

HYDRONEWS

N°35

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Source: VERBUND

Groundbreaking for Austria's most modern pumped storage power plant

PSP Limberg III, Austria

In September 2021, groundbreaking took place in Austria for Limberg III, the new pumped storage power plant. High-ranking delegations from politics, industry and, of course, both the customer and owner, Verbund, collectively celebrated the beginning of this future-oriented project in the powerhouse of the pumped storage plant Kaprun.

The event kicked off with the blasting of the drainage tunnel, which not only marked the celebratory opening of the new power plant, but also the furthered progress of the works.

Approved in 2017, the Limberg III power plant project is a pumped storage power plant with a capacity of 480 MW in turbine mode as well as in pump mode. It is part of the Glockner-Kaprun power plant group in the heart of the Austrian Alps in the municipality of Kaprun. Like the Limberg II power plant, which was commissioned in 2011, it is being constructed completely underground between the two existing reservoirs of Mooserboden with a maximum water level of 2,036 m and Wasserfallboden with its maximum water level of 1,672 m.

ANDRITZ was awarded the contract for the design and engineering of two variable-speed, asynchronous motor-generators, including the excitation system, in May 2021. A follow-up order for the supply of these machines is expected to be awarded in early 2022.



Source: VERBUND



Source: VERBUND



Source: VERBUND

Once completed, Limberg III will feature a design specifically tailored to the future needs of the energy transition. Special machine set points will be used that can react extremely flexibly to the needs for balancing and energy control for the grid. In view of the increasing requirements resulting from the expansion of variable forms of renewable power generation, these are important services for grid stability – and one of the essential prerequisites for a secure and efficient power supply.

Silver Medalist at Paralympics 2021 in Tokyo



Source: GEPA pictures

Florian Brungraber – one of us

Olympic debutant Florian Brungraber, already Bronze Medalist at the European Championship 2019 and ranked ninth globally, won the second silver medal for Austria in the paratriathlon on August 29th.

Florian is also part of the ANDRITZ Hydro family. A highly motivated person and an excellent hydraulic development engineer, Florian joined the company in January 2006. After completing his mechanical engineering apprenticeship, he started in our hydraulic laboratory in Linz as a test bench operator. At this time, he attended and successfully completed a technical college evening course and was announced as a group leader at the end of 2009. In 2011, he had an accident while paragliding. After his rehabilitation in mid-2012, he returned and started in a new role as hydraulic development engineer and project manager.



Source: GEPA pictures

The whole management of ANDRITZ Hydro and all of Florian's colleagues are very proud of his success both on and off the field.

ANDRITZ receives an important rehabilitation order in Oklahoma

Robert S. Kerr, USA

ANDRITZ received a contract from the U.S. Army Corps of Engineers' Tulsa District for the rehabilitation and uprating of the turbines and generators at the 147 MW Robert S. Kerr hydroelectric power plant. Located on the Arkansas River in Eastern Oklahoma adjacent to the town of Cowlington, the plant, once recommissioned, is expected to generate about 152 GWh per year.

The scope of supply for ANDRITZ includes the design, manufacturing, supply, transportation, erection, testing, and

commissioning of four Kaplan turbine generator units with a capacity of 36.8 MW each, along with associated auxiliaries and ancillary equipment. The contract will be executed by ANDRITZ Hydro's USA subsidiary based in Charlotte, North Carolina. Commissioning of the first unit is expected in August 2025.

By securing this prestigious contract, ANDRITZ has further consolidated its position as a leading player in the hydropower market of the United States.



"From water-to-wire" – ANDRITZ' comprehensive hydro expertise

If the concern is heads of up to 2,000 meters, penstocks with a diameter of more than 13 meters, turbines up to more than 800 MW, generators with 850 MVA, or multi-year construction projects, then investors, project developers, and clients rely on a partner that distinguishes itself. A partner that characterizes itself not just through its technical expertise, but also its social competence, financial strength, and solid, long-term project management experience.



More than
180 years'
experience in turbine
design



More than
471,000 MW
of installed and modernized
power capacity



More than
32,000
turbine units delivered



More than
125 years'
experience in electrical
engineering



65
locations
around the world



About
7,000
employees worldwide



More than
50 Small Hydro
units per year



Complete
design range up to
800 MW



20
manufacturing
locations



10
test benches
worldwide

Hydropower – Key to a sustainable green future

Dear Business Friends,

Our world is changing. Aside from the pandemic, which is still impacting our daily life and work, natural disasters like floods and wildfires are putting issues such as climate change and the much-needed energy transition front and center. Important developments are underway worldwide to shift to a zero-emission future, but we must redouble our efforts to reach global decarbonization targets. If we do not accelerate the deployment of clean energy, the climate goals of the Paris Agreement will not be met. It is crucial that all opportunities to develop the huge potential for sustainable hydropower are embraced to secure our world for future generations. It is time!



[Wolfgang Semper](#)



[Harald Heber](#)



[Gerhard Kriegler](#)

In addition to the tremendous demand for new hydropower in developing countries, hydropower projects in combination with other renewable sources will take us much further towards a clean and green future. A pioneering lighthouse project is Kidston in Australia where a pumped hydro storage plant, a solar PV array, and later on a wind farm will be combined to form a high-performance hybrid renewable energy power hub.

The deployment of grid-supporting synchronous condensers in projects such as the EnergyConnect development in Australia, and the combination of hydropower with battery storage systems or floating photovoltaics are other ways to offer more capability in our management of the energy system. The need for more flexibility also opens up new business opportunities in response to the increasing share of intermittent renewables, which is challenging grid operations.

However, even more technological solutions are needed to reach our imperative decarbonization goals – new solutions like green hydrogen. Widely seen as a key part of the future energy toolbox, a lot of research and development effort is necessary to create a green hydrogen economy, but part of our energy will one day be met with green energy from hydrogen converted to electricity, heat, and motion.

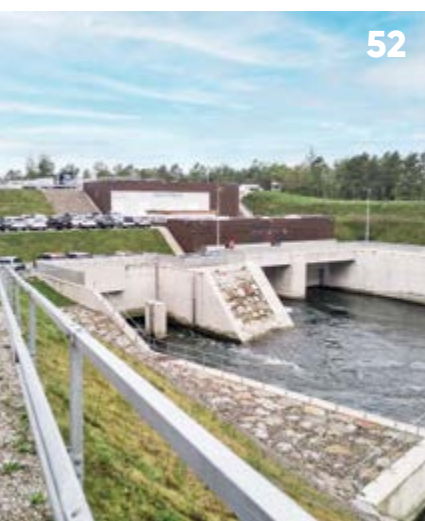
ANDRITZ Group is responding to all these challenges and finding the answers for tomorrow's problems today. "We Care" and with innovation and dedication, we have committed to support our customers and partners in reaching their ambitious environmental, social, and governance-related goals. Together we can build a green and clean sustainable future for all. It's a future we believe in.

With kind regards and sincere thanks for your trust and confidence,


[Wolfgang Semper](#)


[Harald Heber](#)


[Gerhard Kriegler](#)



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With 180 years of energy innovation, ANDRITZ continues to pioneer new ways of greening the global energy system.

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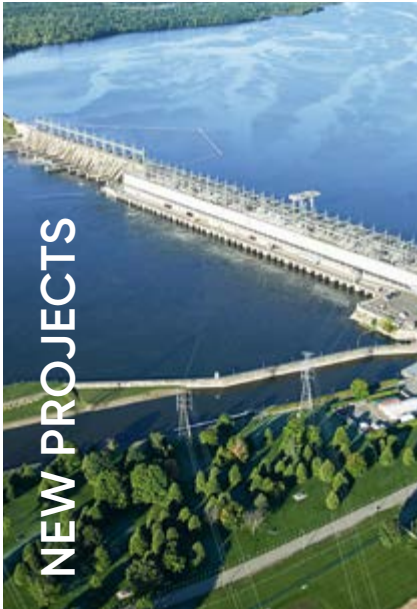
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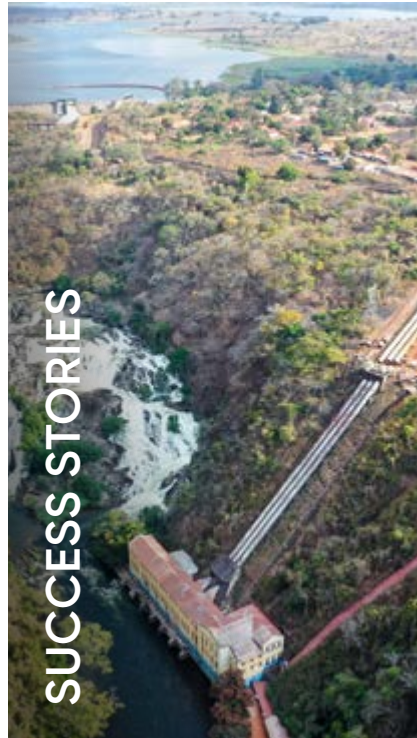
 gold member
advancing sustainable hydropower

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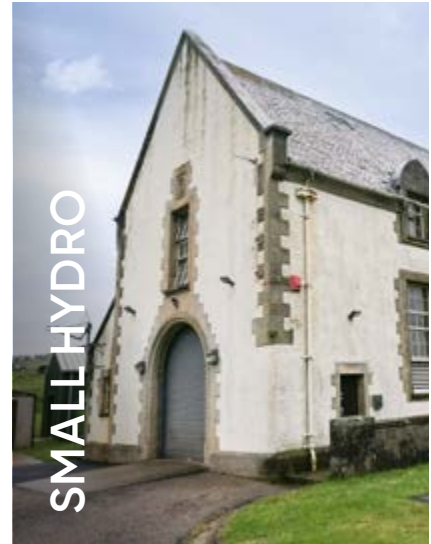
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HYDRO NEWS online magazine,
newsletter and contact information:

<https://www.andritz.com/hydronews>



ANDRITZ App:

Download on our website
or in the AppStore/PlayStore



IMPRINT:

Publisher: ANDRITZ HYDRO GmbH,
A-1120 Vienna, Eibesbrunnnergasse 20, Austria
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Alexander Schwab, Jens Paetz

Art Director and Editorship: Marie-Antoinette Sailer

Online magazine: www.andritz.com/hydronews

Published in: English, German, French, Portuguese,
Russian, Spanish and Chinese

Design: INTOUCH Werbeagentur, Austria

Contributing Photographers & Providers:

Adobe Stock, FreeVectorMaps.com

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ELECTRICITY FOR 150,000 HOUSEHOLDS

Canada — ANDRITZ

Hydro Canada is to re-equip up to fourteen 54 MW turbine generator units at the Carillon generating station after selection by Hydro-Québec, Canada as the exclusive project partner. Under the terms of a contract awarded on September 30, 2020, ANDRITZ will supply and install a first set of six units. Under a second separate contract due to commence on March 31, 2021, ANDRITZ is to rehabilitate the hydraulic passages at the plant. Realization of the project contracts awarded so far will span more than seven years.

Built between 1959 and 1964, the hydroelectric power station is located on the Ottawa River near Carillon in Quebec and on the border with Ontario. A run-of-river generating station with an installed capacity of 753 MW, the plant has a head of 18 m and a 26 km² reservoir.

ANDRITZ was the original equipment manufacturer of the existing turbines and generators. The first phase of the turbine generator contract includes the complete re-equipment of six units with new generators, speed governors, distributor components and Kaplan-type turbines. All removable parts will be replaced. ANDRITZ is responsible for the design, manufacture, transportation, assembly, testing, and commissioning of all the equipment.

Model testing for the Kaplan design was witnessed by the customer in February 2021, during which all performance guarantees were perfectly met. Both the model testing and engineering design activities were done in parallel based on a limited notice to proceed (LNTTP), issued in September 2019 to ensure the tight delivery schedule

for the first unit was met. Most of the design work is being performed at ANDRITZ facilities in and around Montreal where the project management office is located. This is less than 60 km from the Carillon generating station.

Procurement activities started in October 2020. Core laminations are coming from the ANDRITZ workshop in Weiz, Austria, and coil windings are being manufactured in the ANDRITZ workshop in Ontario. Most of the new components are being sourced from local Quebec companies, based on a priced option in the contract. This local content

requirement was initiated as part of the Quebec government's mid-term plans to jump-start the local economy following the downturn due to the COVID global pandemic.

A separate contract comprises all work related to the design, manufacture, and installation of hydro-mechanical equipment required for the repair and/or replacement of six hydraulic passages including civil engineering work. The scope of these contracts includes 18 new intake gates (6 m x 10 m), 18 sets of new embedded guides (25 m), rehabilitation of 18 trash racks (6 m x 20 m), as well as 18 new hydraulic hoist systems. This contract

also includes two further options, each for the rehabilitation of four additional passages, for a total of 14 hydraulic passages. Work has already started on the design and procurement phases.

Site works are due to start in November 2021 with the assembly and winding of the first stator in the service bay. ANDRITZ is also looking at maximizing the pre-assembly of components prior to receiving them on-site to reduce installation work over the 30-week planned outage starting in March 2022. The current plan is to complete one unit per year, with an option to see two units overhauled per year after the third is completed.

Having two contracts in the same powerhouse will allow ANDRITZ to leverage both project teams to find synergies and save overall site costs.

ANDRITZ' knowledge of the existing units, the expertise and local presence of its execution teams, as well as the team's proximity to the Carillon generating station make ANDRITZ the perfect partner for the execution of this important project, which could span over 16 years in total. Commissioning of the last unit is planned for 2036.

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With its 14 generating units Carillon produces 753 MW. That's enough for 150,000 Canadian households.



Source: Hydro-Quebec

TECHNICAL DETAILS

Carillon:

- Total output: 753 MW
- Scope: 6 x 54 MW
- Head: 18 m
- Speed: 100 rpm
- Runner diameter: 6,200 mm



Source: Hydro-Quebec

THE NEW OF AUS

A close-up photograph of a person's hand holding a large quantity of gold nuggets. The nuggets are bright yellow and have an irregular, crystalline shape. The hand is positioned in the lower right quadrant of the frame, with the fingers slightly curled. The background is a dark, textured surface, possibly soil or gravel, which is out of focus.

NEW PROJECTS — AUSTRALIA, KIDSTON

Featuring an innovative approach to integrating solar power and low-cost energy storage, Kidston is set to be the world's first co-located solar pumped storage hydropower plant. Located in an abandoned gold mine in Queensland, Australia, once complete it will deliver 'Renewable Energy on Tap'. ANDRITZ is supplying the electro-mechanical equipment for the pumped storage hydro elements of this ground-breaking new project.

NEW GOLD AUSTRALIA

Renewable Energy on Tap

Australia – Australia is going through an energy transition. With countless new wind and solar farms, a huge amount of variable output renewable energy has been connected to the national grid. Total annual electricity generation in Australia was around 265 TWh in 2019 with renewables contributing about 21%. However, just a year earlier in 2018 the share of renewable energy generation had been 19%.

In parallel, the low-carbon trend is also encouraging the decommissioning of the fossil-fueled generation capacity which provides vital grid stability functions. Indeed, Australia's government is expected to retire all its fossil-fueled power stations by 2050. Managing these two factors and maintaining stable grid characteristics requires bulk energy storage.



GROUND-BREAKING CEREMONY AT KIDSTON

The owner Genex Power invited to the ground-breaking ceremony for the 250 MW flagship project Kidston in Far North Queensland, Australia, on June 10, 2021. Selected guests were transported with chartered flights from Cairns to Kidston to visit the site at the old, abandoned gold mine, where the iconic pumped storage plant will be located. The ceremony included speeches, a site tour and interviews.



Pumped storage technology is a key enabler of variable renewable energy generation as it allows a sustainable approach to developing a zero-carbon power portfolio. A mature technology able to provide dispatchable and synchronous energy when needed, pumped storage hydro technology provides important ancillary services to the grid. These services, such as synchronous inertia, voltage

power hub is a flagship project. After the Kidston goldmine—at one time Australia's biggest and richest mine—closed in 2001, only some large excavations and a nearby ghost town remained. With two massive voids in close proximity and a big difference in their elevation, the site makes a promising location for the world's first co-located solar power pumped hydro storage project.

"The transformation of the old Kidston gold mine into a modern renewable power hub is a flagship project, combining sunshine per day and power at night to a giant battery."

and frequency control and black start capability, are vital to ensure grid stability and security of energy supply.

For these reasons the transformation of the old Kidston goldmine in Far North Queensland into a modern renewable

Renewable energy project developer Genex Power Ltd acquired the Kidston mine and the associated land for the project from the Queensland government. These assets include valuable infrastructure, such as the two open-cut water-filled pits, fully operable camp

infrastructure for accommodation, access to additional fresh water from the nearby Copperfield dam, as well as licenses, access roads and an airfield, a switchyard, and a 132 kV transmission line.

In 2018, a Joint Venture (JV), formed by EPC contractors McConnell Dowell and John Holland, in collaboration with Genex Power, conducted an international tender for the electro-mechanical equipment. ANDRITZ provided the best technical solution and was nominated as the preferred supplier. Over several months, the EPC JV partners and ANDRITZ were involved in a process of Early Contractor Involvement (ECI) to support optimization of the plant equipment, general layout of the underground cavern, construction methodology, and the delivery program.

Early involvement in the project allowed consideration and evaluation of different technical approaches and solutions,





Source: Genex Power



Source: Genex Power

Wises and Eldridge Pits act as the upper and lower reservoirs with a water head of about 218 m (max) to 181 m (min) drop. The head variation of the upper reservoir is only about 3 m, whereas the level of the lower water reservoir varies by about 40 m.

positively impacting costs and delivery. The ECI process also presented an opportunity for developers and EPC contractors to tender preliminary and basic designs and involve expert partners like the plant equipment original equipment manufacturers and international technical consultants. This facilitated the rapid development of an advanced design, reducing time and minimizing project risk for the owner when compared with a traditional tender process. Ultimately, both the EPC JV contractors and the project owners benefited from this process. In April 2021, the Kidston project achieved the milestone Full Notice to Proceed and ANDRITZ was able to sign the contract with the EPC JV contractors.

Since 2017, a 50 MW solar farm has been operating near the site, which provides a continuous revenue stream for Genex Power. A 150 MW wind farm and further solar expansion is planned, which will contribute the energy needed to pump water from the lower to the upper reservoir when needed. Construction of the associated 250 MW pumped hydro plant has now begun.

A closed water system, the plant will feature two 125 MW reversible pump turbines and will be equipped with technically sophisticated features in order to provide reliable and continuous generation capacity. Due to the existing shape of the upper and lower water reservoirs (Wises and Eldridge), the head variation of the upper reservoir is about 3 m only, whereas the level of the

lower water reservoir varies by about 40 m. However, the ANDRITZ pump turbines will be able to overcome this challenge and efficiently generate 2,000 MWh over an eight-hour continuous generation cycle. In 2021, ANDRITZ also secured a full Operations and Maintenance (O&M) contract of more than 10 years. The plant will be fully managed by ANDRITZ and remotely connected to the ANDRITZ control center in Schio, Italy.

“The local people welcome the project as it is also revitalising the remote area. It creates work. It creates opportunities. It creates perspectives.”

The facility is to be connected to the grid through a new 275 kV transmission line, currently being built by a major Australian construction company. This line will stretch approximately 200 km to a new switchyard on the East Coast of Queensland.

After completion in 2024, the Kidston project will generate enough electrical energy to supply approximately 280,000 households with clean and sustainable energy, the equivalent of taking 33,000 cars off the road.

This iconic project is also revitalizing the ghost town of Kidston and the whole

TECHNICAL DETAILS

Kidston:

Total output: 250 MW

Scope:

2 × 125 MW reversible pump turbines

2 × 149 MVA motor-generator units

Head: 220 m

Speed: 375 rpm

Runner diameter: 3,440 mm



region as it creates jobs, initiates opportunities for locals and resuscitates infrastructure and existing facilities.

ANDRITZ is extremely proud to play a key role in this unique development and to be able to support Genex Power and the Australian people on their way to a stable and renewable energy future.

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This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.

ISITG

Powering up to reach

With 180 years of energy innovation, ANDRITZ continues to pioneer new ways of greening the global energy system. From hydro hybrids to hydrogen, our ground-breaking technologies are helping to forge a more sustainable world.

"The energy transition is more urgent than ever. We must act now to achieve the goals. Hybridization offers one of the answers."

Catastrophic flooding across central Europe, crushing heat-waves in the US Midwest, large-scale forest fires in South- and Southeast Europe, record-setting temperatures and plummeting sea ice coverage – across the world it has been a summer of climate change-related calamity. Faced with the very real and growing effects of climate change, there has never been a more urgent need to address the use of fossil fuels and embrace a more sustainable

approach to our energy needs. The recently published IPCC Report confirms this, warning that commitments made in the Paris Agreement to limit global temperature rises to less than 2°C will not be met unless greenhouse gas emissions are sharply reduced.

Despite the impressive gains achieved by wind and solar power over the last decade, the consistency and reliability of hydropower means that it remains by far the single largest source of renewable energy today. According to the latest Renewables Global

approach to our energy needs. The recently published IPCC Report confirms this, warning that commitments made in the Paris Agreement to limit global temperature rises to less than 2°C will not be met unless greenhouse gas emissions are sharply reduced.

REEN?

global green goals

Status Report from REN21, global hydropower generation increased by 1.5% in 2020 to reach an estimated 4,370 TWh. Indeed, over the year, hydropower produced around 16.8% of the world's total electricity generation, about three times the energy that was contributed by wind. Hydropower is still also the cheapest form of renewable energy.

There is still plenty of opportunity for growth though. The year 2020 also saw an estimated 19.4 GW of new hydropower capacity, bringing the worldwide total

to 1,330 GW. But alongside the direct contribution, hydropower also has an increasingly important role as an enabler of other renewables. But we need to accelerate even more! "At the present rate of hydropower development, net zero emissions will not be realized," warns the International Hydropower Association, calling for a near doubling of installed capacity by 2050. "This is a wake-up call for policy-makers, hydropower developers and project financiers and provides clarity for the public," their latest Hydropower Status Report concludes.





Increasing volatile energy sources like wind and solar are increasing the need for the balancing qualities of hydropower.



UNIFYING RENEWABLES WITH HYDRO

One of the key challenges associated with significantly increasing wind and solar is their variability. The grid can become unstable as the proportion of such renewables increases and thermal fossil fueled capacity decreases. This in turn can have serious impacts on power quality and grid-connected equipment, but peaks and troughs in renewable energy generation also rarely coincide with changes in demand.

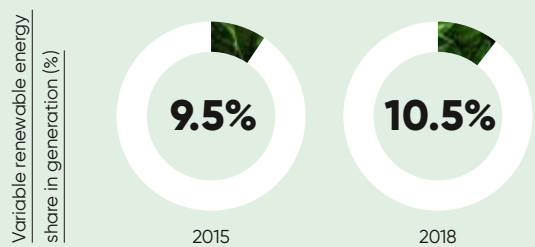
The most obvious solution is to increase the availability of storage that can accumulate excess renewable power and release it on demand. However, although chemical battery technologies have come a long way, pumped hydro storage is by far the cheapest and most effective form of bulk energy storage. According to REN 21, a further 1.5 GW of pumped hydro was added over the course of the year, representing a significant boost for variable output renewables.

While conventional pumped hydro storage continues to see growth, key innovations are set to expand the opportunities available. In Australia, for example, a novel project is underway transforming a disused mine into a renewable energy asset.

RENEWABLE POWER GENERATION – A GLIMPSE AT THE DEVELOPMENT

- At the end of 2020, global renewable generation capacity amounted to 2,799 GW. Renewable generation capacity increased by 260 GW (+10.3%) in 2020.
- Solar energy continued to lead capacity expansion, with an increase of 127 GW (+22%), followed closely by wind energy with 111 GW (+18%).
- Hydropower capacity increased by 20 GW (+2%) and bioenergy by 2 GW (+2%).
- Geothermal energy increased by 164 MW.

Historical
2015–2018





Kidston, Australia – Co-located pumped storage and PV power plant
 → [More on Page 10](#)

“The immense potential of hydropower has by no means been fully exploited. It can make a significant contribution to the redesign of our energy supply system on the road to sustainability.”

Set to be the world’s first co-located solar and pumped storage hydropower plant, Kidston is located at an abandoned gold mine in Queensland. After the mine closed in 2001, the remains included two large voids which were close to each other but feature a large difference in elevation. The project will couple a 50 MW solar farm with a 250 MW pumped hydro power plant. Subsequent phases will see another 270 MW of solar and a 150 MW wind farm added. ANDRITZ is supplying the electro-mechanical equipment for this unique project, including two 125 MW reversible pump turbines. When fully operational in 2024 it will be able to deliver 2,000 MWh over a continuous eight-hour generation cycle.

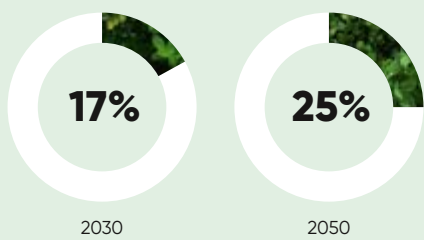
Another innovative large-scale hybrid pumped storage hydro-power and renewables development is underway in India.

The world’s first gigawatt-scale integrated renewable energy storage project, the Pinnapuram Pumped Storage Plant in the state of Andhra Pradesh consists of a 1.2 GW pumped hydro storage plant, a 3 GW solar plant, and 0.5 GW wind park all in close proximity. Once complete in 2023, it will have a daily storage capacity of 10.8 GWh which can be delivered over a nine-hour cycle. ANDRITZ is supplying the complete electromechanical equipment, including six 240 MW and two 120 MW reversible pump turbine units.



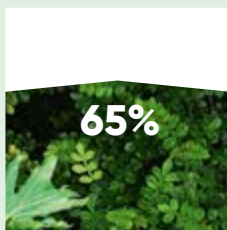
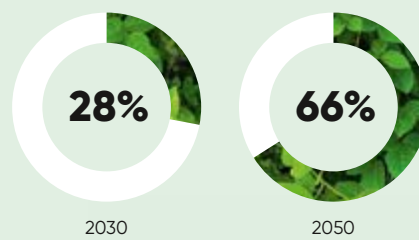
Where we are heading

Planned energy scenario / 2030 and 2050

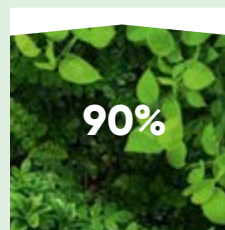


Where we need to be

Transforming energy scenario / 2030 and 2050



2030



2050

Source: IRENA, Global Renewables, Outlook 2020



Xflex Hydro – Roadmap to more flexibility
 → [More on Page 38](#)



Floating PV – A new concept for PV-hybrids
 → [More on Page 46](#)

→ **ANDRITZ INNOVATION POWERING UP OUR ENERGY FUTURE**

Projects like Kidston and Pinnapuram are excellent examples of how revolutionary hydro technologies are expanding the capability of all sustainable energy sources, but ANDRITZ is working hard to develop other technologies that can support the clean energy transition too.

For instance, ANDRITZ Hydro and Mercedes-Benz Energy announced a cooperation agreement in 2020 for a hydropower hybrid solution using modern lithium-ion batteries. HyBaTec increases revenues by shifting the

“For ANDRITZ, a clean and green future is the motivation to find tomorrow's solutions today. ANDRITZ' innovative technologies are helping to forge a more sustainable world.”

availability of renewables to peak periods but can also offer ancillary services for grid stability. Furthermore, HyBaTec is able to reduce stresses on older hydropower plants, increasing their operational lifespan by stepping in to supply short-term power when needed. Available from 500 kWh up to 30 MWh, HyBaTec units can be integrated into any hydropower plant.

The full capabilities of the battery and hydropower hybrid concept are being explored in a research program taking place at the Vogelgrun plant, a run-of-river project on the Rhine owned by EdF. The additional battery delivers a rapid power response and provides frequency containment reserve. ANDRITZ is at the heart of this project as part of XFLEX HYDRO, the Hydropower Extending Power System Flexibility initiative. Under this EU Horizon 2020-funded program, novel technologies that can improve the flexibility of hydropower are being tested at seven operational hydro facilities.

Another area of hydropower hybridization is the rapidly accelerating deployment of Floating Photovoltaics (FPV). Here, solar panels are fitted to pontoons floating on the surface of a hydro reservoir. This approach confers a number of efficiency advantages for solar panels and also makes use of space that would be otherwise unproductive, creating additional revenues as well.

Even beyond direct power generation and hydro hybrids, ANDRITZ innovation is helping to make our world a cleaner place. With nearly two centuries of expertise in rotating machinery, ANDRITZ offers

Australia, EnergyConnect Project –
 Synchronous condensers for a new interconnector
 → [More on Page 26](#)



Source: Transgrid



Hydrogen and Hydro – Fuelling our future
 → [More on Page 28](#)

a portfolio of Synchronous Condensers that provide grid services in support of variable renewables development. Synchronous Condensers provide multiple stabilizing functions to absorb rapid fluctuations between supply and demand, as well as dynamic voltage support and system protection.

ANDRITZ is also exploring and investing in research and development in other related areas, such as hydrogen. Widely perceived as the key to a green energy future, especially for many heavy energy using industries, a hydrogen-based economy will enable the separation between renewable energy and geographical resources. Further development of this concept may lead to a scenario in which Saharan sunshine powers European paper mills or green steel production. Recently, ANDRITZ Hydro and MAN Energy Solutions signed an agreement to jointly develop international projects for the production of green hydrogen from hydropower, starting with a pilot project in Europe.

LEADING THE CHARGE ON CLEAN POWER

While 2021 has been a difficult year for many that has bought the climate challenge into sharp focus, there is cause for optimism that the years ahead will hold better things. ANDRITZ is looking back on 180 years of industry-leading innovation. This long history of invention and discovery remains a central theme for the company to this day. From hybrid hydropower and renewables projects to novel pumped storage schemes, batteries, synchronous condensers, hydrogen and beyond, it is through innovation that the world will become a better and more sustainable place to live. By powering up on innovation, ANDRITZ continues to power us all towards a cleaner future.

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“Not only does its consistency and reliability make it the single largest source of renewable energy today, hydropower is also a primary enabler of other renewables.”



HyBaTec – large-scale battery energy storage for hydro
 → [More on Page 56](#)



megatrends

URBANIZATION

According to current predictions, the global population will increase to about 10 billion people in 2050. By then, half of the world's population will live in major urban centers. Currently, cities cover just 0.5% of the earth's surface. However, they consume 75% of global resources. By 2030, there will likely be 40 megacities with more than 10 million inhabitants each. These megacities will require billions of dollars of infrastructure investment. Furthermore, despite increasing energy efficiency, the energy demands of such megacities will be enormously high. Urban technologies are racing ahead to meet this challenge. An example is the emergence of "smart cities" and "responsive cities". In smart cities, inhabitants are able to interact intelligently and efficiently with their urban environment while in responsive cities, humans and human well-being are the central focus of planning concepts. Production and use of energy using smart and responsive systems are a key part of sustainable development in urban centers.

CONNECTIVITY

As the principle of networking based on digital infrastructures, connectivity describes the dominant basic pattern of social change in the 21st century. Networking and communication technologies are fundamentally changing the way we live, work, and do business. But the digital transformation also has social and cultural impacts. Digitalization should not be equated with technology only but also understood more comprehensively. The digital transformation will play an increasingly important role in all areas of life, resulting in a new awareness of the digital opportunities and a more reflective use of digital devices and technologies.

DEMOGRAPHIC DEVELOPMENTS AND ECONOMIC CHANGES

Every minute the world's total population increases by some 150 people overall and yet there are drastic regional differences in demographic development. In industrialized nations, populations are typically shrinking, and the majority of the people will soon be over 65 years old. Meanwhile, the population of Asian and African nations is growing. For example, Africa's population will probably have doubled by 2050. This is resulting in a political and economic shift, increasing the economic power of these developing countries and their emerging markets. These changes are also having a profound effect on current and future energy use in developing regions like Asia and Africa.

CLIMATE CHANGE AND RESOURCE SCARCITY

With an increasing global population, the trend for urbanization, and growing energy demand, it is clear that conventional fossil-based energy sources will reach their limits in the near future. Alternatives to fossil fuels are urgently needed. Without significant change, the average surface temperature of the planet will continue to rise. Although approximately 27% of the world's demand for electricity is currently satisfied through renewable resources, much more growth in renewable energy capacity is compulsory over the coming years if catastrophic climate change is to be avoided. At 60%, hydropower represents by far the largest share of renewables, even as other renewable sources like wind, biomass, solar, and geothermal energy are growing rapidly. Nonetheless, far more renewable energy capacity, including hydropower, is needed to avoid disaster.

Research and development of other zero-carbon energy concepts, such as green hydrogen, is also in full swing. Integrated solutions that optimally combine various renewable technologies are emerging and will be in even greater demand in the future. Environmental awareness and sustainability are now a central economic factor that already influences investment decisions in all businesses.

Megatrends develop slowly, but they are enormously powerful. Gross global changes affecting every aspect of the economy and society, they are exerting a profound influence on companies, institutions, and individuals. Consequently, they form the basis for the evolution of entire economic

sectors and are often the starting point for far-reaching strategies in government policy, companies, and industries, as well as other organizations and stakeholders.

Megatrends are interwoven too. Globalization and urbanization both have a direct impact on our environment, mobility, and connectivity.

They all are part of the big whole.

Global megatrends are shaping not only our present but our future too. Today, numerous global research and development projects are focused on megatrends. To face the challenges of a changing world, new concepts, innovative ideas, and alternative approaches are needed, especially in how we source, deliver, and use energy.

tr end e



7.8 billion
world population
today



10 billion
projected world
population by 2050



Megatrends and hydropower

Megatrends like urbanization, climate change and the digital transformation are fundamentally changing all aspects of our lives. Change can be challenging but also offers scope for positive change and for even greater opportunities for those companies, organizations and societies willing to embrace new realities.

Although the technically feasible potential of hydropower is an unbelievable 16,000 TWh per year, today not even one third of this potential has been exploited. Around the world people are working to develop this huge clean energy potential by building new hydropower plants, as well as modernizing and upgrading existing ones. According to the 2021 Hydropower Status Report from IHA, an estimated 21GW of hydropower additions took place in 2020 alone, bringing the total installed capacity to 1,330 GW (including pumped storage) and producing some 4,370 TWh, close to 17% of the world's total electricity generation.

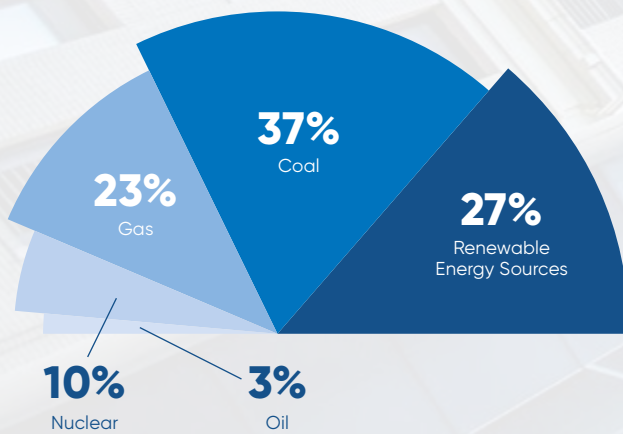
In regions where energy demand will increase dramatically in the next few years – such as in Asia, South America, and Africa – new large plants and a multitude of small hydropower projects will be implemented. There is also huge potential in Europe and North America, since half of the facilities here are older than 40 years and can make a more significant contribution toward power supply in the future

through modernization. Alongside its environmentally friendly generation characteristics, the benefits of pumped storage hydro to provide flexibility and cost-effective bulk storage make it an invaluable asset for the clean energy transition.

The IEA's Net Zero by 2050, A Roadmap for the Global Energy Sector forecasts that hydropower generation will grow by at least 9.5% through to 2025 to reach 4,650 TWh but the report also notes that hydropower capacity growth during 2023–2025 could be 50% higher per year on average if project development were accelerated. It is critical that all opportunities to develop the huge potential for sustainable hydropower are embraced to secure our world for future generations. Indeed, IRENA's Global Renewables Outlook estimates that an additional 850 GW of hydropower is required by 2050 for the world to stay on a climate-safe track in line with the Paris Agreement.

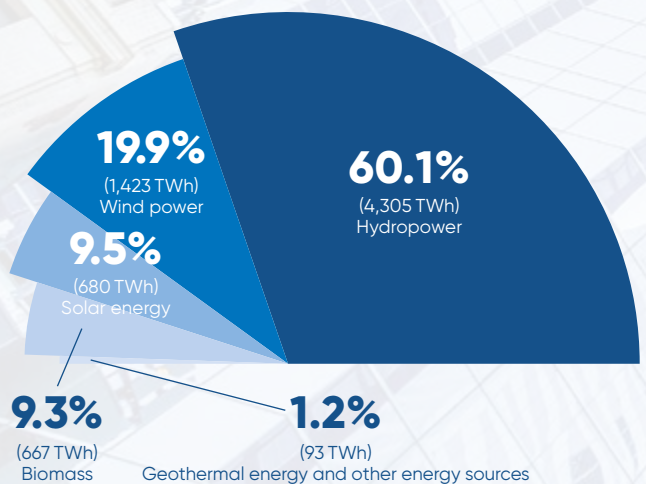
With 180 years of innovation, ANDRITZ has long been at the forefront of development, responding to megatrends with pioneering technologies and concepts and leading the transition to new and better approaches to meet the needs of society. That philosophy holds as true today as it did when the company was first founded. Faced with the profound impacts of global megatrends, hydropower and ANDRITZ innovation will be a long-term megatrend too.

Percentage distribution of worldwide power generation



Source: IEA World Energy Outlook 2020

Percentage distribution of power generation from renewables



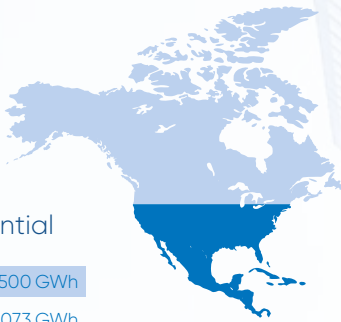
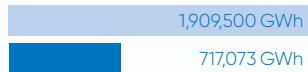
Source: IEA World Energy Outlook 2020

HYDROPOWER POTENTIAL PER REGION

North America

62%

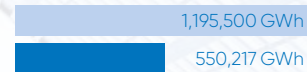
Hydropower potential



Europe

54%

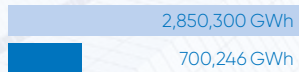
Hydropower potential



South America

75%

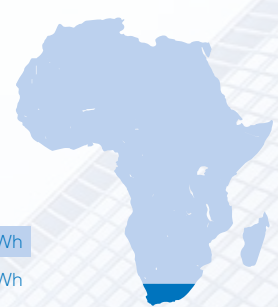
Hydropower potential



Africa

91%

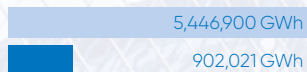
Hydropower potential



Asia (excl. China)

83%

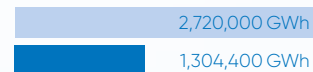
Hydropower potential



China

52%

Hydropower potential



Sources: World Bank, Zukunftsinstitut, PRB Population Reference Bureau, pwc, IEA, REN-21, IRENA, IHA, Hydropower & Dams World Atlas 2020

■ Technically feasible hydropower potential
■ Power generation from hydropower

Auto- mation at its finest

Source: EBY

TECHNICAL DETAILS

Yacyretá:

Total output: 3,200 MW

Head: 21.3 m

Voltage: 13.2 kV



Argentina/Paraguay – ANDRITZ Hydro Brazil is to supply 18 new excitation systems with HIPASE-E technology for the Yacyretá Hydroelectric Plant, located on the Paraná River between Argentina and Paraguay.

“Yacyretá provides clean, renewable, non-polluting, and low-cost energy, improves the navigability of the Paraná River, operates a flood warning system and facilitates the implementation of irrigation systems.”

In commercial operation since 1994, Yacyretá has an installed capacity of 3,200 MW and supplies the electricity needs of 50% of the homes in Argentina as well as many industries.

The contract between ANDRITZ Hydro Brazil and plant owners Entidad Binacional Yacyretá followed an international bid process. As expected, the qualifying process was challenging and demanded a lot of preparation from the entire team on technical, bidding, contractual and commercial aspects.

Through market expertise and excellent competitive position, ANDRITZ submitted a customized offer and won this contract against multi-national competitors. ANDRITZ was chosen for the complete modernization of the excitation systems including automatic voltage regulator, power cubicles, transformers, a set of auxiliary parts and components along with basic and detailed design, manufacture and assembly, factory acceptance tests, transport, site installation, and commissioning. HIPASE-E is an exclusive automation solution from ANDRITZ with proven control and regulatory functions suitable for the latest power generation requirements.

This is a very important project for ANDRITZ that not only highlights our competence and expertise in the automation market but also marks the beginning of a long-term partnership with Entidad Binacional Yacyretá.

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NEW PROJECTS — ARGENTINA / PARAGUAY, YACYRETÁ



ANDRITZ Hydro Brazil opens a new corporate office

A new ANDRITZ Hydro corporate office has opened in São Paulo, Brazil. The transformation is part of the company's overall modernization process and is intended to meet the needs of agility, flexibility and collaboration not only in our current context but also to fulfill the future business evolution. ANDRITZ Hydro Brazil has been using the new, modern space since July 2021 which, like ANDRITZ solutions, is designed for the future.

Sales, engineering, and order execution for automation, electrical power systems, and pumps are located in the building. In addition, the administrative and legal departments will be based in the new office, located at Alameda Tocantins, 350 – Alphaville Industrial, Barueri, in a commercial building of more than 31,000 m².

To learn more about our activities in Brazil please visit our website:
www.andritz.com/hydro-br

The new environment was designed to translate ANDRITZ Hydro's commitment to creating new perspectives for the ANDRITZ GROUP that are based on innovation, collaboration, and solid, long-lasting partnerships.

“With this change, ANDRITZ Hydro Brazil will be even better prepared to accept new challenges and contribute to future hydroelectric development in the country.”

Dieter Hopf, General Director of
[ANDRITZ Hydro in Brazil](#)



LET'S CONNECT

A NEW INTERCONNECTOR IN

Australia – ANDRITZ is going to supply the equipment for two synchronous condenser plants for the EnergyConnect project in Australia, which plays a vital role in Australia's pathway towards a renewable energy future.

As Australia is reinforcing the interconnection between states, the EnergyConnect project will be the new additional interconnector between New South Wales and South Australia with an added connection to north west Victoria. The new interconnector is a joint development between Transgrid and ElectraNet. Transgrid awarded an EPC contract to SecureEnergy, a joint venture between the Spanish company Elecnor, a specialist for energy infrastructure, and the Australian engineering and construction company Clough, to construct the approximately 700 km long high voltage transmission line in New South Wales. SecureEnergy awarded ANDRITZ with the supply of the synchronous condenser plants Buronga and Dinawan. The construction will start in the first quarter of 2022 and is targeted to be finalised in 2024.

EnergyConnect, the new interconnector, will be equipped with two synchronous condenser plants to provide system strength services including synchronous inertia. These services are needed to provide grid stability and will allow to connect additional large-scale renewables, such as wind and solar, into the National Energy Network. Each plant will be equipped with two salient pole synchronous condensers, each with a rated capacity of 120 MVA. The features of the synchronous condensers allow the operator to manage the reactive power of the network (+100/-50 MVar over-excited/under-excited at 330 kV), in addition to services such as short circuit contribution, fault level support and large amounts of synchronous natural inertia. ANDRITZ applied a salient pole technology, because this technology has the advantage of a higher natural inertia, lower losses and less maintenance requirements compared to the round-rotor technology. In addition to the performance-related advantages, these machines will specifically meet the technical performance requirements from the end-user Transgrid, because it is a bespoke design.

ANDRITZ is responsible for engineering, design, manufacturing, transport, technical advisory during installation and the commissioning of the plants. The synchronous condensers will be manufactured in the ANDRITZ Centre of Generator Technology in Weiz, Austria.

“EnergyConnect will enable the conversion of the Australian energy grid to a larger share of renewable energies.”

Australia is at the early stage of a major energy transition in how it generates and manages electricity. Across all states, a continuation on large scale wind and solar farms is expected to remain deployed. Australia's installed capacity of solar is already approximately 21.4 GW and approximately 9.5 GW of wind. Additionally, there is a substantial commitment to build dispatchable energy storage projects, such as pumped hydro, for which ANDRITZ received a contract for the co-located Kidston pumped hydro energy plant in Queensland (read more on page 10). The changing energy market to lower emissions is driven by access to new generation sources as coal-fired plants close, government commitments to reduce carbon emissions, the potential for renewable generation to lower energy prices and the demand for a more reliable energy supply.

EnergyConnect features energy security and enables a greater mix of renewable energy generation from wind and solar to connect to the network and increases reliability and security of electricity supply. With this investment, Australia will march on in the transition from currently mostly fossil fuel generators to a clean renewable energy superpower in the future. ANDRITZ is proud to be part of this transition and to support the country on its way to a green and clean future.

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AUSTRALIA: ENERGYCONNECT

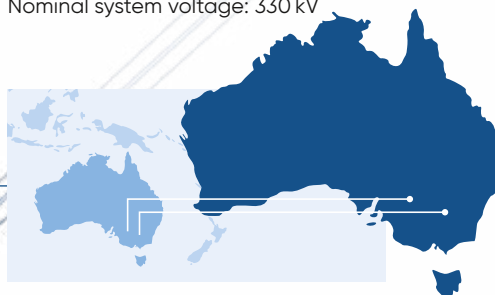
TECHNICAL DETAILS

Buronga & Dinawan:

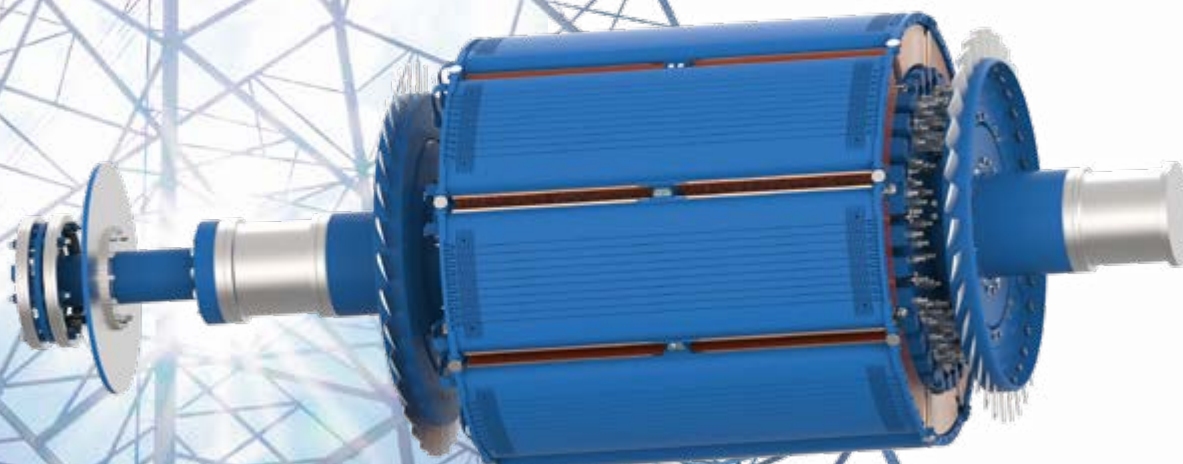
Rated capacity of each synchronous condenser: 120 MVA

Inertia contribution to PCC: 7 MWs/MVA (natural)

Nominal system voltage: 330 kV



ANDRITZ' Synchronous Condensers are a cost-effective and reliable solution for new grid requirements. They help balance the increasing volumes of variable renewable energy and a corresponding loss of system inertia, hence providing important grid stability and a secure electricity supply.



“**Interview with
Dr. Alexander Trattner**

*Chief Executive Officer and
Scientific Research Director*

Hydrogen and Hydro: Fuelling our future

Building the green economy with HyCentA's clean energy collaboration

Dr Alexander Trattner is Chief Executive Officer and Scientific Research Director at the HyCentA research institute and leads their 45-strong hydrogen technology research team. He spoke with Hydro News, setting out the role of green hydrogen as the key to our energy future.

Please provide a brief overview of HyCentA and its activities

HyCentA is an independent research organization located at the Graz Technical University in Austria and conceived as a pure research facility for hydrogen technologies. We offer testing services for system components such as fuel cells, storage systems and electrolyzers, but we are also involved in pilot projects.

We are closing the gap between the basic research-orientated tasks at universities and the development tasks of industry. As a research center we understand both areas and there is an application vision all the way through. We can help companies apply their knowledge and expertise to new areas around the hydrogen economy.

Another key objective is to build a pool of talent and stream of highly-skilled scientists who can help solve some of the energy challenges we are facing.

How important is hydrogen for our clean energy strategy and long-term sustainability goals?

The primary goal is to reduce greenhouse gases and there are just a few strategies available. The first is to extend renewable energy production, but renewables are only available for several thousand hours a year and we need power 8,760 hours a year. As a bulk energy carrier, hydrogen can close this spatial and temporal gap, balancing natural variation in renewable energy supply, as well



Source: HyCentA

ABOUT:

Dr. Alexander Trattner is the CEO and research director of HyCentA Research GmbH at Graz University of Technology, Austria's only hydrogen technology research center since 2005. He heads the team consisting of 45 researchers and is involved in the research and development of technologies for production, distribution, storage and application of hydrogen. Alexander Trattner completed his dissertation in mechanical engineering with distinction in 2015 at the Graz University of Technology, where he has led numerous national and international research projects since 2009, taught thermodynamics for several years and is the author of numerous scientific publications and books.





as storing it seasonally. With hydrogen as an energy carrier, renewable energy is available whenever you need it. It also requires a relatively low level of infrastructure and is therefore potentially lower cost than transporting electricity. Around two thirds of all the primary energy used by Europe comes underground via pipelines. In the future our energy will still come via pipelines, but it will be mostly green energy as hydrogen. This green energy will then be converted into heat and motion or electricity by zero-emission technologies like fuel cells.

“Hydrogen has been used in industry for decades and we know how to safely handle it as an energy carrier.”

How will hydrogen support challenging sectors for green energy, like chemicals, cement and steel?

Around 2% of worldwide energy consumption is already hydrogen. It is not a niche, but an established energy carrier, today mostly produced from natural gas. A key task is to transform production of this grey hydrogen to green. But the potential is much, much, bigger because we have to decarbonize a lot more processes, for example steel production.

For most high-temperature processes like cement or glass, electrification is not an option because you need a gaseous space for the processes itself and sometimes also a chemical reagent, like in iron smelting. Today, these processes run mostly on natural gas and we have to transform them to clean gas - that is hydrogen. There are also completely new sectors emerging in the mobility sector, for example in heavy road traffic and shipping.

In the energy sector itself we need to integrate more renewables and the electrolyzer, especially power-to-gas systems, are key to this. Hydrogen is key to greening all these high intensity energetic processes.



How and when can green hydrogen from renewables become competitive?

First, we have to bring it to added-value processes, for example in some areas of the semiconductor industry which require very high-quality hydrogen. Also, in mobility the gap between cost and price is a little bit bigger than in industry. I think some low-hanging fruits like these will be met with green hydrogen first, in parallel with decreasing the costs of green hydrogen. That is key for the future. At some point green hydrogen will become a cheaper alternative to grey hydrogen and even perhaps natural gas, as in the meantime fossil fuels get more expensive.

In the end, clean hydrogen won't be like expensive champagne, it will be like the cheapest plain tap water.

“We have to extend renewables capacity, and hydrogen as a facilitator for renewables is a really important part of the clean energy transition.”



Source: HyCentA

[State-of-the-art fuel system test bench at HyCentA, an extra-university research society at the Graz University of Technology.](#)

Are there any potential health, safety, or environmental risks associated with hydrogen?

There are several hydrogen vehicles on the market already and all of them have certification for operation and the same safety level as other vehicles. There are really strict standards and tests. Hydrogen has been used in industry for decades and we know how to safely handle it as an energy carrier. Really, hydrogen is just as safe as all other energy carriers.

Regarding environmental risks, hydrogen has a lot of benefits because it has no toxic effects, it is colourless, odourless, and it's not corrosive so it actually has a lot of positives.

What are the key research areas for HyCentA?

HyCentA is focused on making hydrogen production and use much cheaper for the green economy of the future.

We have four research areas within the center. The first is electrochemical technologies, regarding electrolyzers, cells and systems

which are available, but we are also working on novel cells like photoelectrolyzers and doing research on electrochemical compression, for example. The second theme is research on infrastructure technologies and the challenge of storing hydrogen with novel storage technologies like hydrides. The third team is working on mobility systems with fuel cells. The fourth is responsible for measurement and testing. It is really a big range of areas over the entire value chain, and this is really key, so we understand the whole hydrogen economy.

“Clean hydrogen won't be like expensive champagne, it will be like the cheapest plain tap water.”

How can joint R&D projects with commercial entities support our long-term clean energy goals?

Our focus for any research cooperation is to progress with the technology and the prospect of benefit for the technology, the market and society. Around two-thirds of our





activities are in public-funded research cooperation with tendered goals and deliverables, so we set up consortia together with the industry and the academia. Around one third of our activities is bilateral cooperation with enterprises from various industries with our R&D knowledge bringing their products on and improving them. There are a lot of different possibilities to cooperate.

What we expect from a partner is the ability to support the goal of lower cost, more efficient production and use of hydrogen.

“Coupled with power-to-gas facilities like electrolyzers, hydropower can provide cheap and secure electricity and bring down hydrogen costs.”

Why are you considering companies like ANDRITZ as potential partners in HyCentA?

ANDRITZ' experience and expertise address the full hydrogen spectrum from energy to the industrial sector, infrastructure, facilities and power plants. All these technologies and the energy carriers behind them are changing and therefore we see a big opportunity to cooperate.

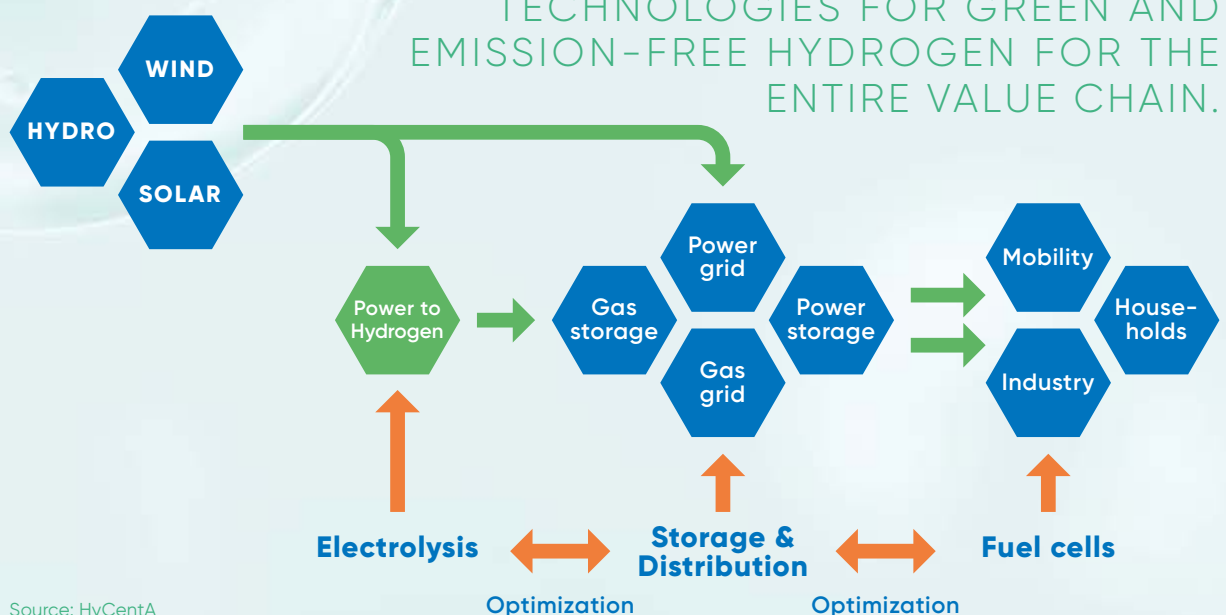
We also have to roll out hydrogen on the international market and ANDRITZ has the understanding and the network to do that. For market development of hydrogen, we need big, strong players. It's a big challenge, but hydrogen can increase its market share from 2% to 20% or 30% with a growth potential for green hydrogen even far beyond.

This requires more than fundamental R&D. There is a commercialization goal and that means pilot projects and getting these technologies off the ground so that they can be benchmarked and proven. This is where partnering with companies like ANDRITZ can have real benefits as they are already working with the industries where we can get these technologies up and running, applying these discoveries in real-world applications.

How will the role of hydropower develop in relation to green hydrogen?

All renewables need to be extended and hydropower has a big advantage because it has the highest operational hours per year. Coupled with power-to-gas facilities like electrolyzers, it can provide cheap and secure electricity as well as hydrogen while bringing down costs. It is simple economics and therefore hydropower will become even more important in the future than it is today.

R&D FOCUS ON ENERGY- AND COST-EFFICIENT TECHNOLOGIES FOR GREEN AND EMISSION-FREE HYDROGEN FOR THE ENTIRE VALUE CHAIN.



Source: HyCentA

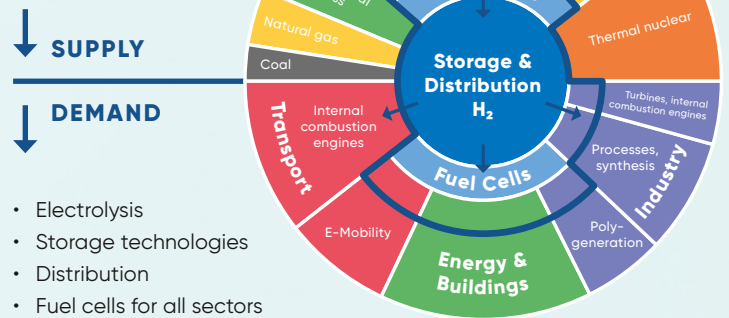
What is the key to securing a green hydrogen energy future?

The challenge is to transform hydrogen from champagne to tap water. It should be as low-cost as its fossil fuel-based alternatives. We also have to extend renewables capacity, and hydrogen as a facilitator for renewables is a really important part of the clean energy transition. Hydrogen must also be the universal energy carrier that can be used in all the different roles that we need. I really believe, and we have shown this in many simulations, that we cannot extend renewables without hydrogen to solve the clean energy challenge.

AUTHOR

Interview by David Appleyard
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GREEN HYDROGEN – THE UNIVERSAL ZERO-EMISSION ENERGY CARRIER



- Electrolysis
- Storage technologies
- Distribution
- Fuel cells for all sectors
- Renewable (green) and emission-free hydrogen (electrochemical technologies)
- Hydrogen infrastructure for all sectors

Source: HyCentA

ANDRITZ Hydro and MAN Energy Solutions agree on hydrogen cooperation

A strategic framework agreement between ANDRITZ Hydro and the German company MAN Energy Solutions will see the joint development of international green hydrogen projects based on hydropower.

platform that aims to efficiently promote the market launch of green hydrogen and hydrogen-based ‘power-to-X’ products. For this purpose, hydrogen energy partnerships are to be established in countries with a correspondingly high potential to provide a long-term, cost-effective and reliable green hydrogen supply to Germany and the EU.



Following the July 2021 agreement, a pilot project in Europe will mark the start of the collaboration before the end of this year. Subsequently, the companies want to jointly identify further projects and implement them in the context of the German Federal Government’s H2 global initiative. H2GLOBAL is a market-based funding

The initial joint pilot project is expected to provide about 650 tonnes of green hydrogen per year by using electrolysis with a capacity of up to 4 MW, initially for local use. In follow-up projects, designed for the hydrogen export market, the installed electrolysis capacity is expected to increase up to 100 MW.

“Hydropower is one of the few completely climate-neutral forms of energy, providing base-load power. We therefore see excellent potential for worldwide expansion – in greenfield projects just as much as in repowering. By adding the possibility of producing hydrogen to hydropower plants, we are taking the next step and also making the energy generated there ready for export and storage without restriction. Together with MAN Energy Solutions, we can open up new markets and opportunities for hydropower plant owners and operators,” stated Frank Mette, CEO of ANDRITZ Hydro in Germany.

FLEXIBLE ENERGY FOR MODERN GRID

In 2021, ANDRITZ and Iberdrola began commissioning the Gouvães pumped storage power plant in northern Portugal, part of the Tâmega Hydroelectric Complex. Built on the Tâmega River close to the city of Porto, Iberdrola contracted ANDRITZ in 2016 to provide the heart of this amazing hydroelectric scheme.

Portugal – The scope of supply from ANDRITZ was divided into three separate contracts and comprises the design, manufacturing, supply, installation and commissioning supervision of the complete electro- and hydro-mechanical equipment. This includes the four 220 MW reversible high-head pump turbines and motor generators, as well as the electrical power systems, which were specially developed for the Gouvães project. In addition, the contracts include the manufacturing, supply, and complete installation of the penstock with a total weight of about 12,000 tonnes of high-grade steel, as well as trash racks, radial- and roller gates and stop logs, including hydraulic equipment. This totals about 14,000 tonnes of steel to be installed across all three generation facilities of the Tâmega complex (Gouvães, Daivões and Alto Tâmega). Gouvães has a net head of about 700 m, using and pumping the water between the upper Gouvães reservoir and the Daivões reservoir below.

The high degree of operational flexibility offered by the four ANDRITZ units will provide peak-load as well as rapid-response regulating power for the region.

This is essential in a modern grid where other green energy sources, like local wind power generation, have an increasingly decisive role within the context of energy management and future generation portfolio characteristics.

“The Tâmega hydroelectric complex represents the largest hydropower project in the history of Portugal and is one of Europe’s most important energy sector initiatives of the last 25 years.”

Highly complex modern greenfield projects demand the precise management of multiple disciplines that only a company like ANDRITZ can provide in order to achieve excellence in challenging projects like Gouvães.

Over the last few years, and in the middle of the project, ANDRITZ was required to develop new concepts and modifications to fulfill changing operational



Through excellent teamwork and close interaction with our customer, the first runs of unit #4 and unit #3 were successfully performed in August and September 2021. The first unit of Gouvães will provide power to the national grid within 2021.



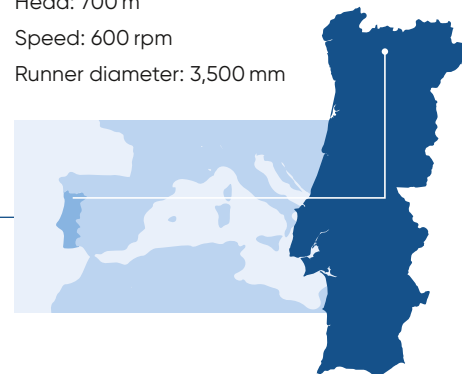
requirements. These changes were needed in order for the project to be connected to the Portuguese national grid. Such a flexible and fast adaptation process – within the confines of an existing project development process – is only possible if the complete team responds to new challenges and because ANDRITZ has the organization to provide a worldwide network with the necessary multidisciplinary resources.

Reaching the commissioning phase of Gouvães is the result of excellent teamwork where all those directly or indirectly involved have the capacity to find solutions to daily challenges and are focused on doing so. All this, together with close interaction with our customer, allowed us to successfully drive the project through to this final phase. The first runs of unit #4 and unit #3 were successfully performed in August and September, 2021, respectively. On the basis of actual site scheduling, as originally expected, the first unit of Gouvães will provide power to the national grid within 2021. The entire 1,158 MW Tâmega Hydroelectric Complex will be finished in 2023, guaranteeing energy supplies for almost three million people.

TECHNICAL DETAILS

Gouvães:

- Total output: 880 MW
- Scope: 4 × 220 MW Francis Pump Turbines
- Head: 700 m
- Speed: 600 rpm
- Runner diameter: 3,500 mm



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CONNECTED

Nepal – At the end of August 2021, the sixth and last unit of the largest hydropower plant in Nepal was connected to the national grid, marking the completion of an important and prestigious project.

Back in 2012, ANDRITZ received a contract from Upper Tamakoshi Hydropower Ltd. (UTKHPL) for the supply of the entire electro-mechanical equipment for the Upper Tamakoshi hydropower plant on the Tamakoshi River. The installation has an underground powerhouse with a total capacity of 456 MW. Its main objective is to meet Nepal's rapidly growing power demand.

As of mid-July 2019, the dry commissioning of all the six generating units had been completed. As part of the project 49 over-dimensioned consignments were successfully delivered to site, overcoming challenges of building by-pass bridges, multiple handling of equipment, storage and preservation at intermediate stores, and convoy management to cope with bad road conditions. The project also has one of the world's biggest spherical valves with a diameter of 2,500 mm and a design pressure of 87.5 bar.

A FURTHER ORDER FOR PENSTOCKS

Based on the excellent performance of ANDRITZ for the electro-mechanical works, the customer awarded ANDRITZ an additional order for penstock installation and on-site repair works.

In February 2021, the pressure test of the lower horizontal penstock was successfully completed to the utmost satisfaction of the customer. A 377 m-long portion of penstock along with six bifurcators and branch pipes was subjected to 115 bar for 30 minutes with a water volume of 1.4 million m³. The entire lower vertical and horizontal penstock was 100% weld repaired on-site and the bifurcators were repaired, modified, and aligned also on-site. The penstock is designed for a head of 905 m, with a diameter varying from 1.47 m to 3.6 m with two vertical and two horizontal shafts. The upper vertical shaft has a depth of 310 m and the lower vertical shall has a depth of 370 m.

“With 456 MW total installed capacity, Upper Tamakoshi is Nepal's largest hydropower plant. Its main objective is to meet the country's growing energy demand.”

The work was very challenging considering the quality issues of the existing equipment, which had been delivered by another contractor, and the difficult site conditions. However, the on-site team from ANDRITZ did an excellent job of not only executing this additional order on time with superb quality, but also building client confidence in the top-tier work of ANDRITZ.



D TO THE GRID



OFFICIAL INAUGURATION BY PRIME MINISTER OF NEPAL

In July 2021, Nepal's Prime Minister inaugurated this project of immense national pride. On the occasion, Deputy Prime Minister and Minister for Energy, Water Resources and Irrigation said that Upper Tamakoshi would contribute 1% of the country's gross domestic product.

By mid-September 2021, all six units were successfully commissioned and handed over to the customer, concluding a remarkable success story.

The successful execution of Upper Tamakoshi once again underlines ANDRITZ' strong market position in Nepal as one of the leading suppliers of equipment and services to the hydro industry, as well as highlighting the company's expertise in project execution and management.

ANDRITZ takes immense pride in being the preferred supplier for the prestigious Upper Tamakoshi project and is very pleased to support Nepal in its energy development ambitions.

TECHNICAL DETAILS

Upper Tamakoshi:

- Total output: 456 MW
- Scope: 6 x 76 MW
- Net head: 805 m
- Transmission voltage: 220 kV
- Speed: 600 rpm
- Penstock length: 760 m
- Penstock diameter: 1.47 to 3.6 m



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XFLEX HYDRO

ROADMAP TO MORE FLEXIBILITY

Europe is shifting away from fossil fuels and the growing share of renewables is changing grid operations. Greater flexibility is needed to respond to these changes.

INSIGHT: HYBRIDIZATION TECHNOLOGY

A run-of-river hydropower plant on the Rhine and owned by Électricité de France, Vogelgrun is testing hybridization technology, where eight partners are contributing.

XFLEX HYDRO, a consortium of 19 partners, is demonstrating how hydropower plants can provide more flexibility to the grid.

Under the Horizon 2020-funded XFLEX project, which started in September 2019, innovative technologies are being tested in seven hydropower plants to boost flexibility. Industry leaders, research organizations and universities are evaluating technologies such as enhanced fixed speed, variable speed, hydraulic short circuit and hybridization solutions under real operating conditions, as well as the run-of-river hydro power plant Vogelgrun, where the hybridization is being demonstrated and evaluated.

Vogelgrun has four low head, double-regulated Kaplan turbines. In early 2021, one unit was hybridized with a battery energy storage system (BESS). Since the beginning of August 2021, this unit is operating 24/7 in hybrid mode (35 MW Kaplan unit + 0.6 MW BESS) to provide 4 MW FCR (frequency containment reserve; primary control). See page 56 for more information on hydro-battery storage hybrid energy systems.

The addition of a battery system delivers a rapid power response to complement the hydraulic unit. A master control, running on a HIPASE* platform, calculates the individual set-points to provide FCR. Furthermore, a smart power plant supervisor is being developed that will minimize wear and tear. Two

KEY FACTS OF THE XFLEX HYDRO DEMONSTRATORS

Project	ALTO LINDOSO (PT)	ALQUEVA (PT)	CANIÇADA (PT)	FRADES 2 (PT)
Rated power	2 × 317 MW	4 × 130 MW	2 × 35 MW	2 × 390 MW
Rated head	276 m	65 m	121 m	414 m
Type	Reservoir storage	Pumped storage	Reservoir storage	Pumped storage
Demonstrated technologies	Enhanced fixed speed (high head)	Hydraulic short circuit	Enhanced fixed speed (medium head)	Variable speed (DFIM) technology

Source: Mathias Magg

RO



Source: Mathias Magg

Vogelgrun is a 142 MW run-of-river hydropower plant in France, situated near the border with Germany along the river Rhine. The plant has four low head Kaplan turbines, in service since 1959. During XFLEX HYDRO, one of the units was hybridized with a battery and the performance is being evaluated.

units were equipped with sensors. The second unit, providing FCR without a battery, serves as a benchmark to optimize and quantify the benefits of the hybridization.

Digitalization is another focus in the project: In particular, a smart power plant supervisor is being developed, including a multi-dimensional hillchart to optimally distribute the set-points to the BESS and the turbine.

Moreover, DiOMera** was deployed. With the DiOMera indicators and developed turbine models, the health index of the unit can be estimated. Additionally, a SIMSEN model (hydro clone) was developed and validated against the real unit.

KEY OBJECTIVES OF THE VOGELGRUN DEMONSTRATOR

- Hybridize the turbine unit with a battery to improve dynamic frequency response as well as reduce governor actions.
- Quantify and significantly reduce turbine wear.
- Evaluate the possibility of upgrading the 35 MW fixed-speed, double-regulated Kaplan turbine unit with an enhanced variable speed, propeller unit.

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Follow the latest updates on the project here:
www.xflexhydro.net

GRAND MAISON (FR)	VOGELGRUN (FR)	Z'MUTT (CH)
8 × 154 MW 4 × 156 MW	4 × 35 MW	1 × 5 MW
900 m	12 m	115 m
Pumped storage	Run-of-river	Pumped storage
Hydraulic short circuit	Battery/Turbine hybrid	Variable speed (FSFC)



The Hydropower Extending Power System Flexibility (XFLEX HYDRO) project received grant funding (No. 857832) from the European Union's Horizon 2020 research and innovation program.

* HIPASE is the unique ANDRITZ Hydro automation platform for protection, excitation, synchronization, and turbine governing. To learn more about HIPASE see: <https://www.andritz.com/hydro-en/hydronews/hydro-news-24/03-hipase>

** Metris DiOMera is a modular and flexible platform for the operation and maintenance of hydropower plants. To learn more about DiOMera see: <https://www.andritz.com/hydro-en/diomera>

RESTORING RENEWABLE ENERGY

ANDRITZ has successfully commissioned the electro- and hydro-mechanical equipment of the upgraded and modernized Mwadingusha hydro-power plant. Located in Tanganyika province (formerly Upper Katanga), the plant is a three-hour drive from Lubumbashi, the country's mining capital.

Democratic Republic of Congo – Since early 2021 and within the framework of a public-private partnership, ANDRITZ together with Société Nationale d'Electricité (SNEL), the Sino-Canadian mining group Ivanhoe, and the international consulting company Stucky have been successfully putting Mwadingusha back online.

Originally commissioned in 1930, the original equipment supplier was Swiss company Charmilles, now

part of ANDRITZ. With no major overhaul for many years, a full rehabilitation and upgrade was needed.

In 2016, ANDRITZ received a contract for the full rehabilitation and modernization of all six 11.8 MW Francis generating units, three brand-new penstocks, intake valves on the upper dam, as well as ancillary hydro-mechanical equipment such as trash rack, stop logs, safety equipment, and valves. For more on this project, see Hydro News No. 31.

CONGO DRC – RICH IN NATURAL RESOURCES

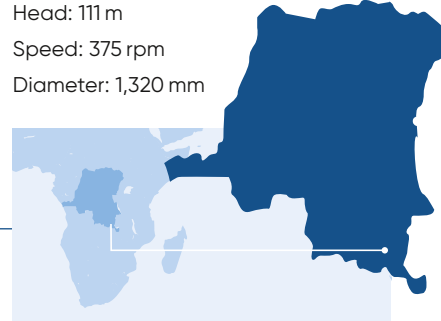
The Democratic Republic of Congo (Congo DRC) has the largest hydropower potential in Africa and one of the largest worldwide. With a technically feasible potential of some 100,000 MW, only about 2.5% of this potential has been developed so far. The new framework for liberalization of the electricity sector could contribute to government plans to increase electricity access rate of the population in the coming years, with upcoming projects such as Inga 3/Grand Inga exceeding an installed capacity of about 11,000 MW.

GLE

TECHNICAL DETAILS

Mwadingusha:

- Total output: 78 MW
- Scope: 6 × 13.05 MW
- Voltage: 6.6 kV
- Head: 111 m
- Speed: 375 rpm
- Diameter: 1,320 mm



The contract award followed the successful completion of Koni, a hydropower plant in a cascade just downstream of Mwadingusha at the mouth of Lake Tshangalele, about 250 km northeast of the Kamoa Mine site.

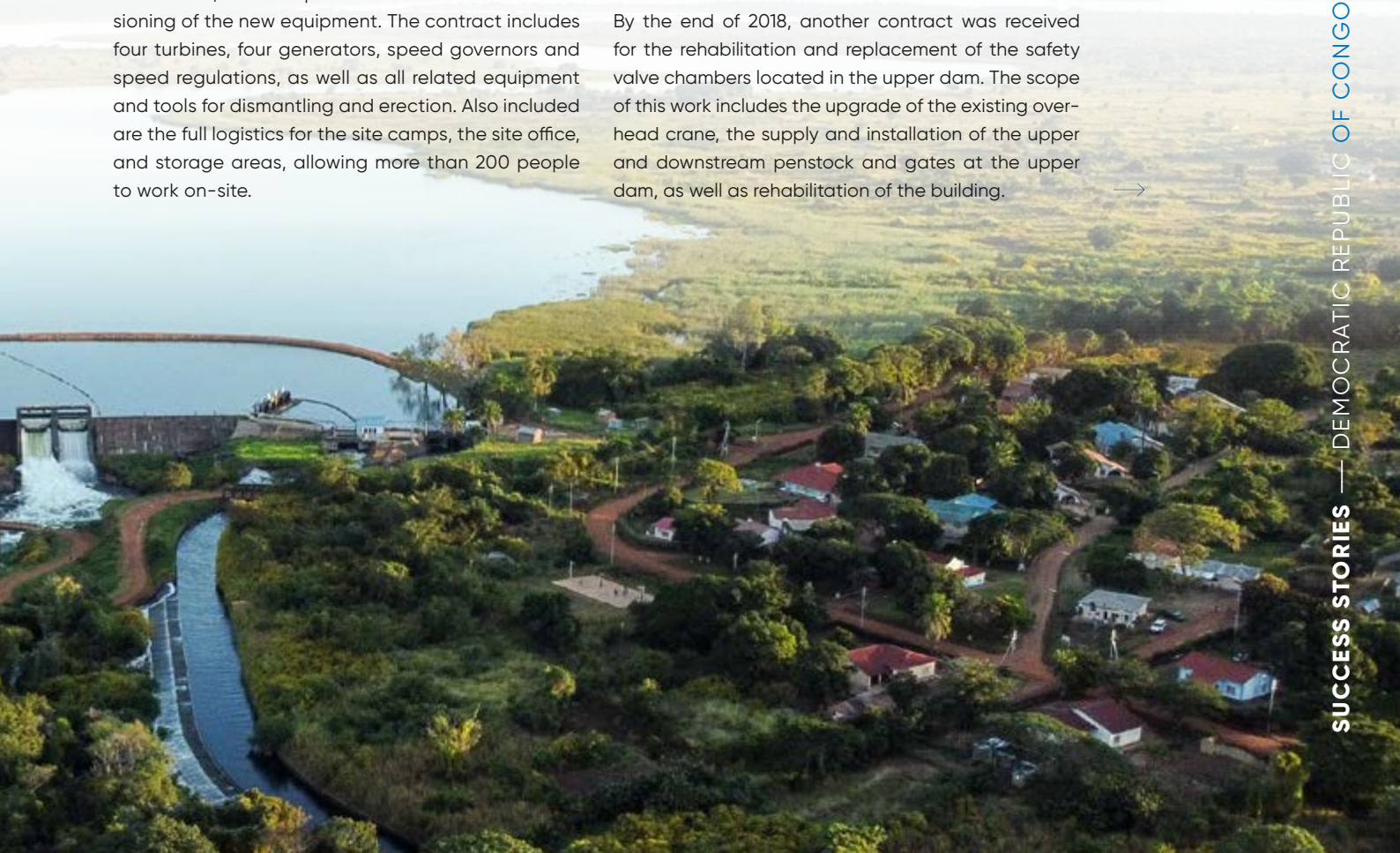
“Once completed, the full upgrade and modernization project is pushing the installed capacity of Mwadingusha to about 78 MW.”

Scope of supply for Mwadingusha comprised engineering, manufacturing, delivery, and dismantling of old units, and complete installation and commissioning of the new equipment. The contract includes four turbines, four generators, speed governors and speed regulations, as well as all related equipment and tools for dismantling and erection. Also included are the full logistics for the site camps, the site office, and storage areas, allowing more than 200 people to work on-site.

In May 2017, following engineering optimization of the four original units, an additional order was awarded to ANDRITZ for the two remaining generating units.

In parallel with rehabilitation of other parts of the Mwadingusha complex such as roads, access bridges, and civil works by Stucky, SNEL, and Ivanhoe, in December 2017, ANDRITZ was awarded a further contract for hydro-mechanical works. This contract covers the supply of three new butterfly valves, a manifold of the penstock, trash racks, motorization of the spillway, as well as replacement of the intake valves, safety valves, and stop logs.

By the end of 2018, another contract was received for the rehabilitation and replacement of the safety valve chambers located in the upper dam. The scope of this work includes the upgrade of the existing overhead crane, the supply and installation of the upper and downstream penstock and gates at the upper dam, as well as rehabilitation of the building.





The rehabilitation and modernization will see each unit at Mwadingusha increase output from 11.8 MW to 13.05 MW. The energy will benefit the people of the DRC as well as the Kamo-a-Kakula copper mine.

→ ANDRITZ was also awarded a contract to replace the three horizontal penstocks and gates located between the upper dam and the powerhouse with a very challenging schedule. The scope of works includes a new camp for a staff of 30, site logistics facilities such as a 150-tonne crane, scaffolding, chariots for working inside the penstocks, and anti-corrosion protection.

An unexpected challenge was the global COVID pandemic and the interruption of activity between March and July 2020. With the combined efforts of all parties, most of the staff on-site could be demobilized

and remobilized once work resumed, although coordination of inland and air travel plans was difficult due to ANDRITZ workers coming from different locations in Europe, India, and the Philippines. Even after remobilization, preventive measures were implemented to protect the on-site personnel against any possible infection. Despite this, the three penstocks of Mwadingusha have been in operation since November 2020. All six generating units were progressively put back on the grid until full simultaneous synchronization in September 2021. The industrial sector in the Democratic Republic of Congo has acknowledged an "outstanding technical and human success" during the National Energy Conference held in Lubumbashi on September 17, 2021.

The rehabilitation and modernization will see each unit at Mwadingusha increase output from 11.8 MW to 13.05 MW. The energy will be distributed by SNEL to serve the needs of the people of the DRC as well as Kamo-a-Kakula, the world's largest undeveloped high-grade copper mine, which is operated by Ivanhoe.

The Mwadingusha project is a success story for the highly skilled service and rehabilitation teams from ANDRITZ in Switzerland and Austria, in combination with the excellent manufacturing competence of our ANDRITZ workshops. Completion of the project is also a sign of our customers' trust, and our technological expertise in electro- and hydro-mechanical solutions.



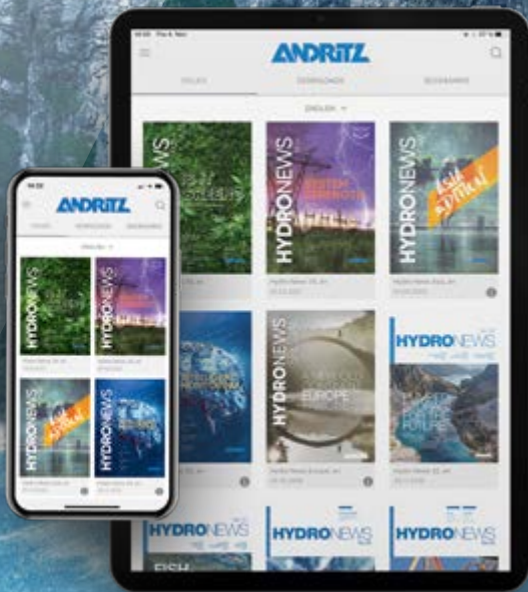
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HYDRO NEWS

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Hydro News is published on a regular basis and for 20 years has continued to provide the latest news about ANDRITZ Group hydropower projects and special topics such as key market trends and technology developments.

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PROTECTED F FLOODING

In September 2021, a new sliding flood gate was installed at Port Albern on the river Danube in the Vienna, Austria.

Austria – This impressive gate was manufactured, delivered, and installed in two parts. After manufacture in Turkey, both segments were transported more than 1,500 km to their final destination in Austria's capital city.

The lower segment was installed on September 2nd, the upper one less than a week later on September 7th. The installation was a masterpiece of precision and skill with our experienced staff maneuvering these very heavy gate elements and installing them safely and professionally. The two parts were subsequently welded together by our specialist teams and the gate will be subjected to a thorough functionality test in January 2022.

Back in 2019, ANDRITZ was awarded with a contract for the supply of the flood protection gate for the port of Albern in cooperation with the construction company PORR.

With a length of about 40 m (clear width of 30 m), a height of 14.5 m and a mass of 250 tonnes, this is the

largest sliding gate in Austria. Three submersible pumps with a total capacity of almost 2,000 liters per second regulate the water level within the harbour basin. Other facilities, including the driving system, a de-icing system, sill- and inlet structure flushing, pillar jib crane, stop logs for the gate chamber, and the whole electrical power system, as well as automation, installation and commissioning completed the ANDRITZ' scope of supply.

“The largest sliding gate in Austria, manufactured by ANDRITZ, will protect the port of Albern in Vienna from flooding.”

Delivery of the new sliding flood gate at Port Albern is part of a safety project along the Danube. It follows the construction of a flood protection dam and a flood protection gate for the port in Freudenau, also in Vienna, and other safety measures on the right bank of the river Danube which have already been implemented.



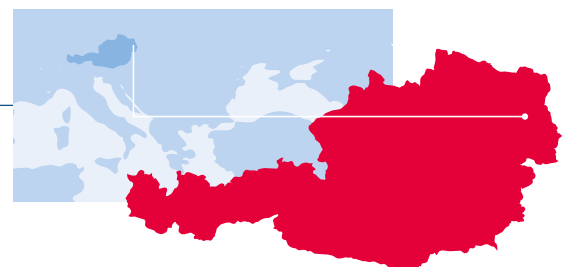
TECHNICAL DETAILS

Port Albern:

Length: 40 m

Height: 14.5 m

Weight: 250 tonnes



ROM



The new flood gate will protect Port Albern and further strengthen this important business location. Port Albern handles building materials, agricultural products and steel products. With its cargo center for high and heavy loads (up to 450 tonnes) and its five large granaries with their total capacity of 90,000 tonnes, Port Albern is one of the most important locations for the shipment of grain in eastern Austria.

ANDRITZ is proud to be part of this project right on the front door of our headquarters in Vienna and to support our customer Wiener Hafen GmbH to secure the port and the riverbanks of the Danube.

ANDRITZ GATES

ANDRITZ designs, manufactures, supplies, and installs all types of gates used for power intakes, bottom outlets, and river diversion works. For low head or run-of-river power plants, our product and service scope comprises all types of hydro-mechanical equipment. This includes weirs, powerhouse inlets, and outlet structures such as intake trash racks, stop logs and draft tube gates. The gates are typically operated by hydraulic hoisting systems but solutions with mechanical rope or chain hoists can also be implemented based on specific market and customer demand.

VIENNA'S PORT INFRASTRUCTURE

The area of the Port of Vienna covers about 3 million m² in total. The Hafen Wien Group, which belongs to the Wien Holding Group, operates the three large cargo ports including its infrastructure. These ports are the Port of Freudenuau, the Port of Albern and the Lobau oil port. All three cargo ports handle around 1,200 cargo ships per year. The waterways are mainly used to transport petroleum products, road salt, building materials such as cement, sand and steel products, and agricultural products such as grain and artificial fertilizers.

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FLOATING

a new concept for PV-

Maximizing green power from water with

Among non-traditional green energy sources and technologies, Floating Photovoltaics (FPV) is no longer a niche energy solution but is commanding a rapidly developing market position.

“FPV projects are very attractive to energy investors, offering a new solution to the ever-increasing demand for green energy.”

As the name suggests, Floating Photovoltaics is a technology which sees the installation of solar panels onto a floating structure, typically plastic or steel pontoons. Aside from the floating element, the PV system is identical to their terrestrial equivalents but offers a number of key advantages. In particular, by using the surface of a water body much of the infrastructure for the plant is located on a space that would otherwise be unused and unproductive.

The relatively recent development of the technology, combined with increased focus on renewable

energies, is making FPV extremely attractive to energy investors and this is reflected in recent growth forecasts. According to analysis from the TERI Institute and Acumen Research and Consulting, the global FPV market was worth around €1 billion in 2019 but will reach some €21.3 billion by 2027.

Indeed, although Asia is at the forefront of the development, large-scale FPV plants of 100 MW or more are already operating in many countries. Due to shallow water and easy permitting, to date the majority of operating FPV plants are located in disused quarries or other mining or agricultural ponds. This is often combined with local electrical demand from the associated infrastructure. However, although only a small minority of modest pilot projects have been installed on hydropower reservoirs so far, the bulk of these plants are reportedly running well. For example, projects such as Sobradinho in Brazil, Alto Rabagão in Portugal, Sirindhorn in Thailand, and the biggest such example at Longyangxa in China. These hydro-FPV hybrid projects are expected to be expanded where possible.



G -hydro hybrids

Source: Zimmermann GmbH

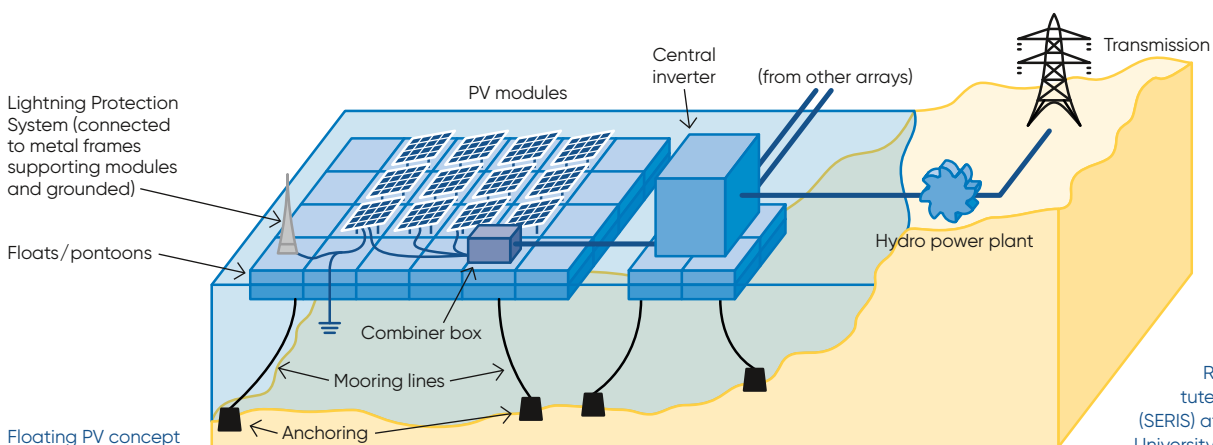
floating solar – HYDROVOLTAIC ENERGY

ANDRITZ AND FPV

ANDRITZ is already looking into this innovative energy solution as an opportunity to maximize hydro asset performance for our clients. We are keen to provide FPV solutions to our hydro business customers as part of an overall optimization approach including as part of Asset Management ISO 55000 Certification.

HYBRIDIZATION BENEFITS

Of course, like every energy source there are some potential downsides. For example, FPV typically has higher maintenance costs when compared with traditional ground-based PV. It is also possible to see reduced oxygenation in the areas of the reservoir beneath the FPV structure. Nonetheless, FPV does →



Source: Solar Energy Research Institute of Singapore (SERIS) at the National University of Singapore



Source: Zimmermann GmbH

→ demonstrate an interesting Levelized Cost of Energy (LCOE) when compared with other emerging energy technologies and very reasonable return on investment (ROI).

“ANDRITZ is applying its expertise to innovative energy solutions that can maximize hydropower asset performance for our clients. Providing FPV solutions to our hydro business customers forms a key part of this philosophy.”

ANDRITZ is a turnkey “from water-to-wire” player for FPV when combined with hydro power plants or pumped storage plants. ANDRITZ’s huge market presence and access to hydro reservoirs, as well as excellent technical and commercial relationships with clients all over the world, are key advantages. Beyond this, very specific hydro plant operations knowledge and awareness gives ANDRITZ key insights into FPV installation on a hydro reservoir.

Today, ANDRITZ offers an in-house “hybridized” solution with a smart governor, which optimizes both FPV and hydropower plant operations. This solution acquires and elaborates on input data like forecast for solar irradiation and water availability, the price of energy, limiting operations of the turbines and other parameters in order to optimize the

whole plant. The full range of in-house electrical and automation systems enables a complete, ‘full-wrap’ solution, limiting the interfaces that need to be managed by the client.

HYBRIDIZATION CONCEPT

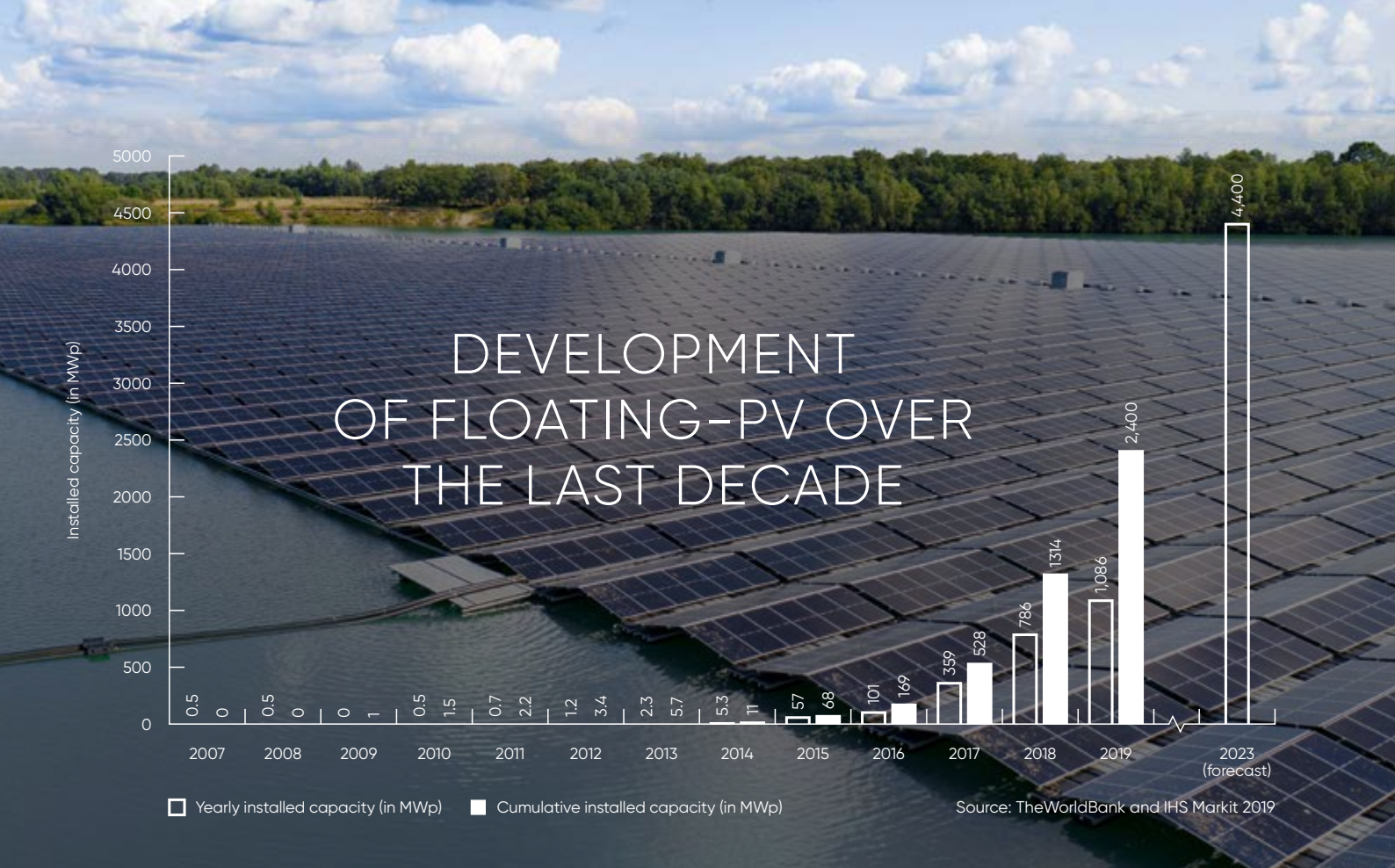
Several large existing utilities company clients are already looking into this innovative energy source to enhance the performance of their hydro assets. Some countries and governments are also preparing specific rules and tenders for FPV, such as Portugal.

A large energy player in Spain is also operatively acting for the construction of an FPV-hydropower hybrid. In early 2021, ANDRITZ signed a Non-Disclosure Agreement as part of an in-depth assessment and the preliminary development of a pipeline of FPV plants combined with existing hydropower reservoirs.

Once again, ANDRITZ is utilizing its multi-disciplinary competences, knowledge and professionalism to help and support our clients to optimize and enhance the performance of their assets. ANDRITZ is ensuring their investments in hybrid hydropower-FPV systems are as profitable as possible.

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DEVELOPMENT OF FLOATING-PV OVER THE LAST DECADE



Source: TheWorldBank and IHS Markit 2019

Source: Zimmermann GmbH

- Better energy density** Compared with a ground-bat, water provides natural cooling, increasing efficiency and thus generation. Furthermore, the reservoir surface is generally not utilized for any other purpose, reducing or eliminating the cost of productive use of land.
- Reduced evaporation** Saving water for drinking or additional generation.
- Reduced algae growth** Reduced light penetration thought the water column results in lower algal growth and less maintenance on the water intake.
- Decarbonization** Additional low-carbon energy helps reach company/country targets for CO₂ equivalent emissions reduction.
- Longer lifetime of HPP** When combined with FPV, operational optimization can help to reduce start/stop cycles and part-load running.
- Increased plant capacity factor** Overall annual energy production is increased, directly increasing plant revenues.
- Compensating for lack of hydro generation** FPV can mitigate the risk of reduced revenues due to lack of water availability.
- Smarter energy management** Can potentially be used in combination with battery energy storage systems such as HyBaTec for increased flexibility.
- Asset optimization** Overall asset optimization, indirectly increasing revenues and achieving Asset Management ISO 55000 status.
- Reduced capital investment** When combining FPV with HPP/PSP sharing of infrastructure such as electrical power, control and transmission systems reduces the investment required.
- Sediment management** FPV can be used as a base/structure for sediment pumping systems and smart sediment management such as Metris DiOMera.
- Lean authorization process** In many cases the regulations governing water usage are already defined for the hydro generation element. Therefore, additional regulatory approvals are not always needed to add FPV.
- Low investment cost** Limited or no additional land acquisition or civil structures are required.

SMALL HYDRO

HIGHLIGHTS

Thanks to the flexibility and cooperative spirit of our customers and ANDRITZ staff, our projects in execution have overcome the various lockdowns and restrictions following the global COVID pandemic surprisingly well. Nonetheless, there certainly has been an impact on new projects. Together with growing environmental concerns and constraints, long licensing and permitting phases, and low tariffs, this is an additional limitation that has contributed to the significant market downturn in Europe.

However, with concern over global warming and increasing environmental pollution, growing the demand for environmentally friendly solutions is also expanding. Small hydro power is a reliable and almost constant source of renewable energy, and therefore plays an important role in balancing increasing energy production from solar and wind. Consequently, markets in Latin America, Southeast Asia and Africa continue showing signs of recovery and interesting project perspectives for decentralized, off-grid solutions or stand-alone systems. Small hydro provides safe, clean, and renewable energy, which is an important precondition for rural development.

Additionally, the transition to a green energy supply system calls for new investments to stabilize networks and grids. Grid system operators struggle globally to manage variable energy produced from wind and solar. Temporary storage systems – either traditional pumped storage schemes or new battery energy storage systems – will be key to help “shift” excess green energy to those periods when natural supply is low. We consider this to be another strong impetus for the small hydro market. Naturally, ANDRITZ has the complete plant engineering in-house expertise to support all our customers on our common journey towards an emission-free future.

“Small hydropower plants are a cost-efficient, environmentally friendly solution for communities to become independent from fossil fuels.”

SUCCESSFUL EXAMPLE OF COOPERATIVE APPROACH

Kamolot, Uzbekistan

In 2019, ANDRITZ received an order from the Chinese enterprise group Dongfang Electric International Corporation (DEC) for the supply of the complete electro-mechanical equipment for the Kamolot hydropower plant in Uzbekistan. DEC is acting as the main contractor for the end customer, JSC Uzbekgi-droenergo, an Uzbek state-run utility.

The contract of supply comprised four bevel gear turbines with a runner diameter of 2,150 mm and a rated power output of 2.13 MW each, together with synchronous generators, hydraulic power units, cooling water system, as well as a package of controls and automation.

The installation and commissioning of the four units took place amid global safety constraints and travel restrictions during a period when mobility was strongly influenced by the global fight against Covid 19.

Manfred Motz, Head of Compact Hydro stated: "I am extremely happy about this success as it shows our ability to deliver and execute projects even under harsh conditions. This is a good example for our cooperative approach to projects – we work hand in hand with our customers."

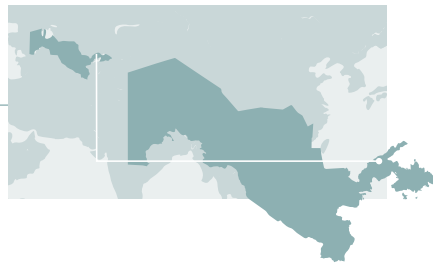
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TECHNICAL DETAILS

Kamolot:

- Total output: 8.5 MW
- Scope: 4 × 2.13 MW
- Head: 7.77 m
- Voltage: 6.3 kV
- Speed: 217 rpm
- Runner diameter: 2,150 mm



HAND IN HAND WITH

Traunleiten, Austria

The hydropower plant Traunleiten in Upper Austria was officially inaugurated on September 18, 2021 with participation from high-ranking politicians and owner's representatives. In their inauguration speeches, the dignitaries particularly emphasized the importance of Traunleiten in the energy transition for this Austrian province.

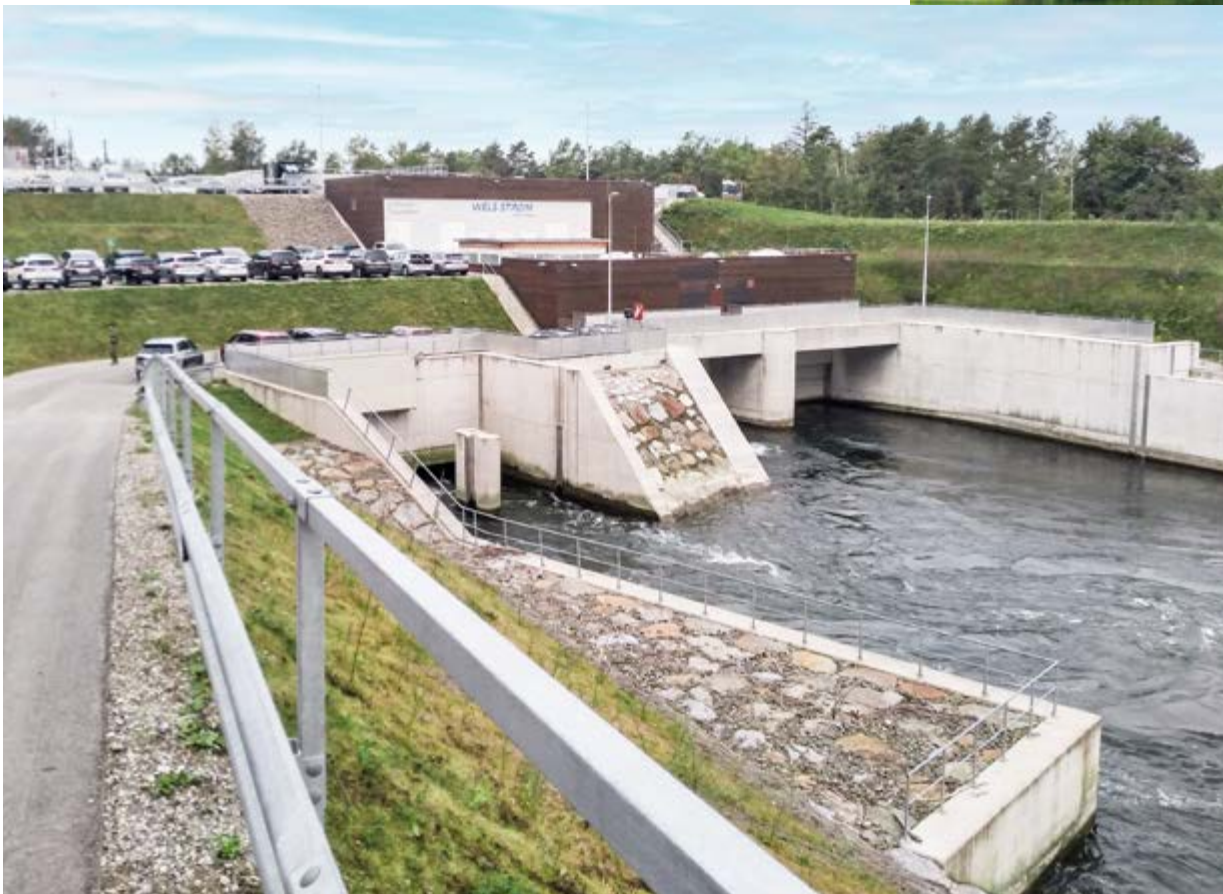
Located in a suburb of the city of Wels and originally built 120 years ago, the original hydropower plant has now been completely replaced by a new plant building and state-of-the-art electro-mechanical equipment. It is the largest project in the history of the owner, Wels Strom GmbH.

ANDRITZ was awarded a contract for the delivery of two 9.2 MW Compact Bulb turbines and a substantial package of auxiliaries, including the hydraulic power units and cooling system. The two bulb turbines as well as the synchronous bulb generators were manufactured at ANDRITZ' own workshop.

UNCOMPROMISING PROTECTION OF FLORA AND FAUNA

The modern powerhouse building was designed with the goal of achieving harmony with nature and with sustainability in mind. The natural recreation area around the Traunleiten power plant has always been very valuable to the citizens of Wels.

"With this centennial project, we are not only pleased to secure a regional supply of green energy for future generations, but to also set sustainability benchmarks for both people and the environment," stated Franz Gruber MBA, Managing Director of Wels Strom.



H NATURE

During construction of the new plant, the surrounding area was renaturalized to become even more attractive as a habitat for animals and a recreational area for the local population. With more than 150 bird species, the Untere Traun Bird Sanctuary is part of the Natura 2000 European protected area. It is one of the last remaining natural flowing water ecosystems in the whole of continental Europe and an important breeding ground and overwintering area for waterfowl.

Due to the horizontal axis of the turbines, the new power plant is almost entirely built into the ground and inconspicuously blends into the surrounding area. The dynamic residual water management of the Traun River also provides new benefits

for flora and fauna and offers endangered breeding bird species a protected habitat.

This pioneering hydropower plant was built within only 26 months. Using top-tier technology, the new plant layout achieves an 80% increase in power output with an estimated hydroelectric power production of 91 GWh annually. Traunleiten will thus provide sustainable and clean energy for over 60,000 local people today and for future generations too.

ANDRITZ is very proud to be part of this lighthouse green energy project.

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TECHNICAL DETAILS

Traunleiten:

- Total output: 17.5 MW
- Scope: 2 x 9.2 MW
- Head: 15 m
- Voltage: 10.5 kV
- Speed: 200 rpm
- Runner diameter: 3.100 mm
- Av. annual production: 91 GWh



AN ARCHITECTURAL PEARL PROVIDING LOCAL POWER

Lussa, Scotland

In June 2021, ANDRITZ received an order from Scottish utility SSE to completely replace the electro-mechanical equipment, including the two Francis turbines, at the Lussa hydropower plant on the Mull of Kintyre.

Receiving water by tunnel and a pressure pipeline from Loch Lussa, the small hydropower station on Scotland's west coast features two small 1.1MW turbines providing power to the local substation at Campbelltown. Lussa is a wonderful example of the use of natural topographic resources for electricity generation. The powerhouse was designed by the well-known Scottish architect Ian G. Lindsay and shows typical Scottish historical design themes from the 17th and early 18th century.

Originally built in 1957, the Lussa hydropower plant will now receive completely new electro-mechanical equipment while the existing buildings are being largely retained. After receiving an initial concept study from SSE in 2019, orders for both the basic engineering and the detail engineering came in 2020. The contract for the supply of the complete electro-mechanical machinery and automation package followed in June 2021.

ANDRITZ' scope of supply comprises two 1.1MW Francis turbines, two 1.28 MVA/11kV synchronous generators, inlet valves, a new control system and instrumentation, as well as all auxiliary equipment. Transport to site, installation, and full commissioning round out the contract scope. Completion of the works is scheduled for the end of 2022.

ANDRITZ has already successfully executed numerous equipment supply and service and rehabilitation orders for SSE in Scotland and is looking forward to continuing to support this valuable customer now with new equipment for the Lussa hydropower plant. With top-quality equipment by ANDRITZ, Lussa will again produce sustainable and clean reliable energy for the local people.



TECHNICAL DETAILS

Lussa:

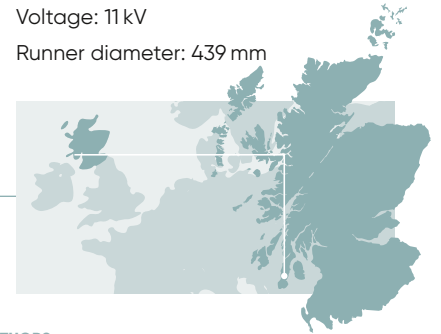
Total output: 2.2 MW

Scope: 2 × 1.1 MW / 1.28 MVA

Head: 116 m

Voltage: 11 kV

Runner diameter: 439 mm



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STRENGTHENING THE LOCAL POWER GRID

Houay Ka-Ouane and Nam Sak, Lao PDR

ANDRITZ has signed two contracts with one of the largest independent power producers in Lao PDR, the Phongsavathay Group, for the electro-mechanical works of Houay Ka-Ouane and Nam Sak hydroelectric projects.

Both projects are run-of-river schemes, with a combined objective of strengthening the structure of the local power grid and to use local resources to develop economic independence by improving infrastructure.

ANDRITZ' scope in both contracts comprises design, engineering, manufacturing, supply, and transportation of electro-mechanical equipment, as well as supervision of installation and commissioning.

We are happy to support the customer on the way to secure the local grid in Laos in order to secure sustainable and green power for the local people. These contracts are again proof of ANDRITZ' competence and expertise in hydroelectric equipment, and strengthen the company's leading position in the hydropower market of Lao PDR.

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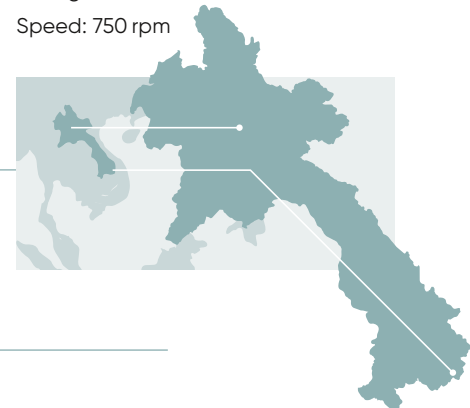
TECHNICAL DETAILS

Houay Ka-Ouane:

Total output: 22.5 MW
Scope: 3 × 7.5 MW
Head: 111.3 m
Voltage: 11 kV
Speed: 750 rpm

Nam Sak:

Total output: 22 MW
Scope: 3 × 7.33 MW
Head: 811 m
Voltage: 11 kV
Speed: 750 rpm



EXPANDING RURAL ELECTRIFICATION

Lao PDR has an immense hydropower potential of about 18,000 MW excluding the main-stream of the Mekong River and up to 27,000 MW with it. This potential makes Laos the "Battery of Southeast Asia". However, the electrification rate of the country is still below the regional average, which causes slow economic growth. In response, the government has launched a strategic masterplan with a golden target of a 90% national electrification rate as part of long-term national development plan. This plan for the improvement of rural electrification includes hydro-power and additional power distribution projects to expand the national grid to encompass off-grid centers and to make electricity affordable for every household. Electrification is a necessary condition for village development that will lead to improved rural productivity and reduced poverty through fair economic growth.



STORING UP NEW STREAMS FOR HYDRO

The age of large-scale battery energy storage for

ANDRITZ Hydro has formed a new partnership with Mercedes-Benz Energy to offer large-scale energy storage in combination with hydropower. Designed to meet the needs of a more diversified market and generate additional revenue streams for our customers, the new venture ties battery storage with hydro power to maximize the earnings potential of hydropower assets.

Large battery energy storage systems are becoming more widely accepted around the world with a growing volume of utility-scale battery storage systems already operating successfully. Typically connected to the electricity grid, large-scale energy storage supports transmission service operators (TSOs) in ensuring system stability but can also store enough renewable energy to power hundreds of thousands of homes.

The main drivers for this development are rapidly falling battery prices and ongoing technological progress that is allowing batteries to store ever-larger amounts of energy cheaply and efficiently. One of the key players in the sector is the global automotive industry, which is continuously developing smaller, cheaper, and more powerful lithium-ion batteries for electric vehicles.

TWO STRONG PARTNERS – ONE INNOVATIVE HYBRID SOLUTION

Always a technology pioneer, ANDRITZ Hydro is one of the first global suppliers to offer a hybrid solution pairing a large battery with a hydropower plant. In December 2020, ANDRITZ Hydro and Mercedes-Benz Energy (MBE) signed a cooperation agreement to promote and supply HyBaTec – the most modern hybrid energy storage solution for the hydropower market.



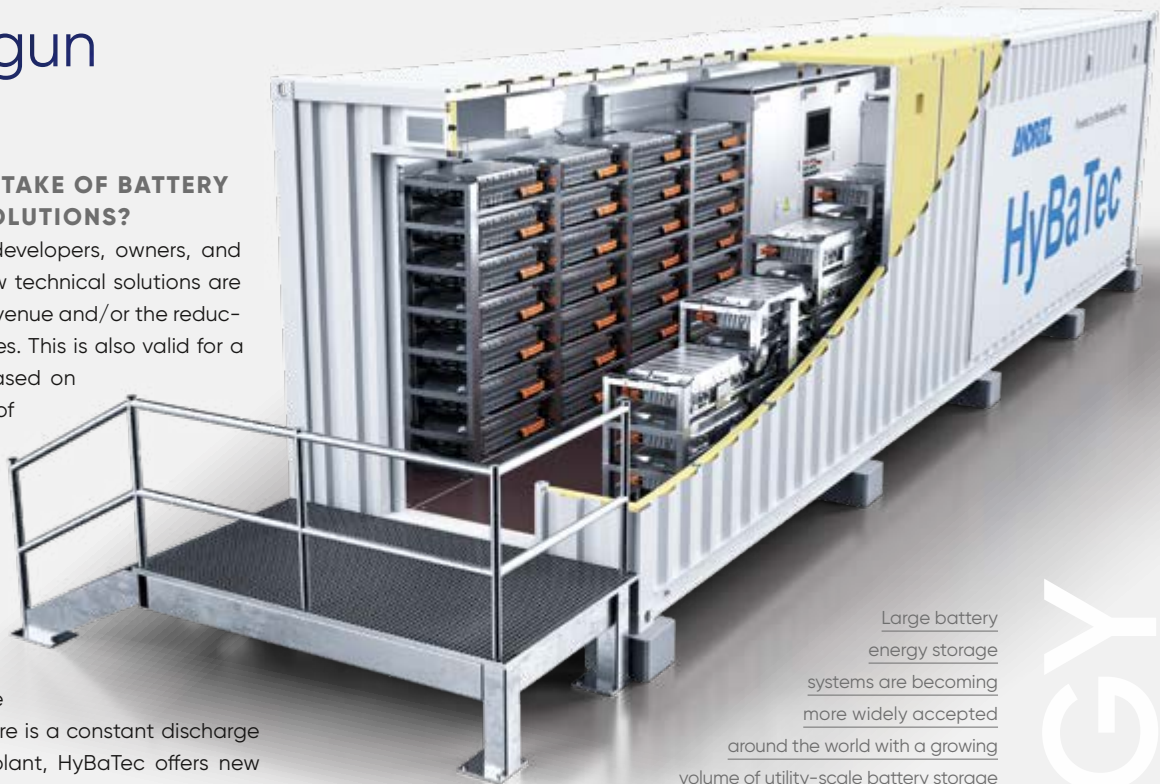
TECHNOLOGY — HYBATEC

NEW REVENUE HYDRO

hydro has begun

WHAT IS DRIVING UPTAKE OF BATTERY ENERGY STORAGE SOLUTIONS?

Key drivers for investors, developers, owners, and operators interested in new technical solutions are the potential increase in revenue and/or the reduction in operational expenses. This is also valid for a hybrid battery solution. Based on the rapid response time of the whole system and the wider energy range, additional, and until now untapped, business opportunities are potentially available for owners that can deliver additional revenue streams from services like primary control. Where there is a constant discharge through the hydropower plant, HyBaTec offers new possibilities to increase daily revenue by shifting grid supply from base load to peak load tariff periods. There are other economic benefits too. A lot of hydropower plants around the world are older than 40



Large battery energy storage systems are becoming more widely accepted around the world with a growing volume of utility-scale battery storage systems already operating successfully.

“ANDRITZ Hydro’s HyBaTec is a dedicated hybrid solution for the hydropower industry, combining a turbine-generator unit with a battery able to meet new requirements and future demand.”

years and the challenge of modern grid codes and the volatility of renewables like wind and solar have a direct impact on the mechanical components of a hydropower plant. HyBaTec has the potential to reduce these impacts and smooth the operation

of the units. This reduces stresses and leads to an extended lifespan.

WHEN SHOULD I CONSIDER A HYBRID BATTERY SOLUTION?

It doesn’t matter if it’s a greenfield or brownfield hydropower plant – it is always possible to benefit from a hybrid energy storage project. At the project development stage, it could offer new technical designs that can reduce the civil and electro-mechanical capital investments needed. For existing projects, it provides an interesting solution to emerging market challenges by widening the energy output range and increasing the flexibility of the plant.



WILL HYBATEC FIT MY PLANT?

Battery-based hybrid solutions have a huge variety of possible applications in hydropower and can be integrated into all types of plants. Low head, high head, run-of-river and across all output sizes from the smallest to the largest hydropower projects, every plant is suitable for additional battery storage capability. Typically, battery capacities range from 500 kWh up to 30 MWh, depending on the specific use case.

In large-scale applications, HyBaTec is able to provide a new approach to compensate for the mechanical stresses found inside penstocks. For mid- to small-size or run-of-river stations, the most requested additional functionalities provided by the HyBaTec system are energy shifting (arbitrage) from base load to peak load or for providing ancillary services for the

grid. Island operation or black start capability is also possible, another particular advantage in some communities and rural areas, for example.

In addition to conventional hydropower applications, HyBaTec is also able to integrate with new hybrid technology approaches such as floating PV, or co-located smaller wind, solar, or tidal current energy generation.

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HYBATEC PRODUCT PORTFOLIO

- HyBaTec Grid (services)
- HyBaTec Storage (energy arbitrage)
- HyBaTec Lifetime

A combination of more than one of these functions is possible, as well as additional features such as virtual inertia, black-start capability and island operation.

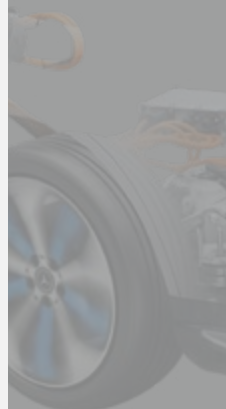
HOW DOES HYBATEC WORK?

The hydropower plant – Renewable hydropower technology is proven and reliable but can face limitations to smooth operations during rapid responses needed to manage grid volatility.

Battery energy storage system (BESS) – Featuring the most modern automotive Li-Ion battery solution for rapid response short-term storage capacity.

The HyBaTec controller – Managing operational setpoints for both the hydropower plant and the BESS, the controller takes into account all necessary parameters such as required operations, schedule, hydropower unit and battery status, for example.

Result – A wider operational energy range, faster response times, the highest operational flexibility and longer asset lifetimes.



COOPERATION WITH MERCEDES-BENZ ENERGY

A cooperation agreement with Mercedes-Benz Energy fuses more than a century of market-leading expertise in hydropower technology with cutting-edge innovative battery technology. This partnership opens up new opportunities for hydropower asset owners and operators.

“The cooperation with a world-renowned automotive manufacturer enables us to offer a top-tier, powerful and innovative large battery energy storage system to add value for our customers.”

The Mercedes-Benz battery is one of the most efficient in its class. An automotive battery made to the highest quality and safety specifications (TS 16949), it originates from the same production line as the batteries used in Mercedes-Benz AG's electric and plug-in hybrid vehicles.

A NEW DIMENSION IN ENERGY MANAGEMENT

Compared with a conventional hydropower application, the hybrid energy solution offered by ANDRITZ Hydro and Mercedes-Benz Energy can significantly enhance the operational range and flexibility of a hydropower unit.

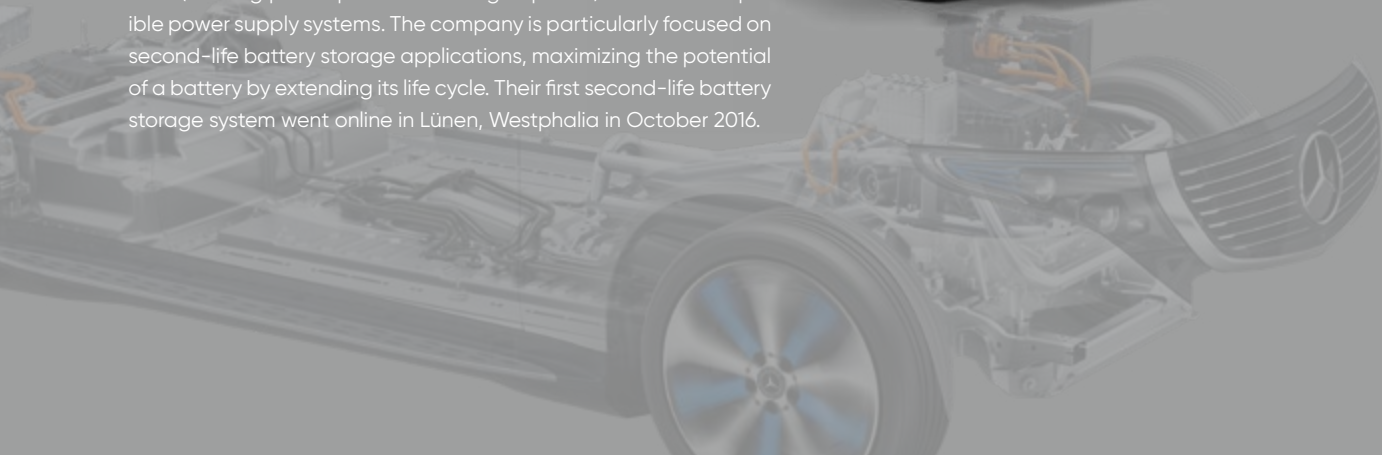
Increasing revenue and decreasing operational expenditure are key to improving the economics of a hydropower plant. Both are addressed by HyBaTec. For proven and hardworking hydropower plants, the rapid response capability of the battery can smooth the impact of grid volatility and therefore contribute to a longer healthy lifetime. HyBaTec also opens up new and previously untapped business opportunities in a growing market.

MERCEDES-BENZ ENERGY GMBH

Mercedes-Benz Energy develops innovative energy storage solutions based on automotive battery technology used in Mercedes-Benz AG's electric and plug-in hybrid vehicles. Based in Kamenz, Germany, the company is a subsidiary of Mercedes-Benz AG. Mercedes-Benz Energy GmbH, in cooperation with partners from the energy industry, is bringing batteries from the electric vehicle to the grid. The spectrum for large-scale storage applications includes time shifting renewables, peak load balancing, black start (starting power plants without grid power) and uninterruptible power supply systems. The company is particularly focused on second-life battery storage applications, maximizing the potential of a battery by extending its life cycle. Their first second-life battery storage system went online in Lünen, Westphalia in October 2016.



Different battery types are used in Mercedes-Benz AG's electric and plug-in hybrid vehicles depending on the application



KEEP YOUR ASSET CYBERSECURE

HyNET and HySEC – The dedicated smart network and security solution for hydropower plants in the digital age

Digital innovations have become an integral part of our world and the energy sector must respond with modern security concepts to keep their operations safe and secure at all times.

Over time, the demands on power plant networks have changed dramatically. Nowadays, a multi-service network is cutting-edge for the hydropower sector and active data exchange between energy producers, distributors, and consumers is making a full spectrum security concept crucial. It must also combine traditional process and control communications systems with modern technology.

“ANDRITZ is offering an all-encompassing cybersecurity tool suite to guarantee hydropower plant systems are able to run in a controlled and secure manner.”

ANDRITZ' HyNET network is the basis for secure communications both within a power plant and between geographically separated power plants and the central control room. Based on our long experience, HyNET combines state-of-the-art network and security technology and guarantees smooth and secure operations.

MULTI-SERVICE NETWORK

Networking of all the necessary components for running a power plant takes place on the control and process level. Special attention is given to network availability and redundancy. Even in the case of an interruption, communications between the automation equipment and the control system must be maintained. This is achieved with a comprehensive network design, as well as the use of high-quality components. By integrating voice and video over IP into the existing Ethernet network, additional costs are avoided. However, for security reasons, a strict separation between control systems, process networks, and service networks is required.

CYBERSECURITY

High-performance networks and their connected processes and control equipment must be unconditionally protected against attacks like unauthorized access, data manipulation, and denial of service attacks. ANDRITZ' dedicated cybersecurity solution is known as HySEC. An all-encompassing and fully integrated solution, it meets the extremely high demands required in the energy business.



Technical pictures courtesy of Cisco and Hirschmann/Belden

SYSTEM PATCHING, ANTIVIRUS AND FALSE-POSITIVE PREVENTION

To safeguard the control environment, a comprehensive system patching and anti-malware solution is indispensable. Operating systems must always be kept up to date. The lack of a single patch could endanger the entire environment. However, only patches that have been tested and files that can be clearly identified and processed in the anti-malware system can prevent the occurrence of false positives. With HySEC's false-positive scanning this threat can be prevented.

WHITELISTING

Whitelisting permits only predefined services to be started in a secure environment, preventing the execution of malicious code. A specially fine-tuned malware scanning engine is the basis for ensuring secure and fault-free operation.

MONITORING AND DIGITAL RISK MANAGEMENT

As well as securing the network and all its connected components, monitoring the infrastructure and cyber risk governance are also essential. Behavior of the data streams, vulnerability management, display and monitoring of attacks and the correlation of logging and system information can all be achieved through the system-wide implementation of HySEC orchestration.

ANDRITZ' HyNET and HySEC are innovative and comprehensive cybersecurity solutions that provide a wide range of services, all with top-tier technology, perfectly defined processes, and our long-standing technical experience.

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WE CARE

THE ANDRITZ ENVIRONMENTAL SOCIAL GOVERNANCE PROGRAM

ESG is about the voluntary contribution of companies to a sustainable development going beyond legal requirements. It stands for Environmental, Social, and Governance.

We have developed a comprehensive ESG program named "We Care" that combines all our activities, plans and

measures in the sustainability sector under one roof.

We have committed ourselves to reaching ambitious environmental, social and governance-related goals. The focus topics and goals of the program were selected in consideration of the areas in which we can make the

largest contribution towards a sustainable future.

More information about "We Care" including strategy, focus areas and goals can be found at

andritz.com/esg
connect.andritz.com/esg

