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ANDRITZ Hydro

CHINA
FENGNING II

New contract; June 2017; 1,800 MW; Fengning Pumped Storage Ltd. Co.; two 306 MW/ 333MVA pump units incl. Balance of Plant, Electric Power Systems (EPS) as well as protection and control systems and governors; closing scheduled for mid-2021;

PORTUGAL
ALTO TAMEGA

New contract; July 2017; 922 tons; Iberdrola Generación Espana S.A.U.; hydro-mechanical equipment including trash racks, gates and stop logs as well as control systems;

VIETNAM
THAC CÁ 2 AND DONG SUNG

New contract; June 2017; 16 MW each; Xuan Thien Yen Bai Co.Ltd.; electro-mechanical equipment including a horizontal shaft Bulb turbine-generator for each plant incl. mechanical auxiliaries, electric power systems, and automation; completion mid- respectively end of 2019;

CANADA
GARTSHORE

New contract; June 2017; 23.5 MW; Great Lakes Power Limited; general major rehabilitation incl. new Kaplan runner, stator winding and turbine governor; completion planned October 2018;

MEXICO
TEMASCAL I

Project update; June 2017; 338 MW; Comisión Federal de Electricidad (CFE); unit #4 successfully delivered and ready for commissioning, guaranteed values of power and efficiency exceeded; site works for unit #3 started;

PAKISTAN
GOLEN GOL

Project update; June 2017; 110 MW; Water & Power development authorities (WAPDA); rotor and stator of unit #1 successfully installed; pre-assembly for unit #2 and #3 ongoing; closing scheduled for end of 2018;

CANADA
CHENAUX GS

New contract; June 2017; 143.7 MW; Ontario Power Generation; replacing of all control and protection systems for eight generators; including design, installation and commissioning; completion scheduled end of 2019;

SMALL & MINI HYDRO

NORWAY
VASSENDEN

"from-water-to-wire" package; 9.96 MW; Helgeland Kraft AS

AUSTRIA
WÖLZERBACH

one 500 kW horizontal axial turbine; Murauer EnergieZentrum

AUSTRIA
TRAUNLEITEN

Bulb turbines and synchronous generators; 2 x 10.3 MW; Wels Strom GmbH

READ MORE ABOUT SMALL & MINI HYDRO PROJECTS
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State-of-the-art technology for fish-friendly design and Mini-Grid solutions

Dear Business Friends,

With some 22% of the world's demand for electricity currently generated from renewable resources, the 74% of that total coming from hydropower already makes it by far the largest clean power contributor. Many developing countries have now also started to realize the low and very low head hydropower potential of their rivers. For all modern hydropower applications optimization across a range of economic parameters and environmentally-friendly solutions are crucial. Fish migration has become a highly significant issue, for instance. ANDRITZ HYDRO is fully committed to the continuous development of fish-friendly solutions for hydropower turbines and structures, and has been for decades. The cover story in this edition of HydroNews provides an overview of the ANDRITZ HYDRO design strategy to ensure high survival rates where fish populations encounter hydropower developments.

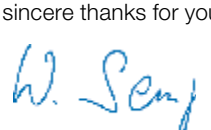
In a generally very challenging energy market, global investment in hydropower plants has remained buoyant and project activities have reflected this stability in recent years. ANDRITZ HYDRO continues to make its contribution with unique projects all over the world. Recent examples include contracts for the three-nation Rusumo Falls project in Rwanda, the fish-friendly solution at Rock Island in the USA, Nam Na 1 in Vietnam and Dnipro 1 in the Ukraine. Originally built in 1932, Dnipro is still the largest hydropower plant in the country and is now being refurbished and the existing generating equipment replaced.

Around the globe, the market for small and mini hydropower is steadily growing. Besides numerous new projects, older and less efficient sites are being modernized and refitted. An example is the historically significant Chaudière Falls site – in the heart of the city of Ottawa, Canada, the country's oldest operational hydropower plant, where the most powerful ECOBulb* turbines to date have been installed by ANDRITZ HYDRO.

Rural Electrification is also becoming a very important element of the hydropower market. To meet this demand ANDRITZ HYDRO has developed special Mini-Grid solutions for off- and micro-grid applications to bring electricity to remote areas and support economic development.

The experienced ANDRITZ HYDRO employees remain very active in project execution worldwide – as the current engagements in Angola, Brazil, Lao PDR and Switzerland demonstrate. With evolving requirements for environmentally-friendly and economic hydropower solutions, new possibilities for small and mini-hydro, as well as refurbishment and rehabilitation opportunities, ANDRITZ HYDRO is confidently looking forward to the future hydropower market.

With kind regards
and sincere thanks for your continued trust,



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climate neutral
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NEW PROJECTS

DNIPRO 1

IN THE FLOW OF HISTORY

Powerhouse

UKRAINE – Ukraine's state-owned PJSC Ukrhydroenergo (UHE), the country's largest hydropower company, has signed a contract with ANDRITZ HYDRO for the rehabilitation of three units at its Dnipro1 hydropower plant. Awarded in late December 2016, this contract sees ANDRITZ HYDRO become the first European contractor for a large hydro rehabilitation project in Ukraine.

At the lower reaches the Dnieper River is filled with rapids, which made it difficult to navigate until the 19th century. Today, this is the location of the Dnipro hydropower plant (also called Dnieper HES-1). The plant spans the Dnieper River like a bridge

between the cities of Zaporizhia and Dnipropetrovsk.

This famous hydropower plant was the first power plant of the Dnipro cascade and was originally built by the former Soviet Union in 1932. Until 2016 this power plant was named after Lenin. In 2016, the Ukrainian government renamed it after the homonymous river.

During World War II the Dnipro plant was severely damaged. After rebuilding, it was re-commissioned in 1949. Some decades later, HPP Dnipro was extended with a second power house (Dnipro 2) on the left river bank. At the time of its construction – at over 800 m length and more than 60 m height – the Dnipro dam was the largest in Europe. Even today, considered jointly with HPP Dnipro 2, with a total of 18 units and an installed capacity of more than 1,500 MW, the Dnipro plant is still the largest hydropower plant in Ukraine. Now, after more than 70 years of operation, the existing generation units of HPP Dnipro 1 have to be replaced with new units, providing higher output, efficiency and reliability.

Experience further content

Contract signing

© PJSC Ukrhydroenergo (UHE)

ANDRITZ HYDRO is responsible for the rehabilitation of three Francis turbines and generators – units #1, #2, #3 – including dismantling of the existing equipment and supply, installation, and commissioning of the new units.

One of the technical highlights of this contract is the implementation of an umbrella design while keeping the historic upper bracket, which will be refurbished and brought into position but without function. According to the contract time schedule, the last unit should be finished and commissioned in late 2021.

This order represents not only a very important step into the Ukrainian hydropower market, but the partial preservation of important historical artifacts at the same time. Rehabilitation of this historic and prestigious hydropower plant making it fit for the future is not only an interesting but also a complex challenge.

Dnipro 1 | Ukraine

Technical data:

Total output:	1,500 MW
Scope:	3 × 75 MW
Voltage:	13.8 kV
Head:	35 m
Speed:	83.30 rpm
Runner diameter:	5,740 mm

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NEW PROJECTS

GRAZ-PUNTIGAM

A 3D simulation of the plant on the Mur River

Experience further content

Graz-Puntigam | Austria

Technical data:

Total output:	17.7 MW
Scope:	2 × 8.85 MW
Voltage:	6.3 kV
Head:	9.65 m
Speed:	150 rpm
Runner diameter:	3,600 mm

AUSTRIA – In March 2017, ANDRITZ HYDRO was awarded the contract to supply the electro-mechanical equipment for a new hydropower plant to be built in the heart of Graz, the capital of the Austrian province of Styria. The project owner and investor is the Styrian energy utility Energie Steiermark, together with VERBUND and Energie Graz. Commissioning of the plant is planned for the first half of 2019.

ANDRITZ HYDRO is going to supply two Bulb turbines with a capacity of 8.85 MW each, including speed controllers, as well as generators, excitation and the entire control system of the plant. The power plant is designed for a gross head of 9.65 m and a flow rate of 200 m^3/s. The major part of the equipment will be produced in the ANDRITZ HYDRO workshop in Weiz, Austria, thus providing substantial local added value.

Currently, the electricity produced in Styria covers less than half of the province's electricity demand. In order to improve Styria's energy balance and to achieve the ambitious climate goals set out under the Paris agreement, the Styrian climate and energy strategy stipulates intensified expansion of renewable energy sources. Initial plans for the Mur River hydropower plant in Graz were presented to the public in 2009. In the course of an environmental impact assessment taking a total of four years, environmental experts from the province of Styria and from the Federal Environmental Senate thoroughly analyzed the project site, as well as all the input and any concerns from NGOs and local residents. Finally, in 2014 the go-ahead for the project was given, and all required legal certifications could be obtained. The hydropower plant will provide about 45,000 Graz residents as well as the numerous electric cars in the city with CO_2-free electricity starting in 2019, and will lead to a sustainable reduction of dependency on electricity imports. Thus, about 60,000 tons of CO_2 will be saved annually once the hydropower plant is in operation.

This order once again underlines ANDRITZ HYDRO's successful and long-term cooperation with both Energie Steiermark and VERBUND while it also strengthens the company's leading market position in the Austrian hydropower market.

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NEW PROJECTS

TILOTH

AN ENGINEERING CHALLENGE

INDIA – Towards the end of 2016, ANDRITZ HYDRO signed a contract with UJVN Limited for the rehabilitation of the Tiloth hydropower plant in Uttarakhand, India.

Located on the Bhagrathi River in the north of India, HPP Tiloth was originally commissioned in 1984. It consists of three generating units with a capacity of 30 MW each.

ANDRITZ HYDRO's contractual scope comprises the supply of three vertical Francis turbines, generator components, electronic governors, static excitation and protection systems, and a SCADA system. The contract also includes electrical and mechanical auxiliary systems, as well as the refurbishment of existing equipment, such as spherical valves, transformers, and switchyard equipment. Installation, testing and commissioning complete the terms of the contract.

A team from ANDRITZ HYDRO locations in Germany, Switzerland, and India are working in close cooperation to meet the challenges of the project. One of these challenges is the tight time frame for delivery of the first unit – within 22 months including reverse engineering. Furthermore, the Bhagrathi River is very silty. Suspended solids can cause serious damage, hence erosion-resistant underwater equipment is necessary. Methods to reduce the impact of silt particles on the equipment include adding a further sedimentation chamber and adaptation of the steel of the runner blades. To design such advanced equipment poses an interesting challenge for the engineers.

The completion of the project and hand over to the customer is scheduled for the second half of 2021.

ANDRITZ HYDRO has already executed rehabilitation work at HPP Pathri (3 × 6.8 MW) in 2010–2014 to the full satisfaction of the same customer.

With successful execution of this project, ANDRITZ HYDRO will further reinforce its position as a technology leader and reliable partner in developing hydropower in India.

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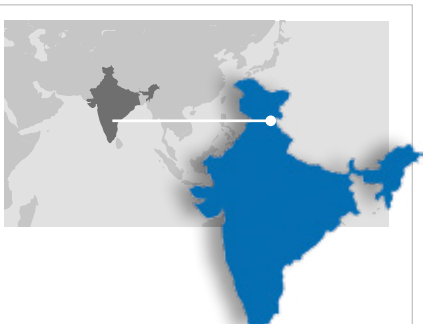


Tiloth | India

Technical data:

Total output:	90 MW
Scope:	3 × 30 MW
Voltage:	11 kV
Head:	145 m
Speed:	428.6 rpm
Runner diameter:	1,620 mm

NEW PROJECTS

ATLANTA

WATER FOR ATLANTA

USA – The former Bellwood granite quarry northwest of Atlanta, Georgia, is to become one of the biggest water storage facilities in the United States as part of a major infrastructure development program to increase drinking water supplies for more than one million residents of the city and its surroundings. As the capital and the most populous city in the state, Atlanta has intensified its efforts to alter the city demographics, politics and culture to become a pioneer in enhancing safe and stable supplies of potable water for its citizens.

> *"Clean and secure water supply is essential to the health of the people and to the economy of a city."*
>
> **Department of Watershed Management**

Atlanta has been striving to modernize its infrastructure and revitalize its neighborhoods since the 1996 Olympic Games. One of the most prestigious and important projects is set to dramatically increase the city's drinking water supplies.

Bellwood quarry – northwest of Atlanta's downtown district – is going to become one of the biggest water storage facilities in the country, storing some 2.4 billion US gallons of water (9.1 billion liters) as part of this program. This expansion of the city's

raw storage capacity will provide Atlanta with a reliable supply of drinking water for the next 100 years and increase the emergency raw water reserve from just three days to 30 days. The Department of Watershed Management, which is in charge of the water supply of about 1.2 million people in Atlanta and its surrounding area, is investing about US$ 300 million in this amazing project.

Converting a 300 ft (91.4 m) deep quarry into a water storage facility and recreation area includes blasting two circular pump station shafts near the quarry, one 35 ft (10.7 m) diameter and 200 ft (61 m) deep and the second with a 20 ft (10.6 m) diameter and 300 ft (91.4 m) deep. Five further 6.3 ft (1.9 m) diameter pump shafts are to be constructed, along with a new power substation and various improvements to existing infrastructure. Central to this project are the 136 million gallons per day (mgd; 29,052 m^3/h) Hemphill Tunnel Pump Station with four vertical turbine pumps and the 200 mgd (40,834 m^3/h) Quarry Pump Station with four vertical turbine pumps and three submersible turbine pumps.

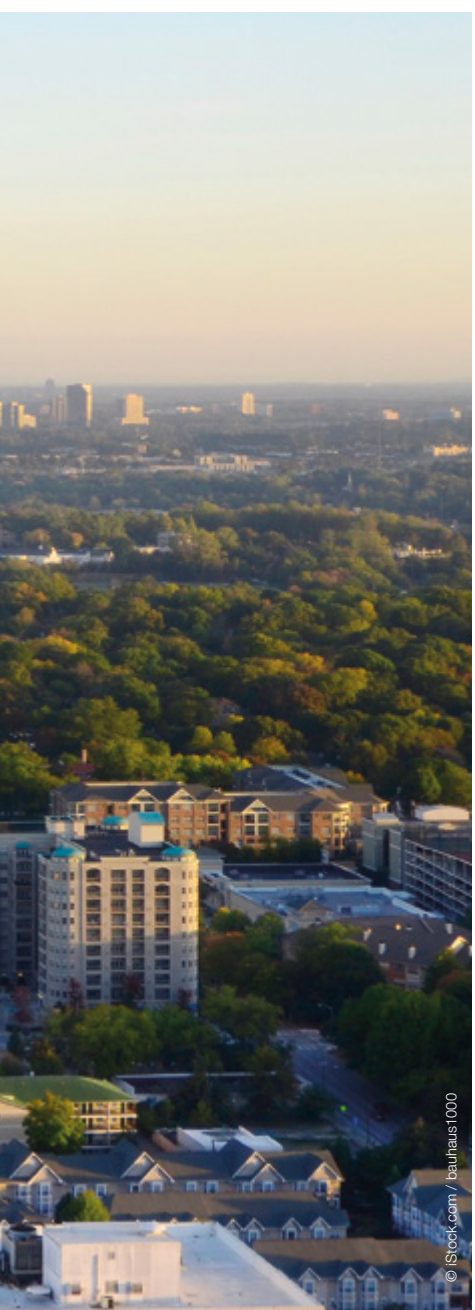
The quarry will be filled through a five-mile-long (7 km) tunnel that will connect it with the Hemphill and Chattahoochee Water Treatment Plants and the raw water intake and pump station at the Chattahoochee River, the city's primary water source. The work also involves boring this 10 ft (3 m) diameter tunnel, as well as the mechanical, electrical and SCADA systems associated with the pump stations.

Drilling is being done by an impressive 400 ft-long tunnel-boring-machine (121 m), which arrived in Georgia in July 2016 on 70 trucks and assembled directly on-site.

After a public naming contest, the tunnel-boring-machine was named "Driller Mike" as a tribute to Atlanta resident Michael Render, aka "Killer Mike", a famous rapper, actor and activist. The artist is honored to be associated with this project.

After completion of the project, the city plans to develop a 300 acre (1.2 km^2) recreation area at the site – the Westside Park. It will be the largest park in Atlanta and will be designed with public input in accordance with the Department of Watershed Management requirements.

The strategically important contract to supply the submersible pumps, including associated equipment for the low level pumping station, was awarded to ANDRITZ on the basis of a technically superior, innovative, and very economical solution. Offering a turn-key solution provides a sustainable, low-maintenance service concept with low follow-up costs. In contrast to previous projects, direct contact between the engineering company and the owner was possible. Consultation and engagement with the owner during the early development stages was a major advantage.



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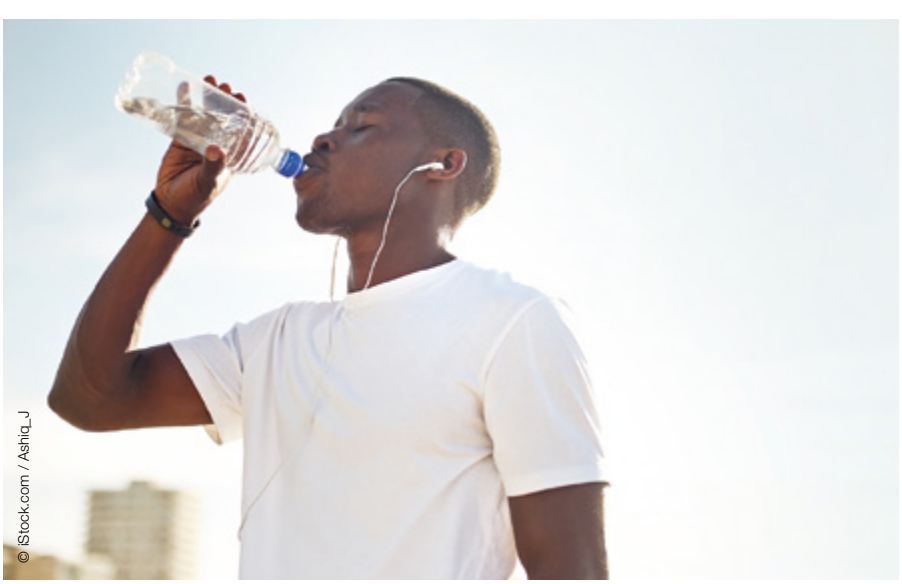
The average domestic water use for each person in the USA totals about 50 gallons (190 liters) a day.



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Submersible pump

"Reinvention of this quarry as a reservoir and as a surrounding park is one of the most creative land reclamation projects going on in the city of Atlanta and certainly in the southeast."

Kasim Reed, Mayor of Atlanta

As water is withdrawn and the water level drops to very low levels, the system requires that each submersible motor pump has a constant capacity rated at 30 mgd (4,842 m^3/h), even under fluctuating water surface levels ranging up to 120 ft (36.6 m). between minimum and maximum. To achieve this system requirement whilst operating under this submergence differential the submersible motors are driven by a variable speed drive, which enables the motors to run at varying speeds between 885 rpm and 1,081 rpm. Variable speeds change the axial forces on the rotating unit, which results

An abandoned granite quarry west of Atlanta – world famous from its appearance in television dramas such as "The Walking Dead", "The Hunger Games", and "Stranger Things" – is on its way to becoming a communal amenity for Atlanta.

Experience further content

in varying shaft elongation and ultimately in undefined dynamic loads on the axial thrust bearings.

One of the major benefits of the proposed ANDRITZ solution using double suction submersible motor pumps is the full compensation of the axial thrust independent of the rotational speed. This characteristic neutralizes the load on the pump, the motor and its thrust bearings. With this technology, two contra-rotating submersible motor pumps are arranged on top of each other and driven by a continuous pump shaft. Each of the two pumps transports half of the capacity to the middle of the pump at full pressure. This significantly reduces wear and tear, increasing service life to up to 20 years and more and provides the maximum possible operational reliability. The division of work between the two pumps not only achieves the complete compensation of axial thrust, it also halves the suction velocity at the pump inlets. This protects the well walls around the intake openings and minimizes the intake of abrasive solids and silt.

ANDRITZ HYDRO received this important order – the largest pump order for ANDRITZ in North America to date – from the Joint Venture PC Construction and H.J. Russell. It marks an important step into this growing market. The ANDRITZ team, comprising engineers and specialists from the US as well as Europe, are proud to prove the high quality of ANDRITZ pumps and equipment and are pleased to contribute to the future supply of hundreds of thousands of people with fresh drinking water.

The completion of the project is scheduled for 2019 and will address Atlanta's goal of achieving a sustainable water infrastructure for future generations and flexibility in systems operation. In the event of a crisis or loss of water service, it provides redundant water storage and can save the city millions of dollars per day.

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Atlanta | USA

Technical data:

Primary Rated Capacity:	30.7 mgd
Primary Rated TDH:	160 ft
Rated Motor Power:	2,210 HP, 60 Hz, max. speed 1,081 rpm

3 × double suction submersible motor pump units with discharge piping and variable speed drives

1 US gal. = 3.78 liters, 1 ft = 0.3048 meters, 1HP = 0.75 kW, 1 acre = 4,046 m^2

NEW PROJECTS

RUSUMO FALLS

A THREE NATIONS PROJECT

BURUNDI / RWANDA / TANZANIA – For the Rusumo Falls Hydroelectric Project Rusumo Power Company Limited has awarded ANDRITZ HYDRO a contract for design, supply, installation, and commissioning of the electro-mechanical equipment.

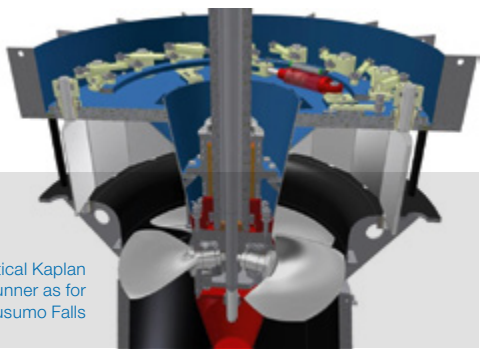
A joint development of three east African nations – Burundi, Rwanda and Tanzania – the implementation of this project will be driven by an investment program of the Nile Basin Initiative, the "Nile Equatorial Lakes Subsidiary Action Program (NELSAP)", on behalf of Rusumo Power Company Limited. Financing for the project is being provided by the World Bank.

The new hyropower station will be located on the Kagera River, about 2 km downstream of the confluence of the rivers Ruvubu and Kagera, at the border between Rwanda and Tanzania.

Under the terms of the contract signed in November 2016, ANDRITZ HYDRO's scope of supply comprises the delivery of three 27.5 MW vertical Kaplan turbines and auxiliaries. In addition, generators, Electrical Power Systems (EPS), powerhouse cranes, draft tube gates, and stop logs, as well as the control and protection systems of the whole hydropower plant, fall within the scope of supply.

Execution of this project will be done by a team from international ANDRITZ HYDRO locations. ANDRITZ HYDRO Germany has the lead of this project, and – working in close cooperation with the customer – will be in charge of all on-site works. ANDRITZ HYDRO India is responsible for the manufacturing and delivery of the main components including generators, EPS, and the draft tube gates, whereas the ANDRITZ HYDRO Austria team is giving technical engineering support.

The first big project milestone was reached at the end of March 2017, when the groundbreaking ceremony took place in



Vertical Kaplan runner as for HPP Rusumo Falls

Contract signing

the presence of important officials from all three involved nations, representatives from the World Bank, the African Development Bank, and key stakeholders. This was the official start of the site civil works contract activities. ANDRITZ HYDRO will start its site activities towards the end of this year, when the access to the powerhouse and the site has been prepared.

Overall the project duration is scheduled to last some 36 months, with completion by the end of 2019. HPP Rusumo Falls is an important project for the whole region. It will provide an additional 27.5 MW to each of the three countries involved and will reinforce regional power interconnection. About 7,000 households in each of the countries will benefit from the power generation of the hydropower plant. Additionally, the site is going to provide job opportunities for over 500 local people.

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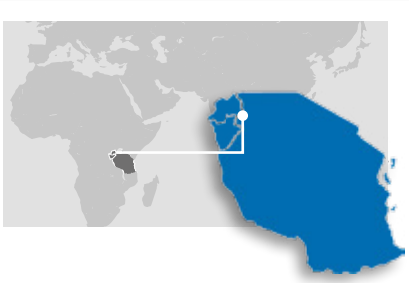

Rusumo Falls | Burundi | Rwanda | Tanzania

Technical data:

Total output:	82.5 MW
Scope:	3 × 27.5 MW
	3 × 30 MVA
Voltage:	11 kV
Head:	25 m
Speed:	187.5 rpm
Runner diameter:	4,050 mm

NEW PROJECTS

ROCK ISLAND

CONNECTING HISTORY WITH FUTURE

© Chelan PUD

USA – Located in Washington State, the Rock Island Hydroelectric Power Plant was commissioned in 1933 and was the first dam to span the Columbia River. Sited about 12 miles (19 km) downstream from the city of Wenatchee, units B1–B4 in Powerhouse 1 were the first turbine generator sets installed on the Columbia River. In the 1950s another six generating units were installed in Powerhouse 1 and a second powerhouse with eight Bulb turbine units was subsequently commissioned in 1979.

ANDRITZ HYDRO was awarded a contract by Chelan County PUD to modernize units B5–B10 starting in 2006. Now, ANDRITZ HYDRO has received a new contract to modernize the first four units, B1–B4, at Rock Island Powerhouse 1.

Kaplan runner

> *"It's a proud moment to move forward with this modernization work and to have the oldest turbines on the Columbia be replaced by the newest turbines."*
>
> **Randy Smith,**
> **Chelan PUD Commission President**

ANDRITZ HYDRO's proposed turbine design increases capacity, at lower heads, and boosts unit efficiency, providing incremental value to Chelan PUD. Another benefit of the new runners is the fish-friendly design, reducing the number of blades from six to four and reducing the risk of blade strike by a factor of 33%. Blade strike is a leading stressor affecting fish survivability. Cavitation is also a key stressor with impact on fish survivability. The design also reduces cavitation so that the runners are essentially cavitation-free over the entire operating range.
(→ **COVER STORY** page 18)

ANDRITZ HYDRO offered an alternate approach to this project by taking three units out of service for simultaneous modernization. This approach will result in the modernization being completed six months earlier than specified. Under the proposed schedule, Chelan PUD achieves greater flexibility to address any future unplanned outages and will have the units available prior to Chelan PUD's "check in" for its Habitat Conservation Plan (HCP). This plan is a 50-year commitment to ensure that Chelan PUD's hydro projects have no net impact on mid-Columbia salmon and steelhead runs. ANDRITZ HYDRO is proud to support Chelan PUD in meeting its HCP commitment.

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Rock Island | USA

Technical data:

Total output:	218 MW
Scope:	4 × 20.7 MW
Voltage:	13.8 kV
Head:	40 ft (12.19 m)
Speed:	100 rpm
Runner diameter:	228 inch (5,791 mm)

Experience further content

NEW PROJECTS

NAM NA 1

30 MW FOR VIETNAM

VIETNAM – The new Nam Na 1 hydropower plant, located on the river of the same name, is just part of Vietnam's impressive hydropower potential of about 120,000 GWh/year. Lai Chau Province, where Nam Na 1 is located, is identified as a significant area for the development of medium-size and small hydropower projects in the country's National Electrical System Development Plan. Hung Hai Group has been promoted as a major strategic investor in the province, having been granted the right to develop many hydropower projects. As part of its investment program, a subsidiary of Hung Hai Group – North-West Power Joint-stock company – has signed a contract with ANDRITZ HYDRO for the electromechanical equipment for HPP Nam Na 1.

The contractual scope of supply comprises design, manufacturing, and installation of two turbine-generator units, including governor, main transformer, GIS, electrical power system, and auxiliary mechanical systems. Erection, commissioning supervision and training are completing the contract.

ANDRITZ HYDRO secured this contract for the Nam Na 1 hydropower plant, about 12 hours drive from the capital Hanoi, on the basis of the quality of its equipment and professional project management, proven during pervious projects executed in Vietnam in recent years.

In order to increase domestic value during the execution of the project, ANDRITZ HYDRO is to involve local suppliers for manufacturing of turbine parts, such as draft tube, hatch cover and embedded piping, local deliveries for the EPS and mechanical auxiliary equipment and installation works.

The newly-established ANDRITZ HYDRO company in Vietnam is playing a key role as first contact for the customer and coordinator of the local supplies and services. The dedicated team of ANDRITZ HYDRO Vietnam is facing a very tight schedule and is keen to accelerate the project development as much as possible, working in tight coordination with the customer.

With eight Large Hydro projects as well as six Compact Hydro projects currently being executed in Vietnam, ANDRITZ HYDRO has again underlined its leading position in the important Southeast Asian region.

Experience further content

Nam Na 1 | Vietnam

Technical data:

Total output:	30 MW
Scope:	2 × 15 MW
Voltage:	6.3 kV
Head:	9.62 m
Speed:	120 rpm
Runner diameter:	4,600 mm

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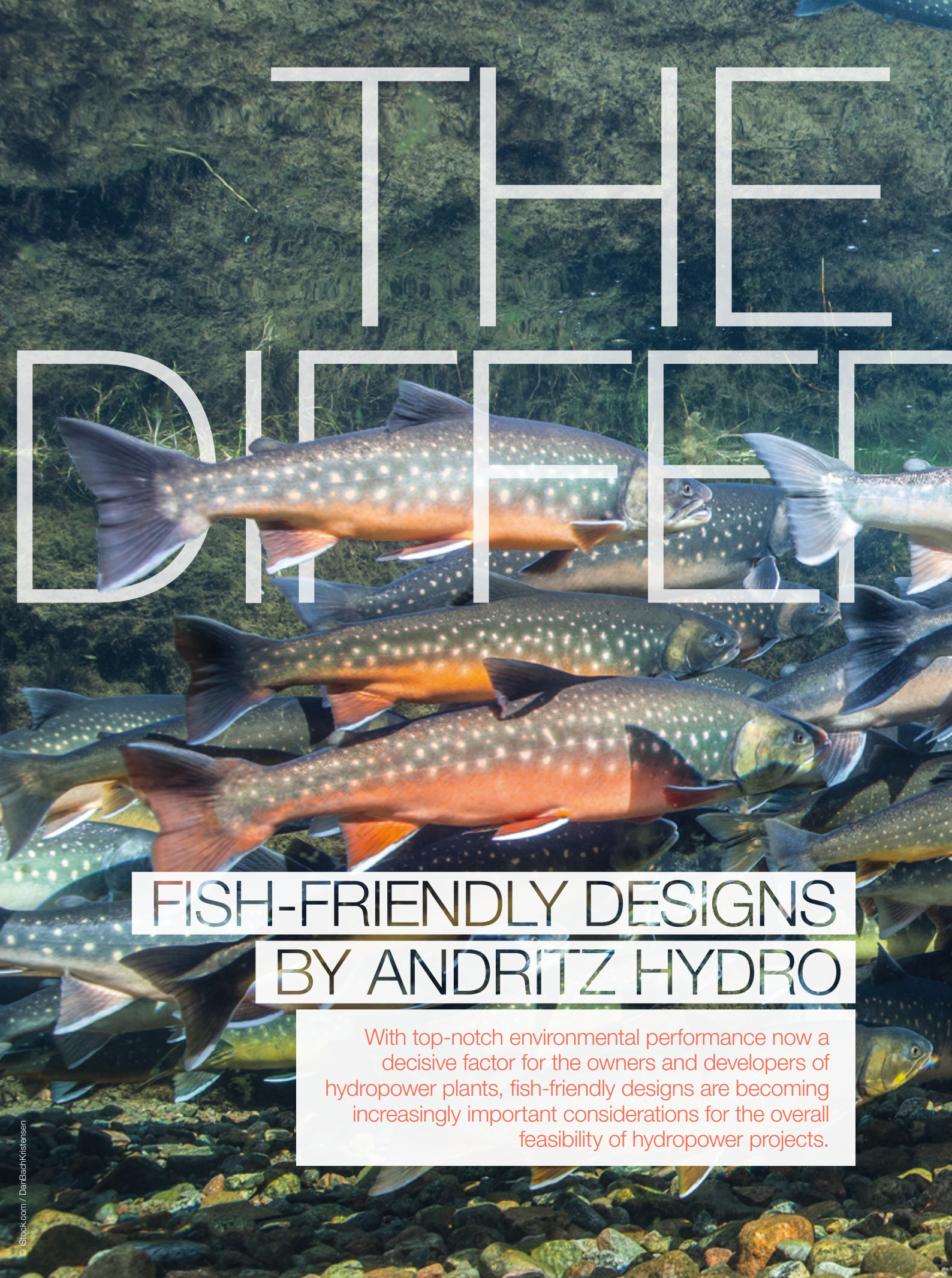


THE DEEP

FISH-FRIENDLY DESIGNS BY ANDRITZ HYDRO

With top-notch environmental performance now a decisive factor for the owners and developers of hydropower plants, fish-friendly designs are becoming increasingly important considerations for the overall feasibility of hydropower projects.

BIG
PENCE

Decisions made during the early design stages of a project, such as those relating to the hydraulic and mechanical design of the turbines can have a dramatic effect on improving fish viability.

Among the many different topics that must be addressed to optimize a run-of-river hydropower project from an environmental point of view, fish migration is a highly significant issue for many water courses.

Fish migration usually occurs in order to feed or reproduce. For example, in upstream migration (anadromous fish migration), adult sea-dwelling species like salmon, striped bass and sturgeon return to their spawning grounds in the tributaries of large rivers.

Once a year, the adults of these species enter rivers and swim upstream, energetically clearing all obstacles and even waterfalls, to reach their destination where they produce fertilized eggs. The young eventually find their way downstream to the sea to mature into adulthood. Every fish faces many sources of danger during migration: professional or leisure fishing and natural predation, but also poor water quality due to pollution and local water temperature changes caused by cooling

→

THE ANDRITZ HYDRO
FISH FRIENDLY OPTIONS

Variable speed

Optimal operating scheme

Reduced gap runner

Reduced turbulence level

water discharge from the industry. Last but not least, hydroelectric power plants can also pose dangers to migrating fish.

Possibilities to influence fish survival

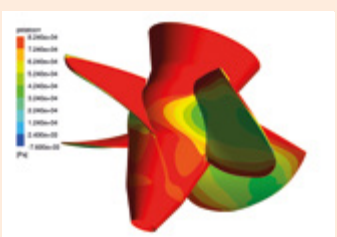
From the first phases of plant design and layout, important parameters are set. For instance, during the powerhouse design phase when the number, type and size of the turbines are selected, many important decisions are made that can potentially reduce fish mortality. In particular, the hydraulic as well as the mechanical design of the turbines offers many opportunities to significantly and positively influence fish survival rates. In order to accurately assess different designs in terms of their fish mortality-related performance, comprehensive knowledge of injury mechanisms and their corresponding mitigation measures is necessary. Thorough studies also have to be conducted, forming the basis of the best hydropower solution for the ecology of the river.

Fish Survival Assessment

There are two kinds of hydropower related influences on fish mortality. Direct impacts due to physical injuries sustained during passage through the turbine; and indirect effects such as increased predation downstream of the discharge, and increased stress and/or disorientation after passage through the unit.

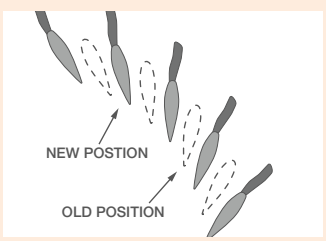
Since the 1990s, ANDRITZ HYDRO has followed a combined design strategy to ensure high rates of fish survival. Different design features are possible in connection to the various injury mechanisms caused by the different stressors (measurable,

Minimum cavitation runner

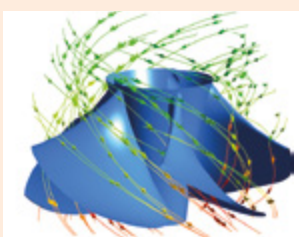


Blunt leading edge

Aligning stay and guide vanes



Biological assessment tool



physical quantities that can be linked to each injury mechanism). It is worth noting that the optimal choice of design parameters for fish survival might be slightly different from those design considerations in which maximizing energy production or minimizing costs are the only targets.

Variable speed ① Bulb turbines with additional speed variation have very high efficiencies across a wide operating range whereas conventional double regulated turbines show high efficiency over a narrower operating range. This efficiency capability is one of the fundamental advantages of variable speed technology in reducing impacts on fish. For example, increased fish survival rates can be achieved by **optimization of the operating scheme** ② for power plants. The strong relationship between the rates of fish survival, the discharge rate and fish length is one of most evident characteristics. During the migration season, recording the sizes of migrating fish allows plant operators to react by changing the operating scheme of the turbines to increase fish survival rates. The more information about fish migration behavior that is available, the more precisely the operating regime of the turbines can be adjusted during periods of significant migration.

ANDRITZ HYDRO focuses intensely on the development of fish-friendly solutions to safeguard the viability of fish populations while delivering high efficiency applied technology. By combining hydraulic knowledge with biological understanding, ANDRITZ HYDRO makes a big difference.

Reducing the gap ③ between rotating and stationary components can also boost survival rates by diminishing the risk of fish being trapped. This can be realized by using a fully spherical discharge ring to minimize the blade tip gap, using a spherical hub with “pockets” to minimize the hub gap.

Smaller gaps at the runner also **diminish the turbulence level** ④ in the draft tube. In general, turbulence in hydraulic passages can be separated between small and large-scale effects, which affect fish differently. Turbulence at small scales (length scales smaller than the fish length) is present in the same locations as high shear, and lead to similar injuries such as compression, stretching, and bending. Thus, small-scale turbulence injuries can usually be lumped together with shear stress injuries. Large scale turbulence (length scales longer than the fish) causes disorientation, hence increased stress on the fish. Such effects taken alone do not harm the fish, but increase the incidence of indirect mortality.

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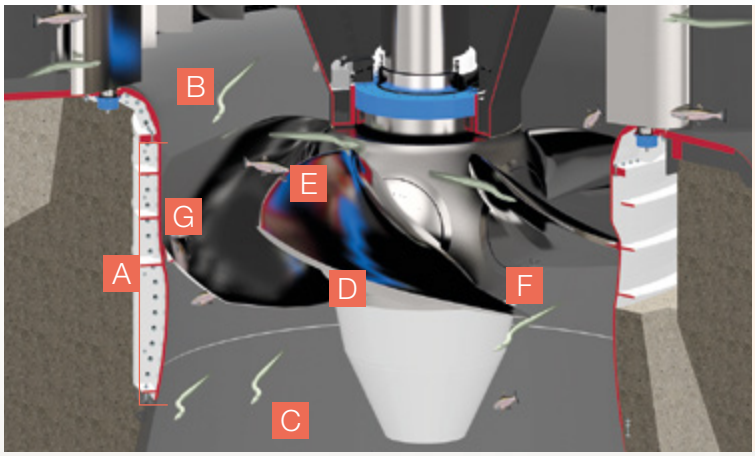

Direct turbine-related fish injury mechanisms

- A - Rapidly pressure changes
- B - Shear stress
- C - Turbulence
- D - Cavitation
- E - Impacts on walls and components
- F - Grinding
- G - Abrasion

A **minimum of cavitation** (5) throughout the whole operating range is also essential for a fish-friendly design. Cavitation occurs when static pressure reaches the vapor pressure, leading to the formation of vapor bubbles. Reaching regions of higher pressure, these bubbles rapidly implode producing extremely energetic micro-jets, which may damage the runner blades and disrupt fish tissues, representing a potential cause of fish mortality. This is very much linked to rapid decompression, which is hazardous if two conditions are met. Firstly, the pressure must drop significantly lower than the pressure that the fish is acclimated to. Secondly, the pressure must drop more rapidly than the fish can accommodate such changes. These conditions usually occur where the absolute pressure can drop in a few instants to a fraction of a fish's acclimation pressure.

A **blunt leading edge** (6) design may also allow a relevant increase in survival rates in particular for small-sized fish species in terms of the ratio of fish length to leading edge thickness. The optimal choice of the leading edge thickness will be achieved with the help of CFD simulations which also allow evaluating their

READ MORE ABOUT FISH-FRIENDLY PROJECTS IN THIS ISSUE:

→ **ROCK ISLAND / USA**
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→ **XAYABURI / LAO PDR**
Page 28

influence on the performance and on the cavitation characteristic of the blade.

Aligning the stay and guide vanes (7) at least in the most important operating points reduces the probability that a fish will hit the wicket gate.

ANDRITZ HYDRO uses a **biological assessment tool** (8) supported by CFD to record the various stressors on a fish along its trajectory through an operating turbine. Based on in-depth knowledge of the stressor limits for injuries to various fish species, survival rates can be calculated with this assessment tool.

ANDRITZ HYDRO is fully committed to continuous development in regard to the fish friendliness of hydropower units and structures. Enhanced understanding of fish behavior and injury mechanisms to ensure more reliable identification of critical design features is a must and advanced methods to improve fish survival through a hydraulic turbine have been developed in conjunction with internationally active groups of biologists. Measures to improve fish survival are possible at all stages during the planning and design of a hydropower plant. Serious consideration of the many parameters affecting mortality rates and optimization of the tools and measures used to mitigate those impacts can have a dramatic and positive effect on the environmental performance of hydropower plants.

ANDRITZ HYDRO is ready to contribute!

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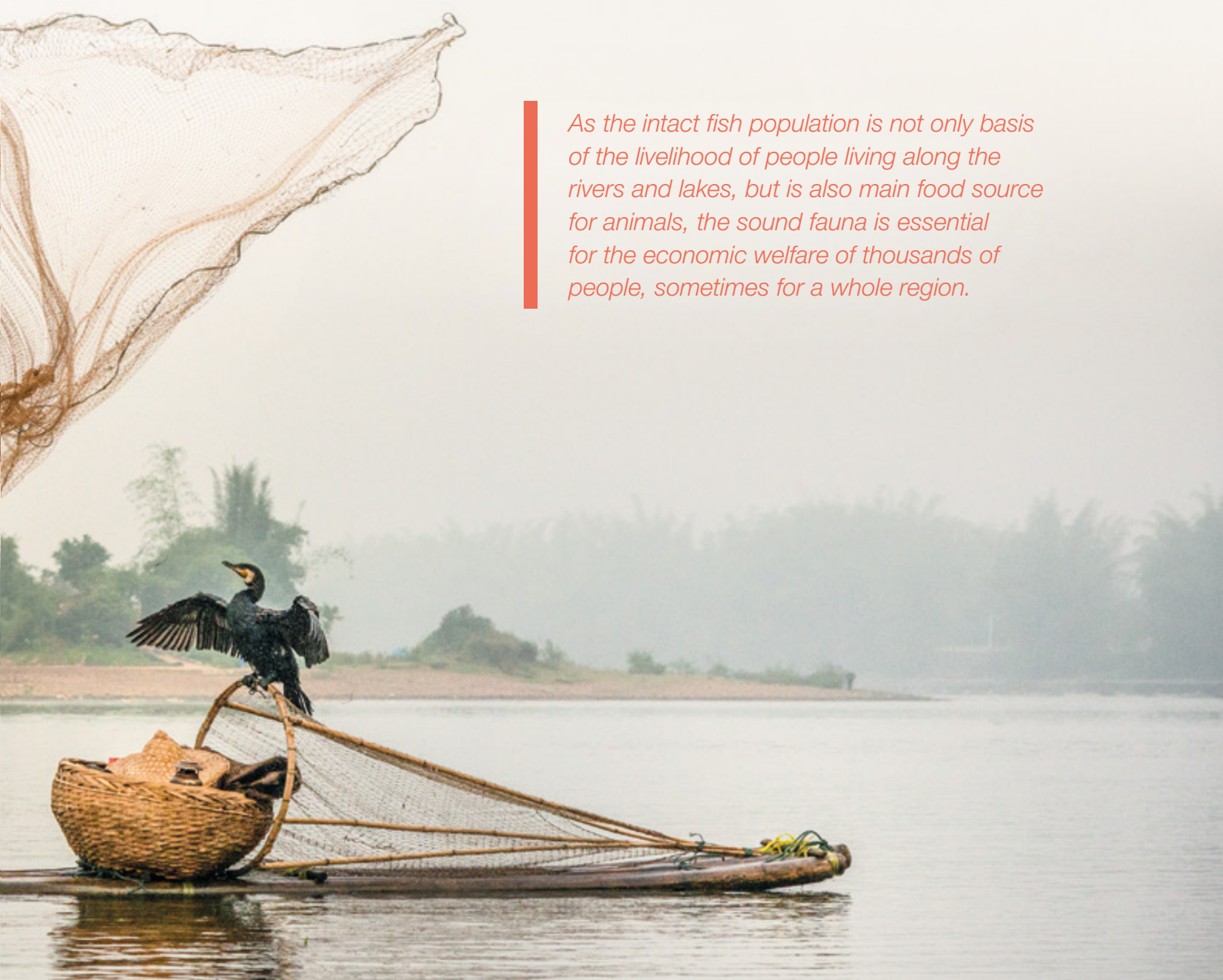


As the intact fish population is not only basis of the livelihood of people living along the rivers and lakes, but is also main food source for animals, the sound fauna is essential for the economic welfare of thousands of people, sometimes for a whole region.

SITE REPORTS

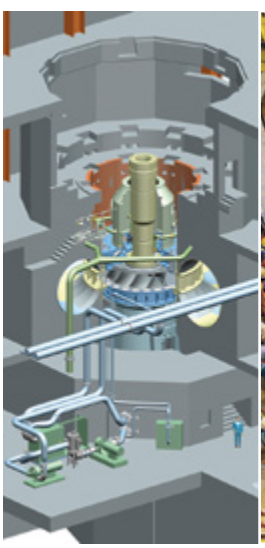
LAÚCA

View of powerhouse, dam and area

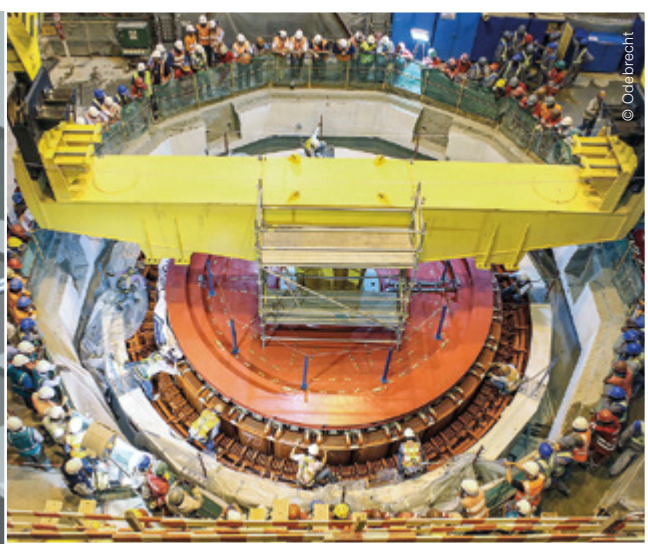
ANGOLA – Angola has one of the fastest growing economies in the world. Due to rapid urbanization and population growth, especially in the capital city of Luanda, there is a huge and growing demand for electricity. As a result Angola has taken steps to improve its energy supply.

In 2014, ANDRITZ HYDRO received a contract to supply the electro-mechanical equipment for the new Laúca hydropower plant located in the middle section of the Kwanza River. This project consists of a main power house with six units and an eco-power house with one further unit. The scope of supply for ANDRITZ HYDRO includes design, supply, installation supervision, and commissioning of the Francis turbines, generators, main transformers, isolated bus ducts, as well as control and protection systems. The security, access control and telecommunication systems for both the main and eco power houses are also included within the scope of supply.

Cross section drawing



Lowering of rotor unit #1



The time schedule was challenging from the very beginning of the project, with the hydraulic development completed within the first four months and the site delivery of the embedded parts started in 2014. A complex sourcing concept was employed to fulfil the very demanding delivery schedule, expediting shop assemblies and functional inspections at the workshops.

After a commissioning phase of two months and successful first synchronization of unit #1 the inauguration ceremony took place in the presence of President José Eduardo dos Santos on August 4th, 2017. Commissioning of the remaining units is being conducted at two-monthly intervals. All six main units will be in commercial operation by mid-2018. With a total capacity of 2,070 MW, HPP Laúca will produce approximately 8,600 GWh of renewable energy per year – enough to supply about 8 mio. Angolan households – making a significant contribution to the fast growing demand of the country.

Corporate social responsibility is taken very seriously by ANDRITZ HYDRO and during the site works at Laúca hydropower plant, several important CSR activities are taking place. A permanent training center was built directly at the Laúca site with the objective of preparing technicians for operations and maintenance activities – and the commercial operation of the plant itself – but also to train local people for future power generation and transmission projects in Angola. ANDRITZ HYDRO completely furnished three laboratories for this training center.

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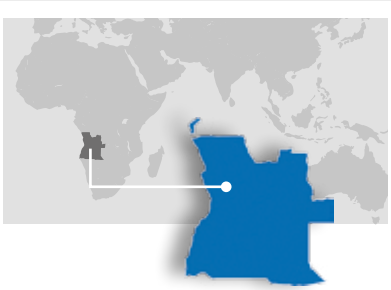

Laúca | Angola

Technical data:

Total output:	2,070 MW
Scope:	6 × 338 MW (Main)
	1 × 42 MW (Eco)
Voltage:	6 × 18 kV (Main)
	1 × 15 kV (Eco)
Head:	200 m (Main)
	118 m (Eco)
Speed:	200 rpm (Main)
	233.77 rpm (Eco)
Runner diameter:	4,790 mm (Main)
	3,220 mm (Eco)

SITE REPORTS

PIMENTAL

DONE WITHIN 364 DAYS

BRAZIL – Pimental hydropower plant, located on the Xingu River in Brazil, is the complementary powerhouse of the Belo Monte Hydroelectric Plant. Belo Monte is the second largest hydropower plant in Brazil and the fourth largest in the world. With six 38.8 MW generating units, all supplied by ANDRITZ HYDRO, the Pimental hydropower station was fully completed at the beginning of 2017 and is now in commercial operation.

ANDRITZ HYDRO received the contract for the Pimental hydropower plant in 2011. The contractual scope of supply included six 38.8 MW Bulb turbine units, six 40.9 MVA horizontal generator units, six speed regulators, six excitation systems, automation control and protection systems, electrical power systems, mechanical auxiliaries, six emergency gates, and two cranes for the power house.

Located in Altamira, in Pará state, the final unit (GU#6) went into operation in the first week of January 2017.

Delivery of the final environmental report in April concluded the company's contractual requirements to the customer, Norte Energia. In June 2017, the Turbine Performance Test was carried out, surpassing the contractual specifications.

After the power plant was officially handed over to the customer and put into commercial operation, ANDRITZ HYDRO executed the final milestone of the plant's development – the dismantling of the lodges, the construction site and the administrative building. All equipment and furniture was given to neighboring schools and charity institutions.

With 18 spillway gates, a total size of 445.5 m and a nominal flow of 62,000 m³/s, HPP Pimental has one of the largest spillways in the world. Operating since July 30, 2015, its erection involved an impressive 8,500 tons of equipment and river diversion was completed in only 364 working days.

The dedication, hard work and commitment of the ANDRITZ HYDRO team was reflected in a record 387 consecutive days without any accidents, a result that reflects ANDRITZ HYDRO's working principles and high quality of work.

Pimental | Brazil

Technical data:

Total output:	233 MW
Scope:	6 × 38.8 MW
	6 × 40.9 MVA
Head:	11.4 m
Speed:	100 rpm
Runner diameter:	6,450 mm

Installation of Bulb generator

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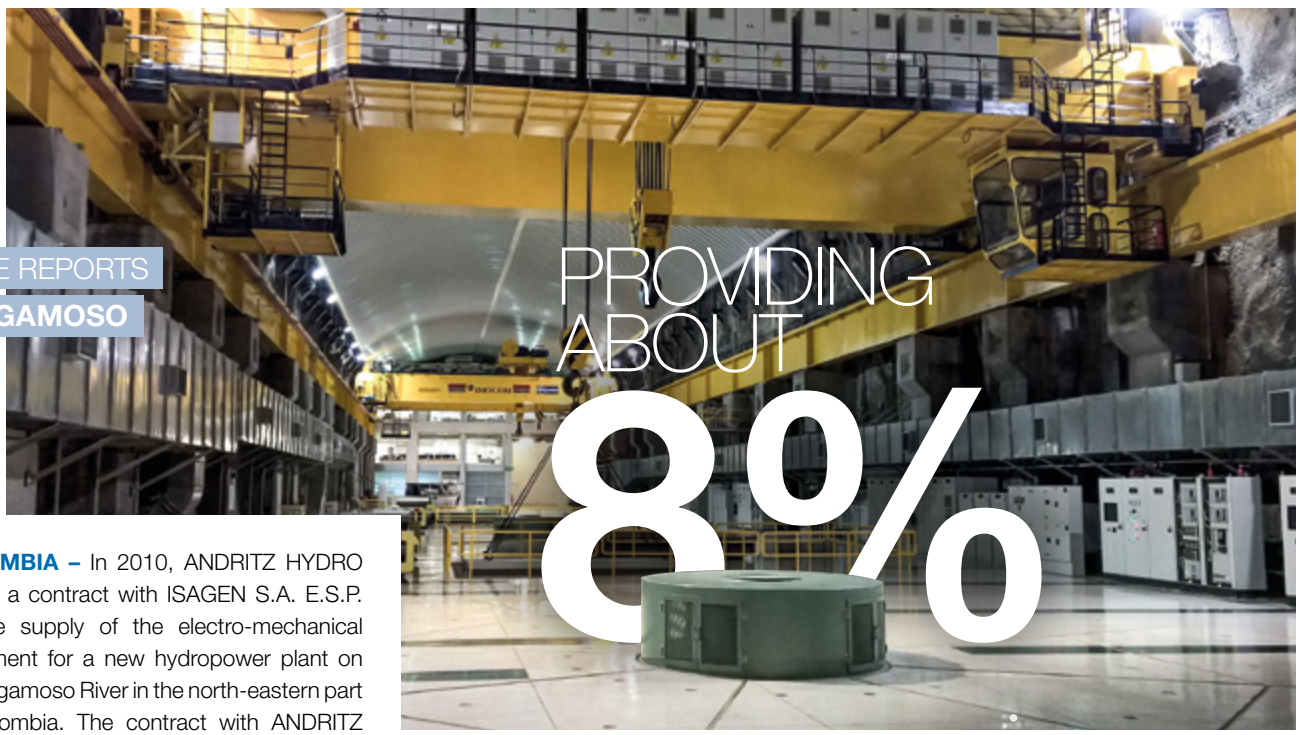
Experience further content

SITE REPORTS
SOGAMOSO



COLOMBIA – In 2010, ANDRITZ HYDRO signed a contract with ISAGEN S.A. E.S.P. for the supply of the electro-mechanical equipment for a new hydropower plant on the Sogamoso River in the north-eastern part of Colombia. The contract with ANDRITZ HYDRO comprised the delivery of three Francis turbines with a capacity of 295 MW each including a fully homologous model test, as well as cylindrical gates, electronic and hydraulic turbine governors, and the mechanical balance of plant equipment for the turbine. Supervision of installation and commissioning complete the contractual terms. The contract was executed by a team of ANDRITZ HYDRO locations in Germany and Colombia.

The hydropower plant was built between the years 2009 and 2014 and has been in commercial operation since then. By the end of 2016 all three units had successfully completed the warranty period, thus leading up to the March 2017 signature of the Final Acceptance Certificate (FAC) for the delivery from ANDRITZ HYDRO. A cavitation inspection after 8,000 hours of operation was also satisfactorily completed on all three units.

Aerial view construction site and river

A particular feature of these units is the use of a cylindrical gate with a diameter of 6,400 mm as a closing device between the guide vanes and stay vanes. Closing and opening of the gate is performed by six hydraulically-operated servomotors, which are kept synchronous without the use of mechanical linkages but by means of an ANDRITZ HYDRO proprietary control system.

With 885 MW of nominal capacity and an annual average generation of 5,056 GWh per year, this is the fourth largest hydroelectric power plant in Colombia, providing the country with about 8% of the energy consumed by Colombians each year. The units of HPP Sogamoso, which are currently the largest in operation in Colombia, are operating stably and safely within an ample performance range, thus providing not only power generation but also contributing to grid stability and regulation.

By providing state-of-the-art products and services in close cooperation with the customers, the successful completion of this project again confirms the commitment of ANDRITZ HYDRO and strengthens the leading position of the company in the Colombian hydropower market.

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Experience further content

Sogamoso | Colombia

Technical data:

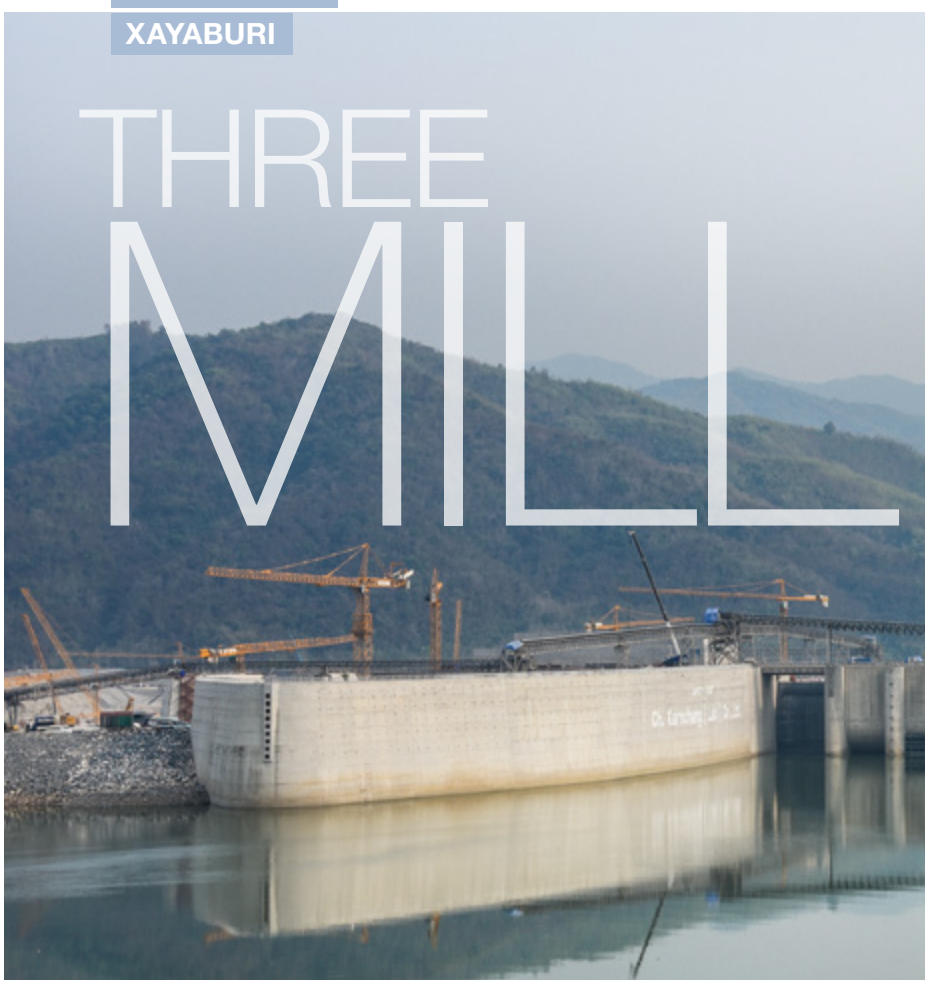
Max. total output:	885 MW
Scope:	3 × 295 MW
Head:	155 m
Speed:	163.64 rpm
Runner diameter:	5,100 mm

SITE REPORTS

XAYABURI

THREE MILL

Draft tube installation



LAO PDR – In 2012, ANDRITZ HYDRO received an order from CH. Karnchang (Lao) Company Ltd. for the supply of electromechanical equipment for the Xayaburi run-of-river hydropower station on the Mekong River. ANDRITZ HYDRO's scope of supply comprises the delivery of seven 175 MW Kaplan turbines (hydroelectric power production for EGAT, Thailand), and one 60 MW Kaplan turbine (hydroelectric power production for EDL, Lao PDR), as well as generators, governors, automation systems, and auxiliary equipment. With a planned capacity of 1,285 MW, HPP Xayaburi will produce more than 7,000 GWh/year of electricity, equivalent to about more than 3 mio. households.

The Mekong is one of the most biologically diverse rivers in the world. About 60 mio. people along the Mekong make their livelihood from the river and its fish population. Therefore specially designed fish-friendly turbines will be installed at HPP Xayaburi. They are characterized by fewer runner blades, lower rotational speed and a different operating scheme.
(→ **COVER STORY** page 18)

A fish ladder with a specially designed fish lock system is also foreseen in order to allow migration of the fish upstream. One-tenth of the total construction costs of the entire power plant are invested in this environmental requirement.

In times of increasing demand for ever more exceptional ecological performance, the release of even very small amounts of oil into river courses has to be avoided. With the objective of reducing the quantity of oil used in hydro turbines, ANDRITZ HYDRO developed oil-free hubs and has applied them in numerous projects over many years. With such a design, the risk of oil leakage into the river water is significantly reduced while the blade seal arrangement prevents water exchange. The oil-free hub design has a major positive impact on the water quality and thus on the environment. For HPP Xayaburi, the use of the oil-free hub concept will save about 14,000 liters of oil per unit.

Navigation lock, spillway, intermediate block, powerhouse and fish ladder

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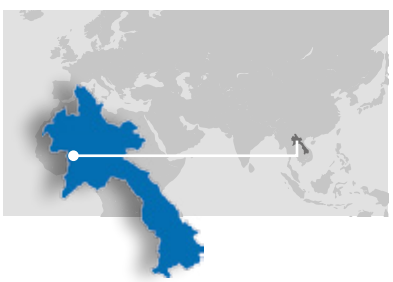

Xayaburi | Lao PDR

Technical data:

Total output:	1,285 MW
Scope:	7 × 175 MW
	1 × 60 MW
Voltage:	16 kV / 13.8 kV
Head:	39 m
Speed:	83.33 rpm / 150 rpm
Runner diameter:	8,600 mm
	5,050 mm

Currently, the turbines and generators are in the manufacturing process. The powerhouse overhead cranes (2 × 380 tons and 2 × 80 tons) have already been installed and are in operation. All eight turbine draft tubes have also been installed while the first four main transformers are currently being transported to the site. Start of commercial operation at HPP Xayaburi is scheduled for October 2019.

HPP Xayaburi is an important project on the mighty Mekong River and with its successful execution ANDRITZ HYDRO proves once again its leading position in the Lao hydropower market and the high quality of its state-of-the-art technology. ANDRITZ HYDRO is proud to contribute to the development of the huge hydropower potential of the country.

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UPDATE

Factory Acceptance Test (FAT)

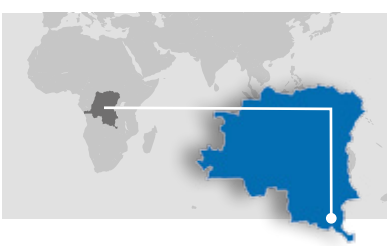
Beginning of June 2017, the first runner at HPP Xayaburi has successfully completed the Factory Acceptance Test (FAT). To date, it is the largest and most powerful oil-free runner ever built.

SITE REPORTS

MWADINGUSHA

ENERGY INTO THE JUNGLE

Experience further content



Mwadingusha | DR Congo

Technical data:

Total output:	78 MW
Scope:	4 × 13.05 MW
Voltage:	6.6 kV
Head:	111 m
Speed:	375 rpm
Runner diameter:	1,320 mm

DR CONGO – In September 2016, an ANDRITZ HYDRO-led consortium was awarded a contract for the refurbishment of the existing Mwadingusha hydropower plant in Katanga Province of DR Congo. This hydropower plant is equipped with six Francis units with a capacity of 11.8 MW each. Financed by Ivanhoe Mines, the final client is Société Nationale d'Electricité (SNEL), while the owner's engineer is the Swiss consulting firm Stucky.

The Mwadingusha hydropower plant is located on the river of Lufira. It was originally commissioned in 1930, and the original supplier was Charmilles, Switzerland, now ANDRITZ HYDRO. Up until today no major overhaul of the hydropower plant and its equipment had been conducted.

For ANDRITZ HYDRO, the scope of supply comprises replacement of four turbine units, generators, governors, inlet valves, exciters, voltage regulators, and draft tube stop logs. This includes dismantling, erection, and commissioning. Transformers and the balance of plant are within the scope of the consortium partner. The original discharge volume and net head remain unchanged, but there will nonetheless be a power increase of about 10% from 11.8 MW to 13.05 MW per unit.

All major equipment, such as the turbines, inlet valves, stop logs, and generators, have already been designed and are in the manufacturing process. Due to road infrastructure conditions in DR Congo, the transport of the equipment to the site is going to be very challenging and can only be done in the dry season, from mid-April to mid-October. Therefore most of the heavy equipment will be delivered to the site by mid-October 2017.

Site mobilization has started mid-August 2017 and will be followed by dismantling of the existing equipment through until April 2018. The contractual commissioning of the first unit is scheduled for February 2019 and by the end of the same year all four units should be commissioned.

After completion and hand over, HPP Mwandingusha will supply electrical energy to the Congo National Grid as well as to the copper mining activities at the Kamoa-Kakula project by Ivanhoe mines.

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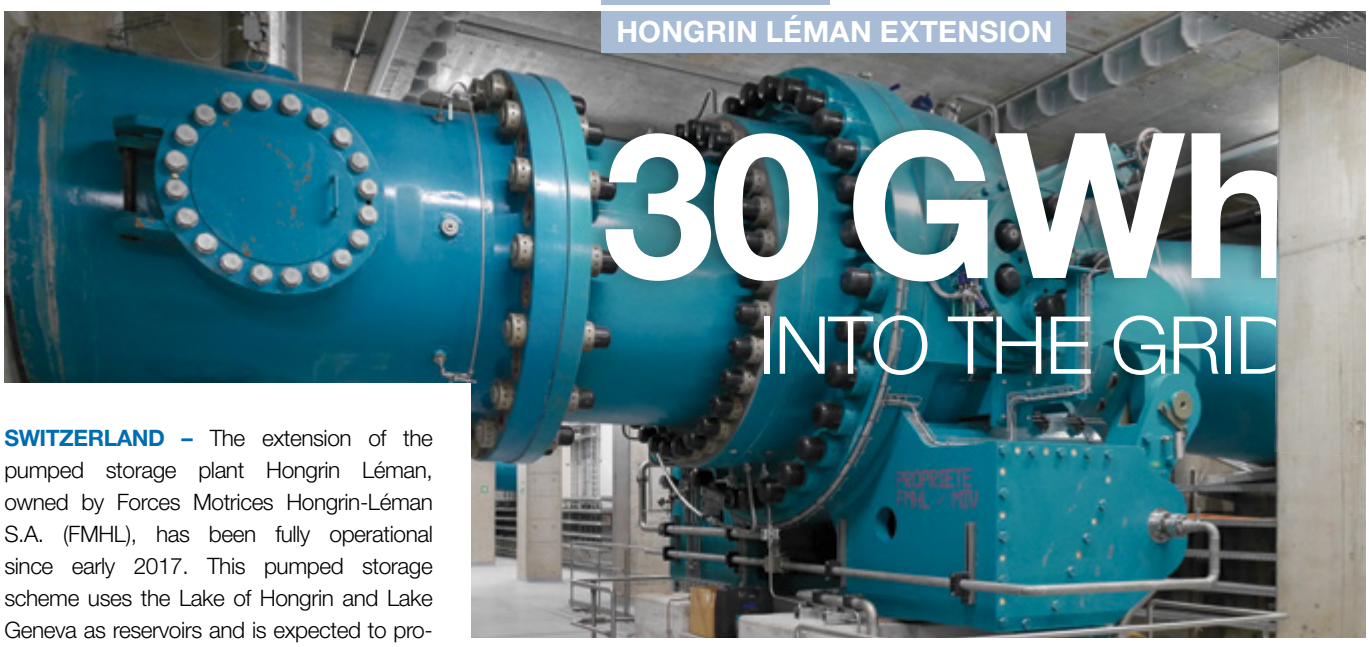
SITE REPORTS

HONGRIN LÉMAN EXTENSION

30 GWh INTO THE GRID



SWITZERLAND – The extension of the pumped storage plant Hongrin Léman, owned by Forces Motrices Hongrin-Léman S.A. (FMHL), has been fully operational since early 2017. This pumped storage scheme uses the Lake of Hongrin and Lake Geneva as reservoirs and is expected to provide about 1,000 GWh of peak power per year, supplying more than 300,000 households with electricity.

In 2011, ANDRITZ HYDRO was contracted to deliver two new ternary generating sets, including motor generators, Pelton turbines, digital and oil hydraulic governors, as well as the cooling water system of the entire plant. Furthermore, as part of a consortium, ANDRITZ HYDRO delivered four of the six high head spherical valves needed, including oil pressure units. Besides design and manufacturing, the scope of supply also comprised installation, commissioning, and efficiency testing of the equipment. Strain gauge tests have been conducted to establish the runner bucket vibration behavior at various operating points of the unit. With a total output of about 480 MW, the capacity of the plant was almost doubled with this extension.

Pumped storage is considered to be an indispensable complement to renewable energy sources; it can provide power at short notice and at large capacities, which is mandatory for the stability of the European grid. FMHL considers the development of renewable energy sources will increase the demand for rapid grid stabilization even further in the future.

Despite winter time, the mild weather during the last two weeks in 2016 entailed a relatively low power consumption in Europe allowing the Hongrin Léman pumped storage scheme to fill its almost empty reservoir, the artificial lake Hongrin. However, due to a temperature drop in Europe between 30th December, 2016, and 8th January, 2017, and the simultaneous low availability of large volumes of other forms of renewable energy, the scheme was able to provide about 30 GWh of electrical energy to the grid at short notice, further proving the advantages of the pumped storage concept.

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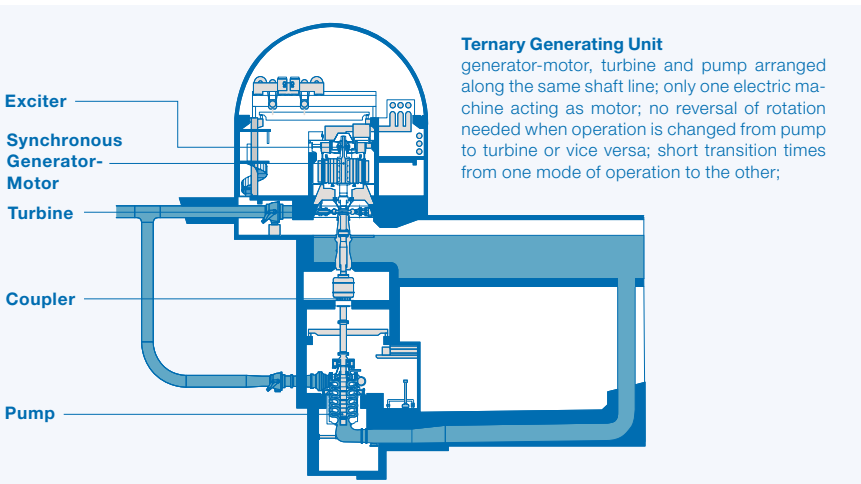
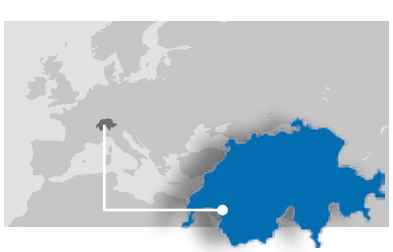


Ternary Generating Unit
generator-motor, turbine and pump arranged along the same shaft line; only one electric machine acting as motor; no reversal of rotation needed when operation is changed from pump to turbine or vice versa; short transition times from one mode of operation to the other;



Hongrin Léman | Switzerland

Technical data:

Total output FMHL:	480 MW
Extension output:	2 × 120 MW
Voltage:	15.5 kV
Head:	880 m
Speed:	500 rpm

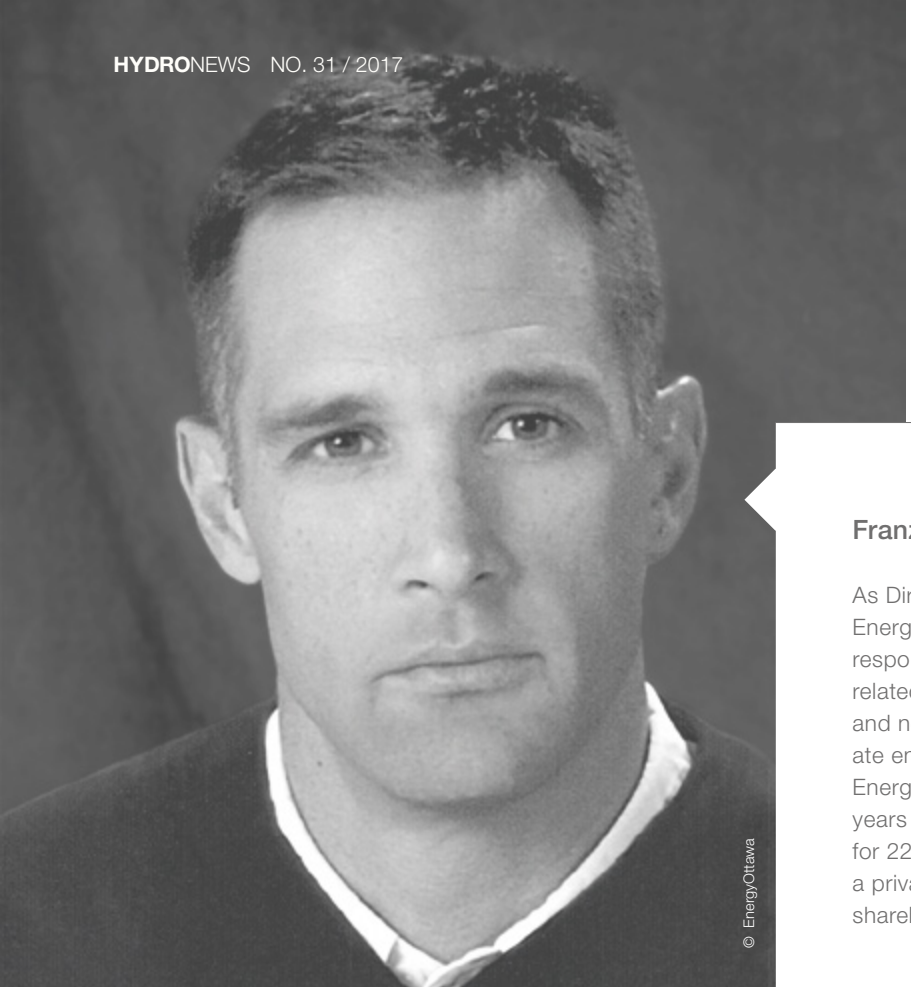
CHAUDIÈRE FALLS

Bringing Hydro to the Heart of the City

In the heart of the Canadian capital city Ottawa, the Chaudière Falls extension project is embracing the site's historical significance with a very modern approach to urban hydropower development. Hydro News discusses the new plant with developer Energy Ottawa's Director of Generation, Franz Kropp.

The Chaudière Falls site in the heart of the nation's capital is of major historical significance. Please explain how the design accommodated the historic context of its location?

From the late 1800s, it is one of the oldest hydroelectric plants that's still in operation in Canada. From a historical context the site is quite rich. The First Nations called the site Asticou, loosely translated to "big kettle". In more modern history, in the 1800s grist and saw mill operators began acquiring lands in the Chaudière Falls so the site is the cradle of Canadian industrialization. There is history related to the city of Ottawa becoming the capital of Canada, there's even a link to the iconic Stanley Cup. That history really needs to be shared and promoted. For example, we did uncover a couple of old stone grist mill wheels that would have been grinding wood into pulp and which are 150 years old. They'll be there on display with an interpretive panel beside them.



Experience
further content

Franz Kropp

As Director of Generation for Energy Ottawa Franz Kropp is responsible for many of the facets related to both on-going operation and new developments. A graduate engineer, Franz has been with Energy Ottawa for just over 15 years and in the energy industry for 22 years. Energy Ottawa is a private corporation but its single shareholder is the city of Ottawa.

Located in the center of the Ottawa-Gatineau metropolitan area, the Chaudière Falls project has been built entirely below ground and is designed to have minimal visual impact, why was this design adopted?

The visual aspects of it go hand in hand with the urban context. When we acquired the project the design included a single story building. We eliminated that. The site is located on high land within the Ottawa River and there are some stunning views.

When you come out to the site you don't see a hydro plant, you see a public park space and you see the river. Some of the elements did come from public consultation, people wanting access to see the Chaudière Falls. These are areas where you can find win-win solutions. We could do it. Even though some risks were involved, they were manageable. We follow rigorous public health and safety guidelines but you can still achieve the physical barriers, for example, and there's a lot what can be done with landscaping to hide some of the security features. With a modest amount of effort you can overcome the technical elements that you need to keep people safe.

Chaudière Falls will supply renewable electricity to around 20,000 homes, reducing greenhouse gas emissions by some 115,000 tons of CO_2 every year. Explain the importance of environmental performance?

In terms of some of the aquatic species, when we acquired the project we did make some significant changes to the design related to aspects that had come into play throughout the time it took to acquire the assets. For example, the American eel went from a "species at risk" status to being listed formally on the "endangered species" register. That had an impact on some of the design decisions. Mitigation measures are required, for example fish ladders, screens and bypass paths to support migration. The power purchase agreement related to the hydroelectric plant was driven by a governmental policy to reduce fossil generation in the province through promotion of renewable electricity.

What unexpected challenges have arisen during the construction and installation phases of this project?

The main challenge was actually a geotechnical problem. The project is founded on a limestone bedrock but it has a characteristic of containing soluble calcitic deposits. When we got into the excavation of the intake canal we uncovered this zone about 5 to 6 m wide which ran perpendicular to the canal at a point where it was about 60 m wide. There was an engineered solution where a concrete cap was built on top which was then anchored into the solid bedrock on either side. It was discovered early on so we were able to avoid any delays.

The new 32 MW run-of-river power plant uses four of the most powerful ECOBulb turbines delivered to date. What were the main considerations in selecting these machines?*

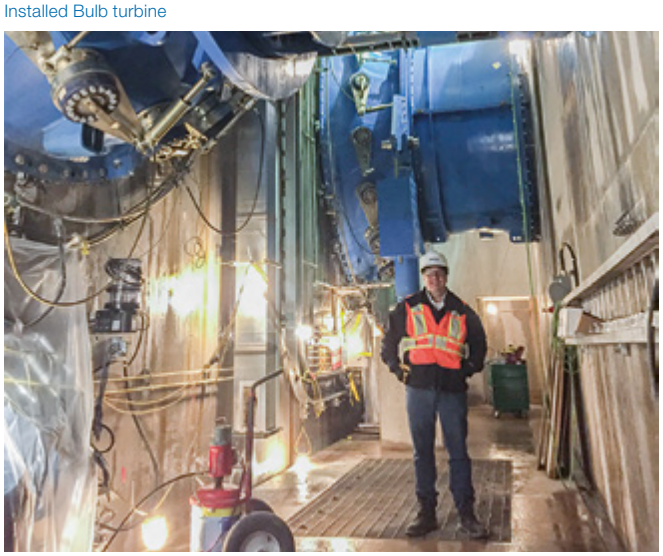
It was actually quite a big step for us to adopt the technology. It was seen as a risk, but when we did the evaluation process – we had five submissions under the competitive tender – this option came out as

→

Ottawa Parkway and Skyline

very attractive from a commercial standpoint. For example, if you go with a vertical unit you have to make the powerhouse deeper, which are additional costs. Everything is also self-contained within the bulb and it's a fairly simple installation. So from the civil engineering side and the installation standpoint there's some significant advantages. There's a proven track record and because the overall costs were lower, those factors ended up out-weighing the risk that we saw with regards to the new technology. Plus it was all founded on fairly sound engineering practice.

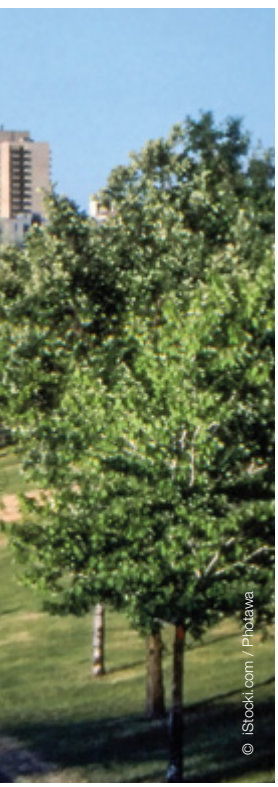
Installed Bulb turbine



We also put in the technical specification that solutions with no gearbox will be preferred, which was related to maintenance of the gearbox and the issue of bulk oil. Then there's the noise. We faced more stringent requirements due to the fact that we've got condominiums and high-rise towers along the intake canal and beside the powerhouse. It ended up becoming an additional benefit, although we didn't realize it at the time, because we likely would have run into noise issues and wouldn't have been able to obtain the noise permit that was required without additional attenuation equipment.

The Chaudière Falls expansion project was developed on a complete "from water-to-wire" basis. What was the motivation behind that decision?

The permitting, the construction and access in and around the site would have been very challenging for any EPC contractor but we felt that there was a lot of value in leveraging the relationships that we had for ease of permitting and getting buy-in from all of the different agencies concerned and in us assuming more of an active role within the construction. From our standpoint we're happy to take some risk on if we think that there's a benefit to it. If there's the opportunity to run further projects we definitely would, but it is very project specific. ANDRITZ HYDRO provided a very strong and very competitive proposal, compelling enough for us to be able to look past our classical hydro hats and the perceived risk of a newer technology and try a different approach to hydro. To date they've delivered. We're very pleased with the quality of the product that was manufactured and delivered on time.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"It comes back to the trying to promote more exposure to the river and to bring public access back to recognize and promote the river itself. It all comes together but I think from a project stand point it's unique."

Franz Kropp


© Hydro Ottawa

AUTHOR

Interview by David Appleyard,
a freelance journalist

What is your outlook on future projects of this kind?

A lot of people are looking at this project as one of the first modern-day hydroelectric developments in an urban setting. It's been done before, but it's been done a long time ago. Obviously the political, environmental and cultural landscapes have changed significantly since the 1930s and 40s, around the last time something like this would have been undertaken. Part of that success is going to be how well is it embraced by the public with the more welcoming approach where we're building a plant and putting a park on top of it. I think time will tell and hopefully it will be in our favor. If you look in Canada, the majority of cities are built on rivers. The river has to lend itself to hydropower generation, but ideally this would be a model for places where there are opportunities for hydroelectric development in the city and will obviously open up some new opportunities.
It can be done successfully. It'll be interesting to look back on it after several years and then see what success or influence it has had on future and similar projects.

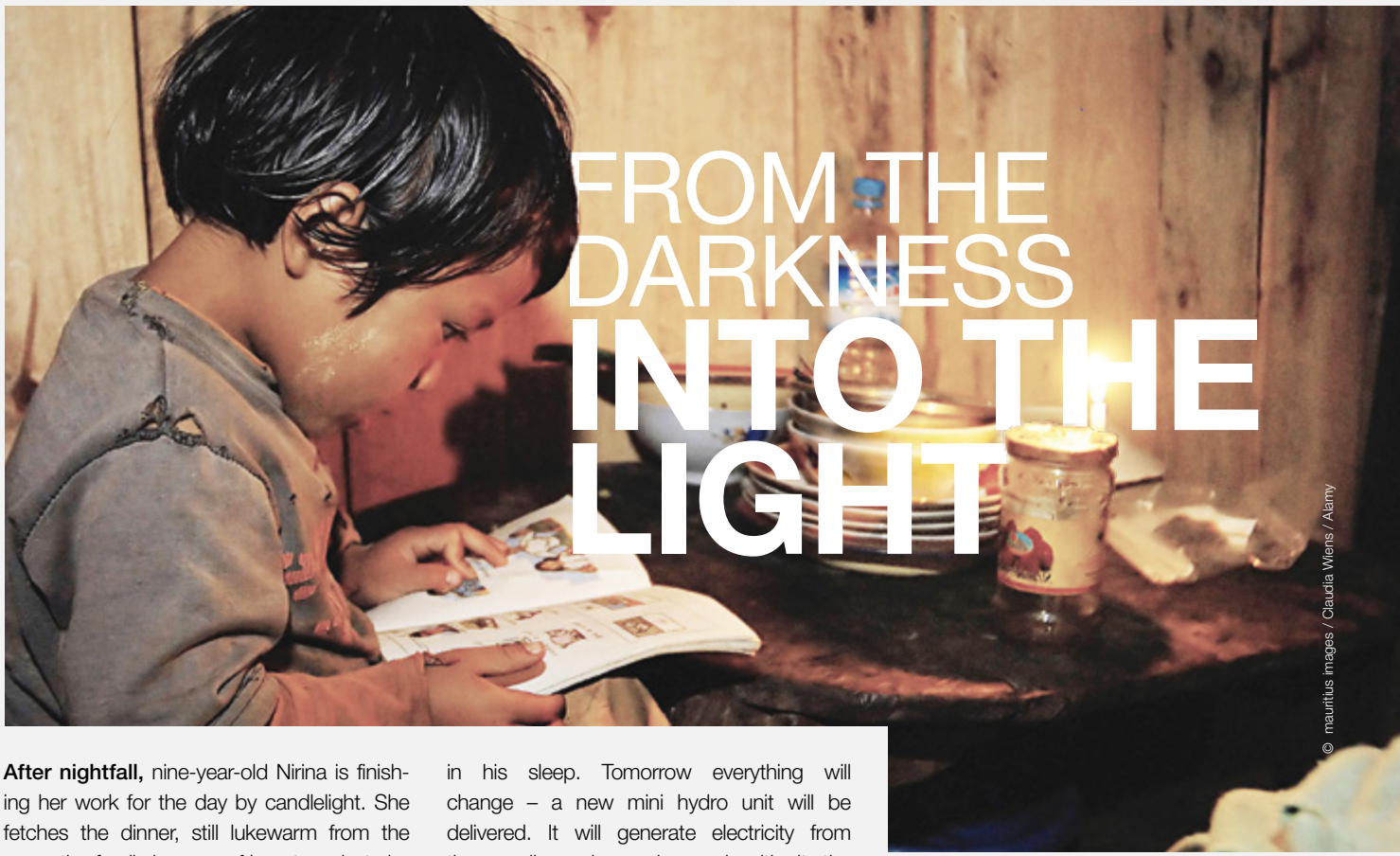
CHAUDIÈRE FALLS IN SHORT

- 4 × 8 MW ECOBulb* turbines – the most powerful to date
- 164 GWh/year electricity feeding the provincial grid
- Powering 20,000 homes with clean, renewable energy
- Saving about 115,000 tons CO_2 emissions

- Home to Canada's oldest hydroelectric station still in operation;
- Safe viewing platforms and greater public access;
- A new bridge across the intake canal open for pedestrians;
- Maintaining elements of the city's industrialist past, including two buildings that survived the Great Fire of 1900;
- For the first time in more than 100 years, Chaudière Falls will be open to the public;



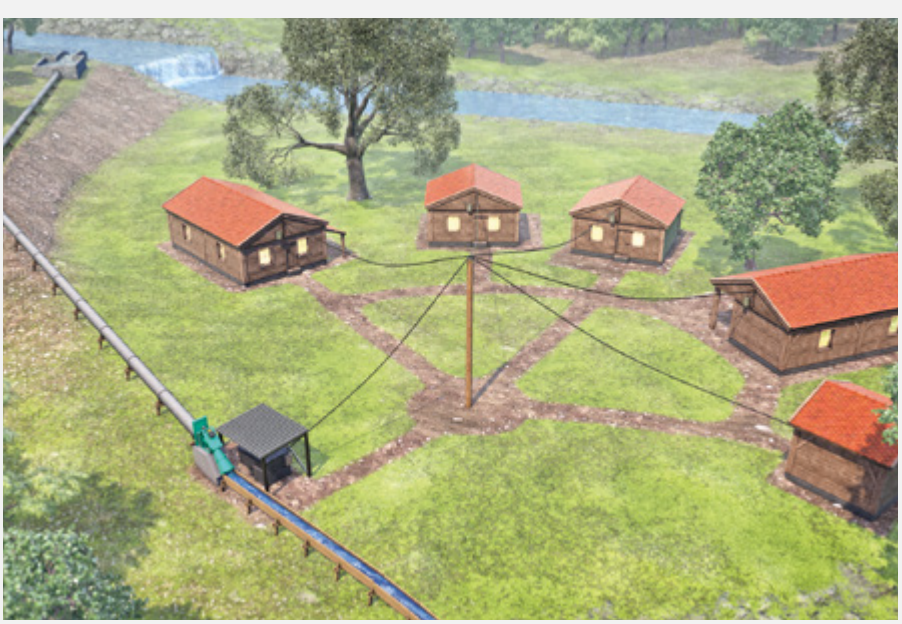

Installation of Bulb turbine



FROM THE DARKNESS INTO THE LIGHT

After nightfall, nine-year-old Nirina is finishing her work for the day by candlelight. She fetches the dinner, still lukewarm from the sun – the family has no refrigerator – but she has to hurry because her little brother Miaro doesn't like to sleep alone, it is too dark. The house has no electricity, they cannot afford the diesel for a generator and candles don't last long enough. After blowing out the candles, Nirina cuddles her little brother in his sleep. Tomorrow everything will change – a new mini hydro unit will be delivered. It will generate electricity from the small creek nearby and with it the whole village will be electrified. This means everyone will have hot water, electric light and maybe a refrigerator or even a pump for the well on the village square. Nirina is full of hope that life will get better.

Safe and secure access to electricity means a more stable economy.



Today more than one billion people worldwide have no access to electricity. Most of these people live in remote rural areas with sparse populations, where extension of a national grid connection is often technically difficult, if even possible, and costly.

Small diesel generators and solar panels are often used to provide minimal electric service, but diesel is expensive and without storage solar panels provide energy only during daylight hours.

Implementing decentralized mini grid solutions or stand-alone systems, providing safe, clean and renewable energy, is an important aspect of rural development. Access to electricity helps to alleviate poverty, to improve health care, supports better education and creates jobs.

Key features of the new **ANDRITZ HYDRO Mini-Grid Solution**

- simple, robust, reliable
- cost effective, affordable
- easy to install
- easy to operate and maintain
- hybrids with other renewable energy source (wind, solar, biomass, etc.)
- combines with potable water supply (use of excess energy)
- combines with waste water treatment

Under these circumstances, ANDRITZ HYDRO has developed a Mini Compact hydropower system with a capacity ranging from 5 kVA to 69 kVA per unit: the Mini-Grid Solution. Its primary objective is to provide robust hydropower technology which can be installed without specialist support. ANDRITZ HYDRO has a dedicated engineering team focused exclusively on this new concept.

The Mini-Grid solution can be applied in small canals, creeks or cascades, and even downstream of larger capacity hydropower projects. Using globally proven ANDRITZ HYDRO turbine models guarantee higher efficiencies. Major design characteristics, such as the need for less civil engineering works and a full workshop assembly, mean a straightforward and shorter site installation with plug and play features, an easier and simpler operation and maintenance regime. Overall, it is a cost-effective approach to providing affordable, sustainable, clean, and renewable energy for local communities.

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Ambatomanoina (Madagascar): 2 × 50 kW

The rural municipality of Ambatomanoina has about 23,000 inhabitants. Agriculture is the main livelihood of the local population. In order to electrify the small town and surrounding areas, a contract for the supply of electromechanical equipment for a 100 kW mini hydropower plant on the Mananara River was awarded to ANDRITZ HYDRO. In future, the town and the small localities of Amparihibe and Mananjary will be supplied with clean, renewable energy by this mini hydroelectric power station, securing energy access for the local people.

SMALL & MINI HYDRO HIGHLIGHTS

NEW

RANNEY FALLS

Trent River, Northumberland | Canada
Output: 1 × 10.5 MW
Scope: "from water-to-wire" package
Highlight: 10 MW ECOBulb* turbine, future largest output worldwide

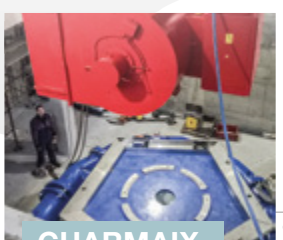
LUZMA I AND II

Antiochia | Colombia
Start of commissioning June 2017
Output: 2 × 11.4 MW each
Scope: electro-mechanical equipment
Highlight: 2 HPPs including dissipation systems of 20 MW each

CHAUDIÈRE FALLS

Ottawa | Canada
Commissiong in finalization
Output: 4 x 8 MW
Scope: "from water-to-wire" package
Highlight: most powerful ECOBulb* turbines by ANDRITZ HYDRO to date

→ INTERVIEW P.32



CHARMAIX

French Alps | France
Installation on schedule
Output: 1 × 1.5 MW
Scope: electro-mechanical equipment; abandoned since 1998, now in rehabilitation
Highlight: Mini Compact project

SCHATTENHALB 1+

Canton Berne | Switzerland
Put into commercial operation
Output: 1 × 2.77 MW
Scope: vertical Pelton turbine
Highlight: Reichenbach Creek famous through Sherlock Holmes novel

DUE

Sucumbios | Ecuador
Start of commissioning June 2017
Output: 2 × 25 MW
Scope: "from water-to-wire" package
Highlight: 65 MW HPP including big pressure relief valves

SIGCHOS

Cotopaxi, Cantón Sigchos | Ecuador
Put into commercial operation
Output: 3 × 6 MW
Scope: electro-mechanical equipment

CARHUAC

Santa Eulalia River | Peru
Project execution on schedule
Output: 2 × 10.5 MW
Scope: "from water-to-wire" package

→ MORE P.41

The market for small and mini hydropower is expanding rapidly. In times of globalization and significant demographic and social change there are many opportunities for medium and small applications and decentralized off-grid solutions. Similarly, requests for smaller standardized units to be installed alongside or even as an alternative to large generating units are increasing, either to supply local communities or to meet economic as well as ecological demands.

INNERTKIRCHEN 3

Canton Berne | Switzerland
Put into commercial operation
Output: 1 × 3.2 MW
Scope: electro-mechanical equipment
Highlight: add 11.5 GWh/year electrical energy for Canton of Berne

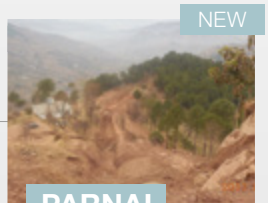
→ MORE P.40

NEW

NAM BAN 3

Nam Ban River, Lai Chau Province | Vietnam
Output: 2 × 11 MW
Scope: electro-mechanical equipment

NEW



PARNAI

Poonch District of Jammu & Kashmir state | India
Output: 3 × 12.5 MW
Scope: "from water-to-wire" package
Highlights: anti-abrasive coating of runner and nozzle assemblies

NEW

NAMGANG

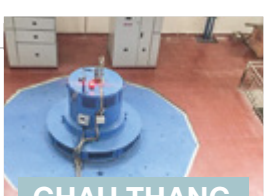
Namgang River | South Korea
Output: 2 × 9.2 MW
Scope: turnkey refurbishment incl. Balance of Plant equipment
Highlight: 20% increase of output

→ MORE P.41

NEW

NKUSI

Nkusi River/Lake Albert | Uganda
Output: 1 × 10.58 MW
Scope: "from water-to-wire" package;
Highlights: high quality delivery with minimal interphases and simplified logistics



CHAU THANG

Quang River | Vietnam
Commissioning June 2017
Output: 2 × 7 MW
Scope: electro-mechanical equipment
Highlights: first low-head Kaplan out of India

NEW

HASANG

North Sumatra | Indonesia
Output: 3 × 13.73 MW
Scope: entire electro-mechanical package for all three generating units
Highlights: major contribution to meet electricity demand of Sumatra Island

NEW

LUACHIMO

Lunda-North Province | Angola
Output: 4 × 9 MW
Scope: electro-mechanical equipment; complete new 36 MW powerhouse next existing power station
Highlight: Compact Axial Turbines (CAT)

→ MORE P.40

NEW

HOUAY KAPHEU

Saravane Province | Lao PDR
Output: 2 × 2,5 MW
Scope: electro-mechanical equipment

SWITZERLAND

INNERTKIRCHEN 3

More power for Grimselstrom.

Since the end of 2016 a new hydropower plant has been producing a further 11.5 GWh of electrical energy per year for the Canton of Bern in western Switzerland. Kraftwerke Oberhasli AG (KWO) awarded an order to ANDRITZ HYDRO for the supply of electro-mechanical equipment for the hydropower plant Innertkirchen 3 in September 2014.

KWO was founded in 1925 in order to exploit the hydraulic potential in the Grimsel/Susten area for the production of electrical energy.

With a total of nine power plants, eight storage lakes, and an installed turbine capacity of 1,368 MW, KWO produces about 2,350 GWh of renewable electrical energy annually.

HPP Innertkirchen 3 is operated as a run-of-river power station, with only a small pondage, but without reservoir management. The scope of supply comprised installation and commissioning of a vertical, six-jet 3.2 MW Pelton turbine, including governor, a 3.5 MVA generator, cooling water system, and main inlet valve (DN 1000, PN 16).

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Technical data:

Total output:	3.2 MW
Scope:	3.2 MW
Voltage:	6.3 kV
Head:	131 m
Speed:	430 rpm
Runner diameter:	1,070 mm

ANGOLA

LUACHIMO

New Compact turbines for more power.

In March 2017, ANDRITZ HYDRO was awarded the contract for delivery of the complete turbine equipment for the new Luachimo hydropower plant in Angola. Located on the Luachimo River, near Dundo village in Lunda-North Province, the Luachimo Dam was originally built in the 1950s.

The general works include the construction of a complete new powerhouse with a total capacity of 36 MW next to the old power station. ANDRITZ HYDRO will deliver four Compact Axial Turbines (CAT) in a horizontal arrangement, each with a runner diameter of 2,850 mm, as well as four hydraulic power units and the sealing and lubricating water supply systems. The electrical governor, the transportation up to the site, and the installation are included within the contractual scope of supply, as is commissioning.

Delivery of the main turbine components is planned for the end of 2018 while commercial operation of the new hydropower plant is scheduled to start in June 2019.

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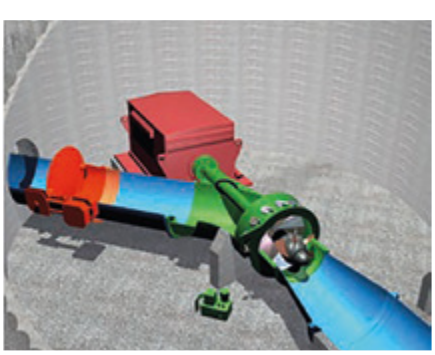

Technical data:

Total output:	36 MW
Scope:	4 × 9 MW
Voltage:	10 kV
Head:	16.7 m
Speed:	230.8 rpm
Runner diameter:	2,850 mm

SOUTH KOREA

NAMGANG

Experience further content

Output increase of about 20%.

At the end of 2016, ANDRITZ HYDRO received an order from Korea Water Resources Corporation (K-water) for the turnkey refurbishment of the existing Namgang hydropower plant in South Korea. The project site is located some 100 km west of Busan, South Korea's second largest city.

ANDRITZ HYDRO is the main contractor, being responsible not only for the entire electro-mechanical scope of supply, but also for the disassembly of the old turbine equipment, the necessary civil work structure for the new turbines, Electrical Power Systems (EPS) and mechanical auxiliary equipment. After refurbishment, HPP Namgang will be equipped with two Compact Axial Bulb turbines – each with a runner diameter of 2,850 mm and a power output of 9 MW. This represents an increase in power output of about 20% over the old turbines.

Along with the previous delivery of 14 Bevel Gear Bulb turbines for the "Four River Restoration Project" in 2011 and 2012, the order for HPP Namgang is an additional important reference for the Compact Hydro business unit of ANDRITZ HYDRO, further strengthening the market position of the company in South Korea.

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Technical data:

Total output:	18 MW
Scope:	2 × 9 MW
Voltage:	6.6 kV
Head:	17.88 m
Speed:	240 rpm
Runner diameter:	2,850 mm

PERU

CARHUAC

Minimizing environmental impact.

Carhuac is a 21 MW hydroelectric power plant in Peru using the waters of the River Santa Eulalia, one of the two main fresh water supply streams of the capital city Lima.

Located about 115 km east of Lima, the project is being developed by Andean Power SAC, a company associated with the Austrian development company Carbon Projektentwicklungs GmbH in partnership with Hidroelectrica Bolivana.

Andean Power SAC awarded an EPC-contract to GCZ Ingenieros SAC including a "from water-to-wire" package, which was subsequently awarded to ANDRITZ HYDRO France. The scope of supply from ANDRITZ HYDRO comprises turbines, generators, main inlet valves, hydraulic pressure units, cooling water system, MV switchgear, automation and SCADA systems, AC/DC auxiliary systems, and a diesel generator.

As a run-of-river plant, involving no dams or impounding of water, the Carhuac hydropower station is designed for minimal environmental impact. Surrounding communities are also benefitting from the project implementation and its operation with job offers and local procurement, as well as the establishment of multiple social development programs.

Contract execution is proceeding according to schedule, with equipment expected to be delivered after 12 months. Commercial operation is anticipated to commence at the beginning of 2018.

The successful execution of this project establishes a path for closer cooperation on further projects with this customer. ANDRITZ HYDRO is looking forward to supporting further Austrian investment in Peru.

Technical data:

Total output:	21 MW
Scope:	10.5 MW
Head:	155.46 m
Speed:	600 rpm
Runner Diameter:	1,070 mm

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Compact Workshop Pakistan

LAHORE

Pakistan has a huge hydropower potential that has barely been developed until today. However, the increasing demand for electrical energy, high dependence on imported oil, and the promotion of renewable sources of energy make the use of hydroelectric power very much the focus of an expanding energy mix. Expansion of small-scale hydropower is also an important factor here.

For the first time, at the end of 2016 ANDRITZ HYDRO organized a "Compact Workshop" in Pakistan to strengthen its position in this competitive market. At this workshop about 70 representatives from planning offices, investors, general contractors, and construction companies met in Lahore to exchange experiences and to keep themselves informed about the latest developments in the small hydropower market. One particular highlight was a lecture on special Compact Hydro low-head turbines, which can be used in existing irrigation channels.

The workshop was a complete success and supported the sales activities of ANDRITZ HYDRO in the promising market for small hydropower in Pakistan.

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HYDRO VISION INTERNATIONAL

ANDRITZ HYDRO was also a participant and gold sponsor at the Hydro Vision International, held 27th–30th June, 2017 in Denver, Colorado, USA. Again the company was front and center with an impressive booth. HYDRO VISION 2017 proved once again to be a valuable resource for strenghtening the ANDRITZ HYDRO brand in the North American hydropower market, highlighting the company's technological know-how and comprehensive portfolio of products and services.

AFRICA 2017

ANDRITZ HYDRO's successful participation in the AFRICA 2017 Conference and Exhibition

MARRAKESH

From 14th to 16th March, 2017, the AFRICA 2017 conference took place at the Palais des Congrès de la Palmeraie in Marrakesh, Morocco.

Following the great success in 2013, this leading African hydropower event offered for the second time a perfect platform for all interested parties in the hydropower industry – utilities, suppliers, investors, project developers and operators. More than 700 delegates attended this important event, not only from Africa but from all over the world.

ANDRITZ HYDRO has been active in Africa for more than 100 years and has supplied about 40% of all turbines installed on the continent. To underline its leading position, ANDRITZ HYDRO was present with a booth, made two paper presentations, and co-hosted the impressive welcome reception at the end of the first conference day. AFRICA 2017 offered ample opportunities for promoting the comprehensive product and service portfolio and overall competence of ANDRITZ HYDRO, improving existing customer relations, and identifying future potentials in the promising African hydropower market.

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Customer Days **2017**

Over recent years ANDRITZ HYDRO has launched Customer Day events in various countries with great success.

These events present superb opportunities for an exchange of experience and fruitful discussion. They also offer an informative platform for ANDRITZ HYDRO to explore its latest developments and technology solutions, bringing the company closer to the market and its customers. ANDRITZ HYDRO is pleased to invite customers, local partners, and suppliers, but also representatives from governmental institutions, hydropower plant operators and private investors to these special events. This year, ANDRITZ HYDRO successfully held three Customer Day events in Asia.

JAKARTA – March 29th–30th, 2017
Underlining its leading position in the Indonesian hydropower market, ANDRITZ HYDRO invited key stakeholders to its first Customer Day Indonesia in Jakarta in March 2017. More than 180 participants accepted the invitation and attended the event, which was a big success. The technical focus of the presentations was on turbine and generator technology, as well as the new HIPASE platform.

VIENTIANE – March 23rd, 2017
In March 2017, ANDRITZ HYDRO organized a second Customer Day in Lao PDR. More than 170 delegates attended this year – a 20% increase on the previous Lao PDR Customer Day. Besides turbine and generator technology, and the new HIPASE platform, the spotlight also fell on the market approach for services and the Mini Compact concept from the Compact Hydro business area. Special attention was paid to the presentations regarding the environmentally-friendly technical solutions available from ANDRITZ HYDRO, which are drawing growing market interest, especially in the Mekong River region.

SEOUL – June 21st, 2017
In June 2017, ANDRITZ HYDRO welcomed more than 150 participants to Seoul for the first Customer Day Korea. Specific rehabilitation work, bi-direction tidal power plants, tidal current power plants, and low-head applications, as well as future challenges and best possible solutions were the special focus of the event. Technical presentations on pumped storage, tidal turbines, and Francis turbine technology made the event a most interesting and informative affair.

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EVENT FORECAST

Experience further content

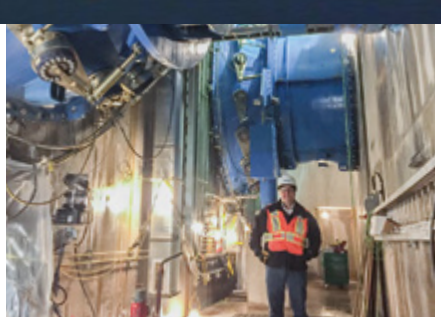
ANDRITZ HYDRO

Hydropower plant Chaudière Falls in Ottawa

© Hydro Ottawa

ANDRITZ HYDRO was awarded a contract by Chaudière Hydro LP., a Hydro Ottawa subsidiary, for a complete "from water-to-wire" package for the Chaudière Falls plant in Ottawa – the first hydropower plant commissioned in Canada in 1891.

Hydro Ottawa will now build a new 32 MW run-of-river power plant with the four most powerful ECOBulb* turbines delivered to date by ANDRITZ HYDRO, generating some 164 GWh of electrical energy per year. **We focus on the best solution – "from water-to-wire".**



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