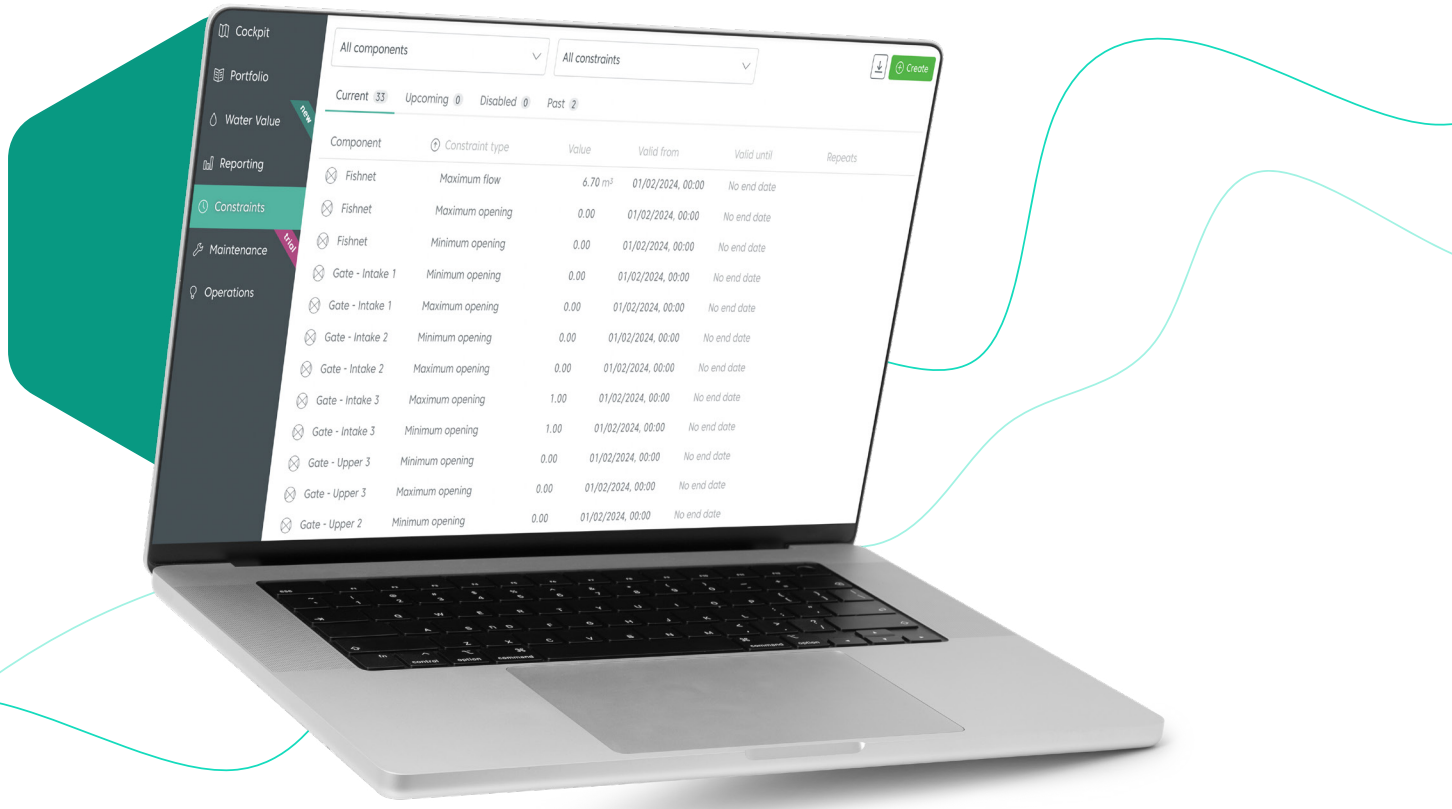
Digital technology can help you deliver strategies for maximizing profit while ensuring regulatory compliance and asset safe operations.

Regarding environmental and operational compliance, our solution logs all the data you need for historical constraint reporting and can automatically generate periodic reports.

It will also communicate your constraint compliance and results in a timely manner in a consistent, engaging format. Furthermore, it will keep you within safe boundaries by managing and optimizing a wide range of constraints for water usage and energy output.

Lastly, digitalization enables you to gain back time and peace of mind. It does this through environmental and operational restriction management, optimal maintenance planning, automating environmental requirements, and creating transparency and documentation for compliance purposes.

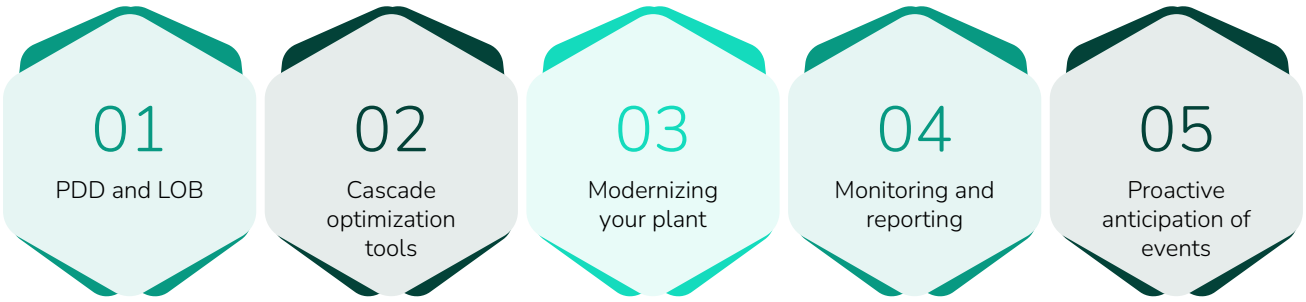
Peace of mind also comes from the ability to log in and make changes - and effect immediate action - to production planning from anywhere that you can access the internet. This flexibility is especially reassuring for hard-to-reach control rooms at isolated plants that need to be supervised 24/7 and can take hours to travel to.



Using digitalization to modernize your plant

With hydro digitalization you can go further still by incorporating dynamic, forward-looking tools into your organization that let you scale fast and with minimal resources.

Driven by the latest artificial intelligence and analytics algorithms, they can transform your plants and make them more responsive and resilient to change. With a technology solution like HYDROGRID Insight, therefore, you can develop new capabilities that yield next-generation results for your plant, such as the following.



Price Driven Dispatch and Limit Order Bidding

Volatile markets have become the norm, as plant operators focus on higher reactivity and strategic water management. Knowing this, we created HYDROGRID Insight to offer hydro asset managers a tool to become proficient in today's volatile market and maximize their water utility profits.

HYDROGRID Insight can provide both Limit Order Bidding (LOB) and Market Order Bidding (MOB).

Firstly, it can offer LOB, with a dispatch plan automatically aligned to the power market peaks, which also respects the present and forecast hydrological situation. As a result, you get a price dependent dispatch plan. Human intelligence refines and enhances your bid to account for market volatility and unpredictable events.

LOB is a bid that closely follows profitability criteria. So, if possible, it will store water instead of dispatching it if the price falls below a price limit. It can only do this in collaboration with market agents who need to know in advance how much will be produced. However, instead of telling the market agent how much you will produce each hour, you tell the market agent how much you will produce if the day-ahead price is in specific ranges.

(LOB only works for plants with significant storage capacity, though any storage facility will have some capability to do LOB.)

One powerful capability that you can achieve through LOB is automated Price Driven Dispatch (PDD). Unlike manual planning methods, PDD constantly monitors real-time spot, intraday and day ahead prices and adjusts production to maximize revenue while containing your operational and environmental constraints.

HYDROGRID Insight also provides MOB, where we translate the output of our optimization algorithms into a tailored Market Order Bid for you. You get a nominated bid, ready to use or adapt with no extra processing. If you want us to handle this for you, we can send it straight to the power exchange.

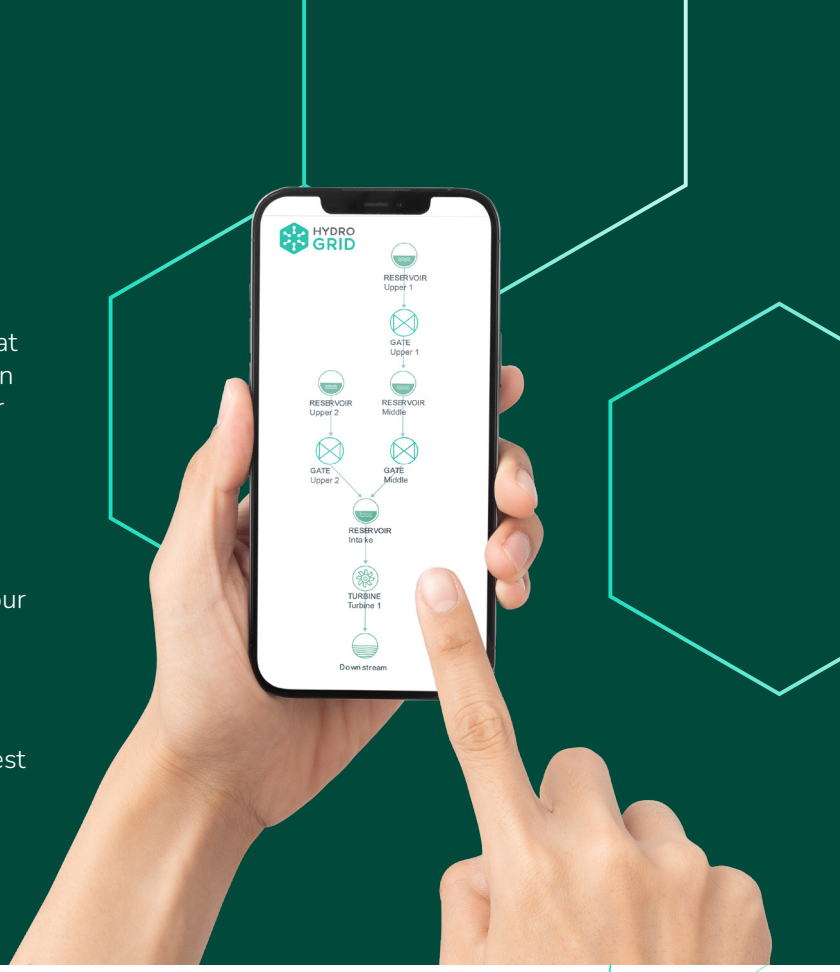
The ability to improve bids is valuable because it addresses the issue of wrongly estimating the available water, which can cause an imbalance of costs for the asset manager. Moreover, improving bids enables the storage plant to capitalize on the treasured advantage of energy storage and release.

With optimal production planning and trading, and the ability to react in real time, twenty-four-seven, HYDROGRID clients have experienced increased revenue by up to 50%.

Cascade optimization tools

Secondly, digitalization provides the means to look at cascades as a holistic system. Consequently, you can manage your water flows through multi-level water systems to maximize your use of every drop at all levels.

Our solution connects all elements of your cascade and its hydrological system. Then, by operating all your connected plants together, you can increase your strengths and reduce risk. You can also achieve full flexibility of an entire cascade, at no computational expense on your end. Finally, you can prepare for market highs or weather events by balancing upstream reservoirs to direct water towards your best performing turbines ahead of the event.



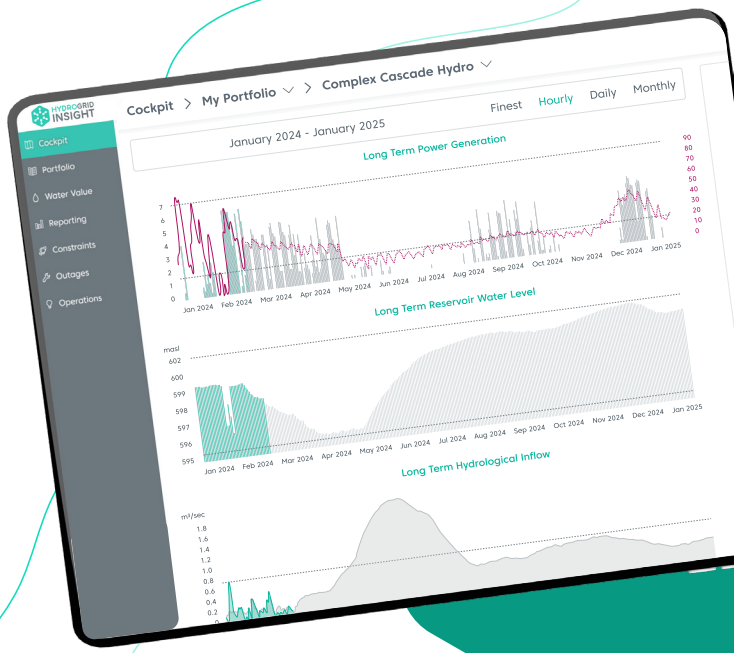
Monitoring and reporting

Hydro digitalization brings new levels of monitoring and reporting functionalities to your plants, based on its ability to create a single source of truth for data, and mobile and remote access to dashboards, among other things.

This makes inflow forecasting more effective for better short, medium, and long-term planning, for example best plan plant maintenance.

Complex inflow predictions are also now available for your run-of-river assets of all sizes. By predicting the inflow, and therefore the expected generation, you can minimize imbalance costs, and preemptively avoid penalties by preparing up to 14 days in advance, or more, for your expected inflow.

In fact, it is possible to plan long term: up to 12 months into the future by detecting seasonal patterns. However, as you'd expect, the further into the future you go, the less we use weather data in favor of historical data, with a larger dataset yielding stronger results, and vice versa.



Proactive anticipation of sudden events

As mentioned above, hydro digitalization can help you with quick reactivity and best possible anticipation to unpredictable occurences. Your response could be to fill reservoirs to the brim to hedge against weather and power market volatility.

Digitalization can also empower you to better anticipate and manage sudden events by using features like advanced hydrological modeling and inflow tracking, meteorological inflow forecast, reservoir level forecast, and cascade optimization.

Through technology-driven features like these, which are incorporated into HYDROGRID Insight, you can increase power generation by up to 10% and minimize your grid costs, as our clients have found.

Hydro digitalization case studies

In this next section we showcase some real-world examples of how our platform has helped hydro plants to overcome challenges and achieve significant improvements.

Large plant operator: SSE gains coordination and data-sharing

About SSE

SSE is a multinational energy company headquartered in Perth, Scotland, with over 12,000 employees. It generates more than 10,200 GWh of renewable energy per year for customers across the UK .

- **Challenge**
  SSE found it difficult to facilitate collaboration between its sizable teams and departments. In particular, the operations and trading teams made decisions and acted separately, leading to potential operational and cost inefficiencies.

- **Solution**
  HYDROGRID Insight gave SSE a single source of truth for its hydro power plant data, with all relevant personnel gaining appropriate access to the information they needed, and the means to collaborate and coordinate their actions.

- **Benefits**
  - HYDROGRID Insight has transformed collaboration at SSE.
  - It has increased production data transparency tenfold.
  - Plant professionals across the organization can now identify issues, inefficiencies, and opportunities.
  - The solution's remote access capability enables changes to be applied instantly, 24/7.
  - This has accelerated the company's responsiveness.

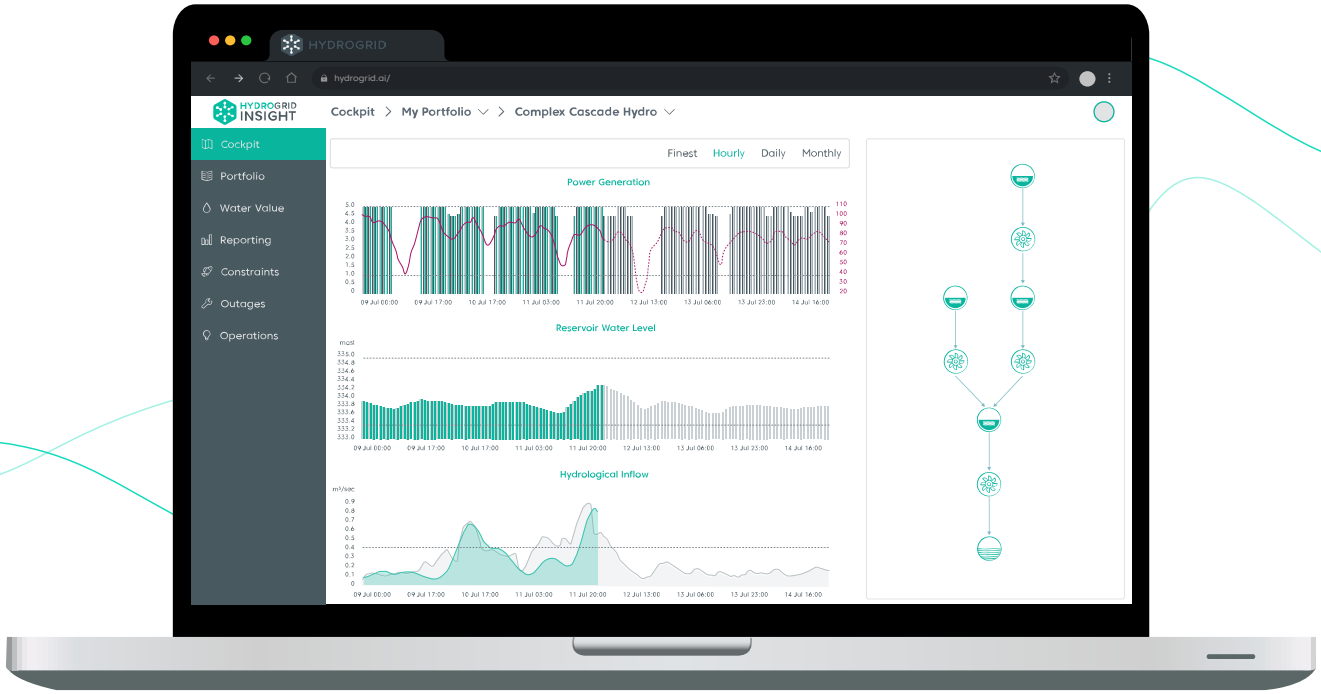
Mid-sized plant operator: Dalane Kraft automates operations

Dalane Kraft AS is a medium-sized Norwegian hydropower producer with 100 years of experience and a hydro portfolio of roughly 45MW installed capacity . The company owns and operates nine power plants in Rogaland County, Norway, and has several cascades in the range up to 10 MW.

- **Challenge**
  One of Dalane Kraft's cascades is Haukland, which was built in 1913. Despite the plant's small capacity (4.9 MW), it was difficult to operate due to the site's complex topology, which includes multiple connected reservoirs and flow control gates. Technical, environmental and other constraints also made matters hard for Dalane Kraft.

- **Solution**
  HYDROGRID Insight brought real-time automation to coordinate Dalane Kraft's system of multiple reservoirs, gates and turbines in real time, to avoid spill and imbalance costs. Digitalization also enabled Price Driven Dispatch, so the operator can exploit revenue opportunities created by market volatility, while ensuring all technical and environmental constraints are respected.

- **Benefits**
  - HYDROGRID Insight has facilitated high quality, efficient optimization of multiple power plants using fewer personnel, which has considerably reduced operational costs.
  - The solution reduced the operations team's manual effort, freeing up resources for other important tasks.
  - Dalane Kraft can now react extremely quickly to external changes and exploit the opportunities provided by power market volatility.
  - It can also execute a limit order strategy, minimize power trading risks, and both optimize and maximize revenues for its cascade system.
  - All environmental restrictions are automatically followed.
  - The solution maximizes efficiency by optimizing water utilization (preventing reservoir spilling) and increasing electricity production from renewable energy sources.



Conclusion:
Get future-ready with hydro digitalization

Hydro plants are operating at a pivotal moment in time, where the world is looking to our industry to be part of the solution in the seismic shift to net zero. Weather and market volatility, plant complexity, inefficiency and regulation are challenges to modernization for sure.

However, hydro digitalization can offer both an answer to these challenges, and a way to make our hydro plants more operationally efficient, profitable, and environmentally sustainable. As a result, by digitalizing your hydro operations, you stand to gain:

- Real-time reactivity and responsiveness to unpredictable events.
- Proactive anticipation of sudden events.
- Connectivity across disparate and disconnected teams and operations.
- Unified collaboration and automation of manual processes
- Enhanced compliance, safety and profitability.
- Price Driven Dispatch and Limit Order Bidding capabilities.
- Cascade optimization tools.
- Monitoring and reporting functionalities.

Click here

Take your next step towards hydro digitalization by booking a demo and seeing HYDROGRID INSIGHT in action.

WHY HYDROGRID?

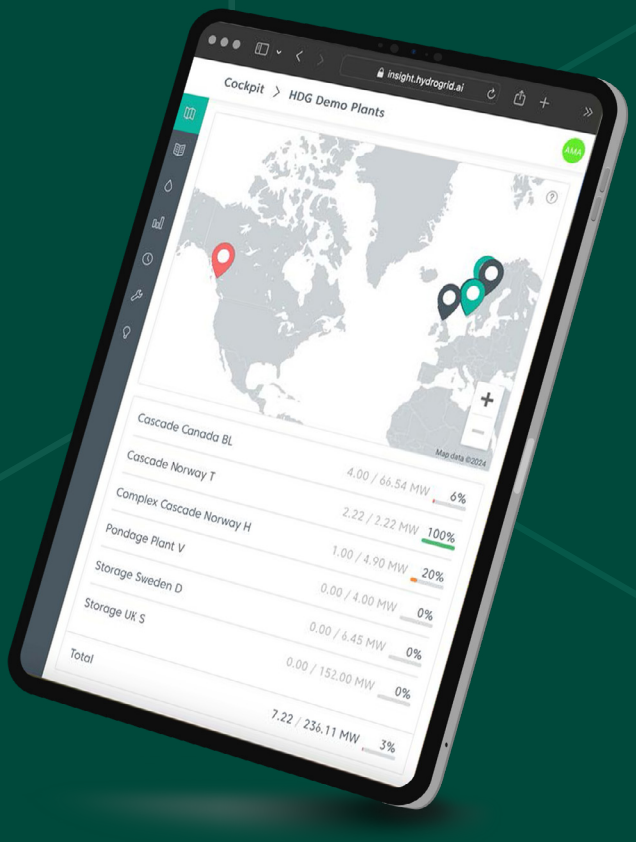
Predictive production planning and dispatch at your fingertips

Tailored to All Hydro Portfolios
Optimized solution to manage all hydro assets from simple run-of-river plants to complex cascades

Real-Time System Monitoring
Optimal planning, dispatch and power trading 24/7

Data-Driven Automation Models
continuously learn & recalibrate based on data

Quick Set-Up
Get up and running in 10 weeks



www.hydrogrid.ai

Walcherstraße 11A / Top 13 1020 Vienna – Austria

optimize@hydrogrid.ai

+43 1 375 3333 30